Fuel poverty and its links with other forms of disadvantage: A quantitative exploration

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Abstract

Fuel poverty – the inability to afford adequate energy services in the home – is an important public health issue and is recognised as a considerable source of health and social inequalities. Although often explored through the lens of a cold home, the literature shows that the experience of fuel poverty is nuanced and that households use a range of coping mechanisms to mitigate the effects of fuel poverty. This has been shown to influence the experience of fuel poverty, with some studies revealing links between fuel poverty and other forms of disadvantage. However, the myriad of objective and subjective ways used to identify the fuel poor in the literature has made it difficult to understand the relationship between fuel poverty and other forms of disadvantage in a consistent manner.

This thesis presents a secondary quantitative exploration of the relationship between fuel poverty and other forms of disadvantage. Using data from two national surveys and two actual expenditure-based fuel poverty indicators, which are based on the official definitions of fuel poverty currently used within the UK, the thesis provides evidence of a relationship between fuel poverty and food insecurity, social isolation, and material deprivation, extending the quantitative literature on the experiences of the fuel poor. Moreover, the thesis finds that levels of disadvantage are altered by the fuel poverty indicator used and that the experience of disadvantage varies within fuel poverty indicators, providing novel contributions to the understanding of the heterogeneous nature of fuel poverty. These findings have important implications for how well the experiences of the fuel poor are captured in official definitions of fuel poverty and draws attention to the need for definitions to incorporate a more complete understanding of fuel poverty that reflects growing knowledge of how it can be experienced.

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List of abbreviations

1PL	1- parameter logistic
2PL	2-parameter logistic
AFP	Alternative fuel poverty indicator
AHC	After housing costs
ANOVA	Analysis of Variance
BEIS	Department for Business, Energy & Industrial Strategy
BHC	Before housing costs
BLS	Bureau of Labor Statistics
BRE	Building Research Establishment
BREDEM	Building Research Establishment Domestic Energy Model
CPI	Consumer Prices Index
CPIH	Consumer Prices Index including owner-occupiers' housing costs
DD	Direct Debit
DECC	Department of Energy & Climate Change
Defra	Department for Environment, Food & Rural Affairs
DWP	Department for Work & Pensions
ECO	Energy Company Obligation
EHS	English Housing Survey
EPC	Energy Performance Certificate
EWD	Excess Winter Deaths
FRS	Family Resources Survey
HRP	Household Reference Person
IRT	Item Response Theory
LCFS	Living Costs and Food Survey
LIHC	Low Income High Costs indicator
MAR	Missing at random
MCAR	Missing completely at random
MNAR	Missing not at random
OAC	Output Area Classifications

OECD	Organisation for Economic Co-operation and Development
ONS	Office for National Statistics
OR	Odds ratio
PPM	Prepayment meter
PSE	Poverty and Social Exclusion
RRR	Relative Risk Ratio
SAP	Standard Assessment Procedure
UKHLS	Understanding Society: The UK Household Longitudinal Study
VIF	Variance Inflation Factor
WFP	Winter Fuel Payment
WHO	World Health Organization

Chapter 1| Introducing the thesis

1.1 Introduction

Domestic fuel is a necessity (Bradshaw et al. 2008; Boardman 2010; Simcock and Walker 2015). It is needed for good physical health and mental wellbeing (Wilkinson 1999; Liddell and Morris 2010; Marmot Review Team 2011; Hernández 2016), a decent quality of life (Simcock et al. 2016), and an acceptable standard of living (Bradshaw et al. 2008; Davis et al. 2014). However, it has been estimated that 12.9 per cent of UK households are unable to afford adequate domestic fuel for their needs (National Energy Action 2018a), a phenomenon that has been termed *fuel poverty*.

Despite official definitions of fuel poverty emphasising the ability to afford *all* domestic energy services, including energy for lighting, for heating water, for cooking, and for all appliances used in the home, as well as for space heating (Boardman 1991; Boardman 2010; Hills 2012), a predominant focus has been placed on the inability to afford adequate warmth in the home (Lewis 1982; Bradshaw and Harris 1983; Boardman 1991; Department of Trade and Industry 2001). This possibly reflects the fact that heating costs are estimated to comprise over half of a household's fuel bill (Hills 2012). As such, a dominant focus on fuel poverty as a cold home has contributed to this being one of the most obvious themes in the fuel poverty literature and is often explored in relation to its impact on physical and mental health (Liddell and Morris 2010; Marmot Review Team 2011; Liddell and Guiney 2015).

Although an important aspect of fuel poverty, focusing predominantly on a cold home provides an insight into only one way that it can be experienced and has resulted in other ways that fuel poverty can be experienced being relatively overlooked, both in research and in policy. In fact, according to content analysis of fuel poverty policy documents dating from 2012 to 2014, Simcock and Walker (2015) found that the mention of non-heating energy uses occurred only 30 times in the five Department of Energy & Climate Change (DECC) documents they analysed, in contrast to 377 times for words relating to adequate warmth. Nonetheless, there is now increasing attention being lent to other ways that fuel poverty can be experienced and it is now widely acknowledged that fuel poverty does not always manifest simply as a cold home, but that it is a multifaceted and complex issue (Baker et al. 2018).

1.2 Fuel poverty beyond a cold home: Insights from the literature

One of the areas that has revealed the multifaceted nature of fuel poverty is the literature that concerns the qualitative exploration of the *lived experience* of fuel poverty. This subset of the literature documents the reality of fuel poor households and has offered a more nuanced view of the issue, providing important insights into how households can experience fuel poverty. Within this area of the literature, it has been observed that fuel poor households do not always experience a cold home, but may instead cut back on other essentials, such as food and clothing, to be able to afford sufficient warmth (Harrington et al. 2005; O'Neill et al. 2006; Anderson et al. 2010). Others have found that other fuel services, such as lighting and hot water, may be rationed as a way of keeping fuel bills affordable (Day and Hitchings 2009; Brunner et al. 2012), and that cooking may be limited (Hernández and Bird 2010). Studies such as these have helped to draw attention to other components of fuel poverty, providing a more holistic understanding of its nature and experience beyond a cold home. Furthermore, these different presentations of fuel poverty have helped to uncover the myriad of underlying methods that households use to cope with fuel poverty, driven often by priorities, preferences, and beliefs, and this suggests that the experience of fuel poverty can vary widely between households and for those living within them (Harrington et al. 2005; Middlemiss and Gillard 2015).

1.3 Is there evidence of a relationship between fuel poverty and other forms of disadvantage?

Understanding the ways in which households experience and cope with fuel poverty has provided a gateway through which links can be made between fuel poverty and other forms of disadvantage. One of the most widely researched themes within this vein of the literature is the *heat or eat* trade-off, which is described as having to choose between heating or eating (Lambie-Mumford et al. 2015; Snell et al. 2018) and, therefore, how households allocate limited financial resources to essential expenditures. However, despite the apparent simplicity of the term, the reality of this decision-making process within fuel poor households is much more complex and varied and there is no literature that provides evidence to suggest that one is completely forgone in place of another (Lambie-Mumford et al. 2015). Instead, the literature highlights that both heating and food expenditure may be rationed simultaneously (Lambie-Mumford et al. 2015), and that households use a wide range of measures to avoid experiencing hunger. For example, low-income households have been shown to purchase smaller quantities of food to be able to afford warmth (Anderson et al. 2010; Cotter et al. 2012; Lambie-Mumford et al. 2015), and more expensive foods, such as fresh meat, fruit, and vegetables, are replaced with tinned foods (Anderson et al. 2010) and pre-prepared foods (Middlemiss and Gillard 2014). This range of behaviours indicates that, instead of forgoing food, fuel poor households make significant changes to their food purchases, suggesting that fuel poverty can impact on the quantity of food and the quality of the diet, which are two aspects linked to food insecurity (Taylor and Loopstra 2016).

Aside from work on the heat or eat trade-off, other forms of coping mechanisms have emerged through the qualitative literature that can help to shed light on how fuel poverty may be linked with other forms of disadvantage. Householders have been found to curb expenditure on essential items (i.e. those that are indicators of material deprivation[1]), such as holidays (Anderson et al. 2010) and clothing (Bhattacharya et al. 2003; Anderson et al. 2010; Cotter et al. 2012), to be able to afford adequate warmth and to avoid falling into debt (Anderson et al. 2010). Others have found that those living in cold homes feel reluctant to invite visitors into their home (Grey et al. 2017a), that social activities outside the home are limited so that finances can be concentrated on keeping the home warm (Harrington et al. 2005; Cotter et al. 2012), and that going out is avoided through fear of returning to a cold home (Department of Trade and Industry 2001). These studies demonstrate that the experience of fuel poverty may be related to other aspects of disadvantage, such as food insecurity, material deprivation, and social isolation.

[1] These are consumption goods and activities that are considered essential in a society at a given point in time (Townsend 1979).

1.4 The multifaceted nature of fuel poverty: different ways of defining and identifying fuel poverty

Although the studies outlined in section 1.3 have provided some insights into the ways that fuel poverty can be linked with other forms of disadvantage, they have inadvertently highlighted the complex issue of identifying the fuel poor. Within these studies, various indicators have been used. For example, Anderson and colleagues (2010) explored the experiences of low-income households living in a cold home, whilst others have focused on consensual indicators[2], such as being unable to afford adequate warmth (Cotter et al. 2012; Lambie-Mumford et al. 2015), or have used expenditure-based definitions to identify the fuel poor (Harrington et al. 2005). These indicators highlight the various ways in which fuel poverty can be experienced and identified. However, the range of indicators used complicates understanding of the links between fuel poverty and other forms of disadvantage as it makes it difficult to compare findings across studies. In part, this difficulty arises from the dearth of knowledge that exists between how subjective and objective ways of identifying the fuel poor align with each other, with the few studies in existence showing a disconnect between the two, suggesting that those who spend disproportionately on fuel do not *feel* fuel poor, and vice versa (Devalière et al. 2011; Waddams Price et al. 2012; Phimister et al. 2015). As such, it is not clear whether the relationship between fuel poverty and other forms of disadvantage is evident only for some ways of identifying the fuel poor, or for only some aspects of disadvantage. Moreover, there is a lack of clarity as to how these ways of identifying the fuel poor align with official indicators of fuel poverty used within the UK and whether these would also show a relationship with disadvantage.

Despite the multifaceted nature of fuel poverty, it is defined within strict technical and objective framings in the UK. Until 2013, each UK nation defined fuel poverty using Boardman's 10 per cent definition, where households would be considered fuel poor if they have *required* (or estimated) fuel costs that exceed 10 per cent of their income (Boardman

[2] Consensual measures of fuel poverty refer to those that are self-reported subjective assessments, such as living in a cold home and the ability to pay utility bills on time (Rademaekers et al. 2016).

2010). However, England has recently moved away from this definition and has used the *Low Income High Costs* (LIHC) indicator since 2013[3]. This indicator defines fuel poverty as having *required* fuel costs that are above the median level and would leave a household's remaining income below the official poverty line after paying these (Hills 2012). These definitions, along with how required fuel costs are modelled, are discussed in the following chapter. As such, the myriad of indicators used may not necessarily align with each other or with official definitions of fuel poverty, and so it is not clear whether the relationship between fuel poverty and other forms of disadvantage would exist for all ways of identifying the fuel poor.

1.5 The research gaps and aims of the thesis

Although the studies outlined in section 1.3 provide evidence of a relationship between fuel poverty and other forms of disadvantage, the lack of a consistent indicator underpinning the understanding of fuel poverty makes it difficult to compare studies and to fully understand these links. Furthermore, given the predominance of qualitative research in this field and the small sample sizes within these studies, it is not clear whether these identified relationships would be present in the larger population.

Drawing on these research gaps presents a novel avenue of research and, as such, the overarching aim of this thesis is to explore the relationship between fuel poverty and other forms of disadvantage using consistent fuel poverty indicators in larger sample sizes. Furthermore, given that these relationships may be impacted by how fuel poverty is identified, the sub-aim of the thesis is to explore whether identified relationships are altered by different indicators of fuel poverty.

[3] After consultation, the LIHC was replaced by the Low Income Low Energy Efficiency indicator in 2021. Under this metric, households who live in a dwelling with an energy efficiency of D or below and whose income is left below the official poverty line after paying for their required fuel bills are considered fuel poor (BEIS 2021).

1.6 The research questions

Focusing on food insecurity, social isolation, and material deprivation, aspects of which have been highlighted by the literature presented in section 1.3, the following research questions are proposed:

1. How does fuel poverty impact on food insecurity?
2. What are the links between fuel poverty and social isolation?
3. Is there a difference in the order of curtailment of material deprivation items between fuel poor and non-fuel poor households?

Each of the research questions aims to further understand the relationship between fuel poverty and these other forms of disadvantage, and, therefore, provide further understandings of the experiences of the fuel poor. In answering these questions, further insights into the experience of fuel poverty using different indicators can be gained, which may have important implications for further understanding fuel poverty using objective indicators and for policy development.

1.7 The research approach

Taking a postpositivist perspective[4] to the research, a secondary quantitative approach is employed to explore the research questions stated in section 1.6 within the context of the UK using data from two national surveys: the *Living Costs and Food Survey* (LCFS) and *Understanding Society: The UK Household Longitudinal Study* (UKHLS). These datasets provide large sample sizes, which are nationally representative and so allow relationships in the wider population to be identified and for the results to be generalisable. Moreover, this approach allows for the consistent application of fuel poverty indicators and for each of the questions to be answered. Detailed food expenditure data is contained within the LCFS, which can be used to answer the first research question, and variables related to social

[4] *Postpositivism* is a worldview that states that knowledge is "based on careful observation and measurement of the objective reality" (Creswell and Creswell 2018, p.44).

isolation and material deprivation are present within the UKHLS, which can be used to answer the second and third research questions, respectively.

1.7.1 Conceptualising and defining fuel poverty

As well as data that can be used to explore the three areas of disadvantage within the research questions, the LCFS and the UKHLS datasets also contain income and fuel expenditure data, which allow for the creation of different fuel poverty indicators based on *actual* fuel expenditure.

As emphasised in section 1.4, *required* fuel costs are central to the definitions of fuel poverty (Hirsch et al. 2011) as, unlike actual fuel expenditure, they are able to capture those who are spending below their needs as a way of coping with fuel poverty and who may otherwise be overlooked in fuel poverty classifications (Hirsch et al. 2011; Moore 2012; Thomson 2013). Required fuel costs also exclude those who may be over-spending through preference or wastefulness (Hills 2011). However, using actual fuel expenditure can shed light on the challenges that the fuel poor may face (Middlemiss 2016), which may not be adequately represented by modelled fuel costs, and who may then forgo or reduce expenditures in other areas (Hirsch et al. 2011).

Taking income and actual fuel expenditure data contained within both the LCFS and the UKHLS, fuel poverty is identified through the conceptualisation of disproportionate fuel costs using *actual* expenditure-based versions of the two national indicators used within the UK at the time of writing: Boardman's 10 per cent definition and Hills' LIHC indicator. These are named the 10 per cent indicator and the Alternative Fuel Poverty (AFP) indicator, respectively, for the purpose of the thesis. Their construction is detailed in Chapter 4, which explains that both fuel poverty indicators are based on expenditure that is inclusive of all household fuel, as proposed by Boardman (1991; 2010) and used widely in government documents (DECC 2012; Hills 2012; Department for Business, Energy & Industrial Strategy (BEIS) 2020a). This includes fuel for lighting, for heating water, for cooking, and for all appliances used in the home, as well as for space heating (Boardman 2010). The purpose of using two different fuel poverty indicators is to explore how disproportionate fuel costs under two different definitions of fuel poverty impact on the relationship with other forms of disadvantage. Applying these definitions consistently to nationally representative datasets overcomes some of the limitations identified in previous studies and fills the research gaps.

1.8 Structure of the thesis: a summary of the chapters

The thesis comprises 9 chapters. In the following chapter, **Chapter 2**, a comprehensive overview of fuel poverty is presented to lay the foundations for understanding the remainder of the thesis. Drawing on both the academic and grey literature, the core aspects of fuel poverty are outlined. This includes how fuel poverty is understood and defined within the UK, the key drivers of fuel poverty, and the health consequences associated with living in fuel poverty. The chapter also details how the two official definitions of fuel poverty currently used in the UK capture different characteristics and provides a critique of how fuel poverty is modelled and how current fuel poverty policy may not be sufficient for eradicating fuel poverty.

Chapter 3 provides the conceptual framework for the research, where the links between fuel poverty and other forms of disadvantage are traced. These links have motivated the direction of the thesis and have facilitated the development of the research questions stated in section 1.6. The framework offers an understanding of the potential mechanisms that could be underlying these links, with focus given to how fuel poverty can affect the home and the way that householders cope with fuel poverty. The reader's attention is drawn to the multitude of ways in which fuel poverty has been identified within studies and how this has hindered the consistent understanding of the relationship between fuel poverty and other forms of disadvantage. Through the development of this conceptual framework, the research gaps are identified. These draw on the need to apply consistent fuel poverty indicators to gain a better understanding of the relationship between fuel poverty and other forms of disadvantage, and to determine whether these relationships exist in the wider population given that qualitative inquiry and, therefore, small sample sizes, predominate in this field of research. In noting these gaps, the research aims and questions are stated.

Chapter 4 presents the justification for the use of a secondary quantitative research approach and introduces the data sources selected to conduct the research (the LCFS and the UKHLS), emphasising their suitability for addressing the breadth of areas incorporated within the research questions. Following this, the data cleaning procedures that are common to all the analysis chapters are outlined, and detailed guidelines are presented for the construction of the two fuel poverty indicators used for the purpose of the research. Using the conceptualisation of fuel poverty as disproportionate fuel costs, actual expenditure-based equivalents of the official definitions of fuel poverty currently used in the UK are created (the 10 per cent indicator and the AFP indicator) and those who are spending to the thresholds within these are classified as fuel poor. The purpose of using two different fuel poverty indicators is to explore whether they alter the relationship between fuel poverty and other forms of disadvantage.

Before embarking on the proposed research questions stated in section 1.6, **Chapter 5** provides a thorough and in-depth examination of the two fuel poverty indicators used throughout the research: the 10 per cent indicator and the AFP indicator. Within this chapter, a comparison of modelled and actual fuel expenditure is provided, the fuel expenditures of fuel poor and non-fuel poor groups are examined, which leads to further investigation of the relationship between income and fuel expenditure. The determinants of fuel poverty under the two created indicators are also explored, and the characteristics of households with the highest likelihood of fuel poverty under each fuel poverty indicator are identified and this acts as a point of reference for the remainder of the analysis chapters. The findings within this chapter underscore how the diverse components of the indicators alter the likelihood of experiencing fuel poverty. This leads to the presentation of two contrasting profiles of the fuel poor and, as such, this chapter emphasises the *compositional heterogeneity* of fuel poverty under two different fuel poverty indicators.

Chapter 6 explores the first of the proposed research questions, which aims to provide further dimensions to the understanding of how the fuel poor may experience food insecurity, further elaborating on the understanding of the heat or eat trade-off.

Within this chapter, food expenditure data contained within the LCFS is used to explore the links between fuel poverty and food insecurity through expenditure on food, in absolute and proportionate terms (the latter being an indicator of food insecurity), and food expenditure patterns created using food expenditure data. As well as showing that differences exist in the burden that food expenditure places on the incomes of the fuel poor under the two different indicators, this chapter also finds that food expenditure patterns and, therefore, the ways in which food insecurity may be experienced, can vary for households under the same fuel poverty indicator. As such, this chapter adds two further dimensions to how the heterogeneous nature of fuel poverty can be understood: *inter*- and *intra-indicator* heterogeneity, showing how differences in the relationship with food insecurity can vary between indicators (inter-indicator heterogeneity) and within indicators (intra-indicator heterogeneity).

Chapter 7 focuses on the second question of the research, which aims to determine whether a relationship exists between fuel poverty and social isolation and to identify the factors underlying this. Creating a scale to measure social isolation using variables contained within the UKHLS, fuel poverty is found to not always be positively associated with social isolation, with the two fuel poverty indicators capturing varying levels of social isolation. By showing that the degree of social isolation varies between the two different fuel poverty indicators used, this further reinforces the inter-indicator heterogeneity that is identified in Chapter 6. Furthermore, the analysis finds several factors that appear to mediate the relationship between fuel poverty and social isolation, such as tenure and urban- or rural-living, and, as such, this chapter helps to understand how the characteristics of those with the highest likelihoods of fuel poverty under different indicators (identified in Chapter 5) may impact on the relationship between fuel poverty and social isolation.

Chapter 8 presents the analysis for the final research question, which investigates whether the order in which material deprivation items (i.e. essential expenditures) are curtailed differs between fuel poor and non-fuel poor households as a way of determining how fuel poverty impacts on the living standards of the fuel poor. The analysis within this chapter uses material deprivation suites for working-age adult and pensioner households, which are present in the UKHLS, and explores material deprivation in working-age adult households (with and without children) and pensioner households.

The chapter finds that rates of material deprivation vary between different household types who are fuel poor under the same indicator and that households under the same fuel poverty indicator do not experience material deprivation in the same way, evidenced through differences in the order in which essential expenditures are curtailed. This suggests that fuel poverty has different impacts on living standards, depending not only on the indicator used, but also on the household type. This expands the understanding of the notions of inter- and intra-indicator heterogeneity, which are highlighted in Chapters 6 and 7.

Chapter 9 brings together the key findings from all the analysis chapters, providing a detailed discussion of their meanings and how they further the understanding of fuel poverty and the experiences of the fuel poor under the indicators used. The novel contributions of the thesis are presented and, based on the findings herein, the policy implications and recommendations are identified, and future research directions, which build on the research presented within the thesis, are detailed. The final remarks and conclusions bring the thesis to a close.

Chapter 2| Setting the scene: Understanding fuel poverty

2.1 The origins of fuel poverty

In October of 1973, following tensions in the Middle East in what is now known as the Yom Kippur War, Arab oil-producing countries under the Organization of the Petroleum Exporting Countries imposed an embargo as punishment for the West supporting Israel against Egypt and Syria (Mallaburn and Eyre 2014). They reduced their oil production by 5 per cent per month, but increased oil prices by 70 per cent (Bradshaw and Harris 1983). By the end of 1973, the effects of this had reached the UK: street lighting was halved, sharing car rides was encouraged, and a three-day working week was implemented to ration electricity (Pisarski and de Terra 1975; Bradshaw and Hutton 1983; Mallaburn and Eyre 2014). The effects of this were also felt in peoples' homes. Households were asked to reduce their heating (Bradshaw and Hutton 1983) and, given the increases in the costs of domestic fuel between 1973 and 1977 (Osbaldeston 1984), additional weekly payments of *Exceptional Circumstances Additions*[5] for central heating had trebled within this period – from 500,000 to 1.5 million recipients (Isherwood and Hancock 1979) – and low-income households struggled to heat their homes (Department of the Environment 1991). By the end of the decade, the term *fuel poverty* had been used to describe the difficulties these households were facing (Hansard 1977; Isherwood and Hancock 1979).

Despite the passing of over four decades since fuel poverty was first recognised and in spite of numerous policies targeted at helping the fuel poor, fuel poverty is still a problem many households face today, with National Energy Action recently estimating that fuel poverty affects around 3.5 million – or 12.9 per cent of – households in the UK[6] (National Energy Action 2018a).

[5] These were weekly additions to benefit payments made to those whose homes were difficult to heat (Bradshaw 1983).
[6] This was estimated by adding together the numbers of households in fuel poverty in each of the UK nations, despite different fuel poverty definitions being used (National Energy Action 2018a).

2.2 Chapter aim and outline

The aim of this chapter is to provide the reader with a comprehensive overview of fuel poverty that lays the groundwork for the remainder of the thesis. The chapter begins with a description of the search strategy used to select the literature to be included in this chapter, and this is followed by how fuel poverty is currently understood and defined, focusing on the two official fuel poverty definitions currently used in the UK. A detailed discussion of their components is provided and the rates of fuel poverty within the UK are illustrated, emphasising how these are impacted upon by different definitions of fuel poverty. Following this, a discussion of the key drivers of fuel poverty and how different fuel poverty indicators can change who is classified as fuel poor is provided, and the health consequences of living in fuel poverty are outlined.

In the later parts of the chapter, specifically sections 2.8 and 2.9, a critical eye is cast over how fuel poverty is modelled, with particular attention given to how modelling required fuel costs, as a way of overcoming the limitations of using actual fuel expenditure to identify the fuel poor, may misestimate fuel poverty. Providing the closing sections of the chapter, a comparison of actual and modelled fuel expenditure is presented and the fuel poverty policies that are currently in place in the UK are detailed with a brief discussion on why these may not be sufficient for eradicating fuel poverty.

2.3 Conducting the literature review: A summary of the literature search strategy

Before embarking on the content of this chapter, it is firstly important to describe the strategy used to identify and select the literature for inclusion. Given that the purpose of this chapter is to provide a comprehensive picture of fuel poverty so that the reader has a solid foundation for understanding the scope of the topic area, it was important to ensure that a broad and inclusive account of the issue was presented. To do this a narrative literature review approach was adopted, which provides a synthesis and evaluation of the literature (Bourhis 2018). Unlike systematic reviews, which follow particular standards and protocols, narrative reviews have no predetermined research question or specified search strategy, only a topic of interest (Bourhis 2018). This flexibility is a strength of this approach as it means that narrative reviews can provide a much broader account of a topic area and provide more potential for individual insights as they are not confined by strict rules (Collins and Fauser 2005; Bourhis 2018). However, because the author subjectively selects the literature to include, all important studies may not be identified and this could lead to a biased review (Pae 2015). In acknowledging this weakness, several strategies were used to ensure that a wide range of literature was included to minimise the risk of bias. The following subsections detail the three steps taken to compile this chapter: 1. Conducting a preliminary search; 2. Identifying the search terms; 3. Selection of the literature for inclusion.

2.3.1 Step 1: Conducting a preliminary search

The first step in constructing the literature review was conducting a preliminary search to identify the type of work that has been published on fuel poverty and to help identify key search terms. Three databases were used to search for relevant literature: ScienceDirect, Scopus, and PubMed. These databases contain a range of literature from peer-reviewed and high impact journals, and this provided reassurance that the selected research was high quality and trustworthy. While ScienceDirect "is the world's leading source for scientific, technical, and medical research" (ScienceDirect 2022), Scopus is the largest database of peer-reviewed literature (Scopus 2022), and PubMed provides research published on topics related to biomedical and life sciences (PubMed 2022). Although they contain similar studies, it was noted that using the same search term in these databases did not always return the same studies and so were used for cross-checking and ensuring that as many different studies as possible were identified.

For this initial search, terms commonly used when discussing fuel poverty were used as a way of exploring the relevant literature. Most importantly, particularly in the context of the UK, the term "fuel poverty" was deemed to be an obvious starting point as this was the first term used to describe fuel poverty as it recognised in the present day. As well as this, it was important to identify synonyms for fuel poverty given the evolution of this topic area over recent years. The following terms were identified as having been used more recently to describe nuances in how fuel poverty is understood and experienced, both in the UK and internationally: “cold home” OR “energy insecurity” OR “energy burden” OR “fuel burden” OR “energy vulnerability”. Drawing on previous knowledge, research published by key authors in fuel poverty was also searched for. These authors included Brenda Boardman, John Hills, Lucie Middlemiss, Christine Liddell, and Harriet Thomson.

This initial search was useful for understanding some of the key areas in fuel poverty and this helped to decide which sections to include and how to structure the chapter. However, it is important to state that decisions around which sections to include in the chapter were based on the author’s perspective on the topics that are deemed important for understanding fuel poverty. Although this could lead to a biased account of fuel poverty, which was an acknowledged weakness of this strategy, a range of topics discussed by key authors in the field were included as a way of minimising the risk of bias.

2.3.2 Step 2: Identifying the search terms

In structuring the review based on the initial literature search, it was then possible to define more specific search terms for each of the sections. Using the keywords stated by authors in the relevant articles identified in the preliminary search, the initial search terms stated above were extended to the following: (“cold homes” OR “energy insecurity” OR “energy burden” OR “fuel burden” OR “energy vulnerability”) AND (“low incomes” OR “income poverty”); “health” AND (“cold homes” OR “energy insecurity” OR “energy burden” OR “fuel burden” OR “energy vulnerability”); (“cold homes” OR “energy insecurity” OR “energy burden” OR “fuel burden” OR “energy vulnerability”) AND “energy efficiency”; “fuel poverty” AND “policy”; “fuel poverty indicators”; “fuel poverty measurement”.

2.3.3 Step 3: Selecting the literature for inclusion

Using the search terms identified in the previous step often returned a large number of articles with potential importance and relevance for this chapter. However, given the large number of research articles found, it was not possible to include them all and so this final step reduced the number of research articles returned to facilitate the selection process. This involved refining the search using several filters. To begin with, “research articles” and “book chapters” were selected for the inclusion criteria. If the number of returned research remained high following these refinements, the publication titles were also limited to those that publish regularly on domestic fuel poverty. The selected publication titles from those available were “Energy”, “Energy Policy”, “Energy Research & Social Science”, “Public Health”, “Social Science & Medicine”, “Health & Place”, and “Applied Energy”. These are all peer-reviewed and high-impact journals that publish high quality research on domestic fuel poverty, again providing reassurance that the literature included was trustworthy and of high calibre. If the number of articles returned was still high after narrowing down the publication journals, then the search was limited by subject to “Social Sciences”. All years of publications were included as this was important for understanding changes in fuel poverty across time. These refining processes substantially reduced the number of articles returned. For example, when using the search term “fuel poverty” in ScienceDirect, over 2,000 articles were returned, but these were reduced to just under 160 when the refinements were applied. Where necessary, primarily to identify work on fuel poverty indicators and policy in the UK, the results were also filtered so that they only included work related to the UK. This was only possible in Scopus.

Once the number of articles was more manageable, the next step in this process was to read through the abstract, focusing on the topic, methods, and outcomes. Whilst doing so, a range of perspectives, methods, and findings was borne in mind to produce a balanced and comprehensive account of the literature. Any papers that were selected for inclusion based on the abstract were then read in full.

Although important for narrowing down the number of articles returned, using a range of filters to limit the search meant that there was a risk that important research was inadvertently excluded. As a way of overcoming this weakness and to find research that may have been missed, the snowballing method was used. This is where the citations and reference list within an article are examined to identify additional papers of interest (Sayers 2007), which may have been excluded by the search terms and filters applied.

As well as peer-reviewed work published in high quality journals, it was felt important to include the grey literature. This type of literature refers to work that is not published in commercial publications and can include academic papers, such as theses and dissertations, research and committee reports, government reports, conference papers and ongoing research (Paez 2017). The inclusion of grey literature helps to reduce publication bias by disseminating studies with null or negative results that may otherwise not be disseminated. This helps to provide a more balanced account of the fuel poverty literature. To search for this type of literature, trusted organisations that conduct research on fuel poverty, such as National Energy Action and End Fuel Poverty Coalition, as well as government bodies, in particular the Department for Business, Energy and Industrial Strategy (BEIS), were explored through their websites. Government reports on fuel poverty were of particular importance within this chapter given that they contain statistics on fuel poverty by different indicators. Including these reports also helped to understand issues around fuel poverty policy by highlighting a mismatch between the government's perspective on the issue and the experience of individuals observed in peer-reviewed and grey literature.

Although only grey literature from trusted organisations was included, further checks on the quality of the research were conducted before being selected for inclusion. This included checking the appropriateness of the methods used, ensuring that the methodology was transparent, that the interpretation of results was substantiated by the data, and that the conclusions drawn were consistent with the study's results.

Overall, these search strategies have yielded a wide range of literature, both qualitative and quantitative, from a range of sources including academic journals, trusted organisations, and government bodies, which has helped to incorporate different perspectives on fuel poverty from different disciplines. Although this is a strength of the evidence base, the range of different perspectives has contributed to different ways of identifying and exploring fuel poverty, which makes it difficult to understand the true nature of the issue and to make coherent comparisons across studies. It was also noted that there is a scarcity of studies on how fuel poverty differentially affects certain groups of the population, such as those with disabilities and those from minority ethnic groups, as well as studies with an intersectional and interdisciplinary approach to fuel poverty research. These are viewed as weaknesses of the evidence base.

Sourcing the included literature from peer-reviewed and high quality journals, as identified by the databases, and trusted organisations, as well as citing the most well-known and established academics in the field ensures the high quality of the research included in this review. Using several strategies to identify as many relevant and important works as possible, and thereby mitigating the possibility of bias, gives strength to such a thorough review. The strategies used herein have provided a broad and balanced account of the literature, which help the reader to gain a comprehensive understanding of fuel poverty, fulfilling the core aim of this chapter.

2.4 Current understandings and definitions of fuel poverty in the UK

The origins of fuel poverty detailed above in section 2.1 form the basis for how it is understood today. It has traditionally been linked to the notion of *affordable warmth* and is most widely interpreted as the inability to afford adequate warmth in the home (Lewis 1982; Bradshaw and Harris 1983; Boardman 1991; Department of Trade and Industry 2001). Given that space heating typically accounts for over half of a household's fuel bill (Hills 2011; Jones et al. 2016), this appears to be a logical connection. However, as emphasised by Boardman (1991; 2010), fuel poverty relates to the ability to afford *all* domestic energy services, including energy for lighting, for heating water, for cooking, and for all appliances used in the home, as well as for space heating. This recognises that fuel poverty is a much broader concept than (in)adequate heating alone.

2.4.1 The development of the 10 per cent definition and the first Fuel Poverty Strategy

Isherwood and Hancock (1979) were amongst the first to attempt to define the fuel poor in the UK (Osbaldeston 1984). Examining the distributions of fuel expenditure proportions using data from the *Family Expenditure Survey* for 1970, 1974, and 1977 (Hutton 1984), Isherwood and Hancock (1979) defined the fuel poor as those spending more than twice the median[7] on fuel, light, and power – a level that was viewed as disproportionate (Boardman

[7] The use of median – rather than mean – expenditure reflected growing interest in the concept of relative poverty made popular at the time by Townsend (see Townsend (1979)).

2010). In 1977, twice the median was 12 per cent of total expenditure (Osbaldeston 1984) and this captured the 30 per cent of households with the lowest incomes, with those in the lowest three income deciles considered to have disproportionate fuel expenditure (Boardman 2010). Isherwood and Hancock's work (1979) built the foundations for the development of the first quantified definition of fuel poverty, which was put forward by Boardman in 1991 – 12 years after the publication of their work.

In her first book, *Fuel Poverty: From Cold Homes to Affordable Warmth*, Boardman defined the fuel poor as those unable to "have adequate energy services for 10 per cent of income" (Boardman 1991, p.227). This definition includes all energy services, including energy for lighting, for heating water, for cooking, and for all appliances used in the home, as well as for space heating (Boardman 1991; Boardman 2010). The decision to set the threshold at 10 per cent was based on Boardman's analysis of the 1988 *Family Expenditure Survey*, the same data source used by Isherwood and Hancock (1979) in their earlier analysis. In 1988, the average expenditure for domestic energy use was 5 per cent of the weekly budget[8], and 30 per cent of households with the lowest income were spending 10 per cent – twice the median amount (Boardman 1991). This reflected the findings of earlier analysis by Isherwood and Hancock (1979) and preserved their twice-median concept. Furthermore, despite spending a larger proportion of their income on fuel, Boardman (1991) found that the 30 per cent of households with the lowest incomes were spending less on fuel in absolute terms compared to those within the remaining 70 per cent of households.

Boardman's fuel poverty definition was initially based on *actual* fuel expenditure (Boardman 2010). However, it was later acknowledged that this may overlook those who are under-spending as a way of keeping fuel bills low and, as a result, may not be achieving adequate energy services. Consequently, the definition then became focused on the *need to spend* or *required* fuel costs, where costs associated with adequate fuel use, especially adequate warmth, are estimated (or modelled) based on various characteristics of the

[8] Only the weekly budget was available at the time of analysis. This was later redefined to income (Boardman 2010).

dwelling and its occupants. This procedure is discussed in later sections of the chapter (see sections 2.8 and 2.9).

The 10 per cent threshold was set using full income, which includes basic income[9], Housing Benefit[10], income support for mortgage interest, and council tax benefit, therefore providing a *before housing costs* (BHC) measure of income (Boardman 2010). The decision to include housing costs was taken as excluding them would have risked capturing too many richer households (Boardman 2010). However, the inclusion of Housing Benefit also presents an important issue. If Housing Benefit is increased as a result of a rent increase, a household may no longer be classified as fuel poor despite Housing Benefit not being available to be used to pay for fuel (Boardman 2010; Moore 2012). This issue disproportionately affects households in high-rent areas, such as London (Boardman 2010). This constituent part of the 10 per cent definition remains a contested issue as different measures of income can influence the types of households who are classified as fuel poor (Liddell et al. 2011). A closer look at this will be taken later in section 2.7.

2.4.1.1 The first Fuel Poverty Strategy

Fuel poverty was officially recognised by the government in 1998 when the Labour Party was in power (Boardman 2010), and in 2001 the first UK Fuel Poverty Strategy was published (DECC 2015b). The Strategy was borne out of the 2000 *Warm Homes and Energy Conservation Act* (WHECA), which defines fuel poverty as "a household living on a lower income in a home which cannot be kept warm at reasonable cost" (DECC 2015b, p.14). The 2000 WHECA made it a legal obligation in England and Wales to eradicate fuel poverty by 2018 as far as reasonably practicable (DECC 2015b), setting an interim target of eradicating fuel poverty in England by 2016, and in Wales by 2018 (Boardman 2010; Kidson and Norris 2014). Despite WHECA only applying to England and Wales, the Strategy covered the whole

[9] This includes all income, but excludes any income directly related to housing, therefore, providing an after housing costs measure of income (Boardman 2010).
[10] This is a type of financial assistance in the UK used to help pay rent for those who are unemployed, on a low income, or claiming benefits (Citizens Advice 2020).

of the UK (Boardman 2010), setting out individual country strategies and targets (Department of Trade and Industry 2001).

The Strategy adopted Boardman's 10 per cent definition of fuel poverty to frame the issue and set targets (Walker et al. 2013). However, apart from the simplicity of having a fixed 10 per cent threshold, it is unclear why this definition was used considering that it was based on data for 1988 and did not reflect fuel poverty at the time of the Strategy's publication (Boardman 2010; Liddell et al. 2012). In work conducted by Liddell and colleagues (2012), the authors found that the 10 per cent definition has not always represented the twice-median concept it was built upon and that there have been periods when this represented a threshold that was closer to three-times the median (Liddell et al. 2012). In fact, in 2001 when the 10 per cent definition was adopted into the Strategy, twice the median was 7 per cent of income BHC and remained at this level until 2006 (Walker et al. 2013). As such, using the 10 per cent definition grossly underestimated the prevalence of fuel poverty at the time.

As well as not always reflecting contemporary levels of fuel poverty, the 10 per cent definition has also been criticised for capturing wealthier households (Koh et al. 2012) and for not responding to variations in income or energy efficiency improvements, making it extremely sensitive to fuel price changes (Robinson et al. 2018) and, therefore, failing to reflect underlying problems (Hills 2012). Despite these issues, it remains one of two operational fuel poverty definitions in use today.

2.4.2 Hills' Low Income High Costs indicator

The drawbacks associated with the 10 per cent definition triggered discussions about its suitability to measure fuel poverty in the UK and in 2011, the UK Government commissioned an independent review of fuel poverty to develop a new measure that could offer greater clarity on the numbers and types of households in fuel poverty to enable a better focus of available resources (Hills 2012). This review was conducted by Professor John Hills of the London School of Economics. Hills developed the *Low Income High Costs* (LIHC) indicator, which defines fuel poor households as having "required fuel costs that are above the median level and were they to spend that amount they would be left with a residual income below the official poverty line" (Hills 2012, p.9). This reflects the nub of the issue more closely in that it describes the impact of disproportionate fuel bills on lower income households and is more consistent with WHECA (Moore 2012). Furthermore, unlike the 10 per cent definition, the LIHC indicator is, essentially, a twin indicator (Hills 2012). As well as capturing the extent of fuel poverty, it also incorporates the *fuel poverty gap*, which represents the "amounts by which the assessed energy needs of fuel poor households exceed the threshold for reasonable costs" (Hills 2012 p.9), providing an indication of the depth of fuel poverty, which the 10 per cent definition is unable to do (Hills 2012).

In contrast to the 10 per cent definition that uses full income, the LIHC indicator is based on an *after housing costs* (AHC) measure of income. Housing costs are not disposable income and are earmarked for an essential expenditure and so it makes sense not to include them. However, removing housing costs alters the types of households classified as fuel poor, an issue that will be looked at later in section 2.7. The LIHC indicator also equivalises income and fuel costs (Hills 2012). *Equivalisation* essentially increases the incomes and fuel bills of single-person households and decreases them for larger households with the aim of making them comparable (Boardman 2010; Hills 2012; Office for National Statistics (ONS) 2015a; BEIS 2020b) and reflects the fact that larger households typically need higher incomes and have higher fuel requirements than smaller households to have the same standard of living (Moore 2012). The equivalisation factors used for income and fuel are presented and described in Chapter 4.

2.5 Fuel poverty trends in the UK

As fuel poverty is a devolved responsibility, each country within the UK has its own fuel poverty definition, targets, and policies for tackling fuel poverty (BEIS 2019a). At the time of writing, the 10 per cent definition – or variants of it – are used in Scotland[11], Wales, and Northern Ireland. However, England now uses the LIHC indicator after moving away from the 10 per cent definition in 2013[12]. Under both the 10 per cent indicator and the LIHC indicator, national estimates of fuel poverty are produced using a modelling procedure to determine the *need to spend* or *required* fuel costs. This is described in more detail in sections 2.8 and 2.9. These definitions are underpinned by different underlying methodological assumptions (BEIS 2019a), which, as a consequence, makes statistics produced by each country non-comparable and hence, official estimates of fuel poverty are not summed for the whole of the UK.

In Figure 2.1 overleaf, the rates of fuel poverty in each of the UK nations are presented over a 10-year period. These rates are at the household level, which is how official statistics on fuel poverty are presented (see DECC 2014a; BEIS 2020a, for example).

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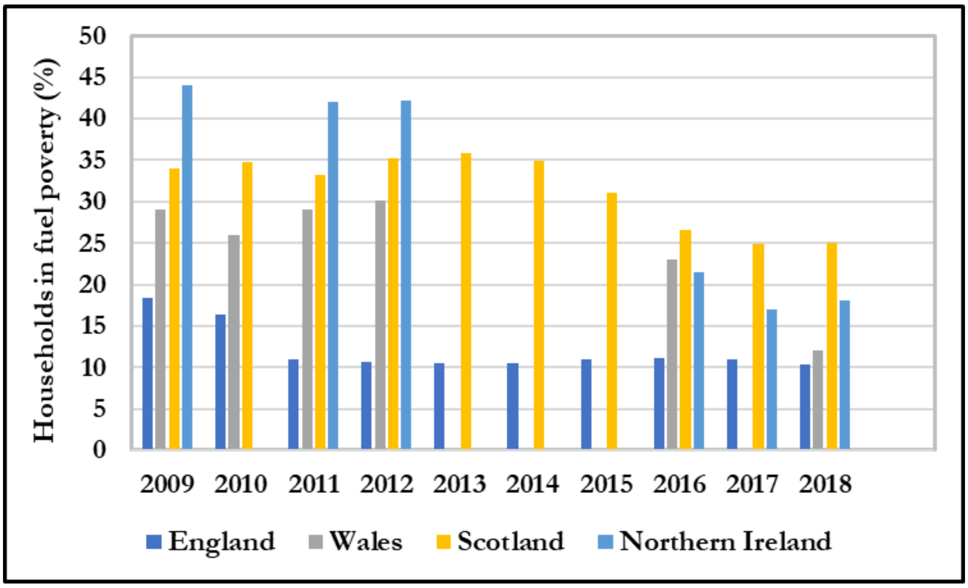
[11] In 2018, the Scottish Government introduced a new definition of fuel poverty, which states that "required fuel costs must be more than 10 per cent of household net income after deducting housing costs and the remaining household net income after the payment of fuel costs and childcare costs (if any) must also be sufficient to maintain an acceptable standard of living for the household" (Scottish Government 2018b, p.2) defined as 90 per cent of the Minimum Income Standard.

[12] After consultation, the LIHC was replaced by the Low Income Low Energy Efficiency indicator in 2021. Under this metric, households who live in a dwelling with an energy efficiency of D or below and whose income is left below the official poverty line after paying for their required fuel bills are considered fuel poor (BEIS 2021).

Figure 2.1: *Rates of fuel poverty in the UK: 2009 – 2018*[13]



Sources: DECC 2011; DECC 2012; DECC 2013a; DECC 2014a; DECC 2015b; BEIS 2017a; Welsh Government 2017; BEIS 2018a; Scottish Government 2019; Welsh Government 2019; BEIS 2020a

Overall, Figure 2.1 shows a steady decline in the rates of fuel poverty in each of the UK nations. However, it is important to note that, from 2013, fuel poverty estimates for England are presented under the LIHC indicator. As fuel poverty estimates are produced from data that are already two years old (Boardman 2010), the first estimate of fuel poverty under the LIHC indicator for England is shown for 2011 and is linked to a substantial fall in the rates of fuel poverty, from 16.4 per cent in 2010 to 11.7 per cent in 2011 (DECC 2013a). For Northern Ireland, the significant fall in rates from 42.0 per cent in 2012 to 22.0 per cent in 2016 is attributed to decreases in the cost of oil (Northern Ireland Housing Executive 2017), which – as will be detailed later – has been one of the key drivers of fuel poverty in Northern Ireland.

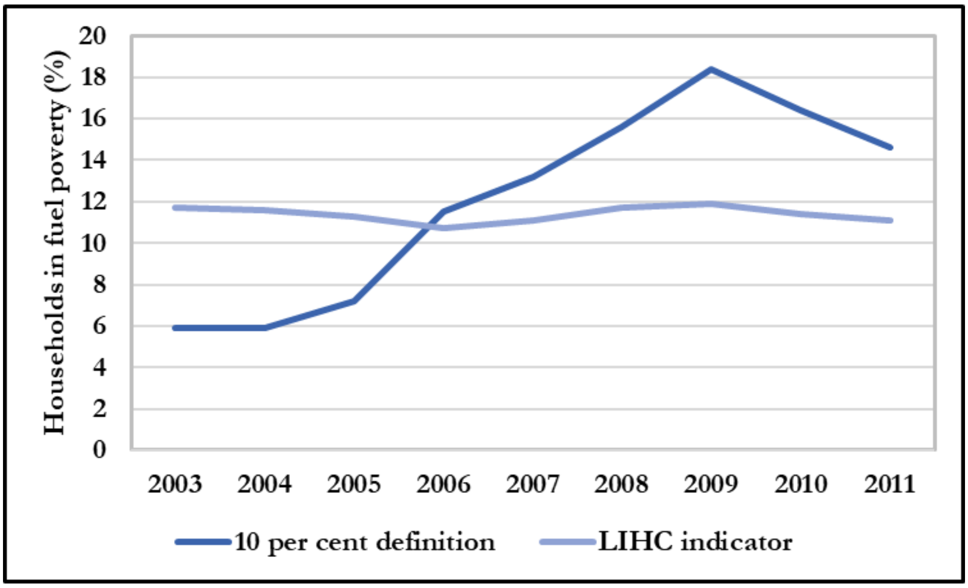
2.5.1 A closer look at the impact of changing fuel poverty definitions

To illustrate the impact of different definitions on the rates of fuel poverty, Figure 2.2 overleaf presents the trends in fuel poverty in England over a nine-year period, from 2003 to 2011. These are the years for which a comparison of fuel poverty rates under the two

[13] Note that not all nations, i.e. Wales and Northern Ireland, produce fuel poverty estimates every year.

definitions of fuel poverty was available at the time of writing and this is presented simply to show how different definitions can change the rates of fuel poverty.

Figure 2.2: *A comparison of fuel poverty rates in England under the 10 per cent definition and the LIHC indicator, 2003 – 2011*



Source: DECC 2013b

Most striking in Figure 2.2 is the stability of fuel poverty under the LIHC indicator compared to fuel poverty under the 10 per cent indicator. This characteristic of the LIHC indicator has received some criticism (Moore 2012; Middlemiss 2016), with Middlemiss (2016, p.11) stating that this "fits with the new problematisation of fuel poverty as a condition which cannot be eradicated". Furthermore, although the 10 per cent definition has been criticised for being *too* sensitive to rising fuel costs, it is of great concern that the LIHC indicator appears to overlook this altogether, masking the affordability of fuel (Walker et al. 2013). It also poorly reflects energy efficiency improvements and the fuel costs of low-income housing (Moore 2012). Moreover, unlike the 10 per cent definition, the LIHC indicator captures fewer high-income households (Middlemiss 2016) and does not capture households who are not fuel poor, but it does fail to capture some who may be experiencing fuel poverty by excluding low-income and single-person households with below average fuel bills (Moore 2012; Middlemiss and Gillard 2014).

2.6 The three main drivers of fuel poverty

It is widely accepted that fuel poverty, regardless of the definition used, manifests as a consequence of three main interacting drivers: a low household income, an energy inefficient home, and the cost of fuel (Boardman 2010; BEIS 2020b). These are often described in isolation from each other, overlooking their connections and neglecting the wider societal events and political decisions that may further bolster these drivers and worsen their outcomes. The following subsections describe each of the drivers and draw links between them, outlining how they are affected by the current-day context.

2.6.1 Driver 1: A low household income

The relationship between a low household income and fuel poverty is relatively uncomplex: it impedes the ability to convert financial resources into energy services that are sufficient for needs. Indeed, there is an evident income gradient in fuel poverty (Palmer et al. 2008; Boardman 2010; Hills 2012; Balfour and Allen 2014), whereby the poorest households are disproportionately represented in the fuel poverty statistics (DECC 2015b; BEIS 2020a). This driver has been magnified by recent changes in welfare support, such as the introduction of Universal Credit (Snell et al. 2014), for example, which has led to long periods in between receipt of income (Brewer et al. 2019). This has contributed to a subsequent rise in referrals to food and fuel banks, increases in energy debt and other types of debt (Drake 2017), and difficulties in topping up prepayment meters (PPMs) (Vyas 2014).

As well as affecting the ability to afford adequate energy services, a low household income can also shape fuel consumption patterns through the adoption of negative, and sometimes dangerous, coping strategies, such as rationing fuel (Gibbons and Singler 2008; Anderson et al. 2010; Boardman 2010; O'Sullivan et al. 2017) and self-disconnection[14] as a way of keeping fuel bills affordable and avoiding debt (Brunner et al. 2012; Mould and Baker

[14] This refers to not topping up the PPM and, as a result, the gas and/or the electricity supply is interrupted (Mummery and Reilly 2010).

2017; Snell et al. 2018). These coping strategies and others, as well as their consequences, are explored further in Chapter 3.

2.6.2 Driver 2: The energy efficiency of the home

As fuel poverty predominantly affects the poorest households in society (Boardman 2010), there has been much debate about whether fuel poverty is simply a symptom of income poverty or whether it is a distinct issue (Boardman 2010; Hills 2012; Watson and Maitre 2015). This is, of course, important from a policy perspective as understanding the characteristics of the issue drive appropriate and effective policy responses (Middlemiss 2016).

There are three important points that disentangle fuel poverty from income poverty. Firstly, despite the strong relationship between a low income and fuel poverty, not all low-income households are fuel poor (Boardman 2010; DECC 2014a), and low income does not explain the "prevalence and patterning" of fuel poverty (Walker and Day 2012, p.70). This suggests that it is not the presence of low income alone that results in fuel poverty, but that there are other contributing factors. Secondly, fuel poverty is specific to the household's existing home, unlike income poverty (Moore 2012), which moves with the occupants. Thirdly, in terms of solutions, income poverty can be eliminated through an increase in household income, but increasing the income of a fuel poor household would only alleviate fuel poverty amongst some, but not eradicate it (Boardman 2010). This is because fuel poverty is believed to be fundamentally linked to the energy efficiency of the home, i.e. how well the home uses energy and retains heat (Boardman 2010; Howden-Chapman et al. 2012). This is the crux of the fuel poverty problem and capital investment in improving the energy efficiency of the dwelling is where its most effective and sustainable solution lies (Boardman 1991; Boardman 2010; Emden et al. 2018), further underscoring its distinctness from income poverty.

2.6.2.1 Measuring the energy efficiency of a dwelling

To assess the energy efficiency of dwellings in the UK, the Government uses the Standard Assessment Procedure (SAP) methodology, which estimates the cost of fuel associated with space and water heating, fixed lighting, and ventilation minus cost savings from energy-generating technologies based on standardised assumptions for occupancy and behaviour (Building Research Establishment (BRE) 2014)[15]. These costs are estimated using the BRE Domestic Energy Model (BREDEM), a methodology for calculating the energy consumption of dwellings based on their characteristics (Henderson and Hart 2013), considering factors such as the thermal efficiency of the building's fabric, the efficiency of the heating systems, and the fuels used for space and water heating, lighting and ventilation (BRE 2014).

SAP scores range from 1 to 100, with higher numbers indicating better energy efficiency and, therefore, lower running costs. These scores are then translated into an Energy Performance Certificate (EPC), which grades SAP scores from A (the most energy efficient) to G (the least energy efficient) (Energy Saving Trust 2019). However, SAP does not consider any costs associated with appliances, such as washing machines and fridges, cooking, or any moveable lighting (Boardman 2010; DECC 2015a), essentially excluding energy-related activities that are not specific to the dwelling (Boardman 2010). This could, therefore, overlook differences in the energy needs and required energy usage of different households, which could underestimate required fuel costs.

Fuel poverty is concentrated in households living in the least energy efficient homes (Stockton and Campbell 2011; DECC 2015a). According to DECC (2015b), approximately 50 per cent of the fuel poor live in dwellings with an EPC of E, F, or G (the three lowest energy efficiency bands). Although the energy efficiency of dwellings has improved over time (BEIS 2018a), vast differences still remain between dwellings in urban and rural areas and between tenures. A brief insight into reasons for these differences is provided in the following two subsections.

[15] A detailed description of the Standard Assessment Procedure methodology is provided by BRE (2014).

2.6.2.2 Differences in energy efficiency between urban and rural dwellings

Rural areas have a higher proportion of older, larger, and detached homes (Ministry of Housing Communities & Local Government 2018), all of which are characteristics related to lower energy efficiency (Baker et al. 2008; Boardman 2010). Their construction also varies, with rural dwellings more likely to be solid-walled, in contrast to urban areas where cavity-walled dwellings are more prevalent (Baker et al. 2008; Roberts et al. 2015). This makes dwellings in rural areas less thermally efficient and more difficult to insulate, earning them the labels of "hard to heat" and "hard to treat" (Baker et al. 2008). Furthermore, there also appears to be a low uptake of energy efficiency improvement schemes in rural areas (Baker et al. 2008) and this has been linked to a lack of information and appropriate improvement measures for these types of dwellings (Baker et al. 2008), as well as poor targeting of schemes (National Assembly for Wales n.d.). Additionally, unlike urban dwellings, rural dwellings are more likely to not be connected to the gas network, which decreases their energy efficiency rating and increases their fuel costs. Further implications of not being connected to the gas network are detailed in section 2.6.3.1.

2.6.2.3 The impact of tenure on energy efficiency

The least energy efficient dwellings are concentrated in the private rented sector (Emden et al. 2018), where tenants have the highest required fuel costs but some of the lowest levels of income (Stockton and Campbell 2011), increasing their risk of fuel poverty. In contrast, dwellings in the social housing sector are, on average, the most energy efficient compared to all other tenures (BEIS 2019a), protecting those on the lowest incomes from fuel poverty (Stockton and Campbell 2011).

With house prices having become less affordable over the past 10 years or so (Lewis 2019), there has been an increase in the number of households living in the private rented sector. According to analysis conducted by the ONS (2019a), 2.8 million households were living in the private rented sector in 2007, but by 2017, this had increased by 63 per cent, to 4.5 million households. This shift has been accompanied by an increase in both the age of the renter and the length of tenancy. However, despite changing needs for those in the private rented sector, the energy efficiency of dwellings within this tenure has increased more slowly. This is linked to a variety of reasons. For landlords, this includes a lack of financial incentives to improve the energy efficiency of the home. Given that the private rented sector houses some of the lowest income households (Stockton and Campbell 2011; ONS 2017a), landlords know that they may not be able to regain the cost of energy efficiency improvements as tenants may be unwilling to pay more to live in an energy efficient property (Ambrose and McCarthy 2019). Tenants, on the other hand, may not be aware of solutions to improve the energy efficiency of their home or may feel less empowered to make these changes (BEIS 2017b). There may be challenges around obtaining the landlord's approval (Chesshire Lehmann Fund 2016) and tenants may be fearful of rent increases following improvements (Ambrose et al. 2016).

In April 2018, the Minimum Energy Efficiency Standard was introduced in England and Wales. This requires private landlords looking to rent out a property with an EPC rating of F and G (the two lowest EPC bands) to improve this to a minimum of an EPC rating of E within a budget of £3,500. This can come from the landlord's own funds, from third-party funding, or from a combination of both (BEIS 2017c). However, landlords can register for an exemption if they show that the property cannot reach this rating within this budget, meaning that properties with the lowest EPC ratings can still be made available to rent. Although achieving an EPC rating of E is a highly welcomed improvement, the risk of fuel poverty remains high within this rating (Emden et al. 2018).

2.6.3 Driver 3: The cost of fuel

As well as a low household income and the energy efficiency of the home, the ability to afford adequate energy services is dependent on the cost of fuel. As fuel costs rise, the capability of lower income households to afford adequate energy services decreases. This was highlighted by the 1973 oil crisis outlined earlier in section 2.1, but also later between 2004 and 2007, where rises in fuel costs doubled the number of households in fuel poverty under the 10 per cent definition, from two million to four million (Bolton 2010). However, of particular importance here, are the inequalities in the price paid for fuel by different groups

(Walker and Day 2012), with the income poor often paying more for their fuel than they should be (Boardman 2010). This driver encompasses several aspects of disadvantage, which can further help to understand some of the underlying complexities of fuel poverty. These can be broadly categorised as follows: fuel type and differences in their costs, the method of fuel payment, and barriers to switching energy suppliers or tariffs. These are outlined in turn in the following three subsections.

2.6.3.1 Fuel type and differences in their costs

Gas is known to be the most economical of the domestic fuels (Wright 2004). However, not all dwellings are connected to the gas network and so are reliant on other types of fuel for heating, such as electricity, oil, and solid fuel, which are more expensive (Boardman 2010; Preston et al. 2014). This partially explains the higher rates of fuel poverty in rural areas, where a higher proportion of households are not connected to the gas network (Baker et al. 2008; Preston et al. 2014). Similarly, in Northern Ireland, where there is a lack of widespread mains gas infrastructure (Committee on Climate Change 2019), almost 70 per cent of households use oil for heating – the highest percentage in Western Europe – and this corresponds to Northern Ireland, until recently, having the highest rates of fuel poverty within the UK (Bryson Energy 2018)[16].

2.6.3.2 The method of fuel payment

There are three main methods by which households can pay for their fuel: PPM, standard credit (i.e. using cash or cheque to pay fuel bills), and Direct Debit (DD) (Boardman 2010; BEIS 2019a). However, there are variations in the unit cost of fuel associated with these methods, with the highest costs typically linked to PPMs and the lowest to DD (Boardman 2010; Hills 2012; Ofgem 2020a). These variations are reflected in differences in the rates of fuel poverty. In a report by Ofgem, the government regulator for gas and electricity markets

[16] Until 2012, 42 per cent of households in Northern Ireland were considered fuel poor, but a focus on improving domestic energy efficiency since 2011 and lower than average fuel prices, particularly for oil, has reduced fuel poverty rates in Northern Ireland to 22 per cent (Northern Ireland Housing Executive 2017; BEIS 2019a).

in Great Britain, it was estimated that 19 per cent of customers using PPMs were fuel poor in England, compared to 16 per cent of customers paying by standard credit and 7 per cent using DD (Ofgem 2014). However, fuel costs between PPMs and cheaper alternatives have narrowed, helped by the *Safeguard Tariff*[17], and this has led to those using standard credit to pay for their energy use now most likely to be fuel poor (BEIS 2020a). However, the Safeguard Tariff is not permanent, but has recently been extended until 2025 (Ofgem 2020b).

Despite the traditionally higher fuel costs associated with PPMs, this method of fuel payment can sometimes be preferred by those on a low income as it allows households to control their fuel expenditure (Boardman 2010; Middlemiss and Gillard 2015) and avoid the worry of an unpredictable bill or of going into debt (Centre for Sustainable Energy 2013). This is because usage is paid for in advance and only a small amount of emergency credit is provided before the meter needs to be topped up again (Boardman 2010; Centre for Sustainable Energy 2013). There is also evidence that demonstrates concern related to using DD to pay for fuel, which is exacerbated by a lack of trust in energy companies to manage these payments without over-charging (Tod et al. 2012). However, not using DD may also reflect financial exclusion amongst lower income households, such as the lack of a bank account (Collard 2001; Boardman 2010). According to estimates provided by the Department for Work & Pensions (DWP) (2015), compared to 97 per cent of the highest income households, only 86 per cent of the lowest income households have a current account. This means that their options for paying for fuel may be limited and they may not be able to benefit from the cheaper tariffs available to those able who pay by DD (Allmark and Tod 2013). Given the limited tariff offerings for those on PPMs (Boardman 2010; Competitions & Markets Authority 2016) and disengagement with the energy market (Lomax and Wedderburn 2009), the fuel poor may be locked into a perpetual cycle of high fuel bills that consume a disproportionate amount of their income, leaving limited resources for other essentials.

[17] The Safeguard Tariff caps the price of each unit of energy used so that those on PPMs do not overpay for their energy use (Ofgem 2018).

2.6.3.3 Barriers to switching energy supplier or tariff

To further understand the inequalities that exist in fuel costs between households, it is important to give some attention to the impact of switching energy supplier or energy tariff. This can offer reductions on fuel bills, having the ability to alleviate – or reduce the depth of – fuel poverty. However, a report by BEIS (2017c) found that only 24 per cent of households with a higher likelihood of fuel poverty[18] had ever switched energy supplier compared to 39 per cent of households with a low likelihood of fuel poverty. This was reflected in differences in knowledge about switching, with 22 per cent of higher likelihood households having no knowledge of how to switch energy suppliers, compared to 14 per cent of low likelihood households.

The switching process is often hindered by the complexity of choice, with energy companies offering a wide range of diverse tariffs, which can make choosing the tariff most appropriate for household needs more difficult (Boardman 2010; DECC 2014b; He and Reiner 2015). Furthermore, the cheapest tariffs are usually only available online and through payment by DD (Davies et al. 2016). However, to access these, there is a need for internet connection and IT literacy, as well as a bank account. This highlights aspects of the digital divide and financial exclusion, respectively, which are prevalent amongst low-income households (Finlay 2013; Davies et al. 2016), older people, those with disabilities (Low Incomes Tax Reform Group 2012), and those belonging to minority ethnic groups (Kempson and Whyley 1999), marginalising these households in the energy market.

Given the widespread distrust that has been expressed between low-income households and energy companies (Day and Hitchings 2009; Lomax and Wedderburn 2009; Anderson et al. 2010), this may trigger anxiety about switching and worry about being left worse off (Anderson et al. 2010), and there has to be strong evidence that sufficiently large financial savings can be made for switching to be considered (DECC 2014b). Furthermore, a report prepared for Ofgem found that the least frequent switchers were older people, those

[18] The likelihood of fuel poverty was assessed using a scoring system that considered income (after housing costs), the presence of children under 16 and adults aged 65 and over, the age of the property, tenure, the presence of a boiler, the method of payment for electricity, the number of bedrooms, and the main fuel used to heat the property (BEIS 2017c, p.8).

belonging to minority ethnic groups, and those living in rented accommodation (Ipsos MORI 2013). In addition to this, those with energy debts, which are common amongst the fuel poor (Lomax and Wedderburn 2009), may not be able to switch energy suppliers or tariffs after a certain level of debt (Middlemiss 2016). This suggests that those who may benefit most from switching energy supplier or tariff often face the most barriers to be able to do so.

2.6.4 Additional drivers of fuel poverty

Beyond the three main drivers of fuel poverty discussed in earlier subsections, it is important to acknowledge other factors that may contribute to – and increase the vulnerability of – a household experiencing fuel poverty. Kearns and colleagues (2019) suggested that occupant behaviour be considered a fourth driver of fuel poverty[19]. This was not the first study of its kind, but earlier studies had focused on the behaviour of householders following energy efficiency upgrades and, in particular, focused on those who remained in fuel poverty following their installation (see Mould and Baker 2017, for example). However, there is a danger that adding occupant behaviour to the fuel poverty drivers could shift the blame and responsibility for fuel poverty away from governments and energy suppliers to those living in fuel poverty or at risk of becoming fuel poor. Furthermore, in doing so, this neglects the importance of influencing factors that have a role beyond occupant behaviour within the home. This includes, for example, the provision of support and advice for using new technologies or operating new heating systems, and guidance on switching energy suppliers as a way of reducing fuel bills.

There is also the issue of those with high energy requirements. This includes those with a disability or a longstanding illness who may be on low incomes, but may have a greater physiological need for warmth to preserve health, or who may need to power specialised equipment (Snell et al. 2015). This issue of high energy requirements also concerns those living in under-occupied dwellings – a property with one or more spare

[19] The authors considered *Housing and use of the home, Heating/energy arrangements & thermal comfort, Household structure and dynamics, Household finances,* and *Social activity and relations* and considered their impact on the following three aspects: *Interest in energy efficiency & conservation, Use of energy,* and *Ability to manage and pay energy bills* (Kearns et al. 2019, p.1145).

bedrooms (Robinson et al. 2018). This issue particularly affects owner-occupiers and pensioner households (Hills 2012), typically those who are living in the old family home (Boardman 2010) and whose incomes may be too limited to afford sufficient energy services for the size of the dwelling. As will be seen later in section 2.10.1, modelling heating costs considers under-occupation of the dwelling, however, the "solution" is far from problem-free.

A final point to be made here is the pressing issue of climate change. Despite the UK having a relatively mild climate, it is predicted that winters will become harsher and that summers will become warmer, with an increased likelihood of more frequent extreme weather events (Levin 2017). This may make fuel poverty equally relevant in cold and warmer weather, which may require a change in how fuel poverty is viewed within the UK context and how it is responded to – from a predominant focus on keeping warm in cold weather to being able to keep cool in warmer temperatures. This has already gained some attention in other European contexts (see Thomson et al. 2019).

2.7 The characteristics of the fuel poor: the effect of changing definitions

Despite sharing the same key drivers, i.e. a low household income, an energy inefficient home, and high fuel costs (Boardman 2010; BEIS 2020a), the differing components of the 10 per cent definition and the LIHC indicator have not only led to changing rates of fuel poverty, as observed in Figures 2.1 and 2.2, but they have also impacted on the characteristics of people that are most likely to be fuel poor. In particular, this is linked to the use of different measures of income in the 10 per cent definition and the LIHC indicator, and the equivalisation of both income and fuel costs within the LIHC indicator, which leads to the generation of two contrasting images of the fuel poor.

The use of unequivalised full income in the 10 per cent definition makes this metric biased towards those who are outright owners (Boardman 2010) and single-person households, the majority of whom are aged 60 years or over (Liddell et al. 2011; Moore 2012). This, in turn, skews fuel poverty under the 10 per cent definition towards rural areas, where there is a greater proportion of older households (Department for Environment Food & Rural Affairs (Defra) 2019a), where dwellings tend to be larger and less energy efficient, and where fuel costs are generally higher due to the use of oil and liquid petroleum gas for heating (Baker et al. 2008; Boardman 2010; Roberts et al. 2015).

In contrast to the 10 per cent definition, the LIHC indicator uses an AHC measure of income and equivalises both income and fuel costs. The inclusion of housing costs in income inflates the incomes of those living in areas where housing costs are higher (Fahmy et al. 2011) and so by removing them under the LIHC indicator, households who have a higher house price to earnings ratio are captured (Robinson et al. 2018). This inadvertently transfers the highest rates of fuel poverty from outright owners to those in the private rented sector (Moore 2012). This brings with it changes to the age structure of those considered fuel poor, given that younger households are most likely to live in the private rented sector. This change in tenure also affects the spatial distribution of fuel poverty, from rural areas under the 10 per cent definition to inner cities under the LIHC indicator, where private rented properties are concentrated (Robinson et al. 2018; ONS 2019a). The LIHC indicator also equivalises both incomes and fuel costs as noted in section 2.4.2, reflecting how larger households require more energy, but have less disposable income compared to smaller households (Robinson et al. 2018). As such, the highest rates of fuel poverty under the LIHC indicator are amongst larger households and those containing children. As larger households are more common in urban areas (Fahmy et al. 2011), fuel poverty under the LIHC indicator disproportionately affects urban households (Robinson et al. 2018), contrasting again with the predominantly rural nature of fuel poverty under the 10 per cent indicator (Boardman 2010).

This comparison of the two fuel poverty definitions currently used within the UK demonstrates that different components within fuel poverty indicators not only change the types of households defined as fuel poor, but also impact on the spatial distribution of fuel poverty (Fahmy et al. 2011; Robinson et al. 2018). These differences between the fuel poor under different definitions may complicate policy development as they provide contrasting profiles of the fuel poor, their dwellings, and their locations, which makes it difficult to design appropriate and effective policy responses.

2.8 The health consequences of living in fuel poverty

Fuel poverty is an important public health issue (O'Neill et al. 2006) and it is now recognised as a considerable source of health and social inequalities (Balfour and Allen 2014) with a wide range of negative effects on the home and those living within it. Given the deep-rooted understanding of fuel poverty as inadequate warmth, the literature displays a predominant focus on the effects of cold and damp living conditions and the ways in which these can impair health (Wilkinson 1999; Somerville et al. 2000; Shaw 2004; Liddell and Morris 2010; Marmot Review Team 2011). Cold homes, in particular, have been linked to an increase in morbidity and mortality (Marmot Review Team 2011; National Institute for Health and Care Excellence 2015) with associated costs to healthcare services of approximately £1.36 billion a year in England (Age UK 2012), over £100 million a year in Wales (End Fuel Poverty Coalition 2016), up to £80 million a year in Scotland (Archard et al. 2014), and around £30 million a year in Northern Ireland (McAvoy 2007).

Living in a cold home is associated with a higher likelihood of cerebro- and cardio-vascular events (Department of Trade and Industry 2001; Wilkinson et al. 2001; Department of Health 2007), an increased risk of respiratory infections, and an increase in the severity and frequency of asthma-associated symptoms in children and adults due to the presence of damp and mould caused by inadequate heating (Strachan 1988; Pirhonen et al. 1996; Williamson et al. 1997; Somerville et al. 2000; Department of Trade and Industry 2001; Collins 2005). Cold homes may also increase the risk of injury and falls through the effect that low temperatures can have on dexterity (Department of Health 2007). Furthermore, cold homes have been associated with low weight gain in infants (Liddell and Morris 2010), with increases in hospital admission rates in both children and adults (Rudge and Gilchrist 2005; Liddell and Morris 2010), with delays in discharge from hospital (Guertler and Smith 2018), and with increases in recovery time following hospital discharge (Burrows et al. 2003).

As well as the effects on physical health, living in a cold home has been associated with negative impacts on mental health, such as anxiety and depression (Marmot Review Team 2011; Liddell and Guiney 2015). This may be due to persistent worry about high fuel bills and falling into debt (Gilbertson et al. 2006; O'Neill et al. 2006; Anderson et al. 2010;

Hernández 2016), thermal discomfort (Evans 2000; Ormandy and Ezratty 2015), the impacts that cold and damp can have on health and on the appearance of the home (Harris et al. 2010), and feeling a lack of control over the home (Shenassa et al. 2007).

2.8.1 Cold homes and excess winter deaths

At its most extreme, living in a cold home can be fatal. The World Health Organization (WHO) (2007) has estimated that around 40 per cent of excess winter deaths[20] (EWD) are caused by living in a cold home, with the Marmot Review Team (2011) estimating that EWD is almost three times higher in the coldest quarter of housing compared to the warmest quarter of housing. Notably, data has highlighted that some of the coldest countries in Europe, such as those in Scandinavia, have much lower rates of EWD compared to warmer countries, such as Spain and Portugal (Healy 2003). This has been partially attributed to differences in the housing stock where there is a lack of protection from the cold indoors, particularly in countries that experience warmer summers (Healy 2003).

Despite the high number of EWD every winter, this appears to be met with acceptance. Shockingly, out of the estimated 50,100 EWD in the winter of 2017/18 – the highest number on record since the winter of 1975/76 – around 15,000 were thought to be caused by living in a cold home (National Energy Action 2018c). These high rates of EWD coincided with two periods of unusually cold weather (the "Beast from the East" and the "Pest from the West"), which occurred in quick succession in the first quarter of 2018, further highlighting how the fuel poor are unable to protect themselves from cold weather shocks[21].

2.9 Modelling fuel poverty: a brief overview

Estimates of fuel poverty are produced using a modelling procedure that considers income, energy prices, and energy requirements (BEIS 2020b, p.7), with several data sources used to compute this information. The data sources vary across the UK, and so to simplify this

[20] Defined as the number of winter deaths minus the average of non-winter deaths. Following the method used by the ONS, the winter period is defined as December to March, and the non-winter period as the preceding August to November and the following April to July (ONS 2019b).
[21] However, the "Pest from the West" covered part of April and so deaths within this period would have been reported in statistics for excess summer deaths and, as a result, have not been linked to fuel poverty.

overview, only the modelling procedure used in England for fuel poverty under the LIHC indicator will be described here.

One of the principal data sources used for modelling fuel poverty in England is the EHS. This is a national survey that gathers information on the housing conditions and energy efficiency of dwellings in England (Ministry of Housing Communities & Local Government 2020) as well as information on income and details needed to estimate energy requirements, which includes the size of the property; the number of people in the household; the energy efficiency of the dwelling; the types of fuels used; and the economic status of the occupants, such as whether they are employed or retired (BEIS 2020b). The EHS collects this information in two ways. Firstly, a household interview with around 13,300 households covers questions on the household composition, the economic status of occupants, the household income, and the method(s) used to pay for gas and electricity. Secondly, a physical survey of dwellings is conducted in a subset of the interviewed households (around 6,000), where details are collected on the number and types of rooms, the types of heating systems in place, and the approximate age of the property (BEIS 2020b; Ministry of Housing Communities & Local Government 2020). However, the EHS does not collect information on the energy supplier or energy tariff of the households (BEIS 2020b), which could contribute to significant variations in fuel costs given that some households may be on a costly tariff that could tip them into fuel poverty.

With information collected from the EHS, annual *required* energy needs are calculated using BREDEM[22], which uses standards of energy service to estimate space heating and hot water requirements, and typical consumption in England to estimate other energy uses (i.e. for lighting, cooking, fans and pumps, and all other appliances used in the home) (Simcock and Walker 2015; BEIS 2020b). These energy requirements are then

[22] Although both being based on BREDEM, the calculation of energy consumption for SAP and energy requirements for fuel poverty estimates vary in several ways. These differences are highlighted by Boardman (2010, p.28).

translated into *required* costs using a range of fuel price data sources[23] and these costs are then deducted from income, which is modelled from data collected through the EHS, to determine whether a household's required fuel costs and income reaches the thresholds necessary to be classified as fuel poor. However, income is inclusive of benefits associated with disability, which may exaggerate the incomes of those in receipt of disability benefits (Parckar 2008). These are specifically to help with the costs associated with disability and should not be considered part of disposable income. This could, therefore, potentially underestimate the rates of fuel poverty in households containing disabled people (Snell et al. 2015). Full details of this procedure are provided by BEIS (2020b).

2.10 Modelling required fuel costs: Overcoming the limitations of using actual fuel expenditure?

As mentioned in sections 2.3.1 and 2.3.2, *required* fuel costs are central to the definitions of fuel poverty (Hirsch et al. 2011) and are considered to be more meaningful than using *actual* fuel expenditure, which has traditionally been viewed as a poor indicator of fuel poverty. This is because actual fuel expenditure may overlook those who are under-spending or intentionally rationing (Hirsch et al. 2011; Moore 2012; Thomson 2013) and who may, therefore, have very low fuel expenditures because they are living at low temperatures (Hills 2011). Furthermore, it can also capture those who may be over-spending through preference or wastefulness (Hills 2011). This could result in inaccurate estimates of the number of households in fuel poverty (Thomson 2013). However, required fuel costs provide an indication of a household's capabilities and are unaffected by decisions made by the household, which can be altered by individual tastes and priorities (Hirsch et al. 2011), such as choosing to keep the home warmer or cooler than recommended temperature thresholds (Koh et al. 2012), or by households who may be wasteful (Hills 2011).

[23] These data sources include the *Quarterly Energy Prices* publication for annual fuel prices for mains gas and electricity; the *Sutherland Tables* provides fuel price data for liquefied petroleum gas and bottled gas; the *Consumer Price Index* for heating oil and smokeless fuel; and SAP 2012 for rarer fuels, such as biofuels and communal heating, and rarer tariffs such as economy 10 and 24 electricity tariffs (BEIS 2020b).

In the following subsections, the methodology for modelling costs associated with heating and non-heating energy uses are described. As variations occur within each nation of the UK[24], for simplicity, only the methodology used in England – which is detailed fully by BEIS (2020b) – is referred to.

2.10.1 Estimating space heating requirements: A focus on heating regimes and temperature thresholds

The required costs associated with space heating are estimated based on meeting defined standards of energy service, which are represented through heating regimes (Simcock and Walker 2015). These regimes consider the number of hours for which heating is required and the temperatures that should be achieved in different rooms to ensure a healthy living environment (Simcock and Walker 2015). Households are matched with a heating regime that best represents whether the dwelling is occupied during the day and whether the dwelling is under-occupied[25]. This information is gathered through the household survey of the EHS. There are four different heating regimes that differ based on dwelling occupation during the day and under-occupation. These are tabulated overleaf.

[24] For example, different datasets are used to model fuel requirements. Wales uses the *National Survey for Wales* and the *Welsh Housing Conditions Survey*; Scotland uses the *Scottish House Condition Survey*: and Northern Ireland uses the *Northern Ireland House Condition Survey* (Royston 2014).

[25] In the context of modelling fuel poverty, under-occupation refers to having both surplus bedrooms and surplus floor area. “Surplus bedrooms” is defined as one or more extra bedrooms than required for homes without dependent children (under 18 years), or two or more extra bedrooms than required for homes with dependent children. “Surplus floor area” is defined by the Parker Morris Standard, which provides required standard living areas (m^2) for the number of occupants (BEIS 2020b).

Table 2.1: *Details of the four heating regimes applied in modelling heating costs*

	Details of STANDARD heating regime
Heating pattern	Weekday: 9 hours of heating Weekend: 16 hours of heating
Heating extent	Whole house
Demand temperature	Primary living zone: 21˚C Secondary living zone: 18˚C
	Details of FULL heating regime
Heating pattern	Weekday: 16 hours of heating Weekend: 16 hours of heating
Heating extent	Whole house
Demand temperature	Primary living zone: 21˚C Secondary living zone: 18˚C
	Details of PARTIAL STANDARD heating regime
Heating pattern	Weekday: 9 hours of heating Weekend: 16 hours of heating
Heating extent	Half house
Demand temperature	Primary living zone: 21˚C Secondary living zone: 18˚C
	Details of PARTIAL FULL heating regime
Heating pattern	Weekday: 16 hours of heating Weekend: 16 hours of heating
Heating extent	Half house
Demand temperature	Primary living zone: 21˚C Secondary living zone: 18˚C

Source: BEIS 2020b, pp.51–52

The standard heating regime is based on the assumption that the dwelling is not occupied during normal working hours and so is heated for two hours in the morning and seven hours from the late afternoon, and 16 hours a day on the weekend. However, the EHS asks a direct question on whether the dwelling is occupied in the morning or afternoon, and for those that are, such as older households and households containing those caring for young children for example, this standard heating pattern does not apply. Instead, a full heating regime of 16 hours of heating are assumed during the day as well as on weekends (BEIS 2020b).

For under-occupied dwellings, a “half-house” or “partial” regime is applied, where it is assumed that only some of the rooms are heated. Within this partial heating regime, a standard or full heating regime is applied based on occupation of the dwelling during the day (BEIS 2020b). This partial approach is not considered in the modelling procedure in Scotland upon the basis that this could lead to cold spots in the home, which could encourage the development of damp, condensation, and mould, and, therefore, could lead to poor respiratory health (Moore 2012; Scottish Government 2017). This could partially explain the higher rates of fuel poverty in Scotland observed in Figure 2.1.

Estimating the required energy needs of each heating regime is conducted using BREDEM, which takes into account information regarding the heating systems, home insulation, dwelling construction and materials, and geographic location, which is collected through the EHS (Simcock and Walker 2015; BEIS 2020b). The required energy needs are then converted to annual required energy costs using several data sources (see footnote 23) depending on the fuel types used within the home.

2.10.1.1 Temperature thresholds in modelling space heating requirements

The consideration of temperature is of obvious importance in modelling fuel costs associated with space heating given the health consequences associated with living in a cold home, which were discussed in section 2.8. For both the 10 per cent definition and the LIHC indicator, modelled energy requirements are based on the assumption that the main living space is heated to 21˚C and that all other occupied rooms are heated to 18˚C (Boardman 2010; Hills 2012), a range that is considered to be a *satisfactory heating regime* (BEIS 2020b). In Scotland, however, a wider temperature band is recommended, with 23˚C in the main living area for households with individuals aged 60 and over or with someone with a longstanding illness or disability (Scottish Government 2018a). This, again, could partly explain why fuel poverty rates in Scotland have recently been the highest in the UK (see Figure 2.1).

The origins of the temperature thresholds behind this satisfactory heating regime can be traced back to a WHO report in which it was stated that “no demonstrable risk to the health of healthy sedentary people” was found between 18°C to 24°C (WHO 1987, p.19). 21°C appears to be a selected midpoint between this range (Hills 2012, p.28) and has been recognised as the *comfort zone* for many people in the European Union (WHO 1987). However, although there is substantial evidence to support a minimum of 18°C, with temperatures below this shown to have negative effects on health (Neild et al. 1994; Shiue and Shiue 2014), there is no evidence to suggest that higher temperatures have any beneficial effects. In a systematic review conducted by Jevons and colleagues (2016), it was concluded that a minimum threshold of 18˚C in all rooms would be sufficient to protect health, but they found no evidence to support a higher temperature threshold of 21˚C in living rooms, with concerns about excessive energy use if implemented by the whole population. However, the authors recognised that older people and certain vulnerable groups, such as children and those with chronic diseases, may be more physiologically vulnerable to low temperatures and be less able to adapt their behaviours to keep themselves warm, and so they acknowledged that slightly higher temperatures may be needed for these groups.

In work by Todd and Steele (2006), it was found that these heating regimes were insensitive to cultural differences in the use of the dwelling, which could lead to inaccurate estimates of required heating. The authors found that, in contrast to White householders who tend to use one room as their main living area, Black and Minority Ethnic householders tend to use two rooms in their home as the main living area, which are heated to a higher temperature (Todd and Steele 2006). This suggests that heating regimes may not reflect how households use and heat their homes, and that thermal comfort (a subjective evaluation) may not be experienced within the recommended range of temperatures.

2.10.2 Estimating costs associated with non-heating fuel requirements

Similar to estimating space heating requirements, hot water requirements are derived through a standard of energy service approach. To calculate the energy costs associated with the use of hot water, BREDEM estimates this based on patterns of typical actual hot water usage in England, taking into account the number of occupants in the household. However, this does not consider the additional needs of those who have a disability or a longstanding illness, which may be associated with greater laundry requirements (Snell et al. 2015), or that some religious practices require more washing (Todd and Steele 2006) and therefore may underestimate these costs.

In contrast to the relatively strict assumptions underlying the standards of energy service guiding the estimation of required space heating and the usage of hot water, estimating the costs associated with lighting, cooking, pumps and fans, and all other appliances used in the home is based on the average consumption in English households, which is computed from the Energy Follow-up Survey[26] (Simcock and Walker 2015) and calculated using BREDEM. Although consideration is given to dwelling and household characteristics, such as floor area for lighting, and household size to account for higher energy requirements of larger households, no consideration is given to different patterns of being home during the day (Simcock and Walker 2015), nor to the energy efficiency of different technologies and appliances used within the home (Simcock and Walker 2015). Moreover, this may overlook the higher energy needs of certain groups, such as those with disabilities or a longstanding illness who may need to power specialised equipment (Snell et al. 2015), and minority ethnic groups who tend to value traditional cooking practices and typically spend more time cooking compared to White ethnic groups (Lawrence et al. 2007). Taking the average consumption of these energy uses in English households overlooks some factors that could lead to an underestimation of required energy and its associated costs and could potentially lead to misestimating the number of households in fuel poverty.

In drawing attention to some of the criticisms surrounding the modelling of fuel costs, such as the lack of tariff information and not accounting for the higher energy needs of some groups, such as those with disabilities or those belonging to minority ethnic groups, it is of interest to take a closer look at the differences between modelled fuel costs and actual fuel expenditure. This is the focus of the next section.

2.11 Modelled vs. actual fuel expenditure: a look at the evidence

Within the *Annual Fuel Poverty Statistics* reports produced by DECC until 2015 and later by BEIS, a comparison is made between actual and modelled fuel expenditure, using actual fuel expenditure data collected through the *Living Costs and Food Survey* (LCFS) and required

[26] This is a survey conducted with a subset of households who were part of the EHS to gather information on domestic energy use to improve modelling procedures and to better inform policy (Hulme et al. 2013)

fuel expenditure data from the *Fuel Poverty Datasets*, which are compiled using data collected through the EHS. In analysis conducted using these data sources for 2012 and presented in DECC's 2014 report (DECC 2014a), it was found that households across all income deciles were spending less than modelled estimates, suggesting that "the heating regimes applied in the fuel poverty model are likely to be aspirational rather than a reflection of actual use" (DECC 2014a, p.73). When compared to households in the highest income decile, who were spending 3 per cent less than their modelled estimates, households in the lowest income decile were spending 33 per cent less (DECC 2014a). However, it is difficult to disentangle whether this is linked to rationing warmth and other energy services or whether this under-spending is linked to limitations in the modelling procedure (DECC 2014a).

In the following year's *Annual Fuel Poverty Statistics* report, the same comparison was presented using data for 2013. This comparison incorporated a change in the methodology used to gather information on domestic fuel expenditure in the LCFS. From 2013, rather than respondents recording fuel expenditure in their expenditure diaries, this information was collected through the household questionnaire, where bills and statements are referred to wherever possible (ONS 2018a). This resulted in significant increases in reported expenditure for both gas and electricity (DECC 2015a). These increases were most pronounced in households using PPMs and, as this method of payment is most prevalent amongst lower income households (Waddams Price et al. 2012; DECC 2015a), this is where the greatest change was observed (DECC 2015a). This comparison is presented in Table 2.2 overleaf.

Table 2.2: *Actual vs. modelled household annual spend on fuel, 2013, England*

Income decile group	Average actual annual expenditure on fuel (£)	Modelled average annual spend on fuel (£)	Percentage difference (actual - modelled)
1st (lowest)	1,050	1,092	-4%
2nd	1,170	1,104	+6%
3rd	1,212	1,205	+1%
4th	1,248	1,241	+1%
5th	1,331	1,328	0%
6th	1,357	1,334	+2%
7th	1,430	1,423	+1%
8th	1,472	1,495	-2%
9th	1,607	1,501	+7%
10th (highest)	1,934	1,727	+12%
All households	**1,378**	**1,345**	**+2%**

Source: DECC 2015a, p.82

Table 2.2 shows that, overall, there is a much closer alignment between actual and modelled fuel costs compared to the analysis using 2012 data, with households in the lowest income decile spending 4 per cent lower than modelled estimates. This is a vast difference from the earlier comparison of 2012 data, where households in the lowest income decile were spending 33 per cent less than their modelled expenditure. It is also noted that those in the highest income decile are spending above their modelled fuel costs by the highest margin (12 per cent). Again, this may highlight limitations in the modelling procedure, or it may indicate that households within this decile are heating their homes to higher temperatures or for longer periods than those recommended within the modelling guidelines (DECC 2015a).

2.12 The persistence of fuel poverty: a brief look at policy and why it has failed

Although Figure 2.1 shows that fuel poverty levels have seen an overall decline within UK nations[27], it is far from being eradicated. Since targets to eradicate fuel poverty were introduced through the first Fuel Poverty Strategy in 2001, there has been a consistent failure

[27] In England, this has occurred through changing the definition of fuel poverty from the 10 per cent definition to the LIHC indicator (Middlemiss 2016). In Northern Ireland, this is partly attributed to a change in the price of heating oil (BEIS 2019a).

to meet these. As a consequence, there are still households who continue to struggle to afford adequate fuel for their needs, and the consistently high number of EWD attributed to cold homes each year reflects the fact that some households are unable to cushion the costs of higher fuel needs in cold weather, highlighting the consequences of inadequate past and present policies.

At present, there is a range of policies aimed at tackling fuel poverty within the UK. These attempt to diminish the effect of high fuel bills by increasing income (the *Winter Fuel Payment*, the *Warm Homes Discount*, and the *Cold Weather Payment*, for example), and increasing the energy efficiency of the home, such as through the *Energy Company Obligation* (ECO). In the following two subsections, a critique of policy responses to fuel poverty is offered, focusing on some of the reasons why policies have failed to eradicate fuel poverty, drawing on two key areas that hamper the intentions of policy: the inadequacies of current policies (with a specific focus on ECO) and the issue of mistargeting.

2.12.1 The inadequacies of current policies: A focus on the Energy Company Obligation

The examples of current policy that have been stated on the previous page demonstrate various strands of assistance that attempt to tackle fuel poverty. This is, of course, a positive step forward as it shows recognition of the issue and acknowledges its complexity. However, no current policies are likely to eradicate fuel poverty as they offer either temporary solutions (such as financial help towards fuel bills), or they offer to increase the energy efficiency of the home (such as the ECO), but may not increase it to a sufficient level to remove a household from fuel poverty.

Take, for example, the ECO – a government energy efficiency scheme that obliges larger energy providers to help low-income households improve the energy efficiency of their home through the installation of a new boiler or improvements in insulation (Ofgem 2019; Hinson and Bolton 2020). This is currently in its third phase (ECO3) and has narrowed its focus to assisting only the fuel poor, vulnerable households, and low-income households (BEIS 2018b). Although this greater focus on the fuel poor is welcomed, ECO3's budget has been cut by 40 per cent, to £640 million (Energy Saving Trust 2017), potentially underestimating the widespread issue of fuel poverty and limiting its reach. As a consequence of this, the Committee for Fuel Poverty (an Advisory Non-Departmental Public Body sponsored by BEIS) has estimated a current funding gap of £15.1 billion for reaching fuel poverty targets under current policy (UK Parliament 2019).

Those eligible for assistance through ECO3 are identified through certain means-tested benefits and non-means-tested disability-related benefits, with additional conditions attached to some of these (BEIS 2018b). For properties in the social housing sector, ECO3 funding is available for all properties with an EPC rating of E and below, regardless of the tenant's benefit eligibility. However, assistance is limited to insulation measures and first-time central heating system installation meaning that, although the EPC rating of a dwelling may increase, the increase may not be sufficient to remove a household from fuel poverty. Furthermore, even if eligibility criteria are fulfilled, the energy supplier can still decide to not install measures (Hinson and Bolton 2020), and energy companies have strict and short time spans for delivering on these outputs. This could lead to rushed and poor quality work, where meeting targets – rather than helping the household – becomes the driver for accomplishment (House of Commons 2019).

2.12.2 The mistargeting of fuel poverty policy

Accurately identifying the fuel poor on the doorstep when offering energy efficiency measures is an extremely difficult task (Boardman 2010). It requires a wide range of detailed information on financial circumstances and expenditure on fuel (Boardman 2010). This is not always available and the non-response rates for this type of information, especially for income, can be quite high (Burholt and Windle 2006). Furthermore, some households may not be spending to the required thresholds to be classified as fuel poor, despite experiencing certain aspects of fuel poverty, such as rationing fuel (Harrington et al. 2005; Anderson et al. 2010) or curbing essential expenditures to afford adequate fuel (Anderson et al. 2010). Because of factors such as these, those delivering policy – such as local authorities, for example – use fuel poverty proxies to identify the fuel poor (Hills 2012). The most commonly used proxy is whether a household is in receipt of a means-tested benefit (The

Energy and Climate Change Committee 2010). However, this identifies whether a household is eligible for free energy efficiency improvements, but not whether they are in fuel poverty (Boardman 2010) and this blurs the distinction between the fuel poor and income poor.

In analysis by the Department for Business Enterprise & Regulatory Reform (2008), under the 10 per cent definition using full (or BHC) income, only 58 per cent of the fuel poor are in receipt of a means-tested benefit, which increases to 71 per cent when using basic (or AHC) income. Under the LIHC indicator, which is based on equivalised income AHC, only 62 per cent of the fuel poor are in receipt of a means-tested benefit (Hills 2012, p.83). This highlights a mismatch between the official definitions of fuel poverty and eligibility for assistance (Boardman 2010). This becomes further complicated by the large number of households not claiming the benefits they are eligible for due to the stigma attached to claiming (Baumberg 2015; Longhurst and Hargreaves 2019) or to low levels of awareness and perceived ineligibility, for example (Radford et al. 2012; Finn and Goodship 2014). These factors appear to be most pronounced amongst certain groups of the population who may also have a higher vulnerability to fuel poverty, such as those with disabilities (Finn and Goodship 2014) or those belonging to minority ethnic groups (Allmark et al. 2010). These factors may also impact on the ability to self-identify as fuel poor, which may lead to missing out on other forms of fuel poverty assistance, such as advice on switching energy suppliers or benefit entitlement checks, for example.

The *Winter Fuel Payment* (WFP) is thought to be one of the most poorly-targeted fuel poverty focused benefits (Boardman 2010). It was introduced in 1997, at around the same time that fuel poverty was officially recognised (Boardman 2010). Older people comprised – as they still do – the majority of EWD (ONS 2019b), and so this was introduced as a way of protecting older people against the effects of cold weather. It is an unconditional cash transfer to households with a member above the female state pension age regardless of income or the energy efficiency of the home (Crossley and Zilio 2017). Given the increasing number of people falling into this eligibility criteria due to rises in the ageing population, the WFP has become one of the most expensive benefits, with over £2 billion spent on this benefit every year (Boardman 2010; Thurley and Kennedy 2018). However, only 12 per cent of recipients are thought to be fuel poor (Thurley and Kennedy 2018).

In spite of this apparent mistargeting, time series analysis conducted by Iparraguirre (2014) found that almost half of the reduction in EWD observed in 2000/2001 was attributable to the WFP. Furthermore, work by Crossley and Zilio (2017) found that the WFP raised fuel expenditure, specifically gas expenditure, in eligible households and this resulted in reductions in disease markers, specifically for circulatory and respiratory illness, potentially protecting health and preventing EWD in these households. However, neither of these studies expanded on the mechanisms by which these results may have occurred and neither explored whether the WFP had an impact on internal temperatures. As such, it is not clear whether WFP recipients were able to heat their homes to higher temperatures or for longer periods of time, which may have offered a partial explanation for lower levels of EWD and disease markers. However, Beatty and colleagues (2014b) found that only 47 per cent of the WFP is spent on fuel and so there may be other types of expenditures that may contribute to improved health outcomes, such as purchasing higher quality food, being able to buy warmer clothing, or participating in more social activities.

These studies suggest that, although the WFP appears to be poorly targeted at the fuel poor under a specific definition, this could be linked to some of the limitations in modelling fuel poverty that were identified in section 2.10. These limitations include the additional energy needs that come with a longstanding illness or disability, both of which become more prevalent in older age (Office for Disability Issues and DWP 2014), the low levels of switching amongst the older population (Finlay 2013), which may mean higher than necessary fuel bills, and the use of the “half-house” heating regime, which may be difficult to implement in reality.

2.13 Chapter summary and conclusions

This chapter has focused on some of the core aspects necessary for understanding the breadth of fuel poverty in the context of the UK. It began by looking at how fuel poverty is defined under the 10 per cent definition and the LIHC indicator and how rates of fuel poverty are altered by changing definitions. The chapter has also detailed the role of the three main drivers of fuel poverty, with low income affecting the ability to purchase energy services that are adequate for the household; the energy efficiency of the home, which influences the cost of bills; and the cost of fuel, which impacts on its affordability.

The chapter then moved on to focus on how the different components within the two official fuel poverty definitions impact on the characteristics of the fuel poor. Particular attention was given to the income measures and equivalisation of both income and fuel costs used within the LIHC indicator, which shifted the focus of fuel poverty from older, and single-person households in rural areas under the 10 per cent definition, to younger, and larger households in urban areas under the LIHC indicator. This provided two contrasting images of the fuel poor, which can have implications for appropriate policy development.

A brief focus was then given to the health consequences of living in fuel poverty, where the impact of living in a cold home on physical and mental health was described. These preventable impacts are associated with high costs to healthcare services and can be fatal. Following this, an account of the way that fuel poverty is modelled was provided, drawing attention to its limitations, particularly for those who have additional needs due to disability or a longstanding illness, and for those belonging to minority ethnic groups whose energy needs may not always match those assumed in the modelling methodology. The chapter also compared modelled fuel expenditure with actual fuel expenditure, the latter of which has consistently been viewed as a poor indicator of fuel poverty. In making this comparison considering changes to the way that fuel expenditure is collected in the LCFS, it was found that the two were closely aligned, but that the poorest households had the largest margin of under-spending compared to modelled estimates, although this margin was small at 4 per cent.

In the final section of the chapter, focus was given to policies that are currently in place with the aim of eradicating fuel poverty. This covered the inadequacy of policy with a focus on ECO3 and the mistargeting of policy with particular attention given to the WFP, which was suggested to be partly linked to limitations in the modelling procedure. Some of the barriers that fuel poor households may face in accessing policy measures, such as not fulfilling the eligibility criteria due to not claiming the necessary benefits, were also addressed.

In the chapter that follows, a conceptual framework is provided that offers a detailed account of how fuel poverty can be experienced beyond a cold home and the ways that households cope, which may change how they experience fuel poverty and which may lead to other forms of disadvantage.

Chapter 3| The links between fuel poverty and other forms of disadvantage: a conceptual framework

3.1 Introduction

Thus far, and in part as a reflection of the prevalent literature in the field, the thesis has lent a predominant focus to fuel poverty as a cold home and the ensuing physical and mental health effects of prolonged exposure to this. This is, without question, an important element in the fuel poverty discourse, particularly given that these health impacts are preventable, placing unnecessary and avoidable pressures on healthcare, social care, and aftercare services (Balfour and Allen 2014), not to mention the potential effects on more immediate networks, such as family and friends. However, focusing on this common understanding of fuel poverty neglects integral aspects of the concept and, by doing so, restricts the understanding of the experience of fuel poverty to this unidimensional relationship between a cold home and poor health.

Over the past 15 years or so, more attention has been awarded to the ways that households can experience fuel poverty. For example, qualitative exploration of the *lived experience* of the fuel poor has helped to expose the realities of these households, enriching knowledge of how fuel poverty can be experienced beyond a cold home (see Anderson et al. 2010 and Brunner et al. 2012, for example). This area of the literature has revealed that those experiencing fuel poverty are not passive, but instead find ways of adapting to circumstances through ways of coping, which can influence how fuel poverty is experienced (Harrington et al. 2005; Anderson et al. 2010; Brunner et al. 2012; Middlemiss and Gillard 2015). This has helped to shed light on some of the wider impacts of fuel poverty, with evidence suggesting that fuel poverty and ways of coping with it can present other forms of disadvantage in fuel poor households (Harrington et al. 2005; Anderson et al. 2010; Cotter et al. 2012; Lambie-Mumford et al. 2015).

3.2 Purpose of the chapter

In contrast to the previous chapter, which provided an overview of fuel poverty, drawing attention to the causes and consequences of fuel poverty together with current policy attempts to eradicate it, this chapter offers a more detailed account of the experiences of the fuel poor, narrowing the focus of the literature to that which has driven the research direction of the thesis.

In pulling together a wide range of qualitative and quantitative studies, this chapter lays out a thematically structured conceptual framework, presenting the literature that supports links between fuel poverty and other forms of disadvantage. To develop this framework, a more complete understanding of fuel poverty is taken by focusing on the literature that explores fuel poverty not only as a cold home, but also as deprivation of other energy services in the home, such as lighting, cooking, and the use of hot water, as incorporated in the current fuel poverty definitions (Boardman 1991; Boardman 2010; Hills 2012). By considering these other elements of fuel poverty, this allows us to piece together a much broader account of the ways that fuel poverty may be experienced and how attempts to cope with it can – inadvertently – lead to the manifestation of other forms of disadvantage in fuel poor households.

3.3 From coping with fuel poverty to experiencing other forms of disadvantage

In a review of the literature concerning the ways that households adapt to fuel poverty, Gibbons and Singler (2008) found that fuel poor households typically use coping strategies that fall into three broad areas: (1) rationing fuel; (2) financial measures; and (3) debt incurrence (Gibbons and Singler 2008, p.17). Knowledge of these strategies had emerged earlier (Richardson 1978), but only more recently have they been examined more closely. It is important to note that ways of coping may often not fit neatly into one strategy or another, but that fuel poor households may simultaneously adopt multiple ways of coping, which may change with priorities and preferences (Harrington et al. 2005; Middlemiss and Gillard 2015). However, these three areas are used to thematically structure the literature and to highlight the ways that these methods of coping with fuel poverty can provide evidence of the experience of other forms of disadvantage.

3.3.1 Strategy 1: Coping with fuel poverty through rationing fuel

Rationing fuel is the first coping strategy offered by Gibbons and Singler (2008) and is one of the most widely acknowledged coping strategies of the fuel poor in the literature (Anderson et al. 2010; Brunner et al. 2012; Lambie-Mumford et al. 2015). This strategy is often deployed as a response to how household finances are perceived and is viewed as a way of gaining control of expenditure (Lomax and Wedderburn 2009; Anderson et al. 2010; Boardman 2010) and avoiding high fuel bills and (further) fuel debt (Boardman 2010; Radcliffe 2010). Within this strategy, different typologies of rationing have been identified. Rationing warmth is by far the most dominant theme within this area, reflecting the most common understanding of fuel poverty as a cold home (Lewis 1982; Bradshaw and Harris 1983; Boardman 1991; Department of Trade and Industry 2001), and because heating typically comprises the largest proportion of a household's fuel bill (Hills 2011; Jones et al. 2016), this is potentially where there is the greatest scope for savings on fuel bills to be made. However, aside from rationing warmth, fuel poor households have also been found to cut back on other types of fuel services, such as lighting and hot water (O'Neill et al. 2006; Day and Hitchings 2009; Brunner et al. 2012; Longhurst and Hargreaves 2019). The following subsections collate the literature that sheds light on the different ways that fuel poor households ration fuel and the implications associated with these.

3.3.1.1 Rationing warmth and alternative ways of keeping warm

Rationing warmth is predominantly linked to the financial burden that fuel costs can place on the incomes of the fuel poor (Lomax and Wedderburn 2009; Anderson et al. 2010). On this point, and before embarking on this strand of the literature further, it is important to highlight a distinction that is made within the literature regarding the reasons for rationing warmth. Some studies, particularly those focused on older people, have linked rationing warmth to a sense of thriftiness and to a belief that a cooler home is better for health, rather than to financial need (see Wright 2004, for example). This distinction is important as the drivers of coping mechanisms and the impacts these can have on health – particularly on mental health – may be different (Wright 2004). Only the literature that focuses on those who ration warmth as a way of coping with fuel poverty is of focus here.

Several studies have identified that fuel poor households often adopt a frugal heating regime as a way of keeping fuel bills low (Harrington et al. 2005; Anderson et al. 2010; Chard and Walker 2016). For example, using a mixed methods approach, Anderson and colleagues (2010) explored the experience of fuel poverty within low-income households, i.e. those whose incomes fell below 60 per cent of the UK median equivalised household income (BHC). Through the qualitative branch of the study, in-depth interviews revealed that 79 per cent of respondents found their fuel bills in the previous winter had been a financial burden, 42 per cent of whom stated that they had been a heavy financial burden (Anderson et al. 2010). Of this 42 per cent, over half of the households were paying for fuel using PPMs (54 per cent) and contained someone with a disability or a limiting long-term illness (53 per cent), reinforcing the impact of higher fuel costs associated with PPMs and the additional energy needs of those who may be living with a disability or a longstanding illness that was noted in the previous chapter.

In response to the burden of fuel bills, Anderson and colleagues (2010) found that rationing warmth was a dominant coping strategy and that it was employed in several ways. Central heating was turned off for periods of the day and in some cases was not used at all, with alternative ways of keeping warm being sought, such as using single room heaters, which are often more costly to use as they are less energy efficient than central heating (Anderson et al. 2010). Not being able to heat the home adequately was shown to lead to impacts on the respondents' social lives, with 26 per cent of respondents not feeling able to invite friends and family into the home. This finding has also emerged elsewhere (Department of Trade and Industry 2001; Harrington et al. 2005; Grey et al. 2017b) and Harrington and colleagues (2005) have linked this to notions of social acceptability, with a warm home viewed as providing a more welcoming environment to visitors.

As well as having negative impacts on health, rationing warmth can have detrimental effects on the home. It can lead to the development of condensation, damp, and mould (Healy and Clinch 2004; Lomax and Wedderburn 2009; De Haro and Koslowski 2013), which have been linked to householders experiencing aspects of social isolation and feelings of loneliness triggered by shame and embarrassment (Packer et al. 1994; Anderson et al. 2010; Cotter et al. 2012; Ormandy and Ezratty 2015). Cold homes may also hinder socialisation outside of the home as householders may feel reluctant to leave their homes in cold or rainy weather for fear of returning to a cold home (Department of Trade and Industry 2001), or if the place they are visiting is not going to be warm enough (Chesshire Lehmann Fund 2016).

Within this subset of the literature, studies have highlighted how contrasting approaches to rationing warmth occur in households and how this can vary by the age of householders and household type. For older people who tend to spend more time at home and where there is a higher prevalence of longstanding illness and disability (Office for Disability Issues and DWP 2014; ONS 2016a), adequate heating becomes more important and there is a stronger reluctance to ration this (Harrington et al. 2005; Chard and Walker 2016) and instead other ways of keeping warm may be sought. In contrast, for families with young children, the heating is kept off during the day as a way of reserving it for when the children are at home (Harrington et al. 2005; Anderson et al. 2010; Doble 2010; Adam and Monaghan 2016), suggesting that there is less scope to ration this and that there may be a higher risk of debt incurrence in these households (Harrington et al. 2005). This demonstrates how the same coping strategy can be applied in unique ways, and how it can lead to different outcomes.

For fuel poor households who ration heating, alternative ways of keeping warm are often sought. This can occur in two main ways which, for the purpose of this chapter, are termed *internal* and *external* warmth-seeking strategies. These refer to the types of warmth-seeking behaviours that occur within (internal) and outside (external) of the home.

<u>Internal warmth-seeking strategies and links with other forms of disadvantage</u>

Taking internal warmth-seeking strategies to begin with, the literature presents a wide range of ways that allow householders to keep warm when rationing heating. One such way is by heating only some rooms in the home (Harrington et al. 2005; Shortt and Rugkåsa 2007; Grey et al. 2017b). This is known as *spatial shrinkage*, where householders reduce the effective living space of the home by closing off internal doors so that fewer rooms are occupied and heated in colder months (McAvoy 2007; Farrell et al. 2008). This allows for savings on fuel bills while still being able to keep warm. Although spatial shrinkage can draw families together and encourage social activities within the home (Harrington et al. 2005), it can also lead to overcrowding and the deterioration of familial relationships due to a lack of privacy (McAvoy 2007), which may evoke feelings of social isolation (Gilbertson et al. 2006; Liddell and Morris 2010). It may have a negative effect on inter-generational relationships, with a particularly negative impact on adolescents due to not being able to spend enough time alone (Kwak 2003) and this could lead to seeking privacy in places outside of the home, such as in shopping centres and parks (Liddell and Morris 2010). Furthermore, spatial shrinkage may also negatively impact on the educational attainment of children due to a lack of appropriate play and study conditions (Gilbertson et al. 2006; McAvoy 2007; Barnes et al. 2008), and may facilitate the transmission of respiratory infections, such as colds and influenza, which may increase time away from school.

Several studies have found that, when rationing heating, householders attempt to keep warm by wearing extra clothing indoors, including winter coats and hats (Harrington et al. 2005; Burholt and Windle 2006; Cotter et al. 2012; Tod et al. 2012; Middlemiss and Gillard 2015; Chard and Walker 2016; Longhurst and Hargreaves 2019), using blankets, duvets, and hot water bottles (Morgan et al. 1996; Day and Hitchings 2009; Anderson et al. 2010; Longhurst and Hargreaves 2019), consuming hot drinks throughout the day (Morgan et al. 1996; Harrington et al. 2005; Anderson et al. 2010; Cotter et al. 2012), and even jogging indoors (Morgan et al. 1996). Furthermore, those who find it difficult to keep warm at home have been found to adopt dangerous coping strategies, such as using unsafe and unserviced heating devices or ovens to keep warm (National Energy Action 2018c) and these ways of coping may emphasise the inability to provide a socially acceptable living environment. Householders have also been found to adjust normal behaviours or daily routines in a bid to keep warm when rationing heating. This can include going to bed early (Harrington et al.

2005; Day and Hitchings 2009; Chard and Walker 2016) or staying in bed for longer periods of the day to reduce the heating period (Brunner et al. 2012; Chard and Walker 2016). This has been found to limit the time available for socialising within the home (Harrington et al. 2005).

External warmth-seeking strategies and links with other forms of disadvantage

The literature also provides evidence to suggest that more time may be spent outside of the home (Anderson et al. 2010; Grey et al. 2017b), finding external sources of warmth as a way of avoiding high fuel bills and debt (Radcliffe 2010). In a survey conducted by National Energy Action (2018c) of frontline workers and through gathering wider feedback from stakeholders, it was found that those seeking warmth outside of the home spent more time in heated public places such as libraries, cafés, and even in Accident & Emergency departments.

Where warmth is sought outside of the home, it has been found that householders spend time in the homes of family and friends (Harrington et al. 2005; Anderson et al. 2010; Longhurst and Hargreaves 2019), and use local amenities, such as libraries and shopping centres, to keep warm whilst saving on energy costs at home (Middlemiss and Gillard 2014). Others have found that younger adults spend more time at work and students spend more time in university libraries rather than in cold homes (Petrova 2018a), and there is evidence to suggest that parents take their children to the shops for the day as a way of keeping them warm (Adam and Monaghan 2016). Although this may indicate a detachment from the home and may prevent social activities from taking place within the home, these external warmth-seeking strategies may provide opportunities for socialisation with family and friends in other environments.

3.3.1.2 Increasing the energy efficiency of the home: self-help attempts and efficiency strategies

Despite the availability of policies that aim to improve the energy efficiency of fuel poor homes, section 2.12 in the previous chapter emphasised the barriers that exist in accessing these measures, such as not being in receipt of benefits that evidence eligibility. Others have found that worry and anxiety about energy efficiency measures are common amongst those eligible (Emden et al. 2018) as well as concerns about the associated disruption of their installation (Armstrong et al. 2006). As such, the fuel poor often find alternative ways to increase the energy efficiency of their home as a way of curbing high fuel bills whilst keeping warm. These have been termed "self-help attempts" (Harrington et al. 2005, p.265) and "efficiency strategies" (Brunner et al. 2012, p.55) and encompass a wide range of measures.

In work by Harrington and colleagues (2005), the authors investigated the experience of and ways of coping with fuel poverty through the use of structured interviews. Fuel poor households were identified as those who needed to spend 7.5 per cent of their disposable income (after tax and housing costs) on fuel to keep their home adequately heated so that those living on the edge of fuel poverty – as defined by the 10 per cent definition – could be included. Householders within this study were found to be using a wide range of measures to improve insulation such as "hanging thick curtains over windows and doors, using blinds rather than net curtains, putting tape round windows to stop draughts, using draught excluders, covering windows with old towels" (Harrington et al. 2005, p.265) as well as spatial shrinkage.

The findings from Harrington and colleagues' (2005) work are not unique and similar outcomes have emerged elsewhere. For example, a qualitative study conducted by Brunner and colleagues (2012) in Austrian households whose income fell below the poverty line[28] or who were at risk of poverty, such as immigrants, single parents, and the long-term unemployed, found that interviewees (67 per cent of whom were spending more than 10 per cent of their income on domestic energy) used a range of measures to preserve indoor warmth, such as sealing leaky windows, using thick curtains, or installing blinds, with some interviewees sitting directly in front of the radiator to avoid the loss of heat. These findings, together with those from Harrington (2005), may reinforce evidence that fuel poor householders find it difficult to provide a socially acceptable living environment, which may

[28] This was identified based on EU Statistics on Income and Living Conditions income limits and is equivalent to €912 for single households (cited in Brunner et al. 2012, p.54).

further emphasise the reluctance to invite friends and family into the home, potentially contributing to feelings and experiences of social isolation.

3.3.1.3 Beyond heating: Rationing lighting, hot water, and other energy services

In the previous two chapters, it has been emphasised that fuel poverty does not only incorporate adequate space heating, but that it also encompasses the inability to afford adequate energy for lighting, water heating, cooking, and for running all appliances in the home (Boardman 2010; Thomson 2013; Jones et al. 2016). However, as identified by Simcock and colleagues (2016), there has been little attention centred on how energy services – other than heating – are affected in fuel poor households. Studies that have acknowledged these other elements of fuel poverty have provided a more comprehensive understanding of the ways in which households can be affected by fuel poverty, illuminating the myriad of ways that households use coping strategies and behaviours to alleviate fuel poverty beyond rationing warmth. This reinforces the fact that fuel poverty is not always experienced simply as a cold home.

Brunner and colleagues (2012) found that, as well as rationing heating, householders also reduced the use of lighting by not fitting light bulbs in every room and not equipping chandeliers with all the lightbulbs needed. In some instances, lighting was only used in one room (normally the main living room) as this was viewed to be sufficient for providing lighting for adjacent rooms. Furthermore, many households used the TV as the only source of lighting in the evening. Similarly, others have found that candles are used instead of lights (National Energy Action 2018c), that lights are not always switched on when necessary (O'Neill et al. 2006; Longhurst and Hargreaves 2019) and that they are turned off more often (Day and Hitchings 2009; Hernández and Bird 2010), endangering "the ability to participate in the customs that define membership of society" (Petrova 2018b, p.360).

From this wider exploration of fuel poverty beyond a cold home, it has been revealed that the consumption of hot water is limited (O'Neill et al. 2006; Longhurst and Hargreaves 2019) and that its temperature is lowered (Day and Hitchings 2009). It has also been documented that households experiencing fuel poverty may not wash their clothing and bedding as much as they would like, and may limit the use of the vacuum cleaner to clean their home (Harrington et al. 2005; Mummery and Reilly 2010). This may have negative implications for personal hygiene and household cleanliness, which may lead to anxiety and stress due to not feeling able to meet social standards and expectations (Longhurst and Hargreaves 2019). This may further hinder social activities taking place within the home and may impinge on wider social relations and social activities outside of the home.

3.3.1.4 Self-rationing and self-disconnection: the use of prepayment meters

As mentioned in Chapter 2 (see section 2.6.3.2), despite being associated with higher fuel costs (Boardman 2010; Hills 2012), PPMs are sometimes the preferred method of paying for fuel as they provide control over expenditure, particularly for households where budgeting is important (Boardman 2010; Middlemiss and Gillard 2015). However, there is increasing knowledge that fuel poor households who use PPMs to pay for their fuel self-ration or self-disconnect. There is a distinction between these two strategies: self-rationing refers to limiting energy use as a way of saving money, or restricting expenditure in other areas to be able to keep the PPM topped-up (Anderson et al. 2010; Mummery and Reilly 2010), whereas self-disconnection refers to not topping up the meter and as a result, the gas and/or the electricity supply is interrupted (Mummery and Reilly 2010). These strategies are used for various reasons, such as controlling expenditure (Brutscher 2012), reducing fuel bills, and avoiding falling into debt (Speak 2000; Anderson et al. 2010; Doble 2010; Mummery and Reilly 2010; Radcliffe 2010; Mould and Baker 2017; Snell et al. 2018).

Although self-rationing and self-disconnection offer some financial control, these strategies have a wide range of negative impacts. Not only do they prevent a household from heating their home adequately and consistently, but they can impact on the use of all appliances used in the home, which can have dire consequences. For example, interrupting the electricity supply may lead to the loss of food stored in refrigerators and freezers (O'Sullivan et al. 2011). It can also impact on food preparation and cooking (Vyas 2014), which may alter the types of foods purchased and consumed. Furthermore, self-rationing and self-disconnection may lead to a temporary lack of hot water (O'Sullivan et al. 2011; Vyas

2014), which may impact on personal hygiene and on the ability to wash clothes (Vyas 2014), potentially impacting on the ability and desire to socialise through not being able to meet social expectations (Longhurst and Hargreaves 2019).

Through the adoption of these coping strategies, householders may be left with no lighting, which can lead to safety issues within the home (Citizens Advice 2018). It may also affect leisure and lifestyle, discourage social activities within the home, and it may cut off connections to the outside world if appliances, such as the TV, cannot be used (Mummery and Reilly 2010). This can have a significant impact on the physical and mental wellbeing of the householders (Mummery and Reilly 2010).

3.3.2 Strategy 2: Financial measures: Cutting back on essential expenditures

A further group of coping strategies that was identified by Gibbons and Singler (2008) was that of financial measures, part of which concerned reducing expenditure on essential items as a way of juggling competing priorities. In some cases, this set of strategies stresses the notion of prioritising fuel use, where households forgo other essential items, such as food and clothing, in order to pay for warmth (Harrington et al. 2005; O'Neill et al. 2006; Day and Hitchings 2009; Cotter et al. 2012).

An area within this set of strategies that has received considerable attention has been the *heat or eat* trade-off. This is described as having to choose between heating or eating (Lambie-Mumford et al. 2015; Snell et al. 2018). However, the literature suggests that one is not completely forgone in place of another, but that this trade-off is nuanced. In qualitative work conducted by O'Neill and colleagues (2006), semi-structured interviews revealed how older women, aged between 61 and 84 years, viewed heating as essential for maintaining health, stating they would cut back on food expenditure as a way of ensuring adequate warmth. However, quantitative studies have shown that food expenditure is reduced when heating requirements increase. Bhattacharya and colleagues (2003) found that, amongst low-income American families, increases in fuel expenditure in winter led to decreases in food expenditure by similar amounts. This was associated with statistically significant decreases in calorie intakes, particularly in households with children, and this was linked to lower levels of dietary quality and increased prevalence rates of vitamin deficiencies amongst children and adults with children. Other quantitative studies have similarly revealed reductions in food expenditures in cold weather (Beatty et al. 2014a), as well as changes in the quality and quantity of food (Lambie-Mumford et al. 2015). However, these quantitative studies have not identified the fuel poor under a fuel poverty definition, but have instead focused only on shifts in fuel and food expenditure in low-income households (Bhattacharya et al. 2003; Beatty et al. 2014a), or have used consensual measures[29], such as the inability to keep the home sufficiently warm and damp-free (Lambie-Mumford et al. 2015).

It has also been found that heating and food are rationed simultaneously (Morgan et al. 1996; Lambie-Mumford et al. 2015), meaning that households can experience a cold home as well as an inadequate diet. Using a questionnaire survey, Morgan and colleagues (1996) investigated the impact of the addition of 8 per cent value added tax to fuel bills, which was added in April 1994 (Boardman 2010), amongst 200 older convalescent patients with a mean age of 82.2 years who had been admitted to hospital for, predominantly, respiratory and circulatory diseases. Before admission, almost a third (31 per cent) reduced their heating use in response to the addition of value added tax to fuel bills, with the majority of patients (64 per cent) unable to keep warm without experiencing financial hardship. This further builds on evidence detailed in the previous chapter, which suggests that households lack resilience to rising fuel costs (see section 2.6.3). Furthermore, the authors found that 29 per cent of patients had reduced expenditure on food before their admission to hospital in order to pay for fuel bills (Morgan et al. 1996), potentially highlighting aspects of a heat or eat trade-off and, therefore, food insecurity.

As well as the impact on food, fuel poverty has also been shown to have negative effects on other types of essential expenditures. Householders have been found to withdraw from social activities in order to concentrate constrained financial resources on ensuring adequate warmth in the home (Harrington et al. 2005; Anderson et al. 2010; Cotter et al. 2012; Grey et al. 2017b), with some evidence to suggest that friends and family may also be

[29] Consensual measures of fuel poverty refer to those that are self-reported assessments, such as living in a cold home and being able to pay utility bills on time (Rademaekers et al. 2016).

reluctant to visit a cold home (Grey et al. 2015a). This provides evidence of a bi-directional relationship between fuel poverty and social isolation: through not feeling comfortable welcoming visitors into the home, but also visitors feeling reluctant to visit a cold home.

There is also evidence of other types of expenditures being reduced as a result of prioritising energy bills to avoid falling into debt, including that related to holidays, furnishings, clothing, socialising, and transport (Bhattacharya et al. 2003; Harrington et al. 2005; McAvoy 2007; Anderson et al. 2010; Cotter et al. 2012; Royston 2014). As these expenditures are considered essential expenditures in society (Gordon et al. 2014), the curbing of these expenditures suggests the presence of material deprivation in fuel poor households. It has also been found that those living in cold homes cut back on buying school equipment and reduce expenditure on school trips (Jones et al. 2016), with possible implications for the educational attainment and socialisation of children.

3.3.3 Strategy 3: Debt incurrence

The final group of strategies for coping with fuel poverty identified by Gibbons and Singler (2008) that can help understand the wider effects of fuel poverty and how there may be a relationship with other types of disadvantage concerns the incurrence of debt.

Debt incurrence may occur when coping strategies are not, or cannot be, adopted and normal spending patterns take place (Kempson et al. 2004; Gibbons and Singler 2008). Although the literature has indicated that there is a strong aversion to debt amongst fuel poor households (Anderson et al. 2010), the evidence highlights a lack of resilience to debt accrual due to competing expenditures on low incomes (Harrington et al. 2005) and a lack of savings (Anderson et al. 2010), which could help to buffer the effects of high fuel costs. However, the presence of debt appears to vary between different household types, with households containing young children showing less aversion towards debt and a strong desire to keep the home warm to protect the health of the children (Harrington et al. 2005), while older households have expressed a dislike of debt and have been shown to cut back on other essential expenditures, such as socialising, to keep up with fuel bills (Day and Hitchings 2009).

Of particular focus in the fuel poverty literature is the issue of energy debt, which has been found to be a common issue amongst fuel poor households (Lomax and Wedderburn 2009). In a report by Williams and colleagues (2015), which focused on families with children, the authors explored the prevalence of energy debt and the reasons why households fell into energy debt. They found that 24 per cent of low-income households (with an income of £15,000 a year) had an energy debt, compared to 15 per cent for households earning above this threshold (Williams et al. 2015, p.9). They found that the primary reason that households fell into energy debt was due to increases in energy prices (53 per cent), again demonstrating the lack of financial resilience that households have towards rising fuel costs mentioned in the previous chapter (see section 2.6.3). This study also identified the various consequences associated with energy debt, with families that had had energy debt being less likely to be able to cook a hot meal every day, needing to cut back on food expenditure, having fewer holidays and family days out, and having to delay the purchase of new clothes and shoes for the family. These findings suggest that aspects of food insecurity and material deprivation may exist in these households.

There is also a strong link between energy debt and mental health problems (Barnardo's 2012), such as anxiety and depression (Mind 2008). In comparison to households who could easily pay their fuel bills, those who had difficulty in paying their fuel bills were four times more likely to suffer from anxiety, depression, or psychological distress, which have been found to have severe impacts on the ability to socialise (Threlfall 2011), again building on the many ways that fuel poverty can, directly and indirectly, contribute to social isolation.

As well as these mental health effects, there is also evidence that energy debt could affect physical health through the impacts it has on the affordability of food. For example, in qualitative analysis conducted by Lambie-Mumford and colleagues (2015), it was found that 34 per cent of households in energy debt could not afford to eat a meat or fish meal every second day, suggesting aspects of food insecurity, and that the greatest effect was observed amongst those who were repaying energy debt through the use of a PPM. This is the principal way of repaying energy debt, but it is also associated with the highest fuel costs and could therefore potentially worsen a household's fuel poverty status (Boardman 2010) and limit the availability of financial resources for other essentials.

Debt in fuel poor households is not restricted to energy debt, with studies evidencing other types of debt, such as credit cards, store cards, loans, and borrowing from family and friends to pay for energy bills and to pay off debts (Middlemiss and Gillard 2015; Williams et al. 2015; National Energy Action 2018c). The presence of debt has been found to contribute to social isolation by limiting the availability of finances for social activities, but also through the negative impact that debt can have on mental health and on relationships with family and friends (Mind 2008).

3.4 Identifying gaps in the research

In exploring the literature that has helped to develop this conceptual framework, fuel poverty and ways of coping with it has been linked with four key areas of disadvantage: food insecurity, social isolation, material deprivation, and poor educational attainment in children. However, throughout this chapter, the ways in which fuel poverty has been identified has been purposely emphasised to draw attention to the myriad of indicators used. This has included the use of proxies (i.e. a low income), consensual measures, such as living in a cold home and being able to keep the home damp-free (Anderson et al. 2010; Lambie-Mumford et al. 2015), and expenditure thresholds (Harrington et al. 2005; Brunner et al. 2012). Although the use of this wide range of indicators has helped to understand some of the intricacies of fuel poverty and has highlighted the different ways fuel poverty can be identified and experienced, a disconnect between objective and subjective assessments of fuel poverty has been found (Devalière et al. 2011; Waddams Price et al. 2012; Phimister et al. 2015) and, apart from a low income (Palmer et al. 2008; BEIS 2020a), there is only limited evidence on how some of these indicators align with official definitions of fuel poverty (Moore et al. 2012). This makes it difficult to compare findings, especially where indicators used are open to subjective interpretation, such as whether someone is able to heat their home adequately, which relies on a perceived level of comfort rather than recommended temperatures.

Moreover, some studies in this chapter have not identified fuel poverty by definition or by using objective or subjective assessments, but have simply explored shifts in expenditure between food and fuel amongst low-income households (Bhattacharya et al. 2003; Beatty et al. 2014a) and this may obscure the understanding of how fuel poverty may be linked to other forms of disadvantage. This critique of the studies lays the foundation for the first research gap, noting that there is no consistent understanding of fuel poverty that underpins the studies presented herein, which makes it difficult to understand whether all elements of fuel poverty and the different ways of identifying the fuel poor are consistently linked with other forms of disadvantage.

The second research gap draws on how qualitative studies predominate in this area and, although they have helped to understand the ways in which other forms of disadvantage may manifest in fuel poor households through the exploration of the lived experience of fuel poverty, it is not clear whether relationships between fuel poverty and other forms of disadvantage identified in these small sample sizes would be observed in the wider population.

3.5 Research aims and questions

In drawing on the research gaps that have become apparent through the development of this conceptual framework, the overarching aim of the thesis is to explore whether other forms of disadvantage exist in households experiencing fuel poverty. Focusing on three of the four areas of disadvantage that have been identified through this conceptual framework, the research questions have been developed with a focus on food insecurity, social isolation, and material deprivation. These are presented below:

1. How does fuel poverty impact on food insecurity?
2. What are the links between fuel poverty and social isolation?
3. Is there a difference in the order of curtailment of material deprivation items between fuel poor and non-fuel poor households?

The importance of these research questions lies in generating a more comprehensive understanding of the relationship between fuel poverty and other forms of disadvantage to extend knowledge of the impacts of fuel. This is important from a policy perspective as a better understanding of the impacts of fuel poverty could help to design better policies that effectively target those in need.

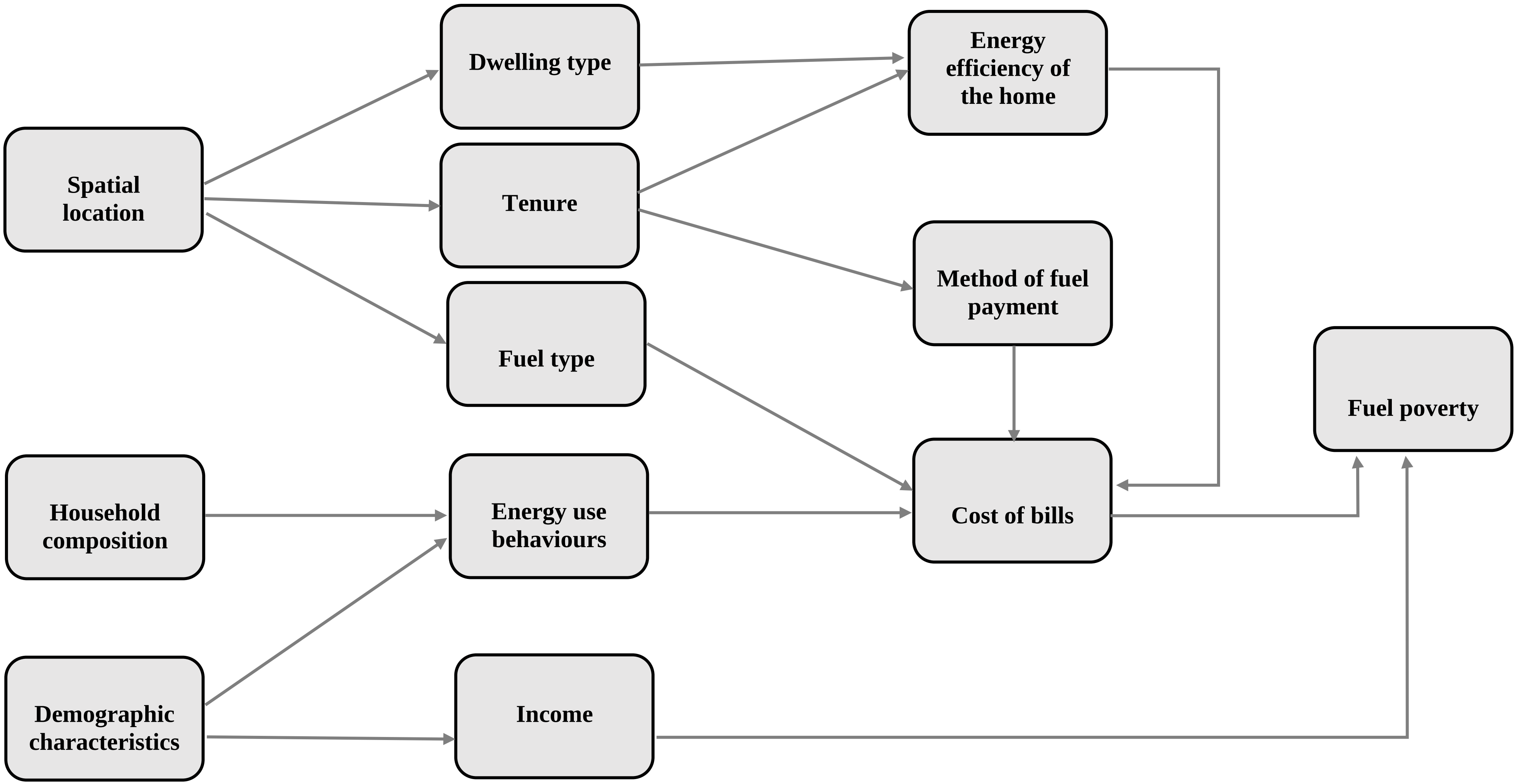
Drawing on the research gaps, these research questions aim to further explore links between fuel poverty and other forms of disadvantage using consistent fuel poverty indicators, therefore, attending to the first research gap. Furthermore, given the limitations of findings from small sample sizes, these research questions will be explored in larger samples, extending the quantitative literature in this area and, therefore, filling the second research gap.

It is so far unclear whether fuel poverty under different definitions impact differently on other forms of disadvantage and so as well as focusing on these three areas of disadvantage, a sub-aim of the research is to explore whether the experience of disadvantage varies under different definitions of fuel poverty, given the important discussions around the different characteristics captured under the two official definitions of fuel poverty (see section 2.7).

3.6 Fuel poverty: A conceptual framework

In building a comprehensive overview of fuel poverty in Chapter 2 and understanding how fuel poverty can impact on different areas of disadvantage within this chapter, it is possible to identify the factors that have been evidenced to be important in influencing fuel poverty from the literature presented across these two chapters. Identifying the important factors helps inform variable selection and the building of the statistical models in the forthcoming analysis chapters. These factors and their relationship with fuel poverty is illustrated in Figure 3.1 and discussed thereafter, again making reference to the literature.

Figure 3.1: *A conceptual framework of the important factors influencing fuel poverty*



3.6.1 Spatial location

Chapter 2 highlighted differences in the rates of fuel poverty within each country of the UK (see Figure 2.1). In part, this is linked to differences in the ways that fuel poverty is measured, but there are also certain characteristics that contribute to differences in fuel poverty rates across the UK, such as the degree of rurality, dwelling type, and fuel type. Within Figure 3.1, "spatial location" has been linked to "dwelling type", "tenure", and "fuel type". These factors were identified in Chapter 2 as contributing to different rates of fuel poverty in urban and rural areas (Baker et al. 2008; Preston et al. 2014; Ministry of Housing Communities & Local Government 2018; Robinson et al. 2018). Dwellings in rural areas tend to be less energy efficient than those in urban areas (Baker et al. 2008; Boardman 2010), which may lead to increased fuel bills (BEIS 2015), thereby increasing the vulnerability to fuel poverty.

Chapter 2 also highlighted how differences in the concentration of different tenures between urban and rural areas influence the spatial distribution of fuel poverty. The private-rented sector, for example, is more concentrated in urban areas and this type of tenure is associated with the least energy efficient dwellings (Emden et al. 2018) and the highest required fuel costs (BEIS 2020), which increases the risk of fuel poverty. However, not only does tenure influence energy efficiency, but it also influences the method of fuel payment available to the household. A consistent finding in the literature is that PPMs are most prevalent in the private-rented and social housing sector and are typically associated with the highest unit cost of fuel (Boardman 2010; Hills 2012; Ofgem 2020a). A report by Ofgem (2014) found that the highest rates of fuel poverty are amongst households who pay for their fuel using PPMs.

There are also differences in fuel types between urban and rural households due to poorer gas infrastructure in rural areas. As such, the use of oil is more prevalent in rural areas and this is associated with higher costs compared to gas and electricity (Boardman 2010; Preston et al. 2014). This has been linked to higher rates of fuel poverty in rural areas (BEIS 2020).

3.6.2 Household composition

This chapter has drawn on the literature that demonstrates that different heating strategies are employed by different household types and that these can alter the risk of fuel poverty. For example, Anderson at al. (2012) showed that rationing warmth varied across different household types. This strategy was significantly more prevalent among single parent households (75 per cent), couples with children (70 per cent) and households without children under pensionable age (69 per cent for both single adults and couples) compared to households over pensionable age (single adults, 47 per cent; couples without children, 53 per cent). Other literature has shown that households with children tend to be more reluctant to ration fuel and are less averse about going into debt in order to preserve the health and wellbeing of their children (Harrington et al. 2005; Longhurst and Hargreaves 2019). These behaviours and strategies can both increase and decrease the cost of bills and can therefore alter the risk of falling into fuel poverty (Harrington et al. 2005; Adam and Monaghan 2016).

3.6.3 Demographic characteristics

Government statistics show that the rates of fuel poverty differ by age, economic status, and ethnicity (DECC 2015; BEIS 2020). This is also evidenced in the literature. For example, in Chapter 2 it was demonstrated that minority ethnic households used energy in different ways and heated rooms to higher temperatures (Todd and Steele 2006), potentially increasing the risk of fuel poverty. Wright (2004) found that older participants (aged between 60 and 90) turned their heating off for a number of hours during the day in winter despite believing that keeping warm was very important. In part, this was driven by worries around the cost of fuel but also a perception that economising on heating was a virtue. In contrast, compared to younger age groups, Anderson et al. (2012) found that older residents in low income households were less likely to ration energy use. As well as the strategies adopted by different household types, these studies show that these strategies may also vary by age and could therefore alter the risk of fuel poverty for different age groups.

Work by Ahmed (2013) showed that household characteristics can impact on the odds of being fuel poor. Through the use of logistic regression, it was found that the economically inactive, unemployed, and retired had higher odds of being fuel poor compared to those who were employed. This could be linked to lower incomes in these groups and more time being spent at home (BEIS 2020). Those with disabilities may have different energy requirements and different patterns of energy use (Snell et al. 2014), which can impact on the cost of fuel bills that may then increase the risk of fuel poverty.

There is also a relationship between demographic characteristics of the householders and fuel poverty through the impact that these may have on income. Fuel poverty tends to be concentrated amongst households with the lowest incomes (DECC 2015b; BEIS 2020a) and incomes tend to be lower amongst certain demographic characteristics, such as non-white ethnic groups (DWP 2019), those with disabilities or a longstanding illness (Snell et al. 2014), and those who are unemployed (BEIS 2020). Income directly affects the affordability of fuel and could make a household vulnerable to fuel poverty.

3.7 Chapter summary and conclusions

This chapter has presented a conceptual framework, which has collated and synthesised the qualitative and quantitative literature to shed light on the links between fuel poverty and other forms of disadvantage. This has provided a gateway through which a much broader understanding of fuel poverty can be sought and has laid the foundations for the research presented within this thesis. This framework has not only reinforced the importance of adequate warmth for aspects beyond physical and mental health, but it has also drawn links between fuel poverty and other forms of disadvantage, including how it impacts on obtaining an adequate diet, how it can impair the maintenance of social networks, and how it can affect the standard of living through curbing essential expenditures. This has helped to develop a more holistic understanding of fuel poverty and its effects.

Through exploring the literature in this way, two research gaps have been identified. The first emphasises the lack of consistent fuel poverty definitions within studies, which makes it difficult to draw consistent links between fuel poverty and other forms of disadvantage, and the second focuses on the small sample sizes from which findings have emerged, given the predominance of qualitative research in this field. Although qualitative studies have helped to explain how fuel poverty may be linked with other forms of disadvantage, it is not clear whether these identified relationships would exist in the larger population. These research gaps have been pulled together to guide the research direction, which aims to explore the relationship between fuel poverty and other forms of disadvantage using consistent definitions of fuel poverty in larger sample sizes, extending the quantitative work in this field. A conceptual framework of the hypothesised links between the factors that have been identified in the literature to have an impact on fuel poverty has also been presented and discussed. This will become of importance as the thesis moves to the analysis chapters, particularly to inform the model-building in Chapter 5.

In the chapter that follows, the methodology used to answer the research questions that have been developed in this chapter is detailed and justified, the data sources are described, and the guidelines for data cleaning are presented.

Chapter 4| Methodology, Data sources, & Methods

4.1 Introduction

In the previous chapter, it was indicated that qualitative inquiry comprises the weight of evidence that has illuminated links between fuel poverty and other forms of disadvantage. This has revealed how other types of energy services play a role in the experience of fuel poverty and, from this, it is understood that fuel poverty does not always manifest as a cold home, but that its experience is dependent on a range of complex decision-making processes, which can be linked to priorities or needs (Harrington et al. 2005; O'Neill et al. 2006; Anderson et al. 2010). This is significant as it widens what is understood by fuel poverty and its experiences beyond the simple relationship between a cold home and poor health. However, qualitative research has, in part, contributed to the research gaps identified in the previous chapter (see section 3.4), with the various ways of identifying the fuel poor in the studies presented making it difficult to draw consistent associations between fuel poverty and other forms of disadvantage and to understand whether the relationships identified in the small samples would exist in the larger population.

In light of these research gaps, a secondary quantitative approach was deemed the most suitable methodology within which to conduct the research, which explores whether fuel poverty is associated with other forms of disadvantage in the wider population and – if these relationships exist – whether they are moderated by different definitions of fuel poverty. As a reminder, the research questions are re-stated below:

1. How does fuel poverty impact on food insecurity?
2. What are the links between fuel poverty and social isolation?
3. Is there a difference in the order of curtailment of material deprivation items between fuel poor and non-fuel poor households?

4.2 Chapter outline

This chapter begins by conceptualising and defining fuel poverty for the purpose of the research and this is followed by a brief discussion of the use of a secondary quantitative approach to answer the research questions, providing a detailed justification for its use and drawing on its ability to fill the research gaps. The datasets selected for the analysis (The *Living Costs and Food Survey* (LCFS) and *Understanding Society: The UK Household Longitudinal Study* (UKHLS)) are then described and their suitability for answering the research questions is emphasised.

From section 4.7 onwards, the chapter focuses on the procedures that were applied consistently across the LCFS and UKHLS datasets throughout the analysis and so they are contained herein to avoid repetition in each of the individual analysis chapters. Firstly, section 4.7 provides information on income and fuel expenditure data within the LCFS and the UKHLS and systematically describes the data cleaning procedures that were implemented throughout the research for these data. The construction of the fuel poverty indicators used throughout the analysis is then detailed in section 4.8, defining key concepts along the way. The final section (section 4.9) gives attention to how the weights for analysis of the LCFS and the UKHLS datasets were selected for different parts of the analysis.

4.3 Conceptualising and defining fuel poverty

In its original conceptualisation put forward by Isherwood and Hancock (1979) and later reinforced by Boardman within the 10 per cent definition (Boardman 1991; Boardman 2010), fuel poverty was understood as an issue of disproportionate fuel costs, where lower income households spent a greater proportion of their income on fuel (around twice the median). The notion of disproportionate fuel costs is still captured by Hills' LIHC indicator, with the fuel poor having high fuel expenditures that leave their residual income below the poverty line. Both of these fuel poverty indicators were described in Chapter 2 (see section 2.4). The research within this thesis uses this conceptualisation of fuel poverty so that those spending disproportionately on domestic fuel, which is inclusive of all energy used in the home (i.e. energy for lighting, for heating water, for cooking, and for all appliances used in the home, as well as for space heating), are classified as fuel poor. Using this conceptualisation, it becomes possible to investigate whether spending disproportionately on domestic fuel impacts on other essential expenditures within the context of the three areas proposed in the research questions: food insecurity, social isolation, and material deprivation.

4.3.1 Defining fuel poverty

Drawing on the first of the research gaps detailed in section 3.4, the literature in the previous chapter presented various ways that fuel poverty has been defined, which has made it difficult for a consistent understanding of the links between fuel poverty and other forms of disadvantage to be made. It was also noted in the previous chapter that it was not clear whether different definitions of fuel poverty alter the relationship with other forms of disadvantage. This formed the sub-aim of the research.

For the purpose of the research, two indicators of fuel poverty were employed. These are based on official definitions of fuel poverty currently used in the UK to produce fuel poverty statistics: Boardman's 10 per cent definition and Hills' LIHC indicator, providing two objective measures that are not altered by subjective interpretations of how a household perceives their fuel poverty status. These definitions have been detailed in Chapter 2 (see section 2.4), but, in brief, the 10 per cent definition classifies a household as fuel poor if they need to spend more than 10 per cent of full income[30] on fuel (Boardman 2010), and the LIHC indicator considers a household fuel poor if they have required fuel costs that are above the median level and if paying for these leaves a household's residual income AHC below the official poverty line[31] (Hills 2012). Households that *are* spending to these thresholds – and are, therefore, considered to be paying disproportionate fuel costs – are the focus of this research

[30] This includes basic income (i.e. all income excluding any income directly related to housing), Housing Benefit, income support for mortgage interest, and Council Tax Benefit (Boardman 2010).
[31] This is defined as 60 per cent of the median equivalised disposable household income AHC.

and thus, the constructed indicators are based on *actual* fuel expenditure rather than modelled fuel expenditure.

Using indicators based on the two official definitions of fuel poverty was not an attempt to determine which best-captured fuel poverty but served as a way of examining how differing constructions of fuel poverty indicators can change the relationship between fuel poverty and other forms of disadvantage. The impact of different components within the 10 per cent definition and the LIHC indicator was briefly evidenced in Chapter 2 (see section 2.7), where the literature presented showed that different measures of income and the use of equivalised income and equivalised fuel costs change the characteristics of the fuel poor under different fuel poverty indicators. However, although there is some literature that shows that how fuel poverty is experienced can be different under different definitions of fuel poverty (Palmer et al. 2008; Waddams Price et al. 2012; Deller et al. 2021), it is so far unclear whether these compositional differences alter the relationship between fuel poverty and other forms of disadvantage.

4.4 Using a secondary quantitative approach: justifications and limitations

The literature in the previous chapter demonstrated that fuel poverty has been explored through qualitative and quantitative approaches. There are distinct differences between these approaches, which are often understood as representing two different worldviews (Hammarberg et al. 2016). A worldview is defined as "a basic set of beliefs that guide action" (Guba 1990, p.17) or "a general philosophical orientation about the world and the nature of research that a researcher brings to a study" (Creswell and Creswell 2018, p.44). It includes the epistemological (i.e. "how we know what we know") and ontological (i.e. "the nature of reality") aspects of the research (Creswell and Creswell 2018, p.60). These form the foundations of research and provide guidelines for how it is conducted. Bearing in mind the research gaps identified in the previous chapter and the aim of the research, which is to explore the relationship between fuel poverty and other forms of disadvantage in the wider population using consistent fuel poverty indicators, this research is conducted from a postpositivist approach. *Postpositivism* is a worldview that states that knowledge is "based on careful observation and measurement of the objective reality" (Creswell and Creswell 2018, p.44). From this epistemological perspective, a secondary quantitative approach was deemed the most suitable for the research task.

Secondary data analysis is often referred to as "the re-analysis of data for the purpose of answering the original research question with better statistical techniques, or answering new questions with old data" (Glass 1976, p.3). Using a secondary quantitative approach provides several advantages over using qualitative methodologies that help to fill the research gaps identified in section 3.4 and to answer the research questions in section 4.1. Firstly, as an attempt to resolve the issue of the inconsistency of applied fuel poverty indicators in the literature, which formed the first research gap, a secondary quantitative approach facilitates the consistent application of these indicators. This fulfils the *reliability* measure of quality in quantitative research, which refers to the ability of a measurement instrument to produce consistent results (Heale and Twycross 2015) and is one of the fundamental elements in the evaluation of a measurement instrument. This means that findings are compatible and can be compared.

Secondly, using secondary quantitative data provides access to a large and nationally representative sample (Smith 2008). The use of large datasets makes it possible to investigate whether the relationship between fuel poverty and other forms of disadvantage exist on a wider scale, filling the second research gap, which stated that the small sample sizes used in the qualitative literature made it difficult to understand whether the identified relationships existed in the larger population. Furthermore, the use of a large and nationally representative dataset enables findings to be generalised to the wider population (Smith 2008).

In spite of these advantages and its suitability for conducting the research, secondary data analysis also has some disadvantages. Even though there is a time-saving element in using secondary data compared to the collection of primary data, there is often an underestimation of the time needed to become familiar with and to understand the oftentimes complex nature of the data. In addition, not all variables that are necessary to conduct the research may be present in the dataset (Bryman 2012) and this may limit the scope of research possibilities. However, secondary data analysis does reduce the costs and resources associated with conducting research (Smith et al. 2011) and provides the most suitable approach for filling the research gaps and answering the research questions.

4.5 Identifying appropriate data sources for conducting the research

It is evident from the research questions stated in section 4.1 that diverse aspects of disadvantage are considered (i.e. food insecurity, social isolation, and material deprivation), demonstrating the breadth of data needed for them to be answered, as well as the need for income and fuel expenditure data to be able to identify fuel poverty.

The *UK Data Service* (2020a) provides a source of publicly available, high-quality data from trusted research organisations and through this service it was identified that the *Living Costs and Food Survey* (LCFS) and *Understanding Society: The UK Household Longitudinal Study* (UKHLS) would be suitable for this research. Both data sources provide large and nationally representative samples and contain detailed information on income and fuel expenditure, which was needed for fuel poverty indicators to be constructed, as well as a breadth of data that would allow each of the research questions to be addressed. Furthermore, these datasets contain a wide range of other variables and their inclusion as control variables can help to account for the complexity of the social world, which could help to better understand the underlying factors in identified relationships. A brief description of each survey and how each one was used to answer the research questions is provided in the following subsections and the reader is directed to further information and guidance on each of the surveys.

4.5.1 The Living Costs and Food Survey: a brief description

The *Living Costs and Food Survey* (LCFS) is a voluntary, repeated cross-sectional and nationally representative survey and is the most significant consumer survey in the UK, collecting information on the cost of living and the expenditure patterns of approximately 5,500 private households across the whole of the UK throughout each year (Bulman 2017).

The LCFS is a source of economic and social data used for understanding society and planning for its needs, and data from this survey provide important information on household spending patterns for the derivation of price indices (Brewer and O'Dea 2012) as well as details of food consumption and nutrition for Defra (Bulman 2017). The LCFS replaced the *Expenditure and Food Survey* in 2008, which had been formed through combining the *Family Expenditure Survey*[32] and the *National Food Survey* in 2001 (UK Data Service 2020b).

The LCFS collects information in two ways. Firstly, interviews are conducted with individual household members aged 16 and over to gather information about the composition of the household, regular items of household expenditure, and income from employment, benefits, and assets (Bulman et al. 2017). Secondly, following the interview, all adults and children within the household are asked to keep an expenditure diary where all expenditure is recorded for the subsequent two weeks and where till receipts for household food purchases are attached to ensure minimal under-reporting (Defra 2014). Children aged 7 to 15 years are provided with a simplified version. Full details of the survey are provided by Bulman and colleagues (2017).

The change in methodology for the collection of fuel expenditure data from 2013 onwards mentioned in Chapter 2 (see section 2.11) (from respondents recording fuel expenditure in their diaries to the collection of this information through the household interview (ONS 2018a)), meant that fuel expenditure data collected prior to 2013 were not

[32] This survey was used by Isherwood and Hancock (1979) and Boardman (1991) in their analysis of fuel expenditure data.

comparable. As such, the LCFS datasets between 2013 and 2015/16[33] were downloaded and the data were pooled to increase the sample size (Defra and ONS 2019; Defra and ONS 2020; ONS and Defra 2020).

As well as collecting information on income and fuel costs, the LCFS collects detailed information on food expenditure and the types of foods purchased and so was appropriate for answering the first research question, which focuses on the relationship between fuel poverty and food insecurity.

4.5.2 Understanding Society: The UK Household Longitudinal Study: a brief description

Understanding Society: The UK Household Longitudinal Study (UKHLS) is a nationally representative survey conducted in the UK by the Institute for Social and Economic Research at the University of Essex (University of Essex: Institute for Social and Economic Research [no date][a]). It provides high-quality longitudinal data on a variety of topics such as income, education, social networks, and health and wellbeing, allowing for research opportunities within and across a wide range of disciplines (Knies 2018).

The UKHLS began in 2009 with members belonging to approximately 40,000 households at wave 1 and, from wave 2 onwards, it incorporated those who were still active in the *British Household Panel Survey*[34] at wave 18 (Knies 2018). Although typically face-to-face interviews are conducted, a small number of respondents were interviewed over the phone from wave 3, and from wave 7 a proportion of the sample provided their information through a web interview (Knies 2018). Each wave covers a 24-month period and respondents are interviewed once a year at around the same time each year. Further information on the survey is provided by Knies (2018).

[33] Up until 2014, the LCFS was conducted on a calendar year basis, but in 2015, this was changed to a financial year (April 2015 – March 2016).
[34] This was a longitudinal multi-purpose study that began in 1991 (University of Essex: Institute for Social and Economic Research [no date][b]).

Waves 1 to 7 of the UKHLS (University of Essex: Institute for Social and Economic Research 2020), covering the years between 2009 and 2017, were available at the time of analysis and were downloaded and used for answering the research questions[35]. As well as income and fuel expenditure data needed to construct fuel poverty indicators, the UKHLS collects information on aspects related to social isolation and material deprivation and so was used to answer research questions 2 and 3, respectively.

4.6 Ethical approval

Ethical approval for conducting the research was obtained from the School of Social Sciences Research Ethics Committee of Cardiff University (reference: SREC/1988).

4.7 Data cleaning procedures: income and fuel expenditure data

Before constructing the two fuel poverty indicators to be used throughout the research, it was important to firstly inspect the data and to deal with any issues presented. This section details how income and fuel expenditure data is collected in the LCFS and the UKHLS and the procedures used for cleaning these data, describing how they were adjusted for inflation and how some of the issues associated with income data collected through these household surveys was dealt with.

4.7.1 The collection of income data in the LCFS and the UKHLS

Income is a vital component of the research presented within this thesis as it is needed to construct both of the fuel poverty indicators and thus needed to identify the fuel poor. The LCFS and the UKHLS collect income data from all adult members (aged 16 and over) of the household. This includes income from all sources, including that from earnings, benefits, allowances, and other sources, such as educational grants and rent from tenants (Bulman et al.

[35] However, wave 1 of the UKHLS was not used due to concerns about income data and this is described further in section 4.7.3. Wave 2 of the UKHLS was dropped from the analysis as questions about the payment method for fuel (specifically gas and electricity) were only asked from wave 3 onwards.

2017; Knies 2018). Individual incomes are then combined so that an estimate of household income can be computed. In the UKHLS, this is provided as an annual value whereas in the LCFS, a weekly average is provided. Unless otherwise stated, full income was used throughout the analysis chapters to make like-for-like comparisons between groups and surveys. As income support for mortgage interest was not available in the UKHLS, full income was composed of net income[36], Housing Benefit, and Council Tax Benefit.

4.7.2 Adjusting income for inflation

As the LCFS and UKHLS datasets span a number of years, adjusting income data was important for a meaningful comparison of the data to be made between survey years. To do this, the Consumer Prices Index including owner-occupiers' housing costs (CPIH) was used. This became the official measure of inflation in March 2017, replacing the Consumer Prices Index (CPI) (ONS 2017b).

Like the CPI, the CPIH can be thought of as a basket of goods containing all the goods and services bought by a household and the CPIH estimates changes to the total cost of this basket (Payne 2016). However, unlike the CPI, the CPIH considers the housing costs of owner-occupiers, which includes the costs associated with owning, maintaining, and living in one's home, as well as council tax (ONS 2018b). These costs are estimated using a rental equivalence approach, i.e. the rent paid for an equivalent house in the private sector as a proxy for the costs faced by an owner-occupier (Restieaux 2013). These costs are an important addition as they are a significant component of household expenditure (ONS 2017b).

CPIH reference tables were downloaded from the ONS (2020a) and the following formula was used to adjust for inflation (i.e. to convert nominal values to real values) using 2016 as the base year to facilitate direct comparisons between the datasets:

[36] Net, or disposable, income is defined as the total household income following deductions for income tax, National Insurance contributions, and receipt of state benefits and tax credits (Bulman et al. 2017; Knies 2018).

Equation 4.1: *The formula used to adjust for inflation*

$$\text{Income x (CPIH}_{\text{base year}}\text{/CPIH}_{\text{year}}\text{)}$$

Source: Thompson 2009

Using this formula and the *overall index* inflation factors provided by ONS in their reference tables (ONS 2020a) produced income values that reflect real values of income in 2016.

4.7.3 Addressing the problems of low income collected through household surveys

After adjusting for inflation and before using the income data contained within the LCFS and the UKHLS datasets, it was important to acknowledge and address the issues associated with income data collected through household surveys, particularly at the lowest end of the distribution.

Despite being important for many policy issues and being the principal way of identifying poverty (Brewer et al. 2017), income data collected through household surveys is well-known to poorly-reflect living standards at the lowest end of the income distribution, at around the 2nd percentile (Brewer et al. 2006; Brewer and O 'Dea 2012; Brewer et al. 2017). Work by Brewer and colleagues (2017) found that those with the lowest incomes in the LCFS had expenditures that far exceeded their incomes, with levels similar to those at the median level of the population. Although consumption-smoothing may partially explain this through using savings or accruing debt, the authors suggest that this is predominantly attributed to under-recording components of income, arguing that there is a mismatch between the amount of cash transfer payments that the government reports paying out and those recorded by UK household surveys (Brewer et al. 2017). Similar findings have been documented for household surveys conducted elsewhere (Meyer et al. 2003; Lynn et al. 2012; Meyer and Mittag 2019).

There were two particular concerns regarding income data in the LCFS and the UKHLS datasets. Firstly, substantially lower incomes were recorded at wave 1 of the UKHLS when compared to later waves. Barnes et al. (2015) suggest that this was due to mis-recording sources of income in this wave, particularly from benefits and pensions. As such, the decision was taken to not use this wave of data in the analysis. Secondly, a further concern was the income related to self-employment in both datasets as there is evidence to suggest that those who are self-employed under-report their income in household surveys (Meyer et al. 2003; Hurst et al. 2010; Brewer et al. 2017). This under-reporting has been linked to challenges in collecting information on this type of income due to the irregular nature of earnings from self-employment and the difficulty of allocating them to a specific period of time (Athow 2017).

4.7.3.1 Winsorising income data

As a way of overcoming problems associated with income at the lowest end of the distribution, the decision was taken to winsorise the income data. *Winsorisation*, also known as *top*- or *bottom-coding*, can be thought of as a particular form of income imputation, where values above or below a chosen threshold are replaced by the mean of that threshold (Van Kerm 2006).

Following the work of Brewer and colleagues (2017), income data in both datasets were winsorised at the 2nd percentile, which is the point at which the authors showed that median expenditure rises with income[37]. It was also noted that the LCFS winsorises income data at the 96th percentile as a way of protecting the identity of those receiving high incomes (Ceraolo 2016) and so the same percentile was used for winsorising high incomes in the UKHLS[38]. Applying the same percentiles for winsorisation across both surveys could help to determine differences in incomes between both surveys, an outcome that can affect the rates of fuel poverty.

[37] This resulted in the lowest weekly full income values being £87.88 per week in the LCFS and £121.62 per week in the UKHLS.
[38] This resulted in the highest weekly full income values being £1,674.54 per week in the LCFS and £1,744.04 per week in the UKHLS.

4.7.4 The collection and adjustment of fuel expenditure data in the LCFS and UKHLS

To create the fuel poverty indicators to be used throughout the research, it was firstly important to understand how fuel expenditure data was collected in the LCFS and the UKHLS datasets so that the constructed fuel poverty indicators were comparable across the datasets, fulfilling the first research gap identified in Chapter 3 (see section 3.4). As noted in Chapter 2, since 2013, the LCFS collects data on fuel expenditure through a questionnaire administered at the household interview, having moved away from collecting this data through the respondent's expenditure diary. This methodology now aligns with that used by the UKHLS.

Despite fuel expenditure data being collected in the same way across both surveys, the period for which it is collected differs. The LCFS asks households how much they paid on their last bills and the period this covered, making reference to fuel bills. For those using PPMs, households are asked about their last payment and the period this usually covers. For purchases of other types of fuels, such as oil or solid fuel, expenditure information is collected for the last three months prior to the interview (ONS 2018a). An estimate of total domestic fuel expenditure is then provided as a weekly average. In contrast, the UKHLS collects fuel expenditure information on an annual basis based on expenditure in the previous year up until the point of the household interview (Knies 2018). Unlike the LCFS, the UKHLS provides annual fuel expenditures on each type of fuel used in the home: gas, electricity, oil, and other fuels, which includes solid fuel.

In light of the different periods for which fuel expenditures are recorded in the surveys, a total fuel expenditure variable was firstly created using the UKHLS data by adding the expenditures on all different types of fuels used in the home. Secondly, this variable was divided by 52 in order to estimate average weekly fuel expenditure to ensure that a direct comparison between fuel expenditure in the LCFS and the UKHLS could be made. All domestic fuel expenditures were adjusted for inflation using the inflation factors for *Electricity, gas, and other fuels* provided by the ONS (2020a) and the formula presented in Equation 4.1, using 2016 as the base year to facilitate direct comparisons between the datasets.

4.7.4.1 Winsorising fuel expenditure data

It was noted that a small number of households had extremely high fuel expenditures – over £300 a week – in both datasets. High fuel expenditures were linked to heating oil purchases, which may have been made at around the time of survey participation. Unlike gas and electricity, the heating oil market is not regulated meaning that there is a lack of consumer protection and transparent pricing (Baker et al. 2008). This means that customers are not protected from sudden price fluctuations, which are driven by the price of crude oil, and costs increase when demand is higher, such as in winter months (Richards and Bolton 2013). Instead, households often choose to pay for heating oil upfront in periods of the year when it is cheaper, such as in the summer. To account for these "lumpy" fuel purchases, fuel expenditure in both datasets was winsorised at the 97th percentile[39].

4.8 Creating the fuel poverty indicators: the use of actual fuel expenditure

Once the cleaning procedures for income and fuel expenditure data were completed, the fuel poverty indicators were created. As mentioned earlier in the chapter (see section 4.3.1), two fuel poverty indicators based on the two official definitions of fuel poverty currently used in the UK were applied throughout the research. This was to investigate whether a relationship between fuel poverty and other forms of disadvantage existed under these definitions and whether any relationships identified were moderated by two different indicators. The methods used to create these indicators are detailed in the following two subsections (sections 4.8.1 and 4.8.2).

Given that the definitions of fuel poverty used throughout the research classify households as fuel poor if they *are* paying disproportionate fuel costs, the two fuel poverty indicators were created based on actual fuel expenditure - a method that has been used in previous studies (Burholt and Windle 2006; Jamasb and Meier 2010; Devalière et al. 2011;

[39] Median fuel costs per week were the same across both datasets: £21.61 in the LCFS and £21.61 in the UKHLS.

Waddams Price et al. 2012; Phimister et al. 2015; Roberts et al. 2015; Deller et al. 2021). As noted in Chapter 2, using actual fuel expenditure to identify fuel poor households has traditionally been viewed as a poor indicator of fuel poverty as it risks overlooking those who may be under-spending or rationing fuel as a way of coping with disproportionate fuel costs (Hirsch et al. 2011; Moore 2012) and may, therefore, risk underestimating the numbers in fuel poverty (Thomson 2013). However, using actual fuel expenditure can help to understand fuel poverty more completely by shedding light on the impact on households whose actual fuel expenditures are considered disproportionate and who may then forgo or reduce expenditures in other areas (Hirsch et al. 2011). These disproportionate fuel costs may not be adequately captured in modelling procedures due to overlooking those who may need to spend above their modelled fuel costs (Middlemiss 2016) because of higher energy requirements, or different patterns of energy use, or cultural needs, for example.

Using the constructed indicators, fuel poverty was identified at the household level. This is the most appropriate level to explore fuel poverty given that it is how national statistics on fuel poverty are presented (see DECC 2014a; BEIS 2020a, for example). In line with all government household surveys, the LCFS and UKHLS define a household as "one person living alone or a group of people who either share living accommodation or share one meal a day and who have the address as their only or main residence" (Bulman et al. 2017, p.14; Fisher et al. 2019, p.9). Any households with zero fuel expenditure were excluded from the analysis as it was not clear whether zero expenditure on fuel was an accurate record or whether the respondent could not remember how much they had spent during the data collection period and did not have fuel bills or receipts for top-ups to refer to. However, given that these households constituted less than 1 per cent of households in the LCFS and UKHLS datasets, their exclusion had a minimal impact.

4.8.1 The 10 per cent indicator

The 10 per cent indicator is based on the original quantified definition of fuel poverty presented by Boardman in the early 1990s (Boardman 1991). This has been discussed in more detail in Chapter 2 (see section 2.4.1). In brief, it considers a household to be fuel poor if it needs to spend more than 10 per cent of its income on domestic fuel. The indicator is based on full income, which is basic income including Housing Benefit, Council Tax Benefit and income support for mortgage interest (Boardman 2010; DECC 2020a). However, given that the research is focused on those with disproportionate fuel costs, instead of using a *need to spend* measure this indicator classifies a household as fuel poor if its actual expenditure on fuel is more than 10 per cent of its full income.

4.8.2 The Alternative Fuel Poverty indicator

The *Alternative Fuel Poverty* (AFP) indicator is based on the concepts of Hills' LIHC indicator and, like the 10 per cent indicator described in the previous subsection, presents an actual expenditure-based version of this. The LIHC indicator classifies a household as fuel poor if their modelled fuel costs are above the national median and if their income AHC falls below the poverty line (defined as 60 per cent of the median equivalised household income AHC) after paying for these (Hills 2012). To create an actual expenditure-based version of this, the guidance provided by BEIS (2020b, pp.59–63) was used and included identifying households whose fuel bills were above the national median (based on actual fuel expenditure in each dataset) and whose residual incomes fell below the poverty line after paying these. The creation of these two key aspects of this indicator is detailed in the following two subsections.

4.8.2.1 Step one: Identifying the threshold for median fuel costs

To identify households whose fuel expenditure was above the median, the procedure used by BEIS (2020b, pp.59–60) was applied and adapted to accommodate actual fuel expenditure rather than required fuel costs. Firstly, the fuel expenditure of each household was equivalised to reflect the fact that larger households have greater fuel needs than smaller households. The equivalisation factors used to do this are presented in Table 4.1 overleaf. It is noted here that the equivalisation factors for fuel costs are different to those used for income, which are presented in Table 4.2. This is because equivalisation factors for income were not viewed as appropriate for equivalising fuel costs as they do not reflect that the economies of scale for fuel are less than for income (Hills 2012). Instead, specific equivalisation factors for required fuel costs were calculated based on three years (2008, 2009, and 2010) of required fuel cost data from the *Fuel Poverty Datasets*, which are produced using data from EHS.

Table 4.1: *Equivalisation factors for fuel costs used in the Low Income High Costs indicator*

Number of people in the household	Equivalisation factor
One	0.82
Two	1.00
Three	1.07
Four	1.21
Five or more	1.32

Source: BEIS 2020b, p.60

Unlike the factors used for equivalising income shown in Table 4.2, fuel equivalisation factors are based on household size, rather than household type, and adults and children are treated equally (BEIS 2020b). For example, a household containing an adult and two children is treated the same as a household with three adults.

To construct the AFP indicator, each household's actual fuel expenditure was equivalised by dividing fuel expenditure by the equivalisation factor that corresponds to the household size. Once each household's fuel expenditure was equivalised, the median fuel costs for the whole sample for each year were calculated, so that 50 per cent of households were above this threshold (indicating high fuel costs), and 50 per cent were below this threshold (indicating low fuel costs).

4.8.2.2 Step two: Identifying households below the poverty line after paying for fuel costs

In the UK, like the rest of Europe, the poverty line is defined as 60 per cent of the median equivalised net (or disposable) household income with figures provided for both *before housing costs* (BHC) and *after housing costs* (AHC) income measures (DWP 2015). Although a BHC measure of income acknowledges that households may choose to pay more for housing to live in better-quality accommodation, variations in housing costs are not always synonymous with housing quality. These variations occur by region, with proximity and travel time to important economic hubs, and with socio-demographic indicators (De Bruyne and Van Hove 2013; McGuinness 2018), with lower income households often spending a larger proportion of their income on housing than higher income households (McGuinness 2018).

Following the methodology provided by BEIS (2020b) for constructing the LIHC indicator, the AFP indicator identifies households below the poverty line as those with an income below 60 per cent of the median equivalised household income AHC. This measure of income is important for understanding the resources that households have available to them after paying for housing costs as money allocated to housing cannot be spent elsewhere. The following subsections explain how housing costs were identified and how income was equivalised.

<u>Identifying and removing housing costs</u>

The LCFS and the UKHLS both provide variables for housing costs. These include variables for both gross and net housing costs, the distinction between them being whether Housing Benefit is included in housing costs (gross) or not (net) (ONS 2015b). For the purpose of this research, given that full income (i.e. including Housing Benefit) was used to identify the fuel poor under the 10 per cent indicator, gross – rather than net – housing costs were used.

The variables for gross housing costs vary slightly between the LCFS and the UKHLS. In the LCFS, “ONS housing (gross)” contains rent and mortgage payments, council tax, and rent rebates as well as costs associated with maintenance and repairs of the main and secondary home, therefore considering the housing costs of owner-occupiers and providing a more complete approach to housing expenditure (ONS 2015b). The UKHLS provides two estimates for gross housing costs, both of which include the housing costs of renters and those paying mortgages, but one of which excludes capital repayments (“w_houscost2_dv”).

So that a fairer comparison of housing costs could be made between the datasets, “ONS housing (gross)” was selected, but costs associated with maintenance and repairs of the main and secondary home were removed, and “w_houscost2_dv” was selected from the UKHLS. This variable was selected as most income AHC estimates exclude repayments of capital included in mortgage payments (Knies 2018). These housing costs were also adjusted for inflation (see Equation 4.1) using the inflation factors for housing costs provided by the ONS (2020a).

Several households in the UKHLS dataset had extremely high housing costs (over £10,000 a month) and so these were winsorised at the 99.9th percentile to remove the effect of these high values and were converted to weekly values to reflect how housing costs are presented in the LCFS[40]. These values were then deducted from full income and any incomes that became negative following the removal of housing costs were set to zero. The purpose of this was to avoid the effect of equivalisation factors on negative incomes, which has been shown to act in the opposite direction to that which is intended (BEIS 2020b). In doing this, the poverty and fuel poverty status of a household remains unaffected.

The equivalisation of income

Once housing costs were removed from full income, the remaining income was equivalised. As mentioned in Chapter 2 (see section 2.4.2), equivalisation essentially increases the incomes and fuel bills of single-person households and decreases them for larger households with the aim of making them comparable (Boardman 2010; Hills 2012; ONS 2015a; BEIS 2020b) and reflects the fact that larger households typically need higher incomes than smaller households

[40] Median housing costs values for the LCFS were £50.98 per week and for the UKHLS were £47.70 per week.

to have the same standard of living (Moore 2012). As such, equivalisation allows for meaningful comparisons to be made as households with the same equivalised income can be said to have a comparable standard of living (ONS 2015a).

To equivalise full income AHC, the Organisation for Economic Co-operation and Development (OECD) *companion* scale was used, as used in the BEIS fuel poverty methodology and by the DWP in their reports on *Households Below Average Income* (DWP 2018b). In contrast to the OECD *modified* scale, which is used to equivalise income BHC, the companion scale takes into account that housing costs are not included in income and adjusts the equivalence factors accordingly. The equivalisation factors for income AHC are shown in Table 4.2 below.

Table 4.2: *Equivalisation factors for income after housing costs*

Number of people in the household	Equivalisation factor
First adult in the household	0.58
Subsequent adults (includes partners and children aged 14 or over)	0.42
Children under 14	0.20

Source: BEIS 2020b, p.61

Income AHC was divided by the household's equivalence value, which is based on its composition, to obtain a measure of equivalised income AHC for each household. Smaller equivalisation values are given to additional adults and to children aged 14 and over to account for economies of scale where resources are shared, and to children below the age of 14 to reflect their lower living costs (ONS 2015a). A couple without children is used as the reference household with an equivalisation value of 1.0 (DWP 2018b). Households were then classified as fuel poor under the AFP indicator if they had fuel costs above the median threshold and, after their subtraction, their residual equivalised income was below 60 per cent of the median household income AHC, aligning with the poverty line used in the LIHC indicator.

4.9 Weighting the data

Using weights in data analysis is important to reduce non-response bias, potential sampling error, and to account for unequal selection probabilities so that higher weights are assigned to those with lower selection probabilities and lower response propensities (Bulman et al. 2017; Knies 2018). This ensures that the sample reflects the population structure in terms of region, age group, and sex (Bulman et al. 2017; Knies 2018) and as such, generates results that are representative of the wider population. The following two subsections detail the weights available in the LCFS and the UKHLS and explain their selection for the different analysis chapters.

4.9.1 Selecting the weight for analysis of the Living Costs and Food Survey

The LCFS dataset provides two types of population-based weights: a quarterly household weight ("weightq") and an annual household weight ("weighta"). The quarterly household weight corrects for "any potential bias from the uneven spread of interviews through the year" (Bulman et al. 2017, p.58) and the annual household weight is simply a division of this weight over the four quarters of the year. The results produced from using either are the same. As such, the annual household weight has been used throughout the analysis where data from the LCFS datasets have been used.

4.9.2 Selecting the weight for analysis of Understanding Society: The UK Household Longitudinal Study

Although selecting the correct weight for the analysis of the LCFS was relatively straightforward, selecting the weight for the analysis of the UKHLS data was more complex, with different weights introduced as samples have been added to the study, and with different weights for longitudinal and cross-sectional analysis depending on those samples and whether households or individuals are of focus.

The UKHLS datasets were used cross-sectionally throughout the thesis, both at the household- and individual-level in different areas of the analysis. As such, different weights were needed. The correct weights for the analysis were selected based on the guidance provided by Knies (2018, p.70). For analysis at the household level, "hhdenub_xw" – the cross-sectional household weight for the combined General Population Sample, the Ethnic Minority Boost, and the British Household Panel Survey in waves 3 to 7 – was selected.

For part of the analysis, specifically that conducted for Chapter 7, where the relationship between fuel poverty and social isolation is explored, the analysis made use of the individual-level data within wave 6 of the UKHLS. For this, "indinub_xw" was used to weight the data. This is a cross-sectional, individual adult weight for the combined General Population Sample, the Ethnic Minority Boost, and the British Household Panel Survey (Knies 2018, p.71), thus reflecting the weight used for analyses at the household level. Knies (2018, pp.67–91) provides further information on the types and design of weights used in the UKHLS as well as guidance for their use.

4.10 Justification of the statistical methods used

Throughout the thesis, a range of methods have been used to explore the relationship between fuel poverty, defined using the indicators described in section 4.8, and the three selected areas of disadvantage: food insecurity, social isolation, and material deprivation. Within this subsection, the selection of methods is justified, drawing on their suitability for answering the research questions, and evaluating their strengths and weaknesses in terms of the questions posed and why they were chosen over other potentially suitable methods. The methods used are described in the order they appear in the forthcoming analysis chapters alongside their main assumptions and how these were tested for.

4.10.1 Logistic regression

The conceptual framework illustrated in Figure 3.1, presents the factors that may influence fuel poverty directly (such as income) and indirectly (such as spatial location) based on information gathered from the literature. However, it is still not entirely clear how these factors affect fuel poverty using the constructed fuel poverty indicators, both individually and in the presence of each other. In Chapter 5, logistic regression is employed to investigate the relationship between fuel poverty and as many of these identified factors that were available in the datasets.

Logistic regression is a predictive modelling technique that explains the relationship between a binary dependent variable and the independent variables, which can be categorical or continuous (Hosmer et al. 2013) and is a method that has been used widely in fuel poverty research (see Baker et al. 2008; Ahmed 2013; Thomson and Snell 2013, for example). Logistic regression was viewed as an appropriate method of analysis for this chapter as this method allows a story-telling approach for understanding the relationships between the selected variables and the constructed fuel poverty indicators and allows for the hypothesised relationships in Figure 3.1 to be explored. Through the sequential addition of variable blocks (as is the case in this research), it becomes possible to understand the role of different variables (for example, whether they are confounders) and to disentangle relationships. It also helps us to understand the unique effect of each variable on fuel poverty once all the variables are entered.

The results of logistic regression are presented as odds ratios, which represent the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure (Szumilas 2010). These indicate the strength and direction of the relationship and are simple to interpret. However, this method has some limitations in terms of the research questions posed. It is difficult to investigate complex relationships and the significant relationships identified do not denote causality, only that there is correlation. Where strong relationships are identified, this could stem from other unmeasured variables and this could lead to a biased model (Jeon 2020). Logistic regression is also prone to issues such as overfitting and multicollinearity. Overfitting is when a model is excessively complex, such as having too many parameters relative to the number of observations (Stoltzfus 2011). Multicollinearity is where correlations exist between the independent variables (Stoltzfus 2011). These issues impact on the performance of the model and make accurate interpretation difficult (Acock 2016). However, checks were conducted to ensure these were not an issue. Given that the LCFS and UKHLS are very large datasets and only a few independent variables were selected with no small numbers in any of the variables or their categories, overfitting was not viewed as being an issue. The Variance Inflation Factor (VIF) was used to check for multicollinearity. VIF indicates “the effect on the standard error of the regression coefficient for each independent variable” (Mooi et al. 2018, p.221) with a VIF above 10 generally indicating a problem (Hair et al. 2013). There were no VIF values above 2.0 in Chapter 5 and so multicollinearity was not viewed as an issue.

Other methods could have been selected to identify causal pathways, such as Structural Equation Modelling (a set of statistical techniques used to measure and analyse the relationships of observed and latent variables) (Beran and Violato 2010). However, Structural Equation Modelling requires an a priori idea of the causal relationship between variables (Suhr 2006). Although the conceptual framework in Figure 3.1 provides some hypothesised relationships based on what has been found in the literature, it is not yet entirely clear how the factors identified in the conceptual framework are related to fuel poverty under the constructed indicators. Therefore, Chapter 5 is a purely exploratory exercise. Structural Equation Modelling has been found not to be a useful exploratory tool as it cannot find relationships outside of the ones specified and the researcher would need to provide multiple hypothetical models and decide on the best model, which is computationally and time intensive (Suhr 2006). Furthermore, this method has drawn criticism because implementation is difficult and the process of interpretation is more complex compared to other methods of data analysis leading to a greater risk of poor or inappropriate interpretation (Jeon 2020). Given these limitations, logistic regression was viewed as a more suitable method for this exploratory chapter due to the simplicity of implementation and interpretability and allowing us to better understand the relationship between the selected variables and the constructed indicators.

4.10.1.1 The main assumptions of logistic regression

Source: Stoltzfus 2011

1. The dependent variable should consist of two categories of unrelated groups, such as a binary variable. This was checked visually.
2. There should two or more independent variables measured at the continuous or categorical level. Again, this was checked visually.
3. There should be independence of observations, which means that the occurrence of one observation provides no information about occurrence of another observation or, to put more simply, that individuals are only counted once. The LCFS is a cross-sectional survey and so each individual only appears once in the sample. However, the UKHLS is a longitudinal survey and so individuals appear more than once. To account for this, the UKHLS has been treated as a cross-sectional survey where every individual is treated as a single person and clustered robust standard errors are used to account for heteroskedasticity across clusters of observations (Baum et al. 2011). In this research, the robust standard errors are clustered on the household reference person (HRP) to account for changes in the HRP over time.
4. There must be little or no multicollinearity amongst the independent variables, which means that the independent variables should not be highly correlated with each other. Where multicollinearity exists, the independent variables do not provide unique or independent information in the regression model and this makes it difficult to accurately interpret the model (Acock 2016). As mentioned above, there were no VIF values above 2.0 in this chapter, indicating that multicollinearity was not an issue.

5. There needs to be a linear relationship between any continuous independent variables and the logit transformation of the dependent variable. As all variables in the logistic regression models are categorical, this was not an issue.
6. There should be no significant outliers in the independent variables as these types of values can have a very negative effect on logistic regression analysis and can lead to inaccurate interpretations (Rahmatullah and Hadi 2008). All variables are categorical in these regression analyses and so this was not an issue.

4.10.2 Multiple linear regression

Multiple linear regression is used in Chapters 6 and 7. In Chapter 6 it is used to investigate the relationship between fuel poverty and food expenditure (both in absolute and proportionate terms), and in Chapter 7 it is used to explore the impact of fuel poverty on social isolation. Multiple regression models the relationship between a continuous dependent variable and more than one independent variable (Acock 2016). Like logistic regression detailed above, this method can indicate the strength and direction of relationships, as well as how the dependent variable changes with the addition of independent variables, but, again, it does not indicate causality. However, multiple linear regression was selected as the most appropriate method for these analyses as the dependent variable is continuous and the independent variables are continuous or categorical – fulfilling these assumptions of multiple linear regression - and, like logistic regression, it is simple to implement and provides an easily interpretable output for understanding relationships.

Despite the advantages associated with multiple regression, this method has limitations. Multiple linear regression only relates variables by a straight line (i.e. linear relationships) and only looks at the mean impact of the independent variables on the dependent variable, which is not a complete description of relationships among variables (Waldmann 2018). By doing so, it is unclear whether relationships at the mean are the same at the extremes of the dependent variable. Quantile regression could have been used to deal with this issue, but this method also has limitations. For example, in quantile regression, parameters are harder to estimate than in other types of regression and inference on them can be complicated because the estimators for coefficients are not available in closed form (Waldmann 2018). This makes this method time-consuming and prone to errors. As such, it has not become a standard tool in statistical analysis (Waldmann 2018).

4.10.2.1 The main assumptions of multiple linear regression

Source: Robert Nau 2020

1. The independent variable should be measured on a continuous scale. This was checked visually.
2. There must be two or more independent variables, which are either continuous or categorical. This was checked visually and all independent variables in this analysis are categorical.
3. There should be independence of observations. As described earlier, the LCFS data is cross-sectional with individuals appearing only once and this dataset was used in Chapter 6. In Chapter 7, only wave 7 of the UKHLS data was used and so all individuals in the sample appear only once.
4. There must be a linear relationship between the dependent variable and the independent variables. As all the variables are categorical, this fulfils the assumption of linearity.
5. The data needs to show homoscedasticity, which means that the variances along the line of best fit remain similar across the line (Acock 2016). This assumption was assessed by plotting a scatterplot of residual versus predicted values and it was found that this assumption was violated (i.e. the plots showed that variances along the line of best fit did not remain similar across the line). As such, robust standard errors were presented, which obtain unbiased standard errors for coefficients under heteroscedasticity (Mansournia et al. 2021).

6. Like in other regression analysis, the data must not show multicollinearity. This has been detailed above. All VIF values were below 3.0 in Chapters 6 and 7 where this method was used, which suggests that multicollinearity is not an issue.
7. Like in logistic regression, there should be no significant outliers in continuous variables which can have a negative effect on the regression equation. As all the variables were categorical, this was not an issue.
8. The residuals (i.e. errors) need to be approximately normally distributed. This was checked by using Q-Q plots, which showed that the residuals roughly followed the 45-degree line in the plot. As this deviation was only slight and regression is robust to departures from normality (Acock 2016), no action was taken to rectify this.

4.10.3 Cluster analysis

K-means cluster analysis is used in Chapter 6 to create food expenditure patterns, which are later used to explore whether fuel poverty is associated with any of the food expenditure patterns created. *K*-means cluster analysis is a data-driven method where, apart from deciding on the number of clusters to be formed (i.e. *k*), there is minimal input from the researcher, allowing the data themselves to form the clusters. This reduces researcher bias in the formation of food expenditure pattern clusters. However, this method requires the researcher to make sense of the clusters to ensure that the clusters produced are meaningful, allowing for the potential of researcher bias.

Although other studies have used other methods to categorise food expenditure patterns and dietary consumption patterns (which are closely related to food expenditure patterns), their limitations mean that k-means cluster analysis was deemed a more suitable approach. For example, Principal Component Analysis (PCA) has been used extensively in categorising food expenditure and consumptions patterns (see Newby and Tucker 2004; Thorpe et al. 2016, for example). PCA is a dimensionality-reduction method that is used to identify common patterns within a dataset in order to account for the largest amount of variation in the diet (Newby and Tucker 2004), therefore reducing a large set of variables into a smaller one that still contains most of the information in the original set. However, this method relies on the researcher to select the number of principal components, which could result in the loss of important information. Additionally, principal components are not as readable and interpretable as the original features. In contrast, *k*-means clustering groups individuals with similar dietary patterns into mutually exclusive categories based on the mean of food expenditure variables.

Given the purpose of the chapter was to segregate individuals based on their food expenditures and retain the detail within the food expenditure patterns, rather than reducing dimensions, *k*-means cluster analysis was viewed as the most appropriate method to answer this research question.

4.10.3.1 The main assumptions of k-means cluster analysis

Source: Jin and Han 2011

There are two main assumptions of k-means cluster analysis:

1. There should be independence of observations. Chapter 6 uses data from the LCFS, which is cross-sectional and so individuals only appear once in the data.
2. The data needs to be standardised if the range or scale of one variable is much larger than another one. Given the large range in absolute expenditure between food items, food groups were created based on the percentage of the food budget allocated to each food group. Transforming absolute expenditure to percentages is a way of standardisation and ensures that extreme values to do not dominate how clusters are formed.

4.10.4 Multinomial regression

Following cluster analysis to define food expenditure patterns and conducting checks to ensure that the clusters were reliable representations of distinct groups of the population and were stable (see Chapter 6 (section 6.11) for more information), Chapter 6 also uses multinomial regression to investigate whether fuel poverty affects the membership of food expenditure patterns and to understand how the addition of other independent variables changes this membership. Multinomial regression is an extension of logistic regression, but where logistic regression explains the relationship between a dependent binary variable and one or more continuous or categorical variables, multinomial regression allows for a categorical dependent variable with more than two levels that is unordered (Hosmer et al. 2013). This method was selected as the dependent variable (the created food expenditure patterns) is a categorical variable with more than two unordered categories, fulfilling this assumption of multinomial regression and has been used previously in the context of food expenditure patterns (Fan et al. 2007).

An alternative that has been used to predict group membership is discriminant function analysis. However, this method has strong statistical assumptions, that are rarely met with real-life data, and obscurities around interpretation, making multinomial regression analysis more attractive and easier to implement (Holdnack et al. 2013).

4.10.4.1 The main assumptions of multinomial regression

Source: Starkweather and Kay Moske 2011

1. The dependent variable should be measured at the nominal level with more than or equal to three values. The dependent variable in this case was the food clusters created using *k*-means cluster analysis, which contains 5-levels (i.e. the five food clusters).
2. There are one or more independent variables that are continuous, ordinal or categorical (including dichotomous variables). All the variables in this part of the analysis are categorical.
3. There should be independence of observations and the dependent variable should have mutually exclusive categories (i.e. no individual should belong to two different categories). Again, this chapter uses the LCFS data, which is a cross-sectional study

where individuals appear only once and using *k*-means cluster analysis to segregate individuals into food expenditure patterns means that individuals are only grouped into one cluster.

4. There should be little or no multicollinearity. VIF values were below 4.0 throughout this chapter, suggesting little multicollinearity.
5. There needs to be a linear relationship between any continuous independent variables and the logit transformation of the dependent variable. There were no continuous variables used in this chapter and so this was not checked.
6. There should be no outliers, high leverage values or highly influential points for the continuous variables. Again, as no continuous variables were used in this chapter, this was not checked.

4.10.5 Item Response Theory

In the final analysis chapter – Chapter 8 – the effect of fuel poverty on material deprivation is investigated. More specifically, the order in which items that are viewed essential by society are curtailed is explored as a way of learning about differences in living standards between the fuel poor and non-fuel poor. To do this, Item Response Theory (IRT) is used. This method was specifically selected for this analysis chapter as it is a tried and tested method in the context of material deprivation, having been previously used in studies that have explored curtailment sequences in the study of material deprivation (see Szeles and Fusco 2013; Deutsch et al. 2015, for example). However, to the author's knowledge, it has not yet been used in the context of fuel poverty and so was used to provide novel insights into the impact of fuel poverty and, in particular, whether the order in which essential items are curtailed differs between fuel poor and non-fuel poor groups in different household types. Although a relatively more complex method to apply than other methods used up until this point in the thesis, the output is easy to interpret and has been simplified by using heatmaps to facilitate interpretation and understanding of the results.

4.10.5.1 The main assumptions of Item Response Theory

Source: Columbia University 2022

1. Monotonicity, which is the assumption that the as the trait level increases (in this case material deprivation) so does the probability of a positive response. This can be shown using an item characteristic curve. An example of this is presented in Appendix E (see Figure E.1).
2. Unidimensionality, which is that there is only one latent trait being measured. Given that the measure of material deprivation is an established measure that has been widely used by government bodies such as DWP, no further checks for unidimensionality were undertaken.
3. Local independence, which means that item responses are unrelated to each other. Again, this was not tested given that the measure of material deprivation used is established and readily used.

4.10.6 Bivariate analysis

As well as the analytical methods used in Chapters 5 to 8 detailed above, these chapters also use One-way Analysis of Variance (ANOVA) and chi-squared tests for the descriptive statistics. The purpose of this is to draw wider inferences relating to the population of interest. ANOVA is used to assess whether there are statistically significant differences between the means of two or more independent (unrelated) groups (Acock 2016) and is used where the dependent variable is continuous and the independent variables are categorical (nominal or ordinal) (Acock 2016). Chi-squared tests are used to determine whether there is a significant association between two categorical variables and "compares the frequency in each cell with what you would expect the frequency to be if there were no relationship" (Acock 2016, p.127). Where these tests have been used within the thesis, they have been noted below the tables.

The reader will notice that there are also several tables throughout the thesis that present median values for certain variables, such as for income, fuel expenditure, and food expenditure. This is because they are skewed. Although ANOVA could have been used given its robustness to this assumption violation, median values are presented in the tables and so other tests for differences between medians were explored, such as the Kruskall-Wallis test, the Equality of Medians test, and the Mann-Whitney U test. These however, do not work with weights or with the survey analysis settings in Stata, and so confidence intervals have been presented as a way of drawing statistical significance between groups.

An issue with bivariate analysis is that it can produce statistically significant results with a large sample size, even with a small effect. It also does not take into account any other variables which may be influencing the relationship between the two variables examined. This is accounted for by extending the analysis to regression and further exploring these relationships in the presence of other variables.

4.10.6.1 The main assumptions of the ANOVA test

Source: Acock 2016

1. The dependent variable is continuous and the independent variable should be categorical, consisting of two or more unrelated groups. This was checked by visually inspecting the data.
2. The errors of the residuals are normally distributed. This was checked
3. Observations should be independent i.e. only appearing once in the sample.
4. The variance of each group is equal i.e. homogeneity of variances, which tests that all groups have the same or similar variance. The Levene's test was used to assess whether two or more groups have equal variances with the p-value larger than 0.05 indicating that the samples have qual variance. This assumption was fulfilled in this research.

4.10.6.2 The main assumptions of the chi-squared test

Source: McHugh 2013

1. Both variables are categorical. This was visually inspected by looking at the data.
2. There should be independence of observation. As already mentioned above, the LCFS data is cross-sectional and so individuals appear only once. Although the UKHLS is a longitudinal dataset, this was treated as cross-sectional.
3. Cells in the contingency table are mutually exclusive meaning that individuals cannot belong to more than one cell. Only mutually exclusive groups were created for this research, for example whether a household is fuel poor or not fuel poor. There are no overlapping groups.
4. The expected value of cells should be 5 or greater in at least 80 per cent of the cells.

4.11 Statistical software used for analysis

All analyses were conducted using Stata 14.2.

4.12 Chapter summary

This chapter has provided justification for the use of a secondary quantitative approach for answering the proposed research questions and filling the research gaps, drawing on the large and nationally representative samples offered by the LCFS and the UKHLS. These datasets provide a breadth of data, which allow for the relationship between fuel poverty and other forms of disadvantage, and the factors underlying this, to be explored, as well as allowing for the consistent application of fuel poverty indicators. This helps to fill the research gaps identified in the previous chapter and for the research questions to be answered.

The chapter also provided a detailed description of the data cleaning procedures used and laid out the methods employed to construct the fuel poverty indicators to be used throughout the research, defending the use of actual fuel expenditure for the purpose of the research. Using actual fuel expenditure can help to identify households who are fuel poor through paying disproportionate fuel costs and this can help to shed light on whether other areas of expenditure are affected as a way of understanding the experiences of the fuel poor through the relationship between fuel poverty and other forms of disadvantage. The final section of the chapter focused on the selection of weights for analysis of the LCFS and the UKHLS.

In the following chapter, a closer examination of the constructed fuel poverty indicators is provided, and a comparative analysis of both fuel poverty indicators used throughout the research is presented as a way of identifying the impact of their diverse components, with a focus on the characteristics they capture, providing a point of reference for the remainder of the thesis.

Chapter 5| Building a profile of the fuel poor: Findings from the Living Costs and Food Survey and Understanding Society: The UK Household Longitudinal Study

5.1 Introduction

In Chapter 2, the literature presented in section 2.7 indicated that – based on their differing components – the 10 per cent definition and the LIHC indicator were not always capturing the same characteristics and, as a consequence, were producing different profiles of the fuel poor, as well as different rates of fuel poverty, which was illustrated in Figure 2.2. As two fuel poverty indicators based on actual fuel expenditure will be used throughout the thesis (the 10 per cent indicator and the AFP indicator), this chapter offers an opportunity to examine and compare these closely and provides an in-depth exploration of how their diverse components can influence the behaviour of the indicators and change the characteristics of those identified as fuel poor by each one.

5.1.1 Chapter aim and objectives

The aim of this chapter is to provide a clear understanding of the 10 per cent indicator and the AFP indicator that are constructed using actual fuel expenditure data from the LCFS and the UKHLS and to understand the characteristics captured by them. To do this, the following six objectives were developed:

1. To examine the differences between modelled and actual fuel expenditure in the LCFS and the UKHLS;
2. To compare the rates of fuel poverty produced by both of the constructed fuel poverty indicators to official fuel poverty statistics;
3. To determine the absolute and proportionate fuel expenditures of the fuel poor under the constructed fuel poverty indicators;
4. To investigate the overlap between both constructed fuel poverty indicators;

5. To understand which experiences of fuel poverty the constructed fuel poverty indicators are capturing;
6. To explore the incidence and determinants of fuel poverty under both fuel poverty indicators and to identify the characteristics of households with the highest odds ratios of experiencing fuel poverty based on each indicator.

Through these objectives, this chapter attempts to assemble a full and clear description of the fuel poor under each indicator and thus serves as a reference point for the remainder of the analysis chapters.

5.2 Data source and methods

The previous chapter (see section 4.7.4) noted that the way fuel expenditure data is collected in the LCFS has changed since 2013. It was also noted that there were concerns about income data in wave 1 of the UKHLS and that questions about the method of fuel payment were asked only from wave 3 onwards. This means that the analysis in this chapter is based on pooled data from the LCFS from 2013 to 2015/16 and waves 3 to 7 of the UKHLS, which span the years of 2011 to 2017. Chapter 4 has detailed the data cleaning procedures and the methods used to construct both actual expenditure-based fuel poverty indicators employed throughout the research (see sections 4.7 and 4.8, respectively).

5.2.1 Ensuring comparability of variables between both datasets

As a comparative approach is taken throughout this chapter, it was important that similar variables were available in both datasets and, where variables were measuring the same construct, that their categories were comparable, where possible. This was determined by consulting the variable information available through the LCFS and UKHLS documentation accessed through the UK Data Service website (2020a). Where comparable variables did not exist, these are presented independently of each other, and where categories were not comparable, this has been highlighted within the analysis. An example of the latter is the type of fuels used in the home. In the LCFS, information collected on fuel type specifically relates to the type of fuel used for central heating, whilst in the UKHLS, this variable relates to all fuels used in the home. A full variable catalogue, which details the categories of each variable that was created or re-categorised as a way of making variables comparable for the analysis, is presented in Appendix A.

5.3 Analysis

The complete case analysis within this chapter is based on 15,711 households within the LCFS (2013 – 2015/16), and 89,118 households within the UKHLS (waves 3 to 7). The unit of analysis throughout this chapter is the household as this is the level at which national fuel poverty statistics are produced and presented (see DECC 2014a; BEIS 2020a, for example), thereby facilitating the comparison of the results produced herein with national fuel poverty estimates.

This section begins with the presentation of the analysis for the first chapter objective, which is to examine the differences between modelled fuel expenditure presented in DECC (2015b, p.82) and actual fuel expenditure in the LCFS and the UKHLS.

5.3.1 Objective 1: Actual versus modelled fuel expenditure

It was noted in Chapter 2 (see section 2.10) that the use of actual fuel expenditure has traditionally been viewed as a poor indicator of fuel poverty, particularly for those at the lowest end of the income distribution who have been shown to spend less on fuel than is required (Hirsch et al. 2011). This was supported by analysis contained within DECC's 2012 *Annual Fuel Poverty Statistics* report (2014a), where a comparison of the modelled average annual spend on fuel (i.e. the amount a household needs to spend to ensure adequate energy services) and the average actual annual expenditure on fuel (i.e. what a household is *actually* spending on energy services) was presented by income decile. Their analysis for 2012 showed that households in all income deciles were spending below their average modelled annual spend on fuel, with the lowest income decile under-spending by 33 per cent (DECC 2014a, p.73). However, it was noted in section 2.11 that the LCFS changed the way they collect domestic fuel expenditure data in 2013 – from respondents recording fuel expenditure in their expenditure diaries to the collection of this information at the household interview, aligning with the methodology used in the UKHLS. This resulted in increases in reported expenditure for both gas and electricity and these increases were most pronounced in households using PPMs (DECC 2015b). This analysis was presented in Table 2.2 and showed a much closer alignment between actual and modelled fuel expenditure, with the lowest income decile spending only 4 per cent below their average modelled fuel spend (DECC 2015b, p.82).

DECC's comparison of modelled fuel costs[41], produced from data collected through the *English Housing Survey* (EHS) and presented in the *Fuel Poverty Datasets*, and actual fuel expenditure from the LCFS (DECC 2015b, p.82) is replicated here to fulfil the first objective of this chapter, which is to examine the differences between modelled fuel costs and actual fuel expenditure. The purpose of this comparison is to identify whether discrepancies between actual fuel expenditure contained in the LCFS and the UKHLS datasets (which is used to construct the fuel poverty indicators used throughout the thesis) and modelled fuel costs exist.

The annual modelled fuel costs used in DECC's comparison are for England in 2013 and so for a like-for-like comparison to be made, these are compared with actual fuel expenditure data from the LCFS and the UKHLS for 2013 in England only. As explained in the previous chapter (section 4.7.4), the UKHLS collects information on fuel expenditure for the previous year up until the point of interview (Knies 2018) and so fuel expenditure data for 2013 was sourced from waves that were conducted in 2014, i.e. waves 4, 5, and 6[42]. The results of this comparison are presented in Tables 5.1 below for the LCFS data and 5.2 overleaf for the UKHLS data.

[41] The modelling procedure has been briefly detailed in section 2.10 in Chapter 2.
[42] Wave 4: 2012-2014; Wave 5: 2013-2015; Wave 6: 2014-2016.

Table 5.1: *Actual (weighted) versus modelled household annual spend on fuel, LCFS, 2013, England*

Income decile group*	**Average actual annual expenditure on fuel (£)**	**Modelled average annual spend on fuel (£)**	**Percentage difference (actual - modelled)**
1st (lowest)	1,051	1,092	-4%
2nd	1,046	1,104	-5%
3rd	1,124	1,205	-7%
4th	1,174	1,241	-5%
5th	1,251	1,328	-6%
6th	1,327	1,334	-1%
7th	1,389	1,423	-2%
8th	1,425	1,495	-5%
9th	1,526	1,501	+2%
10th (highest)	1,828	1,727	+6%
All households	**1,326**	**1,345**	**-1%**

* Based on full income

Sources: Modelled data: DECC 2015b, p.82; Actual data: Author's own analysis using actual fuel expenditure data in the LCFS, 2013

Table 5.2: *Actual (weighted) versus modelled household annual spend on fuel, UKHLS, 2013, England, weighted*

Income decile group*	Average actual annual expenditure on fuel (£)	Modelled average annual spend on fuel (£)	Percentage difference (actual - modelled)
1st (lowest)	897	1,092	-18%
2nd	955	1,104	-13%
3rd	1,042	1,205	-14%
4th	1,149	1,241	-7%
5th	1,174	1,328	-12%
6th	1,243	1,334	-7%
7th	1,302	1,423	-9%
8th	1,375	1,495	-8%
9th	1,454	1,501	-3%
10th (highest)	1,690	1,727	-2%
All households	**1,217**	**1,345**	**-10%**

* Based on full income

Sources: Modelled data: DECC 2015b, p.82; Actual data: Author's own analysis using actual fuel expenditure data in the UKHLS, 2013

Comparing actual fuel expenditure with modelled fuel costs by income decile shows that actual fuel expenditure within the LCFS is closely aligned with estimates for modelled fuel costs (Table 5.1), with the lowest income decile spending 4 per cent less and the highest income decile spending 6 per cent more than their modelled annual estimate. This aligns relatively well with DECC's analysis presented earlier in Table 2.2. In contrast, performing the same analysis with actual fuel expenditure data from the UKHLS (Table 5.2), a consistent under-spending is observed, with the lowest income decile spending 18 per cent below their modelled annual estimate and those in the highest income decile spending 2 per cent below their modelled annual estimate. These observed differences between the datasets may be linked to differences in the period for which fuel expenditure data is collected, with fuel expenditure data covering a longer period in the UKHLS. This could potentially lead to inaccurate estimates of actual fuel expenditure, particularly for more sporadic payments, such as those related to PPMs.

5.3.2 Objective 2: Comparing rates of fuel poverty based on actual fuel expenditure with national estimates

To explore the second of the chapter objectives set out in section 5.1.1, a comparison between the fuel poverty rates produced by the constructed fuel poverty indicators and national estimates available in fuel poverty reports produced by DECC and BEIS are presented in Tables 5.3 and 5.4. Making this comparison provides information on how well indicators based on actual fuel expenditure, as used throughout the analysis, compare to those based on modelled fuel costs.

Table 5.3 presents a comparison of UK estimates of fuel poverty under the official 10 per cent definition and the rates produced by the constructed expenditure-based 10 per cent indicator using the LCFS and the UKHLS datasets. This comparison is only presented until 2013 as, after this point, the LIHC indicator was introduced in England and estimates were no longer provided for the UK as a whole.

Table 5.3: *A comparison of the percentage of fuel poor households in the UK under the official 10 per cent definition and the constructed 10 per cent indicator (weighted) by dataset, LCFS: 2013 & UKHLS: waves 3 - 7*

	2011	2012	2013
National estimate	**17.0**	**16.0**	**17.0**
LCFS	-	-	10.4
UKHLS	7.6	6.4	6.5

Source: DECC 2012; DECC 2013a; DECC 2014a; DECC 2015b

Table 5.3 shows that fuel poverty rates produced by the 10 per cent indicator based on actual fuel expenditure data from the LCFS and the UKHLS are lower than UK estimates produced by the official 10 per cent definition based on modelled assumptions. This may be because the constructed fuel poverty indicators are only capturing households who are spending to the thresholds within the indicators to be classified as fuel poor and this means that those who are experiencing fuel poverty under other definitions, such as through rationing fuel and therefore potentially spending below 10 per cent of their income on fuel, are not being captured. It is also observed that, for 2013, the 10 per cent indicator based on fuel expenditure data contained within the LCFS produces a higher rate of fuel poverty compared to that using the UKHLS data. The lower rates of fuel poverty produced by the UKHLS data may be linked to the higher levels of income in this dataset (see footnotes 37 and 38).

Table 5.4 presents the same comparison as in Table 5.3, but with fuel poverty estimates produced by the LIHC indicator compared to rates produced by its expenditure-based equivalent, the AFP indicator. These are compared for England only as this is the only country within the UK where the LIHC indicator is used and for where national estimates of fuel poverty under this indicator exist.

Table 5.4: *A comparison of the percentage of fuel poor households in England under the LIHC indicator and the rates of fuel poverty under the constructed AFP indicator (weighted) by dataset, LCFS: 2013 – 2016 & UKHLS: waves 3 – 7*

	2011	2012	2013	2014	2015	2016	2017
National estimate	**11.1**	**10.7**	**10.5**	**10.5**	**11.0**	**11.1**	**10.9**
LCFS	-	-	13.9	9.9	10.2	10.7	-
UKHLS	10.7	10.1	10.2	8.1	7.8	7.6	6.9

Source: BEIS 2019c

In comparison to Table 5.3, Table 5.4 shows that there is a much closer alignment between national estimates of fuel poverty under the LIHC indicator and rates of fuel poverty produced by the expenditure-based AFP indicator. However, it is acknowledged that although rates produced by the constructed indicators and the LIHC indicator are similar, they may not be capturing the same households given the differences in methodologies underpinning actual expenditure-based and modelled indicators. Again, it is observed that the AFP indicator created with actual fuel expenditure data contained within the UKHLS produces lower rates of fuel poverty compared to that created with the LCFS data. As already mentioned, this could be linked to higher incomes in the UKHLS. Furthermore, the AFP indicator based on expenditure data contained within the UKHLS shows that rates of fuel poverty are relatively stable over time, reflecting the stability of fuel poverty estimates produced by the LIHC indicator. This is one of the main criticisms of the LIHC indicator as it appears to mask the affordability of fuel (Walker et al. 2013) and suggests that fuel poverty is a problem that cannot be eradicated (Middlemiss 2016).

Despite the divergence between national estimates of fuel poverty and the rates of fuel poverty produced using the constructed expenditure-based indicators, this comparison has been made for exploratory purposes only and has no bearing on the remainder of the research as the focus is to understand whether those classified as fuel poor under the constructed indicators experience other forms of disadvantage and how this relationship may vary under different indicators.

5.3.3 Objective 3: The expenditures of the fuel poor under the constructed fuel poverty indicators

In this section, the expenditures of the fuel poor under the constructed fuel poverty indicators will be explored, both in proportionate and absolute terms, in order to address the third objective set for this chapter. The following tables present a comparison of weekly full income and fuel expenditure, both in absolute and proportionate terms, for households in the LCFS (Table 5.5) and the UKHLS (Table 5.6). These values are compared for fuel poor and non-fuel poor households under each indicator and the income poor as a way of identifying differences between these groups. For comparison purposes, full income has been used to make like-for-like comparisons across households and surveys.

Table 5.5: *Median weekly income and fuel expenditure in fuel poor and non-fuel poor households and the percentage of full income it consumes* [95% confidence intervals], *LCFS (2013 – 2015/16), weighted*

	10 per cent indicator		**Alternative fuel poverty indicator**		**Income poverty**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
Full income (£/week)	588.20 [580.66 – 595.75]	**225.57 [217.75 – 233.39]**	589.72 [581.95 – 597.48]	**307.85 [299.61 – 316.08]**	640.80 [632.85 – 648.75]	**278.26 [272.18 – 284.33]**	543.69 [535.78 – 551.61]
Fuel expenditure (£/week)	20.84 [20.57 - 21.11]	**31.74 [30.84 – 32.65]**	20.27 [20.09 – 20.44]	**30.28 [29.62 – 30.94]**	22.07 [21.79 – 22.36]	**19.52 [19.19 – 19.85**	21.61 [21.42 – 21.80]
Percentage of full income spent on fuel per week (%)	3.6 [3.5 – 3.6]	**13.0 [12.7 – 13.2]**	3.5 [3.5 – 3.5]	**9.9 [9.6 – 10.2]**	3.4 [3.4 – 3.4]	**6.8 [6.6 – 7.0]**	3.8 [3.8 – 3.9]
Rate of fuel poverty (%)	-	**8.8 [8.4 – 9.3]**	-	**11.2 [10.7 – 11.7]**	-	**-**	-
Sample size	**14,278**	**1,433**	**13,957**	**1,754**	**12,548**	**3,163**	**15,711**

Note 1: The median values within the table are taken directly from the dataset. As the distributions of full income and fuel expenditure are skewed, this means that the median percentage of full income spent on fuel cannot be calculated from the median values of full income and fuel expenditure presented in the table.
Note 2: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

Table 5.6: *Median weekly income and fuel expenditure in fuel poor and non-fuel poor households and the percentage of full income it consumes* [95% confidence intervals], *UKHLS, (waves 3 – 7), weighted*

	10 per cent indicator		**Alternative fuel poverty indicator**		**Income poverty**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
Full income (£/week)	596.77 [593.63 – 599.90]	**204.92 [201.73 – 208.12]**	602.76 [599.08 – 606.44]	**325.01 [320.22 – 329.79]**	657.29 [653.47 – 661.11]	**285.22 [282.09 – 288.35]**	567.68 [564.21 – 571.16]
Fuel expenditure (£/week)	21.15 [20.99 – 21.32]	**28.19 [27.75 – 28.64]**	20.54 [20.47 – 20.61]	**29.46 [28.91 – 29.64]**	22.84 [21.64 – 22.05]	**19.54 [19.35 – 19.73]**	21.61 [21.40 – 21.92]
Percentage of full income spent on fuel per week (%)	3.5 [3.5 – 3.5]	**12.7 [12.6 – 12.8]**	3.4 [3.4 -3.4]	**9.0 [8.9 – 9.1]**	3.2 [3.2 – 3.3]	**6.4 [6.3 – 6.5]**	3.6 [3.6 – 3.7]
Rate of fuel poverty (%)	-	**6.0 [5.8 – 6.3]**	-	**9.3 [9.0 – 9.6]**	-	**-**	-
Sample size	**83,386**	**5,732**	**80,338**	**8,780**	**72,569**	**16,549**	**89,118**

Note 1: The median values within the table are taken directly from the dataset. As the distributions of full income and fuel expenditure are skewed, this means that the median percentage of full income spent on fuel cannot be calculated from the median values of full income and fuel expenditure presented in the table.
Note 2: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

In Tables 5.5 and 5.6, the fuel poor and income poor are shown to have statistically significantly lower incomes in comparison to their respective non-fuel poor and non-income poor groups. Although the fuel poor are shown to have the highest proportions of income dedicated to fuel expenditure as expected, perhaps the most striking observation in Tables 5.5 and 5.6 is that the fuel poor spend more on fuel in absolute terms compared to all other groups. This is significantly higher in comparison to their respective non-fuel poor groups and the income poor.

As the majority of fuel poor households are known to be income poor (Boardman 2010) and as fuel expenditure has been shown to increase with income (as can be seen in Tables 5.1 and 5.2), it is thought that the fuel poor spend less in absolute terms, at least under the 10 per cent definition[43]. In fact, Boardman's 10 per cent definition is based on this understanding – that lower income households spend a greater proportion of their income on fuel but spend less in absolute terms, as shown in her analysis (Boardman 1991, p.46).

Although appearing to be in conflict with Boardman's work, other studies that have used an expenditure-based 10 per cent threshold, such as that used herein, have also found that the fuel poor spend more, both in absolute and proportionate terms (Jamasb and Meier 2010; Waddams Price et al. 2012; Deller et al. 2021). However, it is important to note here that higher spending on fuel by fuel poor households may not necessarily mean higher levels of energy consumption. Chapter 2 (see section 2.6.3) has already mentioned that the fuel poor may face higher costs as a consequence of paying for fuel by more expensive means (i.e. by PPM) (Boardman 2010; Hills 2012), using more expensive types of fuel, such as electricity or oil (Boardman 2010; Preston et al. 2014), possessing energy inefficient goods (Jamasb and Meier 2010) or being disadvantaged in the energy market (Ofgem 2008; Lomax and Wedderburn 2009; Anderson et al. 2010; Hills 2011; BEIS 2017c) and, therefore, being on a tariff that is not appropriate for the household's needs. In contrast, it may also reflect higher

[43] This is only relevant to the 10 per cent definition as the LIHC defines the fuel poor as those spending above the median on fuel expenditure, and therefore have high fuel expenditures.

fuel requirements where disabilities and longstanding illnesses may be present within the household (Snell et al. 2015).

Tables 5.5 and 5.6 also show that, for the income poor, fuel expenditure consumes less than 7 per cent of their income, which is less than that for both fuel poor groups. This helps to distinguish the fuel poor from the income poor. Furthermore, these tables show that the income poor spend around a third less in absolute terms on fuel compared to the fuel poor[44]. This finding aligns with work conducted by Jamasb & Meier (2010), who explored the fuel expenditures of the fuel poor - defined by an actual expenditure-based 10 per cent indicator – within different household types. Their work shows that the income poor (i.e. incomes below 60 per cent of median income in the sample) spend 38.9 per cent less on absolute fuel expenditure than the fuel poor as a whole. However, by using an actual expenditure-based indicator it is not known whether the income poor are rationing their fuel use and, as such, whether they may be experiencing fuel poverty under other definitions.

As mentioned in Chapter 2 (see section 2.4.1), one of the limitations of the 10 per cent indicator is that it may capture wealthier households that may not necessarily be experiencing fuel poverty (Boardman 2010) and this may be driving the high fuel expenditures observed for the fuel poor. To further explore this, Tables 5.7 and 5.8 divide the fuel poor groups into those who are income poor and not income poor and present absolute expenditure on fuel, full income and the percentage of income spent on fuel for the fuel poor in the LCFS and the UKHLS, respectively, to explore whether the high fuel expenditures observed for the fuel poor in Tables 5.5 and 5.6 are driven by the presence of wealthier households. As one of the conditions to be classified as fuel poor under the AFP indicator is to have high fuel expenditures, this conflict lies only with the 10 per cent indicator and so it is only this indicator that will be of focus in the following subsections.

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[44] In Table 5.5, the income poor spend 38.5 per cent less than the fuel poor under the 10 per cent indicator ((19.52-31.74)/31.74x 100) and 35.5 per cent less than the fuel poor under the AFP indicator ((19.52-30.28)/ 30.28 x 100). In Table 5.6, the income poor spend 30.7 per cent less than the fuel poor under the 10 per cent indicator ((19.54-28.19)/28.19 x 100) and 33.7 per cent less than the fuel poor under the AFP indicator ((19.54-29.46)/29.46 x 100).

Table 5.7: *Median absolute fuel expenditure and the percentage of income spent on fuel for fuel poor and income poor group [95% confidence intervals], 10 per cent indicator, LCFS (2013 – 2015/16), weighted*

	A	**B**	**C**	**D**	**E**
	Fuel poor, income poor	**Fuel poor, not income poor**	**Not fuel poor, income poor**	**Not fuel poor, not income poor**	**Whole sample**
Full income (£/week)	188.80 [180.67 – 196.93]	289.65 [274.94 – 304.36]	327.09 [317.96 – 336.22]	659.47 [650.84 – 668.11]	544.08 [536.03 – 552.13]
Expenditure on fuel (£/week)	29.20 [28.20 – 30.20]	37.45 [35.95 – 38.96]	17.71 [17.10 – 18.32]	21.61 [21.39 – 21.83]	21.61 [21.42 – 21.80]
Percentage of full income spent on fuel (%)	14.0 [13.6 – 14.4]	11.9 [11.6 – 12.1]	5.5 [5.3 – 5.6]	3.3 [3.2 – 3.3]	3.8 [3.8 – 3.9]
Sample size	**889**	**544**	**2,274**	**12,004**	**15,711**
Percent of sample (%)	**5.7**	**3.5**	**14.5**	**76.4**	**100.0**

Note 1: The median values within the table are taken directly from the dataset. As the distributions of full income and fuel expenditure are skewed, this means that the median percentage of full income spent on fuel cannot be calculated from the median values of full income and fuel expenditure presented in the table.
Note 2: Non-overlapping confidence intervals indicate that differences between groups are statistically significant.

Table 5.8: *Median absolute fuel expenditure and the percentage of income spent on fuel for fuel poor and income poor groups, [95% confidence intervals], 10 per cent indicator, UKHLS (3 - 7), weighted*

	A	**B**	**C**	**D**	**E**
	Fuel poor, income poor	**Fuel poor, not income poor**	**Not fuel poor, income poor**	**Not fuel poor, not income poor**	**Whole sample**
Full income (£/week)	173.17 [170.08 – 174.98]	273.73 [264.18 – 278.45]	330.22 [321.44 – 331.63]	677.21 [668.11 – 679.84]	575.93 [573.24 – 579.44]
Expenditure on fuel (£/week)	26.27 [25.72 – 26.57]	34.17 [33.28 – 34.32]	18.02 [17.88 – 18.14]	21.69 [21.65 – 21.73]	21.61 [21.42 – 22.03]
Percentage of full income spent on fuel (%)	13.3 [13.1 – 13.4]	11.7 [11.6 – 11.9]	5.4 [5.3 – 5.5]	3.2 [3.2 – 3.2]	3.6 [3.6 – 3.7]
Sample size	**4,001**	**1,731**	**12,548**	**70,838**	**89,118**
Percent of sample (%)	**4.5**	**1.9**	**14.1**	**79.5**	**100.0**

Note 1: The median values within the table are taken directly from the dataset. As the distributions of full income and fuel expenditure are skewed, this means that the median percentage of full income spent on fuel cannot be calculated from the median values of full income and fuel expenditure presented in the table.
Note 2: Non-overlapping confidence intervals indicate that differences between groups are statistically significant.

Aligning with the findings in Tables 5.5 and 5.6, Tables 5.7 and 5.8 show that the fuel poor under the 10 per cent indicator– whether they are income poor (column A) or not (column B) – have statistically significantly higher absolute fuel expenditures compared to all other groups, with the fuel poor who are not income poor (column B), having the highest absolute expenditures overall. This is significantly higher as shown by the non-overlapping confidence intervals. These higher fuel expenditures translate into a greater proportion of income being spent on fuel, with the fuel poor who are income poor (column A) spending the greatest proportion of income on fuel and therefore experiencing the greatest burden overall[45]. Again, this is statistically significant as indicated by the non-overlapping confidence intervals.

As expected, the income poor who are not fuel poor (column C) spend the least on fuel overall, in absolute and proportionate terms. This is statistically significantly lower than all other groups as shown by the non-overlapping confidence intervals. Tables 5.7 and 5.8 show that the income poor have relatively high incomes and this is because a full income measure inflates the incomes of the income poor as it includes benefits related to housing i.e. Housing Benefit and Council Tax Benefit.

Of particular interest in Tables 5.7 and 5.8 is that the fuel poor who are income poor (column A) have absolute fuel expenditures that are closer to the fuel poor who are not income poor (column B) than to the income poor (column C). Calculations using the values from Tables 5.7 and 5.8 show that the fuel poor under the 10 per cent indicator who are income poor (column A) spend between 45.8 per cent (Table 5.7) and 64.9 per cent (Table 5.8) more than the income poor who are not fuel poor (column C)[46]. These values are in agreement with work by Jamasb & Meier (2010, p.10), who show that households that are both fuel poor and income poor spend 53.8 per cent more on fuel than households who are income poor only. This finding further reinforces that the fuel poor and income poor are different groups.

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[45] This exploration has also been conducted on the 1988 Family and Expenditure Survey that Boardman used to construct the 10 per cent threshold as well as with modelled fuel costs in the Fuel Poverty Datasets and the findings are consistent with those shown within this chapter.

[46] Calculation for Table 5.7: (29.20-17.71)/17.71 x 100; Calculation for Table 5.8: (26.27-18.02)/18.02 x 100.

Although Tables 5.7 and 5.8 have further clarified the fuel expenditures of the fuel poor under the constructed indicators, a further conflict still remains. Given that Tables 5.1 and 5.2 show that fuel expenditure rises with income and knowing that the fuel poor are predominantly income poor (Boardman 2010), it makes sense that the fuel poor should spend less in absolute terms. Attempts to unravel this conflict will be made in the following two subsections. Firstly, the relationship between income and absolute fuel expenditure will be explored in more depth to gain a better understanding of this. Secondly, the overlap between fuel poverty and income poverty will be investigated in order to understand how these groups overlap and what this means for absolute fuel expenditure.

5.3.3.1 The relationship between income and fuel expenditure

To explore the relationship between income and absolute fuel expenditure, linear regression has been used. This method models the relationship between a continuous dependent variable and one independent variable (Acock 2016). The results of conducting linear regression on income and absolute actual fuel expenditure contained within the LCFS and the UKHLS is presented in Table 5.9.

Table 5.9: *The relationship between income and absolute fuel expenditure (£/week), LCFS (2013 - 2015/16) and UKHLS (waves 3 - 7), weighted*

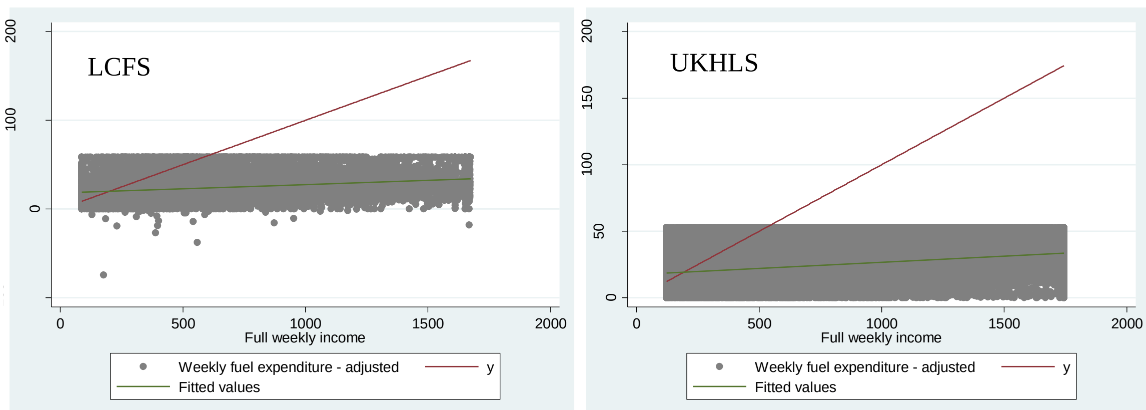
	LCFS	**UKHLS**
Full income deciles (ref: 1st (Lowest))	**Coefficient (Robust standard errors)**	
2nd	1.315 (0.419)**	1.090 (0.149)***
3rd	2.625 (0.425)***	2.671 (0.152)***
4th	3.634 (0.426)***	3.945 (0.154)***
5th	5.073 (0.441)***	5.033 (0.156)***
6th	5.455 (0.434)***	6.246 (0.158)***
7th	6.439 (0.443)***	6.862 (0.161)***
8th	6.953 (0.439)***	8.207 (0.164)***
9th	8.716 (0.452)***	9.684 (0.166)***
10th (highest)	12.669 (0.488)***	13.183 (0.182)***
Constant	18.262 (0.304)***	17.368 (0.106)***
$\mathbf{R^2}$	0.0833	0.122
Sample size	**15,711**	**89,118**

*p<0.05 **p<0.01 ***p<0.001

Although Table 5.9 shows that actual fuel expenditure increases with income, corresponding to patterns observed in Tables 5.1 and 5.2, the low R^2 coefficients suggests that this relationship is very weak. For the LCFS data, the R^2 coefficient suggests that income only explains 8.3 per cent of absolute fuel expenditure and, for the UKHLS, income explains only 12.2 per cent of absolute fuel expenditure. This indicates that income plays a relatively minor role in the amount spent on fuel and that other factors may be of importance, such as the energy efficiency of the home, differing patterns of energy usage, and differing needs. Of particular interest in Table 5.9 are the constants. These show that households with the lowest incomes spend an average of £18.26 a week on fuel in the LCFS, and £17.37 a week in the UKHLS. This may suggest that fuel expenditures are inelastic and reinforces the notion that they are an essential expenditure. However, low incomes in these surveys may be reflecting a temporary period of low income and it is not clear whether savings have been used to pay for fuel.

The following scatterplots shown in Figure 5.1 present the relationship between income and fuel expenditure visually. As the key conflict lies with the 10 per cent indicator, a 10 per cent threshold is applied in these scatterplots in order to better observe the expenditures being captured and the linear regression line is also applied to emphasise the relationship between income and fuel expenditure.

Figure 5.1: *Scatterplots showing the relationship between income and absolute fuel expenditure presented with the 10 per cent threshold and the regression line, LCFS (2013 – 2015/16) and UKHLS (waves 3 - 7)*



Given the weak relationship between income and fuel expenditure explored in Table 5.9, the scatterplots in Figure 5.1 illustrate that the 10 per cent threshold (shown as the diagonal line) inevitably captures high fuel expenditures due to its steepness and this helps to clarify why the 10 per cent indicator captures high fuel expenditures. Scatterplots using unwinsorised absolute fuel expenditure are shown in Figure B.1 in Appendix B and show the same patterns. This conflict of high absolute fuel expenditure may have arisen from different ways of applying the 10 per cent threshold. In this research, the 10 per cent threshold has been applied across the whole sample, but Boardman's analysis divided the sample between income poor and not income poor, as explained earlier in Chapter 2 (see section 2.4.1), and found that the poor spend 10 per cent of their income on fuel, but less in absolute terms compared to households who are not income poor[47].

5.3.4 Inspecting the overlap between fuel poverty and income poverty

In the second attempt to understand the key conflict between high absolute fuel expenditures of the fuel poor, this section now turns to the widely accepted overlap between fuel poverty and income poverty (Boardman 2010). Tables 5.10 and 5.11 present this overlap for the fuel poor under the 10 per cent indicator in the LCFS and the UKHLS, respectively and Tables 5.12 and 5.13 present this overlap for the fuel poor under the AFP indicator in the LCFS and the UKHLS, respectively.

Table 5.10 *The overlap between fuel poverty (10 per cent indicator) and income poverty, LCFS (2013-2015/16), cell percentages, weighted*

10 per cent indicator	Income poverty		Total
	Not income poor	Income poor	
Not fuel poor	75.9	15.3	**91.2**
Fuel poor	3.3	5.6	**8.8**
Total	**79.2**	**20.8**	**100.0**

Table 5.10 shows that 5.6 per cent of households are both income poor and fuel poor under the 10 per cent indicator. Almost two thirds (63.6 per cent) of the fuel poor under the 10 per cent indicator are also income poor (i.e. 5.6/8.8 x 100), meaning that 37.5 per cent of households who are fuel poor under this indicator are not income poor (i.e. 3.3/8.8 x 100). However, only 26.9 per cent of the income poor are also fuel poor under the 10 per cent indicator (i.e. 5.6/20.8x100) and 73.6 per cent of households who are income poor are not fuel poor under the 10 per cent indicator (i.e. 15.3/20.8 x 100). Just over three-quarters (75.9 per cent) of households are neither fuel poor nor income poor.

[47] Dividing the LCFS and UKHLS samples in the same way as Boardman produces a similar finding: that low-income households spend a greater proportion of income on fuel, but less in absolute terms compared to high income households.

Table 5.11: *The overlap between fuel poverty (10 per cent indicator) and income poverty, UKHLS (waves 3 - 7), cell percentages, weighted*

10 per cent indicator	Income poverty		Total
	Not income poor	Income poor	
Not fuel poor	79.4	14.6	**94.0**
Fuel poor	1.7	4.3	**6.0**
Total	**81.1**	**18.9**	**100.0**

Table 5.11 shows that 4.3 per cent of households are fuel poor and income poor and almost three quarters (71.7 per cent) of the fuel poor under the 10 per cent indicator are also income poor (i.e. 4.3/6.0 x 100) in the UKHLS dataset – 8.1 per cent greater than in the LCFS – and 28.3 per cent of households who are fuel poor under the 10 per cent indicator are not income poor (i.e. 1.7/6.0 x 100). However, similar to the LCFS, only 22.8 per cent of the income poor are also fuel poor under the 10 per cent indicator (i.e. 4.3/18.9 x 100) and 77.2 per cent of households who are income poor are not fuel poor under the 10 per cent indicator (i.e. 14.6/18.9 x 100). Almost 80 per cent (79.4 per cent) of households are neither fuel poor nor income poor.

Table 5.12: *The overlap between fuel poverty (AFP indicator) and income poverty, LCFS (2013-2015/16), cell percentages, weighted*

AFP indicator	Income poverty		Total
	Not income poor	Income poor	
Not fuel poor	76.8	12.0	**88.8**
Fuel poor	2.4	8.8	**11.2**
Total	**79.2**	**20.8**	**100.0**

Table 5.12 shows that 8.8 per cent of households are both fuel poor and income poor under the AFP indicator using the LCFS dataset. 78.6 per cent of the fuel poor under the AFP indicator are also income poor (i.e. 8.8/11.2 x 100), meaning that 21.4 per cent of households who are fuel poor under the AFP indicator are not income poor (i.e. 2.4/11.2 x 100). Just over two-fifths (42.3 per cent) of the income poor are also fuel poor under the AFP indicator (i.e. 8.8/20.8 x 100), and 57.7 per cent of households who are income poor are not fuel poor under

this indicator (i.e. 12.0/20.8 x 100). Compared to the 10 per cent indicator, a greater proportion of the fuel poor under this indicator are income poor and this is linked to the nature of the indicator, which requires households to fall below the poverty line after paying for fuel costs to be classified as fuel poor and so those who are already close to the poverty line that have higher than median fuel costs would be pushed into fuel poverty. Just over three-quarters (76.8 per cent) of households are neither fuel poor nor income poor.

Table 5.13: *The overlap between fuel poverty (AFP indicator) and income poverty, UKHLS (waves 3 - 7), cell percentages, weighted*

AFP indicator	**Income poverty**		**Total**
	Not income poor	**Income poor**	
Not fuel poor	79.3	11.4	**90.7**
Fuel poor	1.8	7.5	**9.3**
Total	**81.1**	**18.9**	**100.0**

Table 5.13 shows that 7.5 per cent of households are both fuel poor under the AFP indicator and income poor. Similar to the LCFS data in the table above, 80.6 per cent of the fuel poor are also income poor (i.e. 7.5/9.3 x 100) and 19.4 per cent of households are fuel poor, but not income poor (i.e. 1.8/9.3 x 100). Of the income poor, 39.7 per cent are also fuel poor (i.e. 7.5/18.9x100) and 60.3 per cent of the income poor are not fuel poor under the under the AFP indicator (i.e. 11.4/18.9 x 100). Almost 80 per cent (79.3 per cent) of households are neither fuel poor nor income poor.

Although Tables 5.10 to 5.13 show that the majority of the fuel poor are indeed income poor, they also highlight that only between 22.8 per cent and 42.3 per cent of the income poor are fuel poor, depending on the indicator and the dataset used. This finding suggests that the fuel poor and the income poor are different groups and that fuel poverty and income poverty are distinct issues, as emphasised by others (Hills 2012). This may indicate that the fuel expenditures of the fuel poor may not necessarily resemble those of the income poor and so it should not be assumed that just because their incomes are lower that they spend less than wealthier households, on average.

Having resolved the conflict of high absolute fuel expenditures amongst the fuel poor and attributing this partly to methodological differences in the way that the 10 per cent threshold has been applied herein and in Boardman's original work, the remaining sections of this chapter further examine the constructed indicators from each dataset, focusing on the last three objectives set for this chapter. As a reminder, these are detailed below:

4. To investigate the overlap between both constructed fuel poverty indicators
5. To understand which experiences of fuel poverty the constructed fuel poverty indicators are capturing
6. To explore the incidence and determinants of fuel poverty under both fuel poverty indicators and to identify the characteristics of households with the highest likelihood of experiencing fuel poverty under each indicator.

5.3.5 Objective 4: Investigating the overlap between both constructed fuel poverty indicators

In Chapter 2, it was shown that different indicators of fuel poverty produce different rates of fuel poverty (see Figure 2.2) and do not always capture the same characteristics (see section 2.7). This section explores how the indicators used throughout the thesis overlap with each other, fulfilling the fourth objective of the research.

Table 5.14: *The overlap between both fuel poverty indicators, LCFS (2013 – 2015/16), cell percentages, weighted*

AFP indicator	10 per cent indicator		Total
	Not fuel poor	Fuel poor	
Not fuel poor	85.4	3.4	**88.8**
Fuel poor	5.7	5.5	**11.2**
Total	**91.2**	**8.8**	**100.0**

Table 5.14 shows that almost two thirds (62.5 per cent) of the fuel poor under the 10 per cent indicator are also fuel poor under the AFP indicator (i.e. 5.5/8.8 x 100) and 49.1 per cent of the fuel poor under the AFP indicator are also fuel poor under the 10 per cent indicator (i.e. 5.5/11.2 x 100). Under both indicators, 5.5 per cent of households are fuel poor. However, 50.9 per cent of households who are fuel poor under the AFP indicator are not fuel poor under the 10 per cent indicator (i.e. 5.7/11.2x100) and 38.6 per cent of households who are fuel poor under the 10 per cent indicator are not fuel poor under the AFP indicator (3.4/8.8 x 100).

Table 5.15: *The overlap between both fuel poverty indicators, UKHLS (waves 3 - 7), cell percentages, weighted*

AFP indicator	10 per cent indicator		Total
	Not fuel poor	Fuel poor	
Not fuel poor	88.5	2.2	**90.7**
Fuel poor	5.5	3.8	**9.3**
Total	**94.0**	**6.0**	**100.0**

Table 5.15 shows that the overlap between fuel poverty indicators using the UKHLS data is similar to that for the LCFS data. Around two-thirds (63.3 per cent) of fuel poor households under the 10 per cent indicator are also fuel poor under the AFP indicator (i.e. 3.8/6.0 x 100). Around two-fifths (40.9 per cent) of fuel poor households under the AFP indicator are also fuel poor under the 10 per cent indicator (i.e. 3.8/9.3 x 100) – 8.2 per cent lower than that observed for the LCFS data. Only 3.8 per cent of households are fuel poor under both indicators, which is almost a third less than in the LCFS dataset. However, over half of the fuel poor (59.1 per cent) under the AFP indicator are not fuel poor under the 10 per cent

indicator (i.e. 5.5/9.3 x 100), and 36.7 per cent of fuel poor households under the 10 per cent indicator are not fuel poor under the AFP indicator (i.e. 2.2/6.0 x 100).

5.3.6 Objective 5: Which experiences of fuel poverty are the fuel poverty indicators capturing?

Within the UKHLS, there are two variables that are often used as consensual measures of fuel poverty[48]. Within waves 4, and 6, interviewees were asked whether they are able to keep their home warm enough in winter ("hheat"). Furthermore, as part of their retirement module, waves 4 and 6 of the UKHLS include questions around items of material deprivation[49] for pensioner households. Within these questions, pensioner households are asked whether they have a damp-free home. Using these variables can help to understand whether the characteristics commonly associated with fuel poverty are being captured by the two fuel poverty indicators used throughout the thesis and how these characteristics vary under the two fuel poverty indicators.

Table 5.16 shows the incidence of households who are unable to keep their home adequately heated in the winter and those who are not able to keep a damp-free home under the fuel poverty indicators constructed from fuel expenditure data contained within the UKHLS. The rates are presented alongside those who are income poor as a way of exploring whether differences between the fuel poor and the income poor exist on these variables.

[48] Consensual measures of fuel poverty refer to those that are self-reported subjective assessments, such as living in a cold home and being able to pay their utility bills on time (Rademaekers et al. 2016).
[49] These are consumption goods and activities that are considered essential in a society at a given point in time (Townsend 1979).

Table 5.16: *The rate (%) of fuel poor households unable to heat their home adequately in the winter and unable to have a damp-free home [95% confidence intervals], UKHLS, weighted*

	10 per cent indicator	**AFP indicator**	**Income poor**	**Whole sample**
Inability to heat the home adequately in the winter* (%)	16.4 [14.4 – 18.6]	14.9 [13.4 – 16.6]	15.0 [13.9 – 16.2]	6.5 [6.2 – 6.9]
Sample size	**27,589**			
Does not have a damp-free home (%)**	4.3 [3.1 – 5.9]	5.6 [4.1 – 7.6]	5.4 [4.3 – 6.8]	3.6 [3.3 - 4.0]
Sample size	**12,107**			

Note: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.
*Present in waves 2, 4, and 6
**Present in waves 4 and 6 for pensioner households only, i.e. where there are no children aged 0 to 15 and where there is one or more adults of pensionable age.

Despite spending disproportionate amounts of income on domestic fuel, as indicated in Tables 5.5 to 5.8, there are still some fuel poor households who are not able to achieve a sufficiently warm home in the winter, or a damp-free home, as shown in Table 5.16. The fuel poor under both fuel poverty indicators and the income poor have statistically significantly higher levels of being unable to heat their home adequately in the winter compared to the whole sample as shown by their confidence intervals, which do not overlap with those for the whole sample. The fuel poor under the 10 per cent indicator are shown to have higher rates (16.4 per cent) of not being able to heat their home adequately in the winter compared to the fuel poor under the AFP indicator (14.9 per cent) and the income poor (15.0 per cent), but these are not significantly different from each other. However, the rates of being unable to afford adequate warmth in the winter amongst the fuel poor are low and this mismatch between objective and subjective measures of fuel poverty has been evidenced elsewhere (Palmer et al. 2008; Waddams Price et al. 2012; Deller et al. 2021). In contrast, pensioner households under the 10 per cent indicator have the lowest rates of having a damp-free home (4.3 per cent). This is lower than the income poor (5.4 per cent) and the fuel poor under the AFP indicator (5.6 per cent). However, this variable only applies to pensioner households and may not adequately capture the experience of fuel poverty in other household types.

5.3.7 Objective 6: The incidence and determinants of fuel poverty: exploring the behaviour of the indicators

Table 5.17 presents the incidence of fuel poverty using the 10 per cent indicator and the AFP indicator constructed from actual fuel expenditure data contained within the LCFS and the UKHLS datasets, fulfilling the first part of the sixth, and final, objective set for this chapter. The purpose of this comparison is to identify differences and similarities in how the incidence of fuel poverty under each indicator is altered considering a range of characteristics[50], and to explore whether rates and patterns correspond to published statistics. This can help to understand differences between the characteristics of fuel poor households under actual expenditure-based indicators and those based on modelled fuel costs. The components of all variable categories are presented in the *Variable catalogue* located in Appendix A.

[50] Although fuel poverty may vary by season, this has not been included here as the LCFS and the UKHLS collect fuel expenditure data for different periods at the point of interview and the time of interview may not be related to the period of fuel expenditure. Therefore, the season variable would not be directly comparable and does not necessarily correspond to the period of collected fuel expenditure data.

Table 5.17: *The prevalence of fuel poverty (%) under the 10 per cent indicator and the AFP indicator, LCFS (2013 – 2015/16) and UKHLS (waves 3 – 7) weighted*

	LCFS		**UKHLS**	
	10 per cent indicator	**AFP indicator**	**10 per cent indicator**	**AFP indicator**
Fuel poverty and income				
Fuel poverty [95% confidence intervals]	8.8 [8.4 – 9.3]	11.2 [10.7 – 11.7]	6.0 [5.9 – 6.3]	9.3 [9.1 – 9.5]
Household income deciles (full income)				
1st (Lowest)	46.2***	31.4***	37.0***	27.6***
2nd	18.6***	23.7***	10.3***	17.2***
3rd	10.9**	16.6***	4.7***	12.7***
4th	6.8**	14.6***	2.2***	10.7***
5th	4.1***	12.5	0.3***	8.1**
6th	1.2***	7.2***	0.0***	6.0**
7th	0.0 ***	4.8***	0.0***	2.7**
8th	0.0***	1.1***	0.0***	1.4***
9th	0.0***	0.6***	0.0***	0.5***
10th (Highest)	0.0***	0.1***	0.0***	0.0***
Type of fuel used and method of fuel payment				
Central heating fuel				
Electricity	8.5	8.5*	-	-
Gas	8.0***	11.2	-	-
Oil	18.2***	14.2**	-	-
Other fuel	14.4***	11.0	-	-
No central heating	10.4	11.0	-	-
All types of fuels used				
Electricity only	-	-	5.0*	6.2***
Gas & Electricity	-	-	5.6***	9.4*
Oil & Other fuel	-	-	7.2	5.3**
All fuels	-	-	15.9***	15.7***
Other combinations	-	-	9.2***	10.0*
Method of fuel payment (LCFS) (Gas & electricity)				
Direct Debit (DD)	6.1***	6.2***	-	-
Prepayment meter (PPM)	18.2***	32.4***	-	-
Other	14.0 ***	17.0***	-	-
Combined	9.8	18.4***	-	-

Note: Chi-squared tests were used to assess whether there is a statistically significant association between two categorical variables.
*p<0.05 **p<0.01 ***p<0.001

Table 5.17: *The prevalence of fuel poverty (%) under the 10 per cent indicator and the AFP indicator, LCFS (2013 – 2015/16) and UKHLS (waves 3 – 7) weighted (continued)*

	LCFS		UKHLS	
	10 per cent indicator	**AFP indicator**	**10 per cent indicator**	**AFP indicator**
Method of fuel payment (UKHLS) (Gas & electricity)				
Fixed monthly standing order	-	-	4.2***	6.0***
Monthly bill	-	-	4.3***	5.9***
Quarterly bill	-	-	8.7***	9.4
PPM	-	-	10.8***	23.8***
Other	-	-	8.8***	11.1*
Combined methods	-	-	7.9***	12.4***
No gas or electricity			7.2	5.3**
Housing characteristics				
Dwelling type				
Detached property	8.9	6.5***	6.2	6.3***
Semi-detached property	9.0	12.0*	5.8	10.0***
Terraced property	8.9	14.4***	6.7***	11.8***
Other	8.4	11.0	5.3***	8.0***
Housing tenure				
Owned	7.9***	6.2***	5.6***	5.8***
Private rented	7.0*	16.5***	6.7	15.4***
Social housing	13.5***	23.7***	7.3***	16.9***
Urban or rural				
Urban	8.3***	11.8***	5.6***	9.4
Rural	10.5***	9.3***	7.5***	9.1
Household type				
Single adult	17.2***	11.2	11.7***	8.6**
Single adult, 1 child	15.7***	21.8***	10.8***	20.1***
Single adult, 2+ children	14.4***	31.7***	8.2***	24.4***
2 adults	6.1***	7.6***	3.8***	6.4***
2 adults, 1 child	4.6***	11.4	2.4***	9.5
2 adults, 2 children	3.5***	11.1	2.0***	8.9
2 adults, 3+ children	4.4***	20.2***	3.0***	18.4***
3+ adults	2.9***	9.4**	1.3***	6.6***
3+ adults, 1 child	2.9***	12.5	1.6***	12.9***
3+ adults, 2+ children	3.5**	28.7***	1.5***	21.7***

Note: Chi-squared tests were used to assess whether there is a statistically significant association between two categorical variables.
*p<0.05 **p<0.01 ***p<0.001

Table 5.17: *The prevalence of fuel poverty (%) under the 10 per cent indicator and the AFP indicator, LCFS (2013 – 2015/16) and UKHLS (waves 3 – 7) weighted (continued)*

	LCFS		**UKHLS**	
	10 per cent indicator	**AFP indicator**	**10 per cent indicator**	**AFP indicator**
Longstanding illness or disability in the household				
Yes	9.8***	12.2***	6.4***	9.7***
No	7.6***	9.9***	5.6***	8.8***
Characteristics of the Household Reference Person[51] (HRP)				
Sex				
Male	6.7***	9.4***	4.7***	7.9***
Female	12.1***	13.9***	7.6***	10.8***
Age (banded years)				
16 - 34	6.2***	12.0***	5.3*	12.6***
35 - 54	6.5***	12.2**	4.5***	10.5***
55 - 74	10.3***	10.5**	6.6**	7.8***
75 and over	15.2***	8.8***	9.2***	7.1***
Ethnicity				
White	8.9	10.6***	6.0***	8.9***
Mixed Race	13.6	20.5***	7.8	12.8*
Asian	6.5*	14.8 **	6.0	15.7***
Black	9.4	22.0***	9.4	15.9***
Other	6.1	14.2	7.7***	11.0
Employment status				
Self-employed	9.6	13.2*	7.7***	11.2***
In paid employment	3.3***	6.9***	2.0***	5.7***
Unemployed	25.7***	35.5***	19.8***	27.2***
Retired	13.6***	10.0*	8.0***	7.5***
Inactive	19.6***	27.5***	10.9***	23.4***
Country				
England	8.1***	10.6***	5.4***	8.8***
Wales	7.8	12.3	8.0***	10.7*
Scotland	12.9***	12.6	7.4***	10.6*
Northern Ireland	22.2***	22.2***	16.0***	17.0***
Sample size	**15,711**		**89,118**	

Note: Chi-squared tests were used to assess whether there is a statistically significant association between two categorical variables.
*p<0.05 **p<0.01 ***p<0.001

[51] The Household Reference Person (HRP) is the person who owns or rents the accommodation in which the household lives. If there is more than one owner or renter, then the occupant with the highest income is considered the HRP. If incomes are the same, then then the eldest is considered the HRP (Bulman 2017; Knies 2018).

Table 5.17 shows the rates of fuel poverty for each of the variables. Chi-squared tests have been conducted to assess whether there is a statistically significant association between whether a household is fuel poor or not and the categorical variables included in the table.

Table 5.17 shows that the rate of fuel poverty under each fuel poverty indicator is significantly higher in the LCFS compared to the rates of fuel poverty under each respective indicator in the UKHLS, as shown by the non-overlapping confidence intervals. This is possibly as a result of lower incomes within the LCFS (see Tables 5.5 and 5.6). In both datasets, the AFP indicator shows a statistically significantly higher prevalence of fuel poverty compared to the 10 per cent indicator and this contrasts the pattern of recently published statistics, which show that the LIHC indicator consistently produces lower rates of fuel poverty compared to the 10 per cent indicator (see Figure 2.2 in Chapter 2). As fuel poverty rates under the LIHC are only currently produced for England, the higher rates of fuel poverty under the AFP indicator in this research may be a result of including Wales, Scotland and Northern Ireland, all of which have higher rates of fuel poverty compared to England as a whole (National Energy Action 2018a).

There are similarities between the characteristics captured by both fuel poverty indicators across both datasets. Across both surveys, there is a statistically significant difference in the way that the fuel poor and non-fuel poor are distributed across income deciles, apart from in the 5th decile under the AFP indicator using the LCFS data. Both indicators in both datasets show that the rates of fuel poverty decrease as household income decile increases and that the rates of fuel poverty are highest in households in the lowest income decile. This corresponds with the literature and published statistics (Boardman 1991; Palmer et al. 2008; Boardman 2010; Hills 2012; BEIS 2020a) and emphasises an overlap between fuel poverty and a low income, as shown in Tables 5.10 to 5.13. However, unlike the 10 per cent indicator, the AFP indicator captures higher income households with incomes that fall into the 7th to 10th income deciles for the LCFS and up to the 9th decile for households in the UKHLS.

Across both indicators and both datasets, there are higher rates of fuel poverty in households using PPM to pay for their gas and electricity, which is associated with higher fuel costs (Boardman 2010; Hills 2012), and those living in social housing – where a low income and PPM use are most prevalent (Competitions & Markets Authority 2016). Table 5.17 shows that both PPM and living in social housing have a statistically significant association with whether a household is fuel poor or not. Higher rates of fuel poverty are also found in households where there is a longstanding illness or disability, or where the HRP is female or unemployed. These findings are also statistically significant. These characteristics are linked to a lower income and potentially spending more time at home (BEIS 2020a), which may increase fuel use.

Furthermore, households living in Northern Ireland have higher rates of fuel poverty compared to other countries within the UK, which is a statistically significant finding suggesting that living in Northern Ireland affects whether a household is fuel poor or not. Until recently, Northern Ireland was consistently associated with the highest rates of fuel poverty and this is linked to the widespread use of oil for heating (around 68 per cent of households) due to the lack of mains gas infrastructure (Bryson Energy 2018). As mentioned in Chapter 2 (section 2.5), fuel poverty rates in Northern Ireland have recently halved – from 42 per cent to 22 per cent – according to the latest published statistics due to reductions in the price of oil (Northern Ireland Housing Executive 2019).

There are also similarities between both 10 per cent indicators that differ from both AFP indicators. This can help to understand the impact of their different components. Apart from the AFP indicator created using the UKHLS data, there is a statistically significant relationship between living in an urban or rural area and whether a household is fuel poor or not. The 10 per cent indicator for both surveys show that fuel poverty rates are higher for rural-dwelling households compared to urban-dwelling households. This has been linked to low connection to the gas network and the use of more expensive fuels such as electricity, oil, and solid fuel (Baker et al. 2008), as well as less energy efficient dwellings (Baker et al.

2008). In contrast, both AFP indicators show that the highest rates of fuel poverty are found amongst urban-dwelling households, although this is not significant for the AFP indicator using UKHLS data. This transition of fuel poverty from rural areas (under the 10 per cent indicator) to urban areas (under the AFP indicator) is a consequence of using an AHC income measure, which concentrates fuel poverty in areas where housing costs are high, such as London. This therefore shows that, as well presenting different rates of fuel poverty and capturing different characteristics, the two different fuel poverty indicators impact on the spatial distribution of fuel poverty. This has also been shown elsewhere (see Robinson et al. (2018), for example). Furthermore, there is a significant association between household type and whether a household is fuel poor apart from households containing two adults and one child and two adults and two children for the AFP indicator in both surveys. The rates of fuel poverty are higher within single-adult households under both 10 per cent indicators, and this may be linked to a lower income (Palmer et al. 2008). In contrast, higher rates of fuel poverty under the AFP indicator are found in single-parent households that contain two or more children, and this corresponds with official statistics (DECC 2020a). This is linked to considerably lower than median incomes in these household types (Hills 2012; DECC 2020a).

There is also a statistically significant association between the age of the HRP and whether a household is fuel poor or not fuel poor. Under both 10 per cent indicators, the rates of fuel poverty are highest for those aged 75 and over. This may be a reflection of this indicator capturing single-person households, as shown here and in published statistics (DECC 2015b) and this may be linked to a higher prevalence of living alone amongst older age groups (Reher and Requena 2018). However, the AFP indicator constructed using the LCFS data indicates that higher rates of fuel poverty are found in households where the HRP is aged between 35 and 54, whilst for UKHLS data the highest rates of fuel poverty are amongst households with HRPs aged 16-34. Again, this could be linked to using an income AHC measure, which tends to concentrate fuel poverty amongst households who are renters as shown by BEIS (2020a), therefore making this indicator biased towards younger households, where incomes tend to be lower compared to older households.

As well as these similarities, there are also differences between the indicators regarding fuel type, dwelling type, and the ethnicity of the HRP. The differences in fuel type between both datasets is linked, in part, to differences in how data is collected and categorised. As mentioned in section 5.2.1, the LCFS collects information on the type of fuel used for heating, while the UKHLS collects information on all types of fuel used within the home, not just that for heating. This complicates the comparison of fuel poverty rates for different fuel types across both surveys. The indicators from the LCFS dataset show that higher rates of fuel poverty are found amongst households using oil as their heating fuel, whereas using the UKHLS data, those using *all fuels*, which includes oil and solid fuel as well as gas and electricity, have the highest rates of fuel poverty. These are shown the have a significant association with whether a household is fuel poor or not. Across all indicators, apart from the LCFS 10 per cent indicator, the highest rates of fuel poverty are found amongst those living in terraced properties. This may be reflecting differences in income across dwelling types.

In line with published data, minority ethnic groups have been found to have higher rates of fuel poverty (BEIS 2020a), and this is also shown in Table 5.17 although this is not always significantly significant. Using pooled data, it is possible to explore the rates of fuel poverty amongst more detailed ethnicity categories than those published by BEIS, which groups ethnicities into “White” and “Ethnic minority”. This provides the possibility to investigate whether fuel poverty rates vary for households with HRPs belonging to different ethnic groups. This is a strength in this study. Table 5.17 shows that households with a HRP belonging to a Black ethnic group have higher rates of fuel poverty under the AFP indicator across both surveys and this has significant association with whether a household is fuel poor or not. These higher rates of fuel poverty amongst certain minority ethnic groups may be a reflection of a combination of higher housing deprivation experienced by these groups (De Noronha 2019), as well as higher rates of income poverty (Kenway and Palmer 2007), persistent in-work poverty (Hudson et al. 2013), and a higher prevalence of single-parent households compared to White ethnic groups (Rabindrakumar 2018).

5.3.7.1 Identifying the determinants fuel poverty: logistic regression

Although examining the prevalence of fuel poverty in Table 5.17 provides some indication of how fuel poverty rates can vary by characteristic, it is not possible to understand the unique contribution of each variable on fuel poverty in the presence of other variables. To determine this, logistic regression analysis was employed. As mentioned in Chapter 4 (see section 4.10.1), this is a predictive modelling technique that explains the relationship between a binary dependent variable (in this case, *fuel poverty*) and the independent variables, which can be categorical or continuous (Hosmer et al. 2013). As such, logistic regression was viewed as an appropriate method to explore this area of interest further and fulfils the second part of the final objective set for this chapter.

Logistic regression produces odds ratios (ORs), which is a measure of association between the independent variable and the dependent variable and represents the odds that an outcome will occur given a particular exposure, compared to the odds of the outcome occurring in the absence of that exposure (Szumilas 2010). In the case of this research, an OR greater than one indicates an increased likelihood of fuel poverty; an OR equal to one signifies an equal likelihood of being fuel poor; and an OR below one indicates a reduced likelihood of being fuel poor (holding all other characteristics constant and equal) (Ahmed 2013). The assumptions for logistic regression have been detailed in Chapter 4 (see section 4.10.1.1).

5.3.7.2 Selecting the variables to explore the determinants of fuel poverty: purposeful selection

A common approach in fuel poverty research is the use of *backward elimination*, which has been used previously to predict fuel poverty outcomes (Ahmed 2013; Thomson and Snell 2013). This method begins with all the variables selected, with those that are not significant at the chosen level being permanently removed (starting with the least significant) (Bursac et al. 2008). The model is re-fitted until all remaining variables are statistically significant (Hosmer et al. 2013). This method has significant drawbacks as it relies heavily on the statistical software to find the best model, essentially removing the researcher from the model-building process (Hosmer et al. 2013). There is also the possibility that variables that have been removed from the model would be significant when added to the final reduced model (Hosmer et al. 2013).

Considering the limitations of backward elimination, *purposeful selection* was employed. This is where the decision of including or excluding variables lies with the researcher (Bursac et al. 2008). The selection of variables is based on prior knowledge drawn from the research literature and policy documents and provides the most important rationale for including or excluding variables in a statistical analysis (Walter and Tiemeier 2009). Key variables that were evidenced to be relevant to fuel poverty were identified in the LCFS and UKHLS datasets. These, along with the rationale for their inclusion with reference to the literature, are presented in Table 5.18. This makes reference to differences in characteristics between fuel poverty under the official 10 per cent definition and the LIHC indicator, again highlighting differences in characteristics between the fuel poor under different definitions as identified in Chapter 2 (see section 2.7).

Table 5.18: *Potential variables for logistic regression within the LCFS (2013 – 2015/16) and the UKHLS (waves 3 – 7) and their rationale for inclusion*

Variable category	Variable name	Rationale for inclusion
Dwelling location	Country	The rates of fuel poverty vary by country within the UK, in part due to differences in how fuel poverty is measured and modelled, but also due to the varying characteristics of each country. At present, Scotland has the highest rates of fuel poverty (25 per cent), followed by Northern Ireland (18 per cent), Wales (12 per cent), and England (11 per cent) (Hinson and Bolton 2020).
	Urban or rural	The rate of fuel poverty tends to be higher in rural areas due to dwellings being older, larger, and less energy efficient than those in rural areas (Defra 2017). There is also a higher likelihood of not being connected to the gas network in rural areas and relying on other types of fuels (such as oil and electricity), which are often more expensive (Boardman 2010; Preston et al. 2014).
Dwelling characteristics	Dwelling type	Under the 10 per cent indicator, those in detached dwellings are most likely to experience fuel poverty and this is linked to these dwellings having more external walls and a roof, which increases heat loss (Wilson et al. 2012). However, under the LIHC indicator, the highest likelihood of fuel poverty is amongst those living in converted flats and the lowest likelihood is amongst those living in purpose-built flats (BEIS 2020a). This is linked to differences in energy efficiency, with purpose-built flats having the highest median energy efficiency rating and converted flats having the lowest (BEIS 2020a).
	Housing tenure	It has consistently been shown that the highest proportions of household in fuel poverty are in the private rented sector both under the 10 per cent definition (DECC 2014a) and the LIHC indicator (BEIS 2020a) and this is linked to the poor energy efficiency of dwellings within this tenure and the low incomes of those living within them (DECC 2014a; BEIS 2020a). Living in private rented accommodation also limits the opportunity to improve the property's energy efficiency (Boardman 2010).

Table 5.18*: Potential variables for logistic regression within the LCFS (2013 – 2015/16) and the UKHLS (waves 3 – 7) and their rationale for inclusion (continued)*

Variable category	Variable name	Rationale for inclusion
Fuel poverty drivers	Income	There is an overlap between low income and fuel poverty, with low-income households at a higher risk of fuel poverty (Boardman 1991; Palmer et al. 2008; Boardman 2010; Hills 2012; BEIS 2020a), which is linked to the inability to convert resources into sufficient energy services, but also the high prevalence of PPM amongst low-income households (Waddams Price et al. 2012; DECC 2015a) and being disengaged with the energy market (Day and Hitchings 2009; Lomax and Wedderburn 2009; Anderson et al. 2010), which may mean that low-income households are paying more for their energy use.
	Fuel type	Gas tends to be less expensive than other domestic fuels and the lowest incidence of fuel poverty can be found in those using gas as their main heating fuel (Preston et al. 2014). As already noted in "country" and "urban or rural", oil tends to be more expensive (Boardman 2010; Preston et al. 2014) and this partially explains the higher rates of fuel poverty amongst those not connected to the gas network.
	Method of fuel payment	Prepayment meters are often associated with higher fuel costs and are most likely to be concentrated in low-income households increasing the risk of fuel poverty in these households (Waddams Price et al. 2012; DECC 2015a). Paying by direct debit has been shown to be the most economical method of paying for fuel bills (Ofgem 2020a).
Household characteristics	Household type	Under the 10 per cent definition, single-person older households have the highest rates of fuel poverty (DECC 2014a). In contrast, under the LIHC indicator, single-parent households with dependent children have the highest rates of fuel poverty (BEIS 2020a).
	Highest qualification in household	Although the consideration of education is relatively scarce in the fuel poverty literature, it has been found that those with lower levels of education have a higher vulnerability to fuel poverty (Healy and Clinch 2004; Legendre and Ricci 2015; Simoes et al. 2016). This has been linked to how education may influence access to complex information, such as that related to energy efficiency upgrades and accessing grants (Legendre and Ricci 2015; Simoes et al. 2016).

Table 5.18: *Potential key variables for logistic regression within the LCFS (2013 – 2015/16) and the UKHLS (waves 3 – 7) and their rationale for inclusion (continued)*

Variable category	Variable name	Rationale for inclusion
Household characteristics	Longstanding illness or disability in the household	Longstanding illness or disability may be linked to greater energy needs through a greater physiological need for warmth to preserve health, to power specialised equipment, or for additional laundry requirements (Snell et al. 2015). However, the rates of low income a greater amongst those households containing someone with a disability or longstanding illness (Tinson et al. 2016).
Characteristics of the HRP	Sex	Female-headed households have been found to have a higher likelihood of experiencing fuel poverty due to their generally lower incomes (Healy and Clinch 2002).
	Ethnicity	Under the LIHC indicator, households with a HRP belonging to a minority ethnic group are more likely to be fuel poor compared to households with a White HRP (BEIS 2019a). No statistics were produced by ethnicity under the 10 per cent indicator. However, given that incomes are lower and housing deprivation is higher amongst minority ethnic groups (Kenway and Palmer 2007; De Noronha 2019), it is likely that fuel poverty under the 10 per cent definition would also be higher amongst households with a HRP belonging to a minority ethnic group.
	Age	Under the 10 per cent definition, the rate of fuel poverty increases as the age of the oldest householder increases, with the highest rates of fuel poverty found amongst households where the oldest member of the household is aged 85 and older (BEIS 2014a). Under the LIHC indicator, households where the oldest person is aged between 16 and 24 years are most likely to be fuel poor due to lower incomes in these households (BEIS 2020a).
	Economic status	Under the 10 per cent definition, the highest rates of fuel poverty have been shown to be amongst single-person retired households. In contrast, under the LIHC indicator, the highest rates of fuel poverty are amongst households where the HRP is unemployed (BEIS 2020a) and this is linked to lower incomes amongst the unemployed and spending longer periods of the day at home (BEIS 2020a).

5.3.7.3 Building the models

The logistic regression models were built using a block method, whereby the variables selected through purposeful selection shown in Table 5.18 are arranged into blocks, which are entered one after the other into the model. The purpose of building the models in this way was to assess the change in covariates when adjusting for other factors and to examine the effect of each set of variables on the model fit.

Before deciding on the components of the blocks, it was important to consider whether any of the variables were measuring the same construct as logistic regression is sensitive to multicollinearity amongst the independent variables (Hosmer et al. 2013). *Multicollinearity* refers to independent variables that are highly correlated with each other (Acock 2016), and so it becomes difficult to correctly interpret the relationship between the dependent variable and independent variables. Of particular concern was the use of the *age* and *economic status* of the HRP, as it was found that older ages were highly correlated with the *retired* economic status category. The decision was taken to select the economic status of the HRP as this provides some insights into the age of the HRP, but also on dwelling occupancy during the day. For example, those working full-time may spend more time away from home, while the unemployed or retired may spend more time at home (BEIS 2020a).

Based on the purposefully selected variables in Table 5.18 and the factors identified through the conceptual framework illustrated in Chapter 3 (see Figure 3.1), three theoretically distinct sets of variables were constructed and were used to build the logistic regression models. The composition of each set of variables is shown below and overleaf. All variables are entered as main effects as no interactions were included.

Set 1: This set of variables includes the country and dwelling characteristics (*type of dwelling* and *tenure* and *urban or rural*) as categorical variables. These characteristics were entered first into the model as they provide a high-level snapshot of the spatial distribution of fuel poverty in the UK and encapsulate a range of characteristics. However, as shown in Figure 3.1 discussed thereafter, these are hypothesised to not be direct contributors to fuel poverty, but to have an indirect impact through other variables that will be entered in the second set of variables. These variables are therefore considered covariates as and they will take the role of control variables once further variables are added. In addition, it is expected that some of these variables will have a confounding effect. For example, as illustrated in Figure 3.1, *tenure* is expected to be a confounder of method of payment, which is a variable explored in set 2, and its impact in driving fuel poverty will be isolated in set 2.

Set 2: The second set of variables contains key independent variables that, following the conceptual framework, are expected to drive fuel poverty (the *type of fuel*, the *method of fuel payment, household type, ethnicity* and *economic status of the HRP* and whether anyone in the household suffers from a *longstanding illness or disability*)[52]. *Sex* was included as a control variable as it was not expected to be a main driver by itself but through other factors. *Type of fuel* is entered here rather than in the first set of variables as a way of investigating the effect of fuel type. Given the evidence in the literature regarding living in a rural area and fuel poverty, it was of interest to investigate the impact of urban/rural when adding *type of fuel used* as a way of disentangling how spatial location can drive fuel poverty and so *type of fuel used* is entered here rather than in the first set of variables.

Set 3: The final variable entered is household income. This is entered as a binary variable, which identifies whether a household's income is above or below the poverty line. This is added as a covariate. For the purpose of this analysis, the poverty line was created using a

[52] Initial models included *Highest qualification in the household*, but this obscured the relationship between fuel poverty and income given their close relationship and so was removed when developing the final models so that the full effect of income could be understood.

BHC measure of income and this variable is added as a covariate. Given the importance of income in the fuel poverty literature and the overlap of fuel poverty with low income shown in Table 5.11 and supported by others (Boardman 1991; Palmer et al. 2008; Boardman 2010; Hills 2012; BEIS 2020a), this is entered last and independently. This was to explore not only the impact of income poverty on fuel poverty in the presence of other variables, but also to investigate whether variables already in the model, which may be correlated with income, remain significant when income is added. Given that there is a direct relationship between income and fuel poverty and potentially a relationship between income and other variables used in the model, adding income also controls for its confounding on other variables already included. By adding income last it will then be possible to isolate the effects that the other variables have on fuel poverty without being obscured by income.

5.3.7.4 The results of logistic regression analyses

Tables 5.19 to 5.22 present the results of the logistic regression analyses. The models are presented for each fuel poverty indicator created from each dataset and a comparative approach of the models is taken as a way of understanding the impact of the different sets of variables and their role in fuel poverty under the two different fuel poverty indicators. The reference category used for each variable, i.e. the characteristic that all others are compared to, is shown in brackets alongside each variable.

Table 5.19: *Logistic regression: Identifying the determinants of fuel poverty (odds ratios (robust standard errors)): 10 per cent indicator, LCFS (2013 – 2015/16)*

	Model 1	**Model 2**	**Model 3**
Country (ref: England)			
Wales	0.923 (0.133)	0.803 (0.129)	0.734 (0.136)
Scotland	1.604 (0.149)***	1.605 (0.160)***	1.604 (0.181)***
Northern Ireland	3.149 (0.383)***	1.339 (0.221)	1.095 (0.215)
Urban or rural (ref: Urban)			
Rural	1.297 (0.087)***	1.126 (0.089)*	1.101 (0.095)
Dwelling type (ref: Semi-detached)			
Detached	0.984 (0.081)	0.993 (0.088)	1.229 (0.120)*
Terraced	0.925 (0.072)	0.821 (0.069)*	0.791 (0.073)*
Other	0.803 (0.075)	0.512 (0.055)***	0.476 (0.057)***
Tenure (ref: Owner-occupied)			
Private rented	0.977 (0.095)	0.713 (0.079)**	0.779 (0.094)*
Social housing	2.006 (0.151)***	0.792 (0.076)*	0.801 (0.084)*
Fuel used for heating (ref: Gas)			
Electricity		0.812 (0.109)	0.787 (0.122)
Oil		2.097 (0.266)***	2.499 (0.373)***
Other fuel		1.683 (0.339)*	1.607 (0.366)*
No central heating		1.136 (0.181)	0.913 (0.169)
Method used to pay for gas and/or electricity (ref: DD)			
PPM		3.343 (0.360)***	2.962 (0.361)***
Other		2.169 (0.173)***	1.737 (0.158)***
Combined methods		1.878 (0.288)***	1.898 (0.312)***
Household type (ref: Two adults)			
Single adult		2.794 (0.224)***	2.476 (0.217)***
Single adult, 1 child		2.314 (0.418)***	1.977 (0.406)**
Single adult, 2+ children		1.498 (0.289)*	1.515 (0.324)
2 adults, 1 child		0.995 (0.157)	0.826 (0.141)
2 adults, 2 children		0.762 (0.127)	0.595 (0.105)**
2 adults, 3+ children		0.646 (0.155)	0.441 (0.115)**
3+ adults		0.425 (0.084)***	0.399 (0.081)***
3+ adults, 1 child		0.499 (0.172)*	0.399 (0.137)**
3+ adults, 2+ children		0.401 (0.159)*	0.232 (0.096)***
Sex HRP (ref: Male)		1.341 (0.091)***	1.231 (0.092)**
Ethnicity of HRP (ref: White)			
Mixed Race		1.780 (0.580)	1.540 (0.523)
Asian		1.376 (0.270)	1.092 (0.231)

*p<0.05 **p<0.01 ***p<0.001

Table 5.19: *Logistic regression: Identifying the determinants of fuel poverty (odds ratios (robust standard errors)): 10 per cent indicator, LCFS (2013 – 2015/16) (continued)*

	Model 1	**Model 2**	**Model 3**
Ethnicity of HRP (ref: White)			
Black		1.245 (0.312)	1.523 (0.382)
Other		1.088 (0.344)	0.971 (0.335)
Economic status of HRP (ref: Employed)			
Self-employed		3.102 (0.373)***	2.195 (0.291)***
Unemployed		6.576 (1.034)***	2.033 (0.356)***
Retired		3.028 (0.278)***	1.886 (0.187)***
Inactive*		5.302 (0.573)***	2.301 (0.265)***
Longstanding illness or disability (ref: No)			
Yes		0.947 (0.066)	0.961 (0.072)
Income below the poverty line (BHC) (ref: No)			
Yes			11.026 (0.857)***
Constant	**0.076 (0.005)***	**0.021 (0.002)***	**0.017 (0.002)***
Pseudo R^2 (McFadden adjusted)	**0.023**	**0.167**	**0.295**
Sample size	**15,711**		

*p<0.05 **p<0.01 ***p<0.001

* This group includes full-time university students, those occupied with household duties, those who have no need to be employed, and those involved in unpaid or voluntary work (ONS 2016b).

Table 5.20: *Logistic regression: Identifying the determinants of fuel poverty (odds ratios (clustered robust standard errors))*[53]*: 10 per cent indicator, UKHLS (waves 3 – 7), weighted*

	Model 1	Model 2	Model 3
Country (ref: England)			
Wales	1.420 (0.098)***	1.300 (0.094)***	1.288 (0.104)**
Scotland	1.371 (0.095)***	1.518 (0.105)***	1.684 (0.134)***
Northern Ireland	3.002 (0.173)***	1.815 (0.136)***	2.019 (0.177)***
Urban or rural (ref: Urban)			
Rural	1.236 (0.058)***	1.121 (0.060)*	1.141 (0.066)*
Dwelling type (ref: Semi-detached)			
Detached	1.043 (0.058)	1.043 (0.060)	1.432 (0.092)***
Terraced	1.091 (0.055)	0.905 (0.046)	0.865 (0.050)*
Other	0.818 (0.055)**	0.460 (0.035)***	0.429 (0.036)***
Tenure (ref: Owner-occupied)			
Private rented	1.301 (0.082)***	0.860 (0.063)*	0.940 (0.075)***
Social housing	1.460 (0.079)***	0.611 (0.040)***	0.703 (0.051)***
Types of fuels used in the home (ref: Gas)			
Electricity only		0.667 (0.066)***	0.581 (0.064)***
Oil & other fuel		0.847 (0.160)	0.573 (0.135)*
All fuels		2.107 (0.419)***	2.689 (0.608)***
Other combinations		1.501 (0.099)***	1.773 (0.126)***
Method used to pay for gas and/or electricity (ref: Fixed monthly standing order)			
Monthly bill		1.018 (0.054)	1.055 (0.061)
Quarterly bill		1.683 (0.108)***	1.363 (0.099)***
PPM		2.583 (0.193)***	2.034 (0.172)***
Other		1.547 (0.192)***	0.939 (0.130)
Combined		1.595 (0.135)***	1.405 (0.134)***
No gas or electricity		–	–
Household type (ref: Two adults)			
Single adult		3.568 (0.192)***	2.903 (0.167)***
Single adult, 1 child		2.381 (0.252)***	2.049 (0.243)***
Single adult, 2+ children		1.312 (0.154)*	0.807 (0.106)
2 adults, 1 child		0.701 (0.077)**	0.601 (0.067)***
2 adults, 2 children		0.566 (0.060)***	0.449 (0.049)***
2 adults, 3+ children		0.589 (0.078)***	0.341 (0.046)***

*p<0.05 **p<0.01 ***p<0.001

– Omitted

[53] Robust standard errors were clustered by HRP to account for unobserved changes to the HRP over time.

Table 5.20: *Logistic regression: Identifying the determinants of fuel poverty (odds ratios (clustered robust standard errors)): 10 per cent indicator, UKHLS (waves 3 - 7), weighted (continued)*

	Model 1	**Model 2**	**Model 3**
Household type (ref: Two adults)			
3+ adults		0.319 (0.041)***	0.372 (0.047)***
3+ adults, 1 child		0.365 (0.060)***	0.295 (0.050)***
3+ adults, 2+ children		0.237 (0.068)***	0.152 (0.044)***
Sex HRP (ref: Male)		1.321 (0.060)***	1.244 (0.062)***
Ethnicity of HRP (ref: White)			
Mixed Race		1.409 (0.233)*	1.426 (0.300)
Asian		2.041 (0.204)***	1.792 (0.183)***
Black		2.180 (0.225)***	2.360 (0.266)***
Other		1.836 (0.520)*	1.677 (0.524)
Economic status of HRP (ref: Employed)			
Self-employed		4.401 (0.333)***	2.499 (0.206)***
Unemployed		9.942 (0.853)***	2.054 (0.184)***
Retired		2.762 (0.178)***	1.520 (0.103)***
Inactive*		5.120 (0.401)***	1.873 (0.155)***
Longstanding illness or disability (ref: No)			
Yes		1.020 (0.041)	0.895 (0.040)*
Income below the poverty line (BHC) (ref: No)			
Yes			21.699 (1.078)***
Constant	**0.048 (0.002)*** **	**0.011 (0.001)*** **	**0.007 (0.001)*** **
Pseudo R^2 (McFadden adjusted)	**0.014**	**0.159**	**0.352**
Sample size	**89,118**		

*p<0.05 **p<0.01 ***p<0.001

* This group includes full-time university students, those occupied with household duties, those who have no need to be employed, and those involved in unpaid or voluntary work (ONS 2016b).

Tables 5.19 and 5.20 present the logistic regression models that explore the determinants of fuel poverty under the 10 per cent indicator constructed using income and fuel expenditure data from the LCFS and the UKHLS datasets, respectively. To simplify the interpretation of the output, only the characteristics with the highest or lowest ORs that are statistically significant will be discussed, and the differences and similarities between datasets will be emphasised throughout.

Model 1 contains the country and dwelling characteristics (*urban or rural, dwelling type*, and *tenure*). When compared to England, both tables show that Northern Ireland has the highest OR of experiencing fuel poverty under this definition. The strong relationship between Northern Ireland and fuel poverty may be linked to differences in income – where Northern Ireland has one of the lowest incomes of the four UK countries, following Wales (ONS 2019c), and fuel use – where 68 per cent of households in Northern Ireland use oil for heating (Bryson Energy 2018), which is associated with higher fuel costs (Boardman 2010; Preston et al. 2014). As already noted in Chapter 2, changes in the price of oil mean that Northern Ireland is now no longer associated with the highest rates of fuel poverty.

Both tables also show that rural dwellings have the highest OR of fuel poverty and this may be capturing the higher fuel costs associated with not being connected to the gas network and higher fuel consumption, given that dwellings in rural areas tend to be larger and less energy efficient than those in urban areas, as indicated in Chapter 2 (see section 2.6.2.2). Those living in social housing have the highest OR compared to owner-occupiers and this may be linked to a lower income amongst those in this tenure (Diaz 2009).

Although no association was found between fuel poverty and dwelling type in Table 5.19, Table 5.20 shows that living in *other* (e.g. flats and maisonettes) is significantly associated with a lower OR of fuel poverty compared to living in a semi-detached dwelling. This may be capturing differences in dwelling size, where flats, for example, tend to be smaller than semi-detached dwellings and typically more energy efficient (Department for Communities and Local Government 2012).

Model 2 adds the fuel poverty factors and household characteristics (*fuels used*, *the method of fuel payment*, *household type*, the *sex*, *ethnicity*, and *economic status of the HRP*, and whether anyone in the household has a *longstanding illness or disability*). Northern Ireland remains significant in Table 5.20, but its OR is reduced by almost 40 per cent. This reduction in and the loss of significance in Table 5.19 may be linked to the addition of fuel type. Although the fuel type variable is not directly comparable, *oil* is shown to be associated with the highest OR of fuel poverty in Table 5.19, but *all fuels* are associated with the highest OR of fuel poverty in Table 5.20, which includes electricity, gas, oil, and other fuel (including solid fuel).

Both tables show that semi-detached dwellings, being an owner-occupier, using PPMs to pay for fuel, being in a single adult household, being a female HRP, and where the HRP is unemployed are associated with the highest OR of experiencing fuel poverty, after controlling for all other factors. However, Table 5.19 shows no association between fuel poverty and the ethnicity of the HRP, while Table 5.20 shows that HRPs belonging to a Black ethnic group have the highest OR of being in fuel poverty. Both tables show no association between longstanding illness or disability in the household and fuel poverty.

Model 3 adds household income as a dichotomous variable: above or below the poverty line constructed using income before housing costs. Both tables show that it is households with incomes that fall below the poverty line that have the highest OR of experiencing fuel poverty, with households below the poverty line in the LCFS having ORs of 11.026 compared to those in the UKHLS having OR of 21.699. As already noted, the relationship between fuel poverty and a low income is widely established in the literature (Boardman 1991; Palmer et al. 2008; Boardman 2010; Hills 2012; BEIS 2020a) and this finding further reiterates the relationship between fuel poverty and a low income.

In comparison with model 2, some changes are noted with the addition of income, which suggests that income has a confounding effect. Using the LCFS data, the addition of income means that living in a rural area is no longer significant, however this relationship remains weakly significant ($p<0.05$) using the UKHLS data. Both data sources show that living in a detached dwelling is now associated with the highest OR of experiencing fuel poverty. This is strongly significant using the UKHLS data, but only weakly significant ($p<0.05$) using the LCFS data. The addition of income increases the OR of experiencing fuel poverty for households using *oil* (Table 5.19) and *All fuels* (Table 5.20) meaning that the effect of fuel type on fuel poverty increases in the presence of income. The OR associated with PPM are reduced by 11.4 per cent (Table 5.19) and 21.3 per cent (Table 5.20). Although single-person households continue to have the highest OR of experiencing fuel poverty in model 3, these are reduced by 11.4 per cent in the LCFS and 18.6 per cent in the UKHLS. No significant association remains between fuel poverty and ethnicity of the HRP in the LCFS (Table 5.19), but the significant relationship between a HRP belonging to an Asian or a Black ethnic group and fuel poverty remain highly significant, with the OR for a HRP belonging to a Black ethnic group increasing by 8.3 per cent.

The addition of income reduces the OR associated with fuel poverty across all categories of economic status of the HRP. The LCFS data show that the highest OR of experiencing fuel poverty are for households where the HRP is inactive. In contrast, for the UKHLS data, the highest OR of experiencing fuel poverty are for households where the HRP is self-employed. The OR associated with experiencing fuel poverty for households where there is a longstanding illness or disability remains non-significant using the LCFS data but are now negatively and weakly significant ($p<0.05$) for the UKHLS data.

Tables 5.21 and 5.22 present the logistic regression models that explore the determinants of fuel poverty under the AFP indicator constructed from the LCFS and the UKHLS datasets, respectively.

Table 5.21: *Logistic regression: Identifying the determinants of fuel poverty (odds ratios (robust standard errors)): AFP indicator, LCFS (2013 – 2015/16), weighted*

	Model 1	**Model 2**	**Model 3**
Country (ref: England)			
Wales	1.209 (0.154)	1.176 (0.157)	1.086 (0.154)
Scotland	1.285 (0.124)*	1.331 (0.134)**	1.226 (0.137)
Northern Ireland	2.423 (0.324)***	1.418 (0.228)*	1.163 (0.206)
Urban or rural (urban)			
Rural	0.938 (0.065)	1.006 (0.079)	1.001 (0.084)
Dwelling type (ref: Semi-detached)			
Detached	0.755 (0.066)**	0.762 (0.069)**	0.841 (0.077)
Terraced	0.959 (0.067)	0.853 (0.064)*	0.833 (0.068)*
Other	0.493 (0.043)***	0.499 (0.050)***	0.489 (0.055)***
Tenure (ref: Owner-occupied)			
Private rented	3.485 (0.276)***	2.490 (0.218)***	2.846 (0.271)***
Social housing	5.317 (0.373)***	2.381 (0.201)***	2.406 (0.216)***
Fuel used for heating (ref: Gas)			
Electricity		0.662 (0.089)**	0.636 (0.095)**
Oil		1.298 (0.168)*	1.370 (0.187)*
Other fuel		1.112 (0.265)	1.003 (0.245)
No central heating		0.937 (0.149)	0.787 (0.137)
Method used to pay for gas and/or electricity (ref: DD)			
PPM		3.499 (0.311)***	3.164 (0.323)***
Other		2.038 (0.158)***	1.689 (0.140)***
Combined methods		2.144 (0.279)***	2.221 (0.304)***
Household type (ref: Two adults)			
Single adult		1.050 (0.087)	0.845 (0.074)
Single adult, 1 child		1.696 (0.266)**	1.478 (0.273)*
Single adult, 2+ children		2.223 (0.343)***	2.375 (0.396)***
2 adults, 1 child		1.510 (0.177)***	1.405 (0.182)**
2 adults, 2 children		1.785 (0.214)***	1.636 (0.219)***
2 adults, 3+ children		2.315 (0.345)***	2.023 (0.341)***
3+ adults		1.022 (0.133)	1.020 (0.145)
3+ adults, 1 child		1.784 (0.355)**	1.771 (0.369)**
3+ adults, 2+ children		3.024 (0.599)***	2.502 (0.369)***
Sex HRP (ref: Male)		1.157 (0.075)*	1.121 (0.078)
Ethnicity of HRP (ref: White)			
Mixed Race		1.692 (0.422)*	1.377 (0.378)
Asian		1.412 (0.208)*	1.118 (0.193)

Table 5.21: *Logistic regression: Identifying the determinants of fuel poverty (odds ratios (robust standard errors)): AFP indicator, LCFS (2013 – 2015/16), weighted (continued)*

	Model 1	**Model 2**	**Model 3**
Ethnicity of HRP (ref: White)			
Black		1.527 (0.259)*	1.748 (0.317)**
Other		1.231 (0.309)	1.044 (0.304)
Economic status of HRP (ref: Employed)			
Self-employed		2.256 (0.239)***	1.820 (0.217)***
Unemployed		4.654 (0.676)***	2.053 (0.356)***
Retired		2.257 (0.199)***	1.753 (0.164)***
Inactive		3.207 (0.294)***	1.877 (0.190)***
Longstanding illness or disability (ref: No)			
Yes		1.113 (0.073)	0.835 (0.059)*
Income below the poverty line (BHC) (ref: No)			
Yes			7.122 (0.529)***
Constant	**0.073 (0.004)*** **	**0.027 (0.003)*** **	**0.026 (0.003)*** **
Pseudo R^2 (McFadden adjusted)	**0.082**	**0.159**	**0.243**
Sample size	**15,711**		

*p<0.05 **p<0.01 ***p<0.001

Table 5.22: *Logistic regression: Identifying the determinants of fuel poverty (odds ratios (clustered robust standard errors)): AFP indicator, UKHLS (waves 3 – 7), weighted*

	Model 1	**Model 2**	**Model 3**
Country (ref: England)			
Wales	1.238 (0.077)**	1.159 (0.075)*	1.079 (0.077)
Scotland	1.329 (0.078)***	1.423 (0.084)***	1.480 (0.095)***
Northern Ireland	2.072 (0.117)***	1.451 (0.100)***	1.420 (0.105)***
Urban or rural (ref: Urban)	0.949 (0.040)	1.013 (0.048)	1.000 (0.050)
Dwelling type (ref: Semi-detached)			
Detached	0.838 (0.041)***	0.826 (0.042)***	0.962 (0.050)
Terraced	0.955 (0.038)	0.890 (0.036)**	0.858 (0.039)**
Other	0.437 (0.025)***	0.469 (0.030)***	0.448 (0.033)***
Tenure (ref: Owner-occupied)			
Private rented	3.462 (0.167)***	2.403 (0.129)***	2.878 (0.168)***
Social housing	3.925 (0.172)***	1.906 (0.101)***	2.119 (0.123)***
Types of fuels used in the home (ref: Gas)			
Electricity only		0.618 (0.057)***	0.564 (0.058)***
Oil & other fuel		0.547 (0.114)**	0.412 (0.093)***
All fuels		1.674 (0.318)**	1.849 (0.344)**
Other combinations		1.239 (0.074)***	1.331 (0.080)***
Method used to pay for gas and/or electricity (ref: Fixed monthly standing order)			
Monthly bill		0.982 (0.045)	1.004 (0.048)
Quarterly bill		1.389 (0.080)***	1.199 (0.074)**
PPM		2.408 (0.142)***	2.107 (0.140)***
Other		1.300 (0.136)*	0.950 (0.109)
Combined		1.559 (0.110)***	1.431 (0.114)***
No gas or electricity		–	–
Household type (ref: Two adults)			
Single adult		1.175 (0.060)**	0.863 (0.046)**
Single adult, 1 child		2.053 (0.190)***	1.872 (0.213)***
Single adult, 2+ children		2.013 (0.177)	1.561 (0.164)***
2 adults, 1 child		1.493 (0.106)***	1.444 (0.112)***
2 adults, 2 children		1.441 (0.099)***	1.373 (0.103)***
2 adults, 3+ children		2.241 (0.175)***	1.810 (0.170)***
3+ adults		0.970 (0.069)	1.170 (0.083)*
3+ adults, 1 child		1.800 (0.147)***	1.916 (0.170)***
3+ adults, 2+ children		2.642 (0.281)***	2.710 (0.315)***
Sex HRP (ref: Male)		1.063 (0.041)	1.063 (0.044)

Table 5.22: *Logistic regression: Identifying the determinants of fuel poverty (odds ratios (clustered robust standard errors)): AFP indicator, UKHLS (waves 3 – 7), weighted (continued)*

	Model 1	**Model 2**	**Model 3**
Ethnicity of HRP (ref: White)			
Mixed Race		1.124 (0.173)	1.059 (0.220)
Asian		1.945 (0.127)***	1.511 (0.112)***
Black		1.478 (0.119)***	1.414 (0.131)***
Other		1.048 (0.226)	0.796 (0.215)
Economic status of HRP (ref: Employed)			
Self-employed		2.389 (0.137)***	1.687 (0.106)***
Unemployed		3.815 (0.249)***	1.235 (0.098)**
Retired		1.994 (0.105)***	1.444 (0.081)***
Inactive		3.046 (0.166)***	1.685 (0.105)***
Longstanding illness or disability (ref: No)			
Yes		0.996 (0.035)	0.918 (0.035)*
Income below the poverty line (BHC) (ref: No)			
Yes			10.883 (0.451)***
Constant	**0.065 (0.002)***	**0.028 (0.002)***	**0.021 (0.001)***
Pseudo R^2 (McFadden adjusted)	**0.060**	**0.122**	**0.248**
Sample size	**89,118**		

*p<0.05 **p<0.01 ***p<0.001
– Omitted

In modelling the determinants of fuel poverty under the AFP indicator, the models in Tables 5.21 and 5.22 present a slightly different picture of fuel poverty compared to the 10 per cent indicator, although some similarities can be observed.

In model 1, where country and dwelling characteristics (*type of dwelling* and *tenure* and *urban or rural*) were entered, both tables show that Northern Ireland and living in social housing have the highest OR of experiencing fuel poverty under the AFP indicator. This reflects the findings for fuel poverty under the 10 per cent indicator. However, in contrast to the 10 per cent indicator, where rural dwellings were significantly associated with fuel poverty, no significant association is found between urban or rural dwellings and the AFP indicator. Living in *Other* (e.g. flats, maisonettes) is associated with a reduced likelihood of experiencing fuel poverty compared to living in a semi-detached dwelling in both tables, which reflects findings for the 10 per cent indicator using the UKHLS data (Table 5.22). This may be linked to being smaller dwellings, which tend to be more energy efficient (DECC, 2020b).

Model 2 adds the fuel poverty factors and household characteristics (*fuels used*, *the method of fuel payment*, *household type*, the *sex*, *ethnicity*, and *economic status of the HRP*, and whether anyone in the household has a *longstanding illness or disability*). Similar to findings for the 10 per cent indicator in Tables 5.19 and 5.20, Tables 5.21 and 5.22 also show that households in Northern Ireland, households living in a semi-detached dwelling, using oil (LCFS) and *all fuels* (UKHLS), and unemployed HRPs are significantly associated with the highest likelihood of experiencing fuel poverty. In contrast to the 10 per cent indicator, Tables 5.19 and 5.20 show that households within the private rented sector and households containing three or more adults with children are significantly associated with the highest likelihood of experiencing fuel poverty. This corresponds with analysis by Hills (2012), who found that fuel poverty under the LIHC indicator is associated with a higher proportion of households with children and households living in the private rented sector. Again, no association is found between longstanding illness and disability in the household and fuel poverty under the AFP indicator.

There are also some contrasts between the datasets. Table 5.21 shows significantly higher ORs for female HRPs and for Mixed Race HRPs, whilst table 5.22 shows no association between sex of the HRP and fuel poverty under the AFP indicator, and the highest OR of fuel poverty was found for Asian HRPs.

Model 3 adds income as a dichotomous variable: whether a household's income is above or below the poverty line BHC. Like the analysis for the 10 percent indicator presented in Tables 5.19 and 5.20, Table 5.21 and 5.22 show that households with incomes that fall below the poverty line that have the highest OR of experiencing fuel poverty, with households below the poverty line in the LCFS having a higher OR of experiencing fuel poverty compared to the UKHLS: OR 7.122 vs. OR 10.833.

Although the addition of income changes some of the relationships that were observed in model 2, again indicating that income is a confounder, some relationships remain consistent. Households living in semi-detached dwellings and in the private rented sector still have the highest OR of fuel poverty under the AFP indicator and across both surveys, as does the use of *oil* (Table 5.21) and *All fuels* (Table 5.22), the use of PPMs, and households with three or more adults and two or more children compared to their reference categories.

Like for Table 5.19 and 5.20, the addition of income changes some of the associations that were observed in model 2. Using the LCFS data (Table 5.21), "country" is no longer significantly associated with fuel poverty under the AFP indicator, but Scotland and Northern Ireland remain significantly associated with fuel poverty, with Scotland having the highest OR of experiencing fuel poverty, using the UKHLS data. This suggests that there may be other variables that impact on the odds of experiencing fuel poverty that have not been included in the model. Both datasets show no significant association between fuel poverty under the AFP indicator and *urban or rural*. However, given the predominance of private rented dwellings and households with children in urban areas, this inadvertently shifts attention to urban areas, highlighting the effect of different fuel poverty indicators on the spatial distribution of fuel poverty evidenced in Chapter 2 (see section 2.6).

Although only weakly statistically significant in model 2, the sex of the HRP is now no longer significantly associated with fuel poverty in the LCFS. Using the LCFS data, only households with a HRP belonging to a Black ethnic group have significant OR of experiencing fuel poverty. This has increased by 14.5 per cent compared to model 2 and has a higher level of significance. For the UKHLS data, Asian and Black HRPs still have the highest OR of experiencing fuel poverty, although the OR associated with Asian HRPs is reduced by 22.3 per cent.

For the LCFS data, households with a HRP who is unemployed are still associated with the highest OR of fuel poverty following the addition of income, but it is households with a self-employed HRP that now have the highest OR of fuel poverty using the UKHLS data compared to the reference group. For the UKHLS, the OR associated with "longstanding illness or disability" becomes negative and weakly significant (Table 5.22).

There are also differences between the 10 per cent indicator (Tables 5.19 and 5.20) and the AFP indicator in Tables 5.21 and 5.22. The use of PPM to pay for fuel and the use of *oil* (Table 5.22) and *all fuels* (Table 5.23) is associated with the highest OR of fuel poverty compared to their reference groups. However, in contrast to the 10 per cent indicator where being an owner-occupier and single-adult households were associated with a higher likelihood of experiencing fuel poverty, Tables 5.21 and 5.22 show that living in the private rented sector and households composed of three or more adults with two or more children are associated with the highest OR of fuel poverty. These findings correspond to Hills' work, which shows that the fuel poverty using LIHC indicator captures larger households that include children (Hills 2012).

5.3.7.5 The household characteristics with the highest likelihoods of fuel poverty: a point of reference

From the information provided through the logistic regression models presented in Tables 5.19 to 5.22, it becomes possible to highlight the characteristics of the fuel poor under each indicator that have the highest likelihood of fuel poverty (compared to their reference category) created from each dataset and this acts as a reference point for the forthcoming analysis chapters.

Although both fuel poverty indicators capture similar characteristics, there are several key differences between them, some of which closely align with the published statistics. The characteristics have been presented in Table 5.23 overleaf as a simple way of identifying differences and similarities in likelihood between each of the fuel poverty indicators created from each dataset, focusing on the highest significant OR for each characteristic after controlling for all other factors (i.e. presented in model 3). To ease understanding of the table, characteristics that are the same across both indicators and both datasets are presented in bold and have been shaded. Characteristics that are the same for the same indicator under different datasets are presented in bold.

Table 5.23: *The characteristics of households with the highest likelihood of fuel poverty under the 10 per cent indicator and the AFP indicator for the LCFS (2013-2015/16) and the UKHLS (waves 3-7)*

	10 per cent indicator		AFP indicator	
	LCFS	**UKHLS**	**LCFS**	**UKHLS**
Country	Scotland	Northern Ireland	NS	Scotland
Urban or rural	NS	Rural	NS	NS
Dwelling type	**Detached dwelling**	**Detached dwelling**	**Semi-detached dwelling**	**Semi-detached dwelling**
Tenure	**Owner-occupier**	**Owner-occupier**	**Private rented**	**Private rented**
Type of fuel(s) used	Oil	All fuels	Oil	All fuels
Method of fuel payment	**PPM**	**PPM**	**PPM**	**PPM**
Household type	**Single adult**	**Single adult**	**3+ adults, 2+ children**	**3+ adults, 2+ children**
HRP characteristics	**Female**	**Female**	**NS**	**NS**
	NS	Black	Black	Asian
	Inactive	Self-employed	Unemployed	Self-employed
	NS	Longstanding illness	No longstanding illness	Longstanding illness
Income	**Below the poverty line**	**Below the poverty line**	**Below the poverty line**	**Below the poverty line**

NS: Not significant

Table 5.23 shows that across both indicators and datasets, households paying for gas and/or electricity by PPM, and households whose incomes fall below the poverty line (BHC) have the highest likelihood of experiencing fuel poverty. Under the 10 per cent indicator, both surveys show that the highest likelihood of fuel poverty is associated with households living in detached dwellings, owner occupiers, single-adult households, and households with a female HRP. In contrast, under the AFP indicator, both surveys show that the highest likelihood of fuel poverty is for those in semi-detached dwellings, those living in the private rented sector, and for households containing three or more adults with two more children. Hills (2012) has also identified that respondents with these characteristics have the highest likelihood of fuel poverty under the LIHC indicator. Although the fuel poor under the AFP indicator are not associated with living either in an urban or rural area, the high likelihood of fuel poverty under this indicator in the private rented sector alters the spatial distribution of fuel poverty as the private rented sector is concentrated in urban areas as evidenced by the literature presented in Chapter 2 (see section 2.7). A further similarity is that both surveys showed that households with a female HRP were found to have the highest likelihood of fuel poverty under the 10 per cent indicator compared to male HRPs.

As well as these similarities, there were some differences observed between the two fuel poverty indicators and the data sources used to construct them. These differences included differences between countries, the type of fuel used, the ethnicity and the economic status of the HRP, and whether anyone in the household has a longstanding illness.

It is important to note that although the likelihood is high in these groups, some of these groups constitute a very small percentage of the population, whilst others constitute a relatively larger percentage. For example, 22.9 per cent of households in the LCFS and 23.6 per cent in the UKHLS live in detached dwellings (analysis not presented). However, Table 5.17 shows that only 8.9 per cent and 6.2 per cent of households in these dwellings are fuel poor under the 10 per cent indicator in the LCFS and UKHLS, respectively. From a policy perspective, this would make it difficult to target the fuel poor without further (sub)indicators of likelihood given that rates of fuel poverty are low within a relatively large group. Additionally, Table 5.23 shows that households using PPMs are at likelihood of fuel poverty under both indicators and across both surveys. However, looking at the rates of fuel poverty in Table 5.17 shows that, under the 10 per cent indicator, only 9.3 per cent of households in the LCFS and 12.9 per cent of households in the UKHLS use a PPM to pay for their gas and/or electricity. In contrast, under the AFP indicator, 32.4 per cent of households and 23.8 of households are fuel poor in the LCFS and UKHLS, respectively. This suggests that focusing on the use of PPMs could be an important way of tackling fuel poverty under the AFP indicator but may not be as effective for tackling fuel poverty under the 10 per cent indicator. This further emphasises that, although some characteristics associated with a higher likelihood of fuel poverty are similar across indicators, the effectiveness of policy approaches may vary, and different policy approaches may be required to tackle fuel poverty under different fuel poverty indicators.

As an additional point of inquiry, but not a core component of the thesis, analysis on the fuel poverty gap has been performed and is presented in Appendix B.

5.4 Discussion

This chapter has provided an extensive exploration of the fuel expenditures of the fuel poor under the 10 per cent definition and the AFP indicator and covered various aspects in trying to understand the types of households being captured under the fuel poverty indicators used. Firstly, actual fuel expenditure data contained within the LCFS and UKHLS datasets was compared with modelled fuel expenditure data and has sought to offer an in-depth comparison of the two fuel poverty indicators based on actual fuel expenditure that are used throughout the research: the 10 per cent indicator and the AFP indicator. Given their diverse components, the purpose of this comparison was to explore the behaviour of the indicators, to examine whether the indicators constructed from two different data sources (the LCFS and the UKHLS) provided different profiles of the fuel poor, and to determine the characteristics of households with the highest likelihood of experiencing fuel poverty under each indicator constructed from each dataset. In this way, the chapter presents a thorough exploration of the fuel poverty indicators used throughout the thesis and provides a solid grounding for understanding who the fuel poor are under each indicator for the forthcoming analysis chapters.

5.4.1 Key findings

Through addressing the six objectives set for this chapter, four key findings have emerged from this research and these are discussed in turn.

Firstly, in section 5.3.1, a comparison between actual fuel expenditure contained within the LCFS and the UKHLS and modelled fuel costs from the *Fuel Poverty Datasets* was shown. This was of interest given that both fuel poverty indicators created for the research were based on actual fuel expenditure. This comparison showed that actual fuel expenditure data from the LCFS was closely aligned with modelled fuel costs provided by the EHS, but this was not observed when comparing modelled fuel costs with actual fuel expenditure data in the UKHLS. The close alignment of modelled fuel costs with LCFS fuel expenditure data demonstrates that using actual expenditure to identify fuel poverty may not be as inaccurate as traditionally thought, but that the method used to collect fuel expenditure data and the period for which it is collected may be of key importance. This was evidenced by the LCFS data discussed in section 5.3.1 where there was a change in the method for collecting fuel expenditure data – from recording this in the respondent's diary to collecting this information through the household interview. This resulted in marked increases in fuel expenditure, particularly for those using PPMs to pay for fuel (DECC 2015b). However, although the UKHLS also collects fuel expenditure data through the household interview stage of the study, this showed a much poorer alignment with modelled fuel costs. This suggests that the period for which fuel expenditure data is collected may be important, with the longer period used in the UKHLS potentially leading to inaccuracies, possibly highlighting the difficulty of keeping track of PPM payments over a long period of time.

Secondly, the chapter also examined the fuel expenditures of fuel poor and non-fuel poor households, finding that the fuel poor - whether they are income poor or not - spend more in absolute and proportionate terms than wealthier households who are not fuel poor. Although this contrasted with Boardman's original analysis, further exploration of this provided valuable insights into understanding the constructed 10 per cent indicator used throughout the thesis. Two avenues of analysis were taken to understand this conflict: exploring the relationship between fuel expenditure and income, and further investigating the overlap between fuel poverty and income poverty. Using linear regression to explore the relationship between fuel expenditure and income revealed a weak relationship between these two elements, as indicated by a low R^2 coefficient (see Table 5.9). This relationship was also visually presented with the use of scatterplots in Figure 5.1 and these further emphasised that fuel expenditure appeared relatively stable across the income distribution, reinforcing the conclusion that fuel poverty is an inelastic and essential expenditure. These two avenues of analysis provided a better understanding of the relationship between income and absolute fuel expenditure and how using a 10 per cent threshold to classify fuel poverty inevitably captures high fuel expenditures. The differences found between the research presented herein and Boardman's original analysis have been attributed to methodological differences in the way that the 10 per cent threshold has been applied, with Boardman dividing the sample into the poorest 30 per cent and the remaining 70 per cent and finding that the poorest 30 per cent of the sample spent 10 per cent of their income on fuel. In contrast, the 10 per cent threshold has been applied across the whole sample in this research.

Following this exploration of the expenditures of the fuel poor under the 10 per cent indicator, the overlap between income poverty and fuel poverty was explored and this found that, although the majority of the fuel poor were income poor, aligning with previous research (Palmer et al. 2008; Boardman 2010; Hills 2012; Balfour and Allen 2014), this overlap was not as strong in the opposite direction and it was identified that only a minority of income poor households were fuel poor. This provided evidence that absolute fuel expenditures of these groups may not necessarily be similar.

Thirdly, using logistic regression to isolate the characteristics of households with the highest likelihood of experiencing fuel poverty under each indicator from both datasets highlighted the impact of changing components that closely reflect the published literature. In conducting logistic regression, the analysis found that owner-occupiers had a higher likelihood of experiencing fuel poverty under the 10 per cent indicator, whereas private renters had the highest likelihood of fuel poverty under the AFP indicator. This inadvertently diverts the focus of fuel poverty from a rural issue (under the 10 per cent indicator) to an urban issue (under the AFP indicator) where private rented accommodation is more common (Robinson et al. 2018; ONS 2019a). This finding demonstrates that the two fuel poverty indicators are capturing different groups of people, highlighting compositional heterogeneity, which not only describes the differing risks associated with characteristics under each fuel poverty indicator, but also extends to differences in the spatial distribution of fuel poverty. This builds on evidence presented in the literature (Moore 2012; Fizaine and Kahouli 2018; Robinson et al. 2018) and poses important policy implications because the definition of fuel poverty and the risks associated with different characteristics under different fuel poverty indicators may alter the effectiveness of policy and how well it is targeted at the issue.

Lastly, exploring the determinants of fuel poverty under each indicator through logistic regression analyses has revealed a characteristic that has been relatively overlooked in the study of fuel poverty: the impact of ethnicity. The use of pooled data from the LCFS and UKHLS has been a strength in this study and has allowed for more detailed ethnicity categories to be explored, unlike in published official statistics. The chapter has found that the likelihood of experiencing fuel poverty is not consistent across HRPs belonging to different ethnic groups. Although minority ethnic groups often have lower incomes than White ethnic groups (DWP 2019), the effects of belonging to a minority ethnic group on fuel poverty was not fully explained by the addition of income (see Tables 5.19 to 5.22). This leads to questions about whether fuel poverty is embedded in wider aspects of disadvantage that cannot be explained by income alone and which were not included in the logistic regression models due to variables not being available in the datasets. This may include the energy efficiency of the home and the appliances within it, different habits and preferences, and differing heating patterns.

The effect of ethnicity on experiencing fuel poverty is currently a relatively unexplored area, but one that warrants further investigation. In a recent study by Churchill and Smyth (2020), who used the *Household, Income and Labour Dynamics in Australia* survey, found that ethnic diversity was positively associated with fuel poverty. This is supported by recent fuel poverty statistics produced by BEIS (2020a), which have shown that fuel poverty under the LIHC indicator affects a greater proportion of households with a HRP belonging to a minority ethnic group compared to households with a White HRP. However, more detailed ethnicity categories are not provided, and it is unclear how fuel poverty affects different minority ethnic groups, the driving factors behind this, and whether these driving factors vary for different ethnic groups.

Ethnicity may impact the experience of fuel poverty through differences in heating patterns and energy use, traditions and beliefs, and ways of coping (Todd and Steele 2006; Lawrence et al. 2007). Additionally, there is evidence to suggest that the lowest levels of switching energy supplier are amongst minority ethnic groups (Finlay 2013), and that higher levels of housing deprivation and greater barriers to accessing affordable housing are experienced by minority ethnic groups compared to White groups (ONS 2018c). Furthermore, due to negative perceptions towards claiming benefits, or the inability to claim state support due to language barriers or not having the necessary documentation, minority ethnic groups are also less likely to access help and support (Allmark et al. 2010) and this may create a barrier for changing their fuel poverty status. This may suggest that the higher likelihood of fuel poverty amongst certain minority ethnic groups presented in this chapter may be a consequence of accumulated disadvantages, which may generate differences in how fuel poverty is experienced and the drivers behind this experience. This finding reinforces the need to explore the impact of ethnicity on fuel poverty further.

5.4.2 The limitations of the fuel poverty indicators

Despite these findings and a better understanding of the fuel poor under each indicator created from both datasets, the limitations of the fuel poverty indicators cannot be overlooked. Although actual fuel expenditure and modelled fuel costs were shown to correspond quite closely with each other, at least for the LCFS data, there are distinct differences between them, which makes it difficult to make a direct comparison.

As described in Chapter 2 (see section 2.10), modelled fuel costs are based on achieving adequate energy services (as defined by standards of service and average consumption), including adequate warmth, which is defined as 21˚C in the main living space and 18˚C in all other occupied rooms (Boardman 2010; Hills 2012). In contrast, actual fuel expenditure simply provides an estimate of the amount households are spending on fuel and gives no indication of temperatures within the home or whether households are able to afford adequate levels of other energy services. Despite Table 5.16 showing that the fuel poor had higher rates of not being able to keep their home warm in winter, this assessment relies on the subjectivity of thermal comfort and gives no indication of whether the range of temperatures recommended are achieved within this subjective perception of warmth. Furthermore, modelled fuel costs do not consider energy suppliers or tariffs and so overlooks the possibility of higher fuel costs as a consequence of the inequality of fuel prices driven by being disadvantaged in the energy market. As indicated in Chapter 2 (section 2.6.3.3), fuel poor households may be on an energy tariff that is not appropriate for their needs due to low levels of switching amongst these households, meaning that they may be paying higher fuel costs than is necessary. As such, similar levels of modelled fuel costs and actual fuel expenditure may not mean similar levels of energy usage.

A further limitation is that by using actual fuel expenditure to create fuel poverty indicators, those experiencing fuel poverty under other definitions may not be captured. This is because households who are not spending to the stated thresholds within the indicators are not classified as being in fuel poverty, despite potentially experiencing fuel poverty in other ways. This includes those whose fuel expenditure was low, and those who had zero expenditure on fuel, who were excluded from the analysis. Some of these households may have been rationing their fuel use or may have used self-disconnection as a coping strategy. These households would, nonetheless, be fuel poor as they cope with the pressure of fuel bills through reducing fuel consumption and, therefore, fuel expenditure. As such, the indicators only provide one view of how fuel poverty may be experienced within households as they only capture those spending a disproportionate amount on fuel. Although Table 5.16 showed that the fuel poor under the 10 per cent indicator have the highest rates of living in a cold home and that the fuel poor under the AFP indicator have the highest rates of living in a damp home despite paying disproportionate fuel costs, these rates were quite low and the data did not allow for exploration of whether these households are able to have a well-lit home, whether they are able to power all their appliances to the levels they need, or how fuel expenditure is being allocated to different energy services.

A final limitation is that it was not possible to include information on the energy efficiency of the home given the lack of data on this in both the LCFS and the UKHLS. It is acknowledged that, as this is deemed an important element in understanding fuel poverty, the results of this analysis may have presented a different picture of fuel poverty had this information been included.

5.5 Chapter summary and conclusions

This chapter has provided an in-depth exploration of the fuel poverty indicators created for the purpose of this thesis and that are used to answer the proposed research questions. The chapter has compared actual and modelled fuel expenditure, as well as the rates of fuel poverty produced by the indicators with national estimates. Of key importance were the differences found in absolute fuel expenditures in fuel poor households between the created 10 per cent indicator and Boardman's 10 per cent definition. In attempting to resolve this conflict, the chapter has taken a closer look at the relationship between income and absolute fuel expenditure and the overlap between fuel poverty and income poverty, finding that using a 10 per cent threshold captures high expenditures and that although the majority of the fuel poor are income poor, only a minority of the income poor are fuel poor. This provides evidence that the absolute fuel expenditures of the fuel poor and income poor may not necessarily be similar, which further reinforces the distinction between these two groups. The differences in this analysis and Boardman's original analysis have been attributed to the different ways that the 10 per cent threshold has been used.

This chapter has also investigated the determinants of fuel poverty under both indicators, an exploration that has helped to isolate the characteristics of households with the highest likelihood of experiencing fuel poverty under both indicators, which provides a point of reference for the analysis presented in the following chapters. The analysis has also evidenced the compositional heterogeneity of fuel poverty under the two different indicators and how this affects the rates and distribution of fuel poverty, which highlights important policy implications in terms of the types of fuel poverty solutions offered.

Although actual expenditure-based indicators compare moderately well with published statistics, it is acknowledged that the full breadth of fuel poverty cannot be captured by strict, objective indicators, and that the use of the indicators may exclude those whose spending does not reach the necessary thresholds to be classified as fuel poor despite them potentially experiencing aspects of fuel poverty, such as the rationing of fuel. However, despite the indicators not providing information on internal temperatures or energy consumption more broadly, they do capture those who spend a disproportionate amount of their income on fuel, and this is the segment of the fuel poor that are of focus in the remainder of the thesis.

In the following chapter, the first question of the research is addressed, which investigates the impact of fuel poverty under the created indicators on food insecurity.

Chapter 6| How does fuel poverty impact on food insecurity? A focus on food expenditure and food expenditure patterns

6.1 Introduction

Much of the literature that has explored the impact of fuel poverty on food is centred on the *heat or eat* trade-off (Bhattacharya et al. 2003; O'Neill et al. 2006; Beatty et al. 2014a; Lambie-Mumford et al. 2015; Snell et al. 2018). This trade-off suggests that fuel poor households are faced with a choice between heating and eating. However, although one may be prioritised over another (O'Neill et al. 2006; Hernández and Bird 2010; Lambie-Mumford et al. 2015; Snell et al. 2018), there is no literature indicating that one is completely forgone in place of another (Lambie-Mumford et al. 2015). In fact, the literature reveals that this trade-off may be mitigated by other behaviours and strategies, such as rationing both food and fuel simultaneously (Gibbons and Singler 2008; Anderson et al. 2010; Lambie-Mumford et al. 2015), opting for cheaper food items and making within-category substitutions (Anderson et al. 2010; Lambie-Mumford et al. 2015), reducing the quality and variety of the diet (Anderson et al. 2010; Lambie-Mumford et al. 2015; Snell et al. 2018), and shopping at lower cost supermarkets (Middlemiss and Gillard 2014). These represent integral aspects of food insecurity (Taylor and Loopstra 2016) and suggest that links may exist between fuel poverty and food insecurity. However, given the myriad of ways that fuel poverty has been identified within these studies, significant gaps in understanding the nature of these links remain.

6.2 Chapter aim and objectives

This chapter aims to further understanding of the relationship between fuel poverty and food insecurity. Focusing on two relatively under-explored areas in the fuel poverty literature, this study investigates the impact of fuel poverty on food expenditure (i.e. the absolute amount spent on food and the proportion of income it consumes) and food expenditure patterns (i.e. the types of foods households are purchasing), and sets the following two objectives:

1. To identify how fuel poverty impacts on food expenditure;
2. To explore how fuel poverty impacts on food expenditure patterns.

Although food expenditure and food expenditure patterns are only two aspects of a much broader picture of the ways that fuel poverty may impact on food insecurity, focusing on food expenditure can identify differences in absolute spending between fuel poor and non-fuel poor households as well as the financial burden that food purchasing places on these households through the proportion of income allocated to food. Complementing this, food expenditure patterns can provide a valuable understanding of how the fuel poor allocate their food budget and the types of food purchases made. Being closely related to dietary intake (Fan et al. 2007; Humphries et al. 2017), food expenditure patterns can provide insights into dietary exposure, which may help to shed light on some of the root causes for the health inequalities that exist between fuel poor and non-fuel poor households.

6.3 Chapter outline

This chapter firstly presents a brief background to food insecurity, describing its causes and health consequences. Following this, the chapter then turns to the literature that provides an insight into the ways that fuel poor households may experience food insecurity and how tackling fuel poverty has been documented to have had positive impacts on aspects of food insecurity, such as improving the quality of the diet through increasing the availability of disposable income (Ellaway et al. 2000; Gilbertson et al. 2006). A detailed account of the methods used to explore the objectives set in section 6.2 is then provided, focusing on how food expenditures were adjusted for inflation and how these were categorised for the purpose of exploring food expenditure patterns. The analysis is then presented for the two objectives set for this chapter and the results are discussed, drawing attention to how they further the understanding of food insecurity in the context of fuel poverty. A summary of the chapter is provided in the final section.

6.4 Understanding food insecurity

Before tracing the links between fuel poverty and food insecurity with evidence provided by the literature, it is important to gain a broader sense of how food insecurity can be understood. Although there is no official government definition of food insecurity in the UK (Taylor and Loopstra 2016), Dowler and colleagues (2001) have defined this as “the inability to acquire or consume an adequate quality or sufficient quantity of food in socially acceptable ways, or the uncertainty that one will be able to do so” (Dowler et al. 2001, p.12). Furthermore, food insecurity can be experienced on varying levels of severity: *mild food insecurity*, which involves worrying about the ability of obtaining food; *moderate food insecurity*, when the quality and variety of foods are reduced; and *severe food insecurity*, when hunger is experienced (Taylor and Loopstra 2016). These levels provide further elements for understanding how food insecurity may be experienced.

6.4.1 The causes of food insecurity in the UK

There are three main factors that can contribute to food insecurity in the UK: a low income, food availability, and physical accessibility (Deeming 2011; Douglas et al. 2015). A low income can constrain the food budget and this can influence the types and quantities of foods purchased (French et al. 2019). The literature suggests that low-income households tend to opt for lower cost food items, which are often high in fat and sugar, but offer a considerably cheaper source of calories compared to fruit and vegetables (Maillot et al. 2007; French et al. 2019). This impacts on the quality of the diet (French et al. 2019).

A low income also ties in closely with the issue of availability and physical accessibility, which draws attention to characteristics of the built environment. Of particular interest in this field of the literature is the notion of *food deserts* – areas where supermarkets and other types of food stores are scarce (Corfe 2018) and where access to an affordable and healthy diet is limited (Cummins and Macintyre 2002). Those living in food deserts may be reliant on local convenience stores, especially where costs associated with travelling to a larger supermarket cannot be met. These types of stores tend to offer a limited variety of foods whilst charging higher prices compared to supermarkets (Corfe 2018; Whitham 2018) and this may make eating well more difficult on a restricted budget. This has been linked to the *poverty premium* – when low-income households have to pay more for essential goods and services compared to higher-income households (Davies et al. 2016). Although the evidence in this area is conflicting, the poverty premium can arise from not being able to access cheaper food stores due to the lack of private transport and affordable public transport, not being able to take advantage of bulk-buy discounts and special offers often available at larger supermarkets, and the higher likelihood of being digitally excluded and therefore not being able to benefit from online food shopping (Tipping et al. 2019), which can increase accessibility to lower cost food items and special offers.

6.4.2 The health consequences of food insecurity

As noted from the levels within which food insecurity can be experienced, food insecurity can limit access to food, reduce food intake and the quality of the diet, and disrupt normal eating patterns (Adams et al. 2003; Nord and Kantor 2006), and as such can manifest as underweight, or overweight and obesity. This illustrates the varying ways in which food insecurity can be experienced and how it may be coped with. As well as experiencing poorer mental and physical health (Lang 2020), which can affect both younger and older age groups (McLaughlin et al. 2012; Ciciurkaite and Brown 2017), other adverse outcomes associated with food insecurity can affect different stages of the life course. Children in food insecure environments (i.e. where there is a lack of quantity and quality of food) have been found to experience diverse developmental consequences, such as poorer academic performance (Jyoti et al. 2005), which may be linked to absenteeism as a result of illness (Tamiru and Belachew 2017), and poorer social skills (Jyoti et al. 2005). In adults, a poor diet as a consequence of food insecurity, can lead to type 2 diabetes, cardiovascular disease, and diet-related cancers, with diet related ill-health estimated to cost the National Health Service £5.8 billion per year (National Health Service 2014). Additionally, Gao and colleagues (2009) found that older adults who were experiencing food insecurity had lower cognitive performance, although the direction of causality is unclear.

6.5 The links between fuel poverty and food insecurity: a review of the literature

An essential gateway to understanding the links between fuel poverty and food insecurity is through examining the literature that has provided an insight into the ways in which fuel poor households make decisions around food expenditure and food purchases, with qualitative studies often finding a trade-off occurring between the cost of food and its quality or quantity (Gibbons and Singler 2008; Anderson et al. 2010; Lambie-Mumford et al. 2015). Quantitative studies have found that low-income households reduce expenditure on food as fuel expenditure increases (Morgan et al. 1996; Bhattacharya et al. 2003; Beatty et al. 2014a), and that food insecurity (measured by the ability to afford enough nutritious food items for all household members) increases as energy insecurity[54] increases (Cook et al. 2008).

In qualitative work conducted by Anderson et al. (2010) and Lambie-Mumford and colleagues (2015), the authors found that both food and fuel were being rationed simultaneously in low-income households and that food purchasing behaviours were modified

[54] Defined as lacking “consistent access to the amount or the kind of energy needed for a healthy and safe life” (Cook et al. 2008, p.e870)

so that hunger could be evaded. Cheaper foods were purchased and fuel poor households forwent costlier food items such as fresh meat, fruit, and vegetables (Anderson et al. 2010; Lambie-Mumford et al. 2015), and opted for tinned foods (Anderson et al. 2010). Brunner and colleagues (2012) appear to suggest that fuel poor households, identified through a low income, might adopt a more monotonous diet that lacks variety to be able to afford fuel costs, with one interviewee stating that she ate "vegetable soup and potatoes with butter'' (Brunner et al. 2012, p.56). Hernández and Bird (2016) also provide evidence to suggest that less time is spent cooking in low-income households that have a high energy burden[55], whilst others have found that microwaves are used instead of ovens (Longhurst and Hargreaves 2019), that cold foods are consumed as a way of saving on fuel (Adam and Monaghan 2016; National Energy Action 2018c), and that lower cost supermarkets are preferred (Middlemiss and Gillard 2014).

Although these coping mechanisms may have negative consequences for health, they illustrate the resourcefulness of fuel poor households and convey the way they perceive the food market and their ability to adapt food purchases to accommodate their experience of fuel poverty. In contrast to feelings of distrust towards energy companies (Day and Hitchings 2009; Lomax and Wedderburn 2009; Anderson et al. 2010), the studies presented herein show that respondents engage with the food market and exhibit a wide range of flexibility associated with food purchasing, with householders shopping around to look for bargains and cheaper alternatives.

6.6 Tackling fuel poverty and its impact on food

Alongside the literature that suggests that fuel poverty can impact on food expenditure and food expenditure patterns, there is also documented evidence of positive dietary impacts following energy efficiency improvements aimed at tackling fuel poverty. These have been

[55] Where the majority of participants – almost 80 per cent – reported experiencing problems with utilities, such as the lack of affordability, falling behind on bills, and being disconnected (Hernández and Bird 2010).

found to lessen the burden of fuel costs and increase disposable income, which in turn has been found to have a positive impact on food choices and diet, allowing for better quality and a wider variety of foods to be purchased (Ellaway et al. 2000; Gilbertson et al. 2006). Greater warmth in kitchens has also encouraged more time to be spent preparing food in them and this could potentially benefit food intake and health (Caldwell et al. 2001)

6.7 Study hypothesis

The literature drawn on herein has highlighted that those experiencing fuel poverty struggle to eat well and that a myriad of food purchasing behaviours are adopted in an attempt to avoid hunger when dealing with fuel poverty, indicating aspects of food insecurity. Based on the literature presented in section 6.5, it is hypothesised that fuel poor households spend less on food as a way of dealing with the burden of high fuel bills and that they are purchasing poorer quality foods in response to this.

6.8 Data and methods

To fulfil the research objectives stated in section 6.2, expenditure data on food and non-alcoholic beverages contained within the *Living Costs and Food Survey* (LCFS) between the years of 2013 and 2015/16 were used, pooling data over these years to increase the sample size. A brief description of this data source was provided in Chapter 4 (see section 4.5.1), together with the data cleaning procedures used for income and fuel expenditure data (see section 4.7) and the methods used to construct both fuel poverty indicators used throughout the thesis (see section 4.8).

In the LCFS, detailed data on food and non-alcoholic beverage expenditure is collected through a two-week diary provided to all adult members (aged 16 years and over) in the household (Bulman et al. 2017). Within this, adults are asked to record details of all foods and drinks purchased under three categories: “food and drink brought home (excluding takeaways)”; “takeaway meals and snacks eaten at home”; and “meals, snacks, and drinks consumed away from the home” (Bulman 2017, p.22). For children aged 7 to 15 years, a simplified version of the diary is provided where they are asked to record, on a daily basis, details of each item of food and non-alcoholic beverage expenditure, the amount paid, where it was purchased, and where it was consumed. For both adults and children, these expenditures are supported by receipts, where possible (Ralph and Manclossi 2016). Using these diaries, the LCFS then provides estimates of average weekly expenditures on a wide range of food items and non-alcoholic beverages for adults and children, as well as estimates for average weekly expenditure on these items at the household level (Ralph and Manclossi 2016).

Following the data cleaning procedures for income, housing costs, and fuel expenditure detailed in Chapter 4 (see section 4.7), additional methods were used to adjust food and non-alcoholic beverage expenditures for inflation and to create food groups, which were used to explore food expenditure patterns. The methods used for these aspects of the research are detailed in the subsequent sections (sections 6.8.1 and 6.8.2).

6.8.1 Adjusting food expenditures for inflation and creating a total food expenditure variable

Before embarking on the analysis, it was important to adjust all expenditures on food and non-alcoholic beverages for inflation so that they were comparable over the survey years. Using the formula presented in Equation 1 (see Chapter 4), the relevant components of the CPIH were used to adjust these expenditures for inflation using 2016 as the base year[56].

Once all food and non-alcoholic beverage expenditures had been adjusted for inflation, these expenditures were combined to create a total food and non-alcoholic beverage expenditure variable, hereinafter referred to simply as “total food expenditure”. Upon closer inspection of the data, it was noticed that there was a very small number of households that

[56] This was the most recent year of the LCFS data available at the time of analysis.

had extremely high expenditures on food, with an average of over £2,300 a week. These were specifically linked to contract catering and could suggest that a special occasion had taken place at the time of diary recording. As this type of expenditure is not typically an everyday expenditure, the decision was taken to not include it in the analysis so that only normal expenditure patterns were reflected. As such, the total food expenditure variable included all expenditure on food and non-alcoholic beverages, except for that related to contract catering.

6.8.2 The creation of food groups

As the second of the research objectives for this chapter concerns itself with food expenditure patterns, it was necessary to create food groups using the food expenditure variables within the LCFS so that food expenditure patterns could be identified. Although the *Eatwell Guide* – a policy tool that reflects government recommendations on how to eat healthily and achieve a balanced diet (Public Health England (PHE) 2016) – was used initially as a way of instructing categorisation, the resulting groups were found to be too broad and lacked sufficient detail for the purpose of this research. As such, the food groups within the *Consumer Expenditure Survey*, conducted by the US Bureau of Labor Statistics (BLS), were used as a framework to disaggregate these groups further, as shown and applied in work by Fan and colleagues (2007, p.39). However, as the BLS combines all foods consumed away from home into one category (BLS 2019), two further categories were created to differentiate between food expenditures not prepared or cooked at home: *Restaurants, cafés, & canteens* (including school dinners) and *Takeaways*. This differentiation was important as the demographic characteristics of those using these types of food outlets have been found to vary. For example, Smith and colleagues (2013) found that those with higher education were more likely to consume restaurant food, whilst those living in urban areas, belonging to larger households, and younger age groups had a higher likelihood of fast-food consumption. The final food expenditure categories and their constituents are presented in Table 6.1 overleaf.

Table 6.1: *Food expenditure categories and their components using data from the LCFS (2013-2015/16)*

Main food category	Food sub-category	Food items
Food and drink brought home (excluding takeaways)		
Bread, pasta, & rice	–	*Rice; Bread; other breads and cereals; pasta*
Pastry and potatoes	–	*Pastry; potatoes*
Meat & meat products	Meat	*Beef*
		Pork
		Lamb
		Poultry
	Other fresh/frozen/chilled/processed meats	*Other fresh/frozen/chilled/processed meats; sausages; offal/pâté; bacon and ham; other preserved/processed meat*
Fish & seafood Seafood	Fish	*Fish*
	Seafood	*Seafood*
	Other fresh/frozen/chilled/processed fish or seafood	*Dried, smoked or salted fish & seafood; other preserved/processed fish and seafood and fish & seafood preparations*
Milk & milk products	Milk	*Whole milk; low-fat milk, preserved milk*
	Yoghurt and other milk products	*Yoghurt; other milk products*
Cheese & curd	–	*Cheese & curd*
Eggs	–	*Eggs*
Fresh fruit & vegetables	Fresh fruit	*Citrus fruit (fresh); Bananas (fresh); Apples (fresh); Pears (fresh); Stone fruits (fresh); Berries (fresh); Other fresh/chilled/frozen fruits*
	Fresh vegetables	*Leaf & stem vegetables (fresh/chilled); Cabbages (fresh/chilled); Vegetables grown for their fruit (fresh/chilled/frozen); Root crops, non-starchy bulbs & mushrooms (fresh/chilled/frozen)*

Table 6.1: *Food expenditure categories and their components using data from the LCFS (2013 – 2015/16) (continued)*

Main food category	Food sub-category	Food items
Food and drink brought home (excluding takeaways)		
Preserved fruit & vegetables	Processed/preserved fruit	*Dried fruit & nuts; Preserved fruit & fruit-based products*
	Processed/preserved vegetables	*Dried vegetables; Other preserved/processed vegetables; Other tubers & products of tuber vegetables*
Sugar, jam, chocolate, confectionery	–	*Buns, crispbreads, and biscuits; Cakes & puddings; Sugar; Other sugar products; Jams & marmalades; Chocolate; Confectionery products; Edible ices & ice-cream*
Fats & oils	–	*Butter; Margarine & other vegetable fats; peanut butter; olive oil; Edible oils; Other edible animal fats*
Non-alcoholic beverages	–	*Coffee; Tea; Cocoa & powdered chocolate; Fruit juices (including squash); Vegetable juices; Mineral/spring waters; Soft drinks (including fizzy & ready to drink fruit drinks)*
Miscellaneous	–	*Sauces/condiments; Baker's yeast, dessert preparations, soups; Salt, spices & culinary herbs; Other food products*
Eating out and takeaways		
Restaurants, cafés, & canteens	–	*Catered food/non-alcoholic drinks eaten/drunk on premises; food/non-alcoholic drinks eaten/drunk on premises* *School meals; meals bought and eaten at the workplace*
Takeaways	-	*All foods consumed off premises*

Note: Adding together expenditures within each of these food categories equalled the variable for total food expenditure.

6.9 Analysis

The analysis within this chapter is based on 12,074 households from the LCFS (2013 – 2015/16), which is the unit of analysis throughout this chapter. Like in all other analysis chapters within the thesis, this study was a complete case analysis, meaning that a household with missing data on any of the variables used was excluded. Households with zero food expenditure (less than 1 per cent of the sample) and those that had missing data on any other variable used were excluded. This resulted in the loss of 3,637 cases, around 23 per cent of households, from the analysis conducted in the previous chapter.

6.9.1 Dealing with missing data

Before conducting the analysis, it was important to understand why data were missing so that produced estimates would be unbiased and generalisable. There are three classifications of missing data: Missing completely at random (MCAR), meaning that missing values are not related to other variables in the dataset; Missing at random (MAR), where missing values are related to other variables in the dataset; and Missing not at random (MNAR), where the probability of missing varies for reasons unknown (Acock 2016; Pampaka et al. 2016). Excluding households with missing data does not pose a problem where the missing data is less than 5 per cent or if they are MCAR. However, if the missing data are MAR or MNAR and comprise more than 5 per cent of the sample, then this requires further action.

6.9.2 Reweighting the data

To determine whether the data were MCAR or not, Little's test was used, which tests the assumption that the missing data are MCAR. This produced a statistically significant result (p=0.000) meaning that the missing data were not MCAR. Given that the missing data were not found to be MCAR and considering around 23 per cent of the sample were removed from the analysis, the decision was taken to reweight the data to ensure that the remaining data used in the analysis were representative of the population, allowing for results to be generalisable. To do this, the *calibrate* function in Stata was used, which adjusts the sampling weights in the dataset to population totals. This is fully described by D'Souza (2010). This uses variables that are used for sampling in the LCFS, which include the sex and age of individuals within the households and the region where they live. To ensure that this had been executed correctly, this was firstly performed on the entire dataset to ensure that the existing sample weights could be replicated. In confirming that they were correct, this method was then conducted on the reduced sample, producing adjusted weights that allow for findings to be generalisable.

Following the presentation of descriptive analysis showing how income and food expenditure varies for fuel poor and non-fuel poor groups in Table 6.2, the control variables selected to explore the relationship between fuel poverty, food expenditure and food expenditure patterns are presented and Table 6.3. Table 6.4 then presents average expenditure, both in absolute and proportionate terms, by the variables presented in Table 6.3 to examine variations in absolute expenditure and the proportion of income spent on food by these variables before conducting the statistical analysis.

The statistical analysis is then presented in two parts. Firstly, attention is given to food expenditure and its relationship with fuel poverty, using multiple regression analyses to explore the relationship between these and fuel poverty. Secondly, food expenditure patterns are identified using cluster analysis, and their relationship with fuel poverty is investigated using multinomial regression. These two methods of analysis are described in sections 6.11 and 6.12, respectively. For both parts of the analysis, results will be presented for the whole sample and the poor sample, which includes all households – whether fuel poor or not – whose income falls below the poverty line[57]. The purpose of restricting the sample to the poor is to investigate whether fuel poverty has a separate and additional effect on food expenditure and

[57] Throughout the thesis, the poverty line is defined as 60 per cent of the median equivalised household income AHC unless otherwise specified.

food expenditure patterns amongst the poor. The characteristics of fuel poor households with the highest likelihood of experiencing fuel poverty under each indicator using the LCFS datasets are shown in Chapter 5 (see Table 5.23).

6.9.3 Differences in food expenditure between fuel poor and non-fuel poor households

Table 6.2 presents the median weekly income and food expenditure – as well as the proportion of income it represents – for fuel poor and non-fuel poor households defined by each of the fuel poverty indicators, and households who are income poor only. Expenditure on food is presented as an unequivalised absolute value as there are no equivalisation factors currently available for food expenditure or food consumption in the UK [58].

[58] In analysis presented later in sections 6.10 and 6.12, household type is used to adjust absolute expenditure and the proportion of income spent on food as a way of accounting for differences in food expenditures by household type.

Table 6.2: *Median full income and food expenditure in fuel poor and non-fuel poor households [95% confidence intervals], LCFS (2013 – 2015/16), weighted*

	10 per cent indicator		**Alternative fuel poverty indicator**		**Income poverty**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
Rate of fuel poverty	-	**8.4 [7.9 – 8.9]**	-	**11.9 [11.3 – 12.5]**	-	**-**	-
Median full income (£/week)	668.01 [658.92 – 677.09]	**245.21 [234.45 -255.97]**	679.55 [669.46 – 689.64]	**365.05 [350.53 – 379.56]**	774.61 [734.20 – 755.03]	**334.61 [324.78 – 344.43]**	629.10 [620.20 - 638.01]
Median expenditure of food and non-alcoholic beverages (£/week)	82.96 [81.59 -84.34]	**48.24 [44.97 – 51.50]**	81.68 [80.36 – 82.99]	**67.79 [64.37 – 71.21]**	87.36 [85.84 – 88.88]	**58.08 [55.94 – 60.23]**	80.18 [78.92 – 81.44]
Median proportion of full income spent on food per week (%)	12.2 [12.1 – 12.4]	**18.7 [17.6 – 19.8**	12.1 [11.9 – 12.2]	**17.8 [17.2 – 18.5]**	11.7 [11.5 – 11.8]	**17.5 [17.1 – 18.0]**	12.5 [12.4 – 12.7]
Sample size	11,035	**1,039**	10,644	**1,430**	9,429	**2,645**	**12,074**

Note 1: The median values within the table are taken directly from the dataset. As the distributions of full income and food expenditure are skewed, this means that the median percentage of full income spent on food cannot be calculated from the median values of full income and fuel expenditure presented in the table.
Note 2: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.
*p<0.05 **p<0.01 ***p<0.001

Within this sample, 8.4 per cent of households are fuel poor under the 10 per cent indicator and 11.9 per cent are fuel poor under the AFP indicator. These rates are significantly different from each other as indicated by their non-overlapping confidence intervals. Both fuel poor groups and the income poor have significantly lower incomes and fuel expenditures compared to the non-fuel poor and the non-income poor. However, the proportion of full income spent on food is statistically significantly greater for the fuel poor and income poor groups compared to their respective non-fuel poor and non-income poor groups.

The fuel poor under the 10 per cent indicator have the lowest median income overall (£245.21 a week) and the lowest median expenditure on food (£48.24 a week). These values are statistically significantly lower than for all other groups as indicated by the non-overlapping confidence intervals. Their expenditure on food, which consumes almost a fifth of their income (18.7 per cent), is the highest proportion across the whole sample. This could be due to the predominance of single-person households under this indicator as shown by the analysis in Chapter 5, see Table 5.19, which is associated with a lower income (Barnard et al. 2017), lower expenditure on food (ONS 2019d), but a greater proportion of income spent on food (ONS 2019e). Comparing both fuel poor groups with the income poor, the income poor have a higher income (£334.61 a week) compared to the fuel poor under the 10 per cent indicator (£245.21 a week), but a lower income than the fuel poor under the AFP indicator (£365.05 a week). The income poor spend less in absolute terms on food (£58.08 a week) than the fuel poor under the AFP indicator (£67.89 a week), but they spend less in proportionate terms compared to both fuel poor groups. This suggests that food expenditure places a greater burden on the incomes of the fuel poor, with the fuel poor under the 10 per cent indicator experiencing the greatest burden as indicated by the largest percentage of income spent on food.

6.9.4 Identifying the relationship between fuel poverty and food expenditure: Multiple regression

As a way of further understanding the impact of fuel poverty on food expenditure and the factors that may magnify or mitigate this relationship, multiple regression was employed. This method is an extension of simple linear regression, but where linear regression models the relationship between a continuous dependent variable and one independent variable, multiple regression models the relationship between a continuous dependent variable and more than one independent variable (Acock 2016). It is used here to explore absolute expenditure on food and the percentage of income spent on food. The latter was examined to better understand the relative affordability of food expenditure and the burden that it can place on households (Defra 2020).

Multiple regression was performed on the whole sample and the poor sample, i.e. only households whose income falls below the poverty line (defined as 60 per cent of the median equivalised household income AHC), which includes both fuel poor households and income poor only households. Although both analyses aim to determine the separate and additional effect of fuel poverty on absolute food expenditure and the percentage of income spent on food, focusing on the poor sample helps to identify whether fuel poverty has a separate and additional impact on the poor.

6.9.5 Selecting the control variables to explore the relationship between fuel poverty, food expenditure and food expenditure patterns

Purposeful selection, the rationale for which has been described in Chapter 5 (see section 5.3.7.2), was used to identify the control variables that the literature has indicated to influence food expenditure and food expenditure patterns, providing a sound base for their inclusion. The selected control variables and the reasons for their inclusion, are presented in Table 6.3. The same set of control variables were used in both parts of the analysis (i.e. the analysis on absolute food expenditure and food expenditure patterns) given the interrelation between food expenditure and food expenditure patterns, with connections between them highlighted in Table 6.3.

Table 6.3: *Control variables for exploring the relationship between fuel poverty, food expenditure and food expenditure patterns and their rationale for inclusion, LCFS (2013 – 2015/16)*

Variable name	Rationale for inclusion
Household type	Household type gives an indication of the size of the household and its composition, and larger households have been found to spend more on food in absolute terms (ONS 2019d). The presence of children has been shown to influence the types of foods purchased, particularly in terms of processed and frozen foods, cereals, and crisps, with less influence on meats, fruit and vegetables, and pasta (Wilson and Wood 2004).
Highest qualification in the household	Low levels of education have been linked to low levels of nutritional knowledge, which has been found to influence food choices and dietary patterns (Stephens et al. 2018). Higher levels of nutritional knowledge have been linked to healthier food choices, such as higher intakes of vegetables (Asakura et al. 2017) and lower intakes of fat and cholesterol (Yahia et al. 2016). These differences in food choices and food consumption may contribute to differences in expenditure on food given the variations in the cost of healthy and less healthy foods (Jones et al. 2014). Smith and colleagues (2013) also noted that those with higher education were positively associated with restaurant food consumption.
Longstanding physical or mental illness in the household	Illness can impact on food access (Seligman et al. 2010) and so reliance on convenience stores may be greater amongst those with a physical or mental illness. These stores may offer less variety and may be more expensive than larger supermarkets (Corfe 2018; Whitham 2018). Illness may also lead to poorer food choices due to dietary restrictions (Sathyanarayana Rao et al. 2008; Shatenstein 2008), or healthier food choices as a way of preserving health (Glanz et al. 1998).
Sex of the HRP	Women have been found to have more concerns about healthy eating compared to men (Rolls et al. 1991; Wardle et al. 2004) and this filters through into their dietary patterns, with women less likely to consume high-fat foods compared to men (Wardle et al. 2004). As foods that are considered more healthful tend to be more expensive (Jones et al. 2014), this may lead to differences in the food expenditures between men and women. There is also evidence to suggest that men tend to have poorer cooking skills in comparison to women (Taillie 2018) and this may, in part, explain why men are more likely than women to eat away from home (Fan et al. 2007; Orfanos et al. 2007). Although this may be perceived as a value for money option and a time-saving alternative to preparing a meal at home from scratch, it may be more expensive (MacKay et al. 2017).

Table 6.3: *Control variables for exploring the relationship between fuel poverty, food expenditure and food expenditure patterns and their rationale for inclusion, LCFS (2013 – 2015/16) (continued)*

Variable name	Rationale for inclusion
Economic status of the HRP	The economic status of the HRP provides an indication of age (i.e. whether retired or not) and the time available for food shopping and meal preparation, two factors that have been linked to food expenditure and food expenditure patterns (Hambly 2002; Foster 2015). Expenditures on food have been found to vary by age (Foster 2015), with a decrease around retirement (Smith 2004), and employment has been linked with a perceived lack of time, which has been linked to lower levels of healthy eating and higher levels of fast food and convenience food consumption (Inglis et al. 2005; Welch et al. 2008).
Ethnicity of the HRP	Non-white ethnic groups have been shown to spend less on food (Charron-Chénier et al. 2017). However, there is some evidence to suggest that minority ethnic groups purchase traditional foods even though they may be more expensive, which could place a burden on available resources, and have low nutritional content (Chowbey and Harrop 2016). Furthermore, those belonging to non-White ethnic minorities have been found to consume takeaways foods more frequently compared to those belonging to White ethnic groups (Mills et al. 2018)
Country	Available data show that, in absolute terms, households in Northern Ireland spend the most on food compared to the other UK nations, and households in Wales spend the least (Defra 2020). Households in Northern Ireland also spend the greatest proportion of income of food compared to the other UK nations (ONS 2020b) and this has been linked to lower incomes (ONS 2019c), larger household sizes (ONS 2020b), but also cultural differences, with an emphasis on high quality cuts of meat (Smith et al. 2009), and the highest expenditure on takeaway meals eaten at home (ONS 2020b).
Urban or rural	The cost of food tends to be higher in rural areas compared to urban areas, with rural households spending more on food in absolute terms (Liese et al. 2007; ONS 2019f). This may be linked to the higher prevalence of food deserts in rural areas and the reliance on local convenience stores, which tend to be more expensive (Corfe 2018). However, there is a higher exposure to fast food outlets in urban areas compared to rural areas (Corfe 2018) and this may influence differences in food choices between urban- and rural-dwelling households.

Table 6.3: *Control variables for exploring the relationship between fuel poverty, food expenditure and food expenditure patterns and their rationale for inclusion, LCFS (2013 – 2015/16) (continued)*

Variable name	Rationale for inclusion
Number of cars in household	Car ownership may reduce food expenditure by increasing access to a wider range of food outlets, which may offer a wider variety of food items at lower prices compared to local food stores (Fitzpatrick and Ploeg 2010; Corfe 2018).
Season	Seasons can influence the availability and cost of fruit and vegetables, and low-income households have been found to reduce their purchases of these in winter months with consequences to the quality of the diet (Bhattacharya et al. 2003).
Household income	The level of income influences how much of it is dedicated to food, with lower income households allocating a greater proportion of their income to food compared to higher income households (Defra 2020). Income can also affect the types of foods purchased and consumed. For example, low-income households have been found to purchase smaller amounts of fruit and vegetables (French et al. 2019), consume higher levels of sugar (Ntouva et al. 2013), and spend a higher proportion of their income in fast food outlets (French et al. 2010), focusing more on price and quantity rather than preference and quality.

6.9.6 Absolute food expenditure and the proportion of income spent on food by control variables

Table 6.4 explores how absolute food expenditure and the proportion of income spent on food varies by the control variables presented in Table 6.3. The purpose of this is to explore how absolute expenditure and the proportion of income it consumes varies with sociodemographic characteristics. The percentage of income that is allocated to food purchases expresses the relative burden of this type of expenditure on income and is an indicator of food insecurity, with a higher percentage of income spent on food suggesting higher levels of food insecurity (International Dietary Data Expansion Project 2018). However, there are currently no percentage thresholds available to identify food insecurity in the UK.

Table 6.4: *Median absolute expenditure and percentage of income spent on food per week by sociodemographic characteristics, [95% confidence intervals], LCFS (2013 – 2015/16), weighted*

Variable	Absolute expenditure (£/week)	Percentage of income spent (%)
Household type		
Single adult	38.18 [36.97 – 39.39]	10.7 [10.4 – 11.1]
Single adult, 1 child	50.54 [47.18 – 53.90]	13.9 [13.0 – 14.9]
Single adult, 2+ children	68.29 [63.38 – 73.19]	15.3 [14.3 – 16.4]
2 adults	79.80 [78.24 – 81.37]	11.9 [11.6 – 12.1]
2 adults, 1 child	91.20 [88.58 – 93.83]	12.9 [12.3 – 13.4]
2 adults, 2+ children	110.29 [106.81 – 113.77]	13.6 [13.2 – 14.0]
2 adults, 3+ children	117.28 [109.50 – 125.05]	15.2 [14.3 – 16.1]
3+ adults	116.10 [111.97 – 120.23]	13.1 [12.6 – 13.6]
3+ adults, 1 child	130.89 [124.83 – 136.94]	14.0 [13.1 – 14.9]
3+ adults, 2+ children	**135.17 [119.83 – 150.50]**	**16.0 [14.7 – 17.3]**
Highest qualification in the household		
Degree or equivalent	**93.34 [91.18 – 95.50]**	11.5 [11.3 – 11.7]
Other higher qualification	83.50 [79.67 – 87.33]	13.0 [12.6 – 13.4]
A-level or equivalent	78.00 [74.96 – 81.05]	13.5 [13.1 – 13.8]
GCSE or equivalent	67.40 [64.79 – 70.01]	13.8 [13.4 – 14.3]
Other below degree level	59.39 [56.02 – 62.75]	13.1 [12.5 – 13.7]
No formal qualifications	58.99 [49.57 – 68.41]	**14.0 [12.7 – 15.3]**
Longstanding physical or mental illness in the household		
Yes	**81.60 [79.62 – 83.58]**	**13.2 [12.9 – 13.4]**
No	78.73 [76.90 – 80.55]	11.9 [11.7 – 12.1]
Sex of the HRP		
Male	**87.13 [85.26 – 89.00]**	12.4 [12.2 – 12.6]
Female	70.25 [68-59 – 71.91]	**12.8 [12.5 – 13.0]**
Economic status of the HRP		
Self-employed	**89.73 [84.61 – 94.85]**	13.6 [13.0 – 14.2]
Employed	85.06 [83.52 – 86.60]	11.7 [11.5 – 11.9]
Unemployed	45.15 [38.66 – 51.64]	13.3 [11.9 – 14.7]
Retired	73.50 [71.03 – 75.98]	14.7 [14.2 – 15.1]
Inactive*	61.97 [58.28 – 65.66]	**15.4 [14.7 – 16.0]**
Ethnicity of the HRP		
White	**81.64 [80.32 – 82.95]**	**12.7 [12.5 – 12.8]**
Mixed Race	59.47 [48.06 – 70.89]	11.8 [10.2 – 13.5]
Asian	70.24 [64.97 – 75.52]	10.9 [10.0 – 11.8]

Table 6.4: *Median absolute expenditure and percentage of income spent on food per week by sociodemographic characteristics [95% confidence intervals], LCFS (2013 – 2015/16), weighted (continued)*

Variable	Absolute expenditure (£/week)	Percentage of income spent (%)
Ethnicity of the HRP		
Black	61.14 [53.19 – 69.08]	10.7 [9.4 – 11.9]
Other	74.52 [65.83 – 83.22]	12.5 [11.5 – 13.5]
Country		
England	80.47 [79.15 – 81.79]	12.4 [12.2 – 12.6]
Wales	74.37 [69.00 – 79.74]	12.2 [11.5 – 13.0]
Scotland	75.25 [71.17 – 79.33]	12.7 [12.0 – 13.3]
Northern Ireland	**90.50 [84.58 – 96.42]**	**17.7 [16.4 – 18.9]**
Urban or rural		
Urban	76.81 [75.49 – 78.14]	12.5 [12.3 – 12.7]
Rural	**92.21 [89.67 – 94.74]**	**12.8 [12.4 – 13.1]**
Number of cars in the household		
None	51.09 [48.60 – 53.57]	12.3 [11.9 – 12.7]
One	74.14 [72.78 – 75.49]	**12.9 [12.7 – 13.2]**
Two or more	**107.40 [105.16 – 109.64]**	12.2 [12.0 – 12.5]
Season		
Spring	80.20 [77.63 – 82.76]	12.6 [12.3 – 12.9]
Summer	78.31 [75.88 – 80.75]	**12.7 [12.4 – 13.1]**
Autumn	78.18 [75.71 – 80.64]	12.1 [11.8 – 12.4]
Winter	**83.43 [80.61 – 86.25]**	**12.7 [12.3 – 13.1]**
Household full income deciles		
1 (Lowest)	35.83 [33.77 – 37.90]	**17.8 [16.9 – 18.8]**
2	48.78 [46.61 – 50.94]	14.9 [14.2 – 15.6]
3	59.73 [57.08 – 62.38]	14.6 [14.0 – 15.1]
4	71.49 [68.67 – 74.41]	14.5 [13.9 – 15.2]
5	77.73 [74.26 – 81.21]	13.5 [12.9 – 14.1]
6	85.46 [82.16 – 88.75]	12.8 [12.3 – 13.3]
7	95.66 [91.69 – 99.64]	12.2 [11.7 – 12.6]
8	102.78 [99.04 – 106.52]	11.2 [10.8 – 11.6]
9	116.10 [110.75 – 121.46]	10.4 [10.0 – 10.8]
10	**144.74 [139.39 – 150.08]**	9.5 [9.1 – 9.8]
Sample size	**12,074**	

* This group includes full-time university students, those occupied with household duties, those who have no need to be employed, and those involved in unpaid or voluntary work (ONS 2016b). **Note:** Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

Table 6.4 shows that it is not always those who have the highest absolute food expenditure who experience the greatest food expenditure burden, as represented by the percentage of income spent on food. Households containing three or more adults with two or more children spend the highest in absolute terms (£135.17 a week) and this consumes 16.0 per cent of their income, although this is not statistically significant. Single-adult households spend statistically significantly less on food than all other household types, both in absolute and proportionate terms, as indicated by the non-overlapping confidence intervals.

Absolute expenditure on food decreases as the highest level of qualification in the household decreases, with households where the highest qualification is "degree or equivalent" spending statistically significantly more than households with other types of qualifications. However, the burden on income increases overall as the highest qualification in the household decreases, with those with no formal qualifications having the highest food burden (14.0 per cent), which is significantly greater than the proportion of income spent on food by households where the highest qualification is "degree or equivalent". Other household characteristics that have the highest food burden is where longstanding illness is present (13.2 per cent), where households have a female HRP (12.8 per cent), and households where the HRP is inactive (15.4 per cent), although this is not always statistically significant. Compared to households with a White HRP, all other ethnic categories spend significantly less on food in absolute terms. However, it is households with a White HRP that have the highest food burden (12.7 per cent) and this is statistically significantly higher than for households where the HRP is Asian or Black.

Households in Northern Ireland have the highest absolute expenditure on food (£90.50) as well the highest proportion of income spent on food (17.7 per cent) and this is statistically significantly higher compared to other nations within the UK. This reflects available information regarding food expenditure in Northern Ireland that shows that households are larger in Northern Ireland (ONS 2020b), that they have a preference for higher quality foods (Smith et al., 2009), and that they have lower incomes (ONS 2019c).

Households in rural areas spend more on food in absolute terms (£92.21) compared to urban households (£76.81), but this consumes around the same proportion of income by comparison. This may be linked to households in rural areas being, on average, wealthier (Defra 2019b), and as such, a higher expenditure on food does not consume a higher proportion of income.

Although absolute food expenditure increases with increasing number of cars, the burden of this is similar across the categories, which may reflect increasing income with increasing number of cars (ONS 2019g). Households with two or more cars spend statistically significantly more in absolute terms, but significantly less in proportionate terms, than households with no cars or one car, as indicated by their non-overlapping confidence intervals.

Households interviewed in winter spent the most in absolute terms (£83.43) compared to households interviewed in other seasons, although this is not statistically significant. However, there is little variation in the percentage of income this consumes across seasons, ranging from 12.1 to 12.7 per cent of income being spent on food. It is also noted that there is a decreasing proportion of income spent on food as income decile increases despite increasing absolute expenditure. Table 6.4 shows that households in the 10th income decile, who spend £144.74 a week, spend significantly more compared to households in all other income deciles. However, only 9.5 per cent of income is spent on food by these households and this is significantly lower than for all other households. It is households in the lowest income decile that spend the highest proportion of income on food at 17.8 per cent, which is significantly higher than for households in all other income deciles. This is consistent with Engel's Law – an economic theory that states that the proportion of income spent on food falls as income rises, even if actual expenditure on food increases (O'Connor et al. 2016).

6.9.7 Building the models: selecting the groupings and order of variables

Using the purposefully selected control variables presented in Table 6.3, the following three sets of variables have been used to build the models that explore the impact of fuel poverty on food expenditure and food expenditure patterns. The components of each variable set have been detailed below and overleaf:

Set 1: *Fuel poverty* and *household type* make up the first set of variables. As there are no established equivalisation factors for food expenditure of food consumption, household type is being used simply as an adjuster for food expenditure. This set of variables is entered first into the model to assess the effect of fuel poverty before controlling for other factors.

Set 2: The second set of variables includes factors related to the household and demographic characteristics of the HRP[59] (*highest qualification in the household, longstanding physical or mental illness in the household, the sex, economic status, and ethnicity of the HRP),* dwelling factors (*country* and *urban or rural*), and *season*.

Set 3: *Household full income deciles* is the last variable to be added to the model and is entered as income deciles to ease interpretability. It is entered last in the regression as a way of disentangling the effect of income from other variables already in the model and to investigate whether the effect of fuel poverty is simply a low-income effect.

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[59] *Number of cars in the household* was initially included, but the decision was taken to exclude this variable as it was showing the reverse of what the evidence suggests. Instead of the proportion of income spent on food decreasing with increasing number of cars, it was shown to increase with increasing number of cars.

6.10 The impact of fuel poverty on food expenditure: the results of multiple regression analysis

In the following tables, the results of multiple regression analysis are presented, focusing on the effects of fuel poverty on absolute food expenditure (Table 6.5) and the percentage of income spent on food (Table 6.6), respectively. In both tables, the outcomes of the analysis are presented for each of the two fuel poverty indicators for the whole sample and the poor sample. Only the results related to fuel poverty are presented here, with the full models shown in Appendix C (see Tables C.1 to C.4 for analysis on absolute food expenditure and C.5 to C.8 for analysis on the percentage of income spent on food). In discussing the results, a comparative approach is taken, drawing attention to similarities and differences in the effect of fuel poverty using different fuel poverty indicators on food expenditure and the impact of adding the sets of variables presented in section 6.9.5.

6.10.1 Fuel poverty and absolute expenditure spent on food

Table 6.5 presents the results of multiple regression analysis that explores the impact of fuel poverty under the 10 per cent indicator and the AFP indicator on absolute food expenditure on the whole sample and on the poor sample, the latter of which was used to investigate whether fuel poverty has a separate and additional effect on food expenditure and food expenditure patterns amongst the poor. Absolute food expenditure was converted to its natural logarithm[60] to account for any outliers, helping to normalise the distribution and therefore, fulfil this assumption of multiple regression.

[60] The natural logarithm of a number is its logarithm to the base of *e*, which is equal to (approximately) 2.718.

Table 6.5: *Multiple regression: The impact of fuel poverty on absolute food expenditure (natural log) for the whole sample and the poor sample[1] (coefficients (robust standard errors)), LCFS (2013 – 2015/16), weighted*

	Model 1	**Model 2**	**Model 3**
Whole sample analysis			
10 per cent definition			
Fuel poverty (ref: No)	-0.239 (0.030)***	-0.117 (0.028)***	0.061 (0.030)
Adjusted R^2	**0.321**	**0.370**	**0.415**
AFP definition			
Fuel poverty (ref: No)	-0.242 (0.026)***	-0.136 (0.025)***	0.025 (0.027)
Adjusted R^2	**0.322**	**0.371**	**0.414**
Sample size	**12,074**		
Poor sample analysis			
10 per cent definition			
Fuel poverty (ref: No)	0.001 (0.040)	0.028 (0.037)	0.059 (0.041)
Adjusted R^2	**0.314**	**0.368**	**0.384**
AFP definition			
Fuel poverty (ref: No)	0.083 (0.034)*	0.072 (0.033)*	0.076 (0.032)*
Adjusted R^2	**0.317**	**0.370**	**0.385**
Sample size	**2,645**		

[1] Model 1 contains fuel poverty and household type as an adjuster variable; model 2 adds the second set of variables: highest qualification in the household, longstanding physical or mental illness in the household, the sex, economic status, and ethnicity of the HRP, country, urban or rural, and season. Model 3 adds the third set of variables: household full income deciles.
*p<0.05 **p<0.01 ***p<0.001

Whole sample: In model 1, *fuel poverty* and *household type* are entered, with *household type* being used to adjust food expenditure based on the composition of the household. To reiterate, this is to account for the fact that there are no equivalisation factors available for food expenditure or food consumption and this allows for a sense of equivalisation. In this model, fuel poverty under both indicators is shown to be associated with a significantly lower expenditure on food compared to non-fuel poor households, with similar levels of expenditure observed for both fuel poor groups.

Model 2 adds the household and demographic factors (*highest qualification in the household, longstanding physical or mental illness in the household*, the *sex, economic status,* and *ethnicity of the HRP*), dwelling factors (*country* and *urban or rural*), and *season*. Although the addition of these factors increases food expenditure for the fuel poor under both indicators, it remains significantly lower for fuel poor households compared to their non-fuel poor counterparts, with the fuel poor under the AFP indicator having lower levels of food expenditure compared to the fuel poor under the 10 per cent indicator.

In model 3, *household full income deciles* are added and this increases expenditure on food for the fuel poor once again so that fuel poverty under both indicators is now associated with higher absolute expenditure on food compared to non-fuel poor households, but this is now no longer significant suggesting that absolute expenditure on food for the fuel poor is explained by income.

Poor sample: Conditioning on low income by conducting the same analysis on the poor sample, it is noted that the large negative effects observed for the whole sample analysis are dampened. In contrast to the fuel poor under the 10 per cent indicator where fuel poverty has no significant impact on absolute food expenditure amongst the poor, fuel poverty under the AFP indicator is significantly associated with increased expenditure on food amongst the poor, contrasting the analysis on the whole sample.

In model 2, the addition of the second set of variables (*highest qualification in the household, longstanding physical or mental illness in the household,* the *sex, economic status,* and *ethnicity of the HRP*, *country*, *urban or rural*, and *season*) increases food expenditure for the fuel poor under the 10 per cent indicator, but this remains non-significant. Contrastingly, this set of variables reduces food expenditure for the fuel poor under the AFP indicator, but this relationship remains statistically significant.

Adding *household full income deciles*[61] in model 3, only fuel poverty under the AFP indicator is shown to be significantly associated with increased food expenditure amongst the poor.

6.10.2 Fuel poverty and the percentage of income spent on food

Table 6.6 presents the multiple regression outputs that investigate the effect of fuel poverty on the proportion of income spent on food for the whole sample and the poor sample. The proportion of income spent on food provides an insight into the relative burden that food expenditure places on household income (Defra 2020), with food insecurity increasing with the proportion of income spent on food (International Dietary Data Expansion Project 2018). In this case, the coefficients are presented as percentages and are interpreted as such.

[61] For analysis of the poor sample, household full income deciles were created for this sample to explore more detailed income levels at the lower end of the income distribution.

Table 6.6: *Multiple regression: The impact of fuel poverty under the 10 per cent indicator on the percentage of full income spent on food for the whole sample and the poor sample[1](coefficients (robust standard errors)), LCFS (2013 – 2015/16), weighted*

	Model 1	**Model 2**	**Model 3**
Whole sample analysis			
10 per cent definition			
Fuel poverty (ref: No)	14.152 (1.657)***	12.964 (1.731)***	6.629 (1.280)***
Adjusted R^2	**0.097**	**0.119**	**0.215**
AFP definition			
Fuel poverty (ref: No)	9.762 (1.364)***	8.601 (0.952)***	3.507 (1.088)**
Adjusted R^2	**0.059**	**0.089**	**0.206**
Sample size	**12,074**		
Poor sample analysis			
10 per cent definition			
Fuel poverty (ref: No)	11.647 (2.042)***	11.242 (1.889)***	2.923 (1.023)**
Adjusted R^2	**0.069**	**0.126**	**0.333**
AFP definition			
Fuel poverty (ref: No)	4.578 (1.551)**	4.089 (1.374)**	3.255 (1.104)**
Adjusted R^2	**0.030**	**0.091**	**0.335**
Sample size	**2,645**		

[1] Model 1 contains fuel poverty and household type as an adjuster variable; model 2 adds the second set of variables: highest qualification in the household, longstanding physical or mental illness in the household, the sex, economic status, and ethnicity of the HRP, country, urban or rural, and season. Model 3 adds the third set of variables: household full income deciles.
*p<0.05 **p<0.01 ***p<0.001

Whole sample: In model 1, where *fuel poverty* and *household type* are entered, both fuel poor groups are associated with a higher percentage of income spent on food, with the fuel poor under the 10 per cent indicator spending 4.4 per cent more of their income on food compared to the fuel poor under the AFP indicator. This suggests that food expenditure exerts a greater burden on the fuel poor, and the greatest burden on the fuel poor under the 10 per cent indicator, which may be linked to their lower incomes (see Table 6.2). This suggests that the fuel poor may experience some elements of food insecurity.

Model 2 adds the household and demographic factors (*highest qualification in the household, sex, economic status, and ethnicity of the HRP, longstanding illness*), dwelling factors (*country and urban or rural*), and *season*, and this reduces the proportion of income spent on food by 1.2 per cent for both fuel poor groups, although the fuel poor under the 10 per cent indicator continue to spend the greatest proportion of their income on food, 4.4 per cent greater than the fuel poor under the AFP indicator.

In model 3, *household full income deciles* is added and although this reduces the proportion of income spent on food by 6.3 per cent for the fuel poor under the 10 per cent indicator and 5.1 per cent for the fuel poor under the AFP indicator, fuel poverty remains significantly associated with a greater proportion of income spent on food compared to non-fuel poor households, with the fuel poor under the 10 per cent indicator spending 3.1 per cent more of their income on food compared to the fuel poor under the AFP indicator. This suggests that the fuel poor under the 10 per cent indicator experience a higher food burden, and possibly higher levels of food insecurity, compared to the fuel poor under the AFP indicator.

Poor sample: In conducting the same analysis on the poor sample to investigate the effect of fuel poverty on the burden of food expenditure on income amongst the poor, the fuel poor under both indicators in model 1, which includes *fuel poverty* and *household type*, are shown to spend a significantly greater proportion of their income on food compared to their non-fuel poor counterparts, with the fuel poor under the 10 per cent indicator spending 11.6 per cent more of their income on food and the fuel poor under the AFP indicator spending 4.6 per cent more of their income. The higher proportion of income spent on food by the fuel poor under the 10 per cent indicator again may be attributed to their lower incomes, as shown in Table 6.2.

Adding the demographic and dwelling variables in model 2 reduces the percentage of income spent on food by less than 1 per cent for the fuel poor under each indicator, suggesting that these variables have very little effect on the relationship between fuel poverty and the percentage of income spent on food amongst the poor. When controlling for income in model 3, the proportion of income spent on food by the fuel poor under the 10 per cent indicator is reduced by 8.3 per cent, but this addition has a marginal effect on the proportion of income spent on food by the fuel poor under the AFP indicator. In this final model, fuel poverty under the 10 per cent indicator is significantly associated with a 2.9 per cent increase in the percentage of income spent on food and a 3.3 per cent increase for the fuel poor under the AFP indicator compared to their non-fuel poor counterparts. This suggests that the experience of fuel poverty may increase levels of food insecurity amongst the poor.

6.11 Identifying food expenditure patterns: Two-step clustering methodology

The higher absolute expenditure on food and the greater burden of food expenditure for the fuel poor shown in the previous sections, which persisted after controlling for a range of explanatory variables, including income, could highlight differences in the types of foods purchased and the types of establishments used for food consumption. This warranted further investigation and the next stage of the research focuses on food expenditure patterns as a way of exploring these findings further, fulfilling the second objective set for this chapter.

To identify food expenditure patterns, cluster analysis was used. This method has been used in previous studies to identify patterns of food expenditure (Fan et al. 2007), dietary patterns (Glanz et al. 1998) and other expenditure patterns (Hayes and Finney 2014) and provides an empirically-based method to identify patterns of expenditure. This method has been defined by Kaufman and Rousseew as “the art of finding groups in data” (2005, p.1) and is a descriptive and exploratory multivariate technique that attempts to group observations into homogeneous and distinct groups (Everitt et al. 2011) so that these groups contain observations that are similar to one another but dissimilar to observations in other groups (Johnson and Wichern 2007).

Food expenditure patterns were determined using a two-step clustering methodology based on household patterns of budget allocation to the different food groups defined in Table 6.1, which were then converted to the percentage of the food budget they consume. The first step of this methodology involved performing *hierarchical cluster analysis*[62]. The purpose of this was to identify a range of cluster solutions that could then be used to conduct *k*-means clustering – the second step of this two-step clustering methodology.

Hierarchical cluster analysis does not perform well with large samples and so it was performed on a random subsample of 300 households. *Average linkage*, which measures the average distance between objects was used as it is less affected by outliers compared to other measures such as *complete linkage* and *Ward's method* (Yim and Ramdeen 2015). Once the hierarchical clustering was complete, cluster stopping rules identified an optimum cluster solution of between 3 and 6 clusters. These cluster solutions were then used to conduct *k*-means clustering. This type of clustering performs well with larger samples and is a non-hierarchical partitioning-based method where observations are assigned to the cluster with the nearest mean (Everitt et al. 2011). To ensure that the results were reproducible, the random seed was set to "123" to determine the initial cluster centres and this was used in all remaining clustering procedures.

An important part of *k*-means clustering is the measures of (dis)similarity. These estimate the distance between pairs of observations (Mooi et al. 2018) and play a fundamental role in how the clustering algorithm performs, with different measures producing different clustering solutions (Bora and Gupta 2014; Mooi et al. 2018). The *Euclidean distance* was applied as the measure of (dis)similarity, following the method used by Fan and colleagues (2007). This distance measure travels in a straight line from the cluster centre to every object,

[62] This method produces hierarchical representations in which clusters at each level of the hierarchy are created by merging clusters at the next lower level. At the lowest level, each cluster contains a single observation, and at the highest level, there is only one cluster, which contains all observations (Hastie et al. 2009).

with objects being assigned to the cluster centre with the shortest distance to it (Yim and Ramdeen 2015).

After running the *k*-means cluster analysis for the 3 to 6 cluster solutions identified through hierarchical clustering, the clusters were examined closely, and the 5-cluster solution was found to have the most distinct and meaningful food expenditure patterns. Identifying the optimum number of clusters ensures that under- or over-segmentation does not occur (Mooi et al. 2018), a factor that could lead to unstable clusters that are not well-separated or homogeneous (Hennig 2006). The 5-cluster was tested for stability through the use of different distance measures (the Manhattan and squared Euclidean distances) and it was found that the same clusters emerged, indicating cluster stability.

6.11.1.1 The results of k-means cluster analysis

Table 6.7 presents the results of the *k*-means cluster analysis. Five distinct clusters of food expenditure patterns were identified and have been labelled based on their key characteristics as follows**:** *Most common, Highly processed, Fruit & Vegetable burden, Takeaways, and Restaurants, cafés, & canteens.* The key characteristics of each cluster are in bold and shaded in grey within the table as a simple way of identifying their defining characteristics. Table 6.8 then presents the characteristics of the households that fall into each of the food expenditure patterns identified through cluster analysis.

Table 6.7: *Five clusters of food expenditure patterns and the percentage of the food budget spent on each food group [95% confidence intervals], LCFS (2013 – 2015/16), weighted*

Food category	Sample average	Cluster 1 Most common	Cluster 2 Highly processed	Cluster 3 Fruit & Vegetable burden	Cluster 4 Restaurants, cafés, and canteens	Cluster 5 Takeaways
Bread, pasta, and rice	7.5 [7.4 -7.5]	6.7 [6.5 – 6.8]	9.9 [9.6 – 10.0]	9.0 [8.8 – 9.3]	4.1 [4.0 – 4.2]	6.5 [6.2 – 6.7]
Pastry, and potatoes	2.2 [2.1 – 2.2]	1.9 [1.9 – 2.0]	2.9 [2.8 – 3.0]	2.7 [2.6 – 2.8]	1.2 [1.1 – 1.2]	1.8 [1.7 – 1.9]
Fresh meats	6.3 [6.1 – 6.4]	5.8 [5.6 – 6.0]	5.8 [5.6 – 6.0]	**10.7 [10.3 – 11.0]**	3.0 [2.8 – 3.2]	4.7 [4.4 – 4.9]
Processed meats	8.4 [8.3 – 8.6]	7.6 [7.4 – 7.8]	**14.0 [13.7 – 14.3]**	7.8 [7.5 – 8.0]	4.2 [4.0 – 4.4]	6.9 [6.6 – 7.2]
Fish & seafood	1.3 [1.2 – 1.3]	1.3 [1.2 – 1.4]	0.9 [0.8 – 0.9]	2.4 [2.3 – 2.6]	0.7 [0.6 – 0.8]	0.7 [0.6 – 0.8]
Preserved/processed fish & seafood	1.7 [1.6 – 1.7]	1.7 [1.6 – 1.7]	1.9 [1.8 – 2.0]	2.4 [2.2 – 2.5]	0.9 [8.3 – 9.8]	1.1 [1.0 – 1.2]
Milk	3.1 [3.0 – 3.2]	2.5 [2.4 – 2.6]	4.0 [3.8 – 4.1]	4.1 [3.8 – 4.3]	1.8 [1.7 – 1.9]	2.8 [2.7 – 3.0]
Cheese & other milk products	4.8 [4.7 – 4.9]	4.6 [4.5 – 4.7]	5.6 [5.5 – 5.8]	6.5 [6.3 – 6.7]	2.7 [2.5 – 2.8]	3.4 [3.2 – 3.5]
Eggs	0.9 [0.9 – 0.9]	0.8 [0.8 – 0.8]	1.0 [1.0 – 1.1]	1.4 [1.3 – 1.5]	0.5 [0.5 – 0.6]	0.7 [0.6 – 0.7]
Fresh fruit and vegetables	11.6 [11.4 – 11.7]	10.8 [10.6 – 11.0]	10.5 [10.3 – 10.7]	**19.6 [19.2 – 19.9]**	6.7 [6.5 – 6.9]	7.8 [7.6 – 8.1]
Preserved/processed fruit and vegetables	2.8 [2.8 – 2.9]	2.8 [2.7 – 2.9]	2.8 [2.7 – 2.9]	4.2 [4.1 – 4.4]	1.6 [1.5 – 1.7]	1.9 [1.8 – 2.0]
Fats & oils	1.6 [1.5 – 1.6]	1.3 [1.3 – 1.4]	2.0 [1.9 – 2.1]	2.2 [2.1 – 2.3]	0.8 [0.7 – 0.8]	1.1 [1.0 – 1.2]
Sugar, cakes, and confectionary	13.0 [12.8 – 13.1]	11.7 [11.5 – 11.9]	**22.0 [21.6 – 22.4]**	10.8 [10.6 – 11.0]	7.1 [6.8 – 7.3]	11.0 [10.7 – 11.3]
Miscellaneous	1.6 [1.5 – 1.6]	1.5 [1.4 – 1.6]	1.9 [1.7 – 2.0]	2.1 [1.9 – 2.2]	0.8 [0.7 – 0.9]	1.2 [1.1 – 1.3]
Non-alcoholic beverages	3.3 [3.2 – 3.4]	3.1 [3.0 – 3.2]	4.1 [3.9 – 4.2]	4.1 [4.0 – 4.3]	2.0 [1.9 – 2.1]	2.7 [2.5 – 2.8]
Restaurant, cafés, and canteens	19.2 [18.9 – 19.5]	27.1 [26.8 – 27.3]	4.5 [4.3 – 4.7]	5.4 [5.2 – 5.6]	**53.0 [52.4 – 53.5]**	12.0 [11.5 – 12.5]
Takeaways	11.0 [10.8 – 11.2]	8.7 [8.5 – 9.0]	6.4 [6.1 – 6.7]	4.6 [4.4 – 4.8]	9.0 [8.6 – 9.4]	**33.7 [33.1 – 34.3]**
Sample size	**12,074**	**3, 528**	**2,666**	**2,582**	**1,676**	**1,622**
Percent of sample	**100.0**	**29.2**	**22.1**	**21.4**	**13.9**	**13.4**

Note: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

Table 6.8: *Characteristics of each cluster [95% confidence intervals], LCFS (2013 – 2015/16), weighted*

	Sample average	Cluster 1 Most common	Cluster 2 Highly processed	Cluster 3 Fruit & vegetable burden	Cluster 4 Restaurants, cafés, and canteens	Cluster 5 Takeaways
Rate of fuel poverty (%)						
10 per cent indicator	8.4 [7.9 – 8.9]	4.9 [4.2 – 5.7]	12.5 [11.2 – 13.9]	11.5 [10.2 – 12.9]	5.0 [4.1 – 6.2]	8.2 [6.9 – 9.7]
AFP indicator	11.9 [11.3 – 12.5]	8.0 [7.1 – 9.0]	17.4 [16.0 – 19.0]	14.0 [12.6 – 15.6]	6.3 [5.2 – 7.6]	14.0 [12.3 – 15.8]
Rate of income poverty (%)	22.7 [21.9 – 23.6]	14.9 [13.6 – 16.2]	33.0 [31.2 – 35.0]	27.3 [25.5 – 29.3]	12.7 [11.0 – 14.6]	26.4 [24.2 – 28.8]
Median full income (£/week)	623.26 [613.60 – 632.92]	716.63 [697.23 – 736.04]	497.65 [480.82 – 514.48]	543.18 [522.27 – 564.09]	760.73 [729.91 – 791.56]	617.64 [594.17 – 641.10]
Household type (%)						
Single adult	19.3 [18.5 – 20.0]	13.9 [11.8 – 14.3]	22.4 [20.8 – 24.2]	23.1 [21.4 – 24.9]	23.3 [21.2 – 25.5]	17.5 [15.7 – 19.5]
Single adult, 1 child	3.0 [2.7 – 3.3]	2.5 [2.0 -3.0]	3.9 [3.2 – 4.7]	3.3 [2.7 – 4.1]	1.5 [1.0 – 2.2]	3.7 [2.9 – 4.6]
Single adult, 2+ children	2.6 [2.3 – 2.8]	1.9 [1.6 – 2.4]	4.1 [3.4 – 4.9]	2.2 [1.7 – 2.8]	1.5 [1.0 – 2.1]	3.1 [2.4 – 3.9]
2 adults	32.6 [31.7 – 33.5]	35.1 [33.4 – 36.7]	26.6 [24.9 – 28.3]	34.8 [32.9 – 36.8]	41.6 [39.1 – 44.1]	24.6 [22.4 – 26.9]
2 adults, 1 child	10.4 [9.9 – 11.0]	11.2 [10.2 – 12.4]	10.0 [8.8 -11.2]	9.3 [8.2 – 10.6]	8.8 [7.5 – 10.3]	12.7 [11.1 – 14.5]
2 adults, 2 children	11.1 [10.5 – 11.6]	13.6 [12.5 – 14.8]	11.3 [10.2 – 12.6]	9.7 [8.5 – 10.9]	7.3 [6.2 – 8.7]	11.3 [9.9 -12.9]
2 adults, 3+ children	4.1 [3.8 – 4.5]	4.0 [3.4 – 4.7]	5.4 [4.5 – 6.3]	3.4 [2.7 - 4.3]	1.7 [1.2 – 2.5]	5.9 [4.8 – 7.2]
3+ adults	11.8 [11.2 – 12.5]	13.8 [12.6 – 15.2]	11.0 [9.7 – 12.5]	10.2 [9.0 – 11.7]	10.9 [9.2 – 12.8]	12.3 [10.6 -14.2]
3+ adults, 1 child	3.2 [2.9 -3.6]	3.5 [2.9 – 4.3]	2.8 [2.2 - 3.6]	2.2 [1.6 – 3.0]	2.6 [1.8 – 3.6]	5.3 [4.2 – 6.6]
3+ adults, 2+ children	1.9 [1.7 – 2.2]	1.4 [1.0 – 1.9]	2.5 [1.9 – 3.3]	1.6 [1.2 – 2.3]	1.0 [0.0 – 0.1]	3.7 [2.7 – 4.9]
Sample size	**12,074**	**3, 528**	**2,666**	**2,582**	**1,676**	**1,622**
Percent of sample	**100.0**	**29.2**	**22.1**	**21.4**	**13.9**	**13.4**

Note: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

Table 6.8: *Characteristics of each cluster [95% confidence intervals], LCFS (2013 – 2015/16), weighted (continued)*

	Sample average	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**
		Most common	**Highly processed**	**Fruit & vegetable burden**	**Restaurants, cafés, and canteens**	**Takeaways**
Highest qualification in the household (%)						
Degree or equivalent	40.6 [39.6 – 41.5]	47.3 [45.6 – 49.1]	24.5 [22.8 – 26.3]	44.1 [42.1 – 46.2]	52.4 [49.8 – 54.9]	34.1 [31.7 – 36.6]
Other higher qualification	13.1 [12.5 – 13.7]	13.4 [12.3 – 14.6]	13.8 [12.5 – 15.2]	11.8 [10.5 – 13.1]	13.2 [11.6 – 14.9]	13.3 [11.7 – 15.1]
A-level or equivalent	17.1 [16.4 – 17.8]	15.8 [14.6 – 17.2]	20.1 [18.5 – 21.7]	15.0 [13.6 – 16.5]	14.0 [12.3 – 15.9]	21.5 [19.4 – 23.7]
GCSE or equivalent	18.6 [17.9 – 19.4]	15.2 [14.0 – 16.4]	26.6 [24.9 – 28.5]	17.2 [15.7 – 18.8]	12.4 [10.9 – 14.1]	22.0 [20.0 – 24.1]
Other below degree level	9.4 [8.9 – 9.9]	7. 4 [6.6 – 8.4]	13.0 [11.7 – 14.3]	10.6 [9.5 – 11.9]	7.0 [5.9 – 8.3]	8.4 [7.1 – 9.9]
Highest qualification in the household (%) (continued)						
No formal qualifications	1.2 [1.0 – 1.4]	0.9 [0.6 – 1.2]	2.0 [1.5 – 2.6]	1.3 [1.0 – 1.8]	1.0 [0.1 – 1.2]	0.7 [0.4 – 1.3]
Sex of the HRP (%)						
Female	37.3 [36.4 – 38.2]	33.9 [32.3 – 35.6]	40.9 [39.0 – 42.9]	39.0 [37.1 – 41.1]	36.8 [34.4 – 39.3]	36.7 [34.3 – 39.1]
Economic status of the HRP (%)						
Self-employed	10.0 [9.4 – 10.6]	9.6 [8.6 – 10.7]	8.6 [7.5 – 9.8]	10.7 [9.4 – 12.1]	10.2 [8.7 – 11.9]	11.5 [10.0 – 13.3]
Employed	64.7 [63.8 – 65.6]	71.3 [69.7 – 72.9]	57.1 [55.1 – 59.1]	58.5 [56.4 – 60.5]	66.2 [63.7 – 68.5]	70.7 [68.3 – 72.9]
Unemployed	2.9 [2.5 – 3.2]	1.6 [1.2 – 2.2]	4.6 [3.9 – 5.7]	3.8 [3.1 – 4.8]	1.8 [1.3 – 2.7]	2.4 [1.7 – 3.4]
Retired	10.8 [10.2 – 11.3]	10.2 [9.3 – 11.2]	11.3 [10.1 – 12.6]	14.9 [13.5 – 16.3]	12.3 [10.8 – 13.9]	3.7 [2.9 – 4.8]
Inactive*	11.7 [11.1 – 12.3]	7.3 [6.4 – 8.3]	18.4 [16.9 – 20.1]	12.2 [10.9 – 13.6]	9.6 [8.2 – 11.2]	11.7 [10.1 – 13.4]
Sample size	**12,074**	**3, 528**	**2,666**	**2,582**	**1,676**	**1,622**
Percent of sample	**100.0**	**29.2**	**22.1**	**21.4**	**13.9**	**13.4**

Note: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

Table 6.8: *Characteristics of each cluster [95% confidence intervals], LCFS (2013 – 2015/16), weighted (continued)*

	Sample average	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
		Most common	**Highly processed**	**Fruit & vegetable burden**	**Restaurants, cafés, and canteens**	**Takeaways**
Highest qualification in the household (%) (continued)						
No formal qualifications	1.2 [1.0 – 1.4]	0.9 [0.6 – 1.2]	2.0 [1.5 – 2.6]	1.3 [1.0 – 1.8]	1.0 [0.1 – 1.2]	0.7 [0.4 – 1.3]
Sex of the HRP (%)						
Female	37.3 [36.4 – 38.2]	33.9 [32.3 – 35.6]	40.9 [39.0 – 42.9]	39.0 [37.1 – 41.1]	36.8 [34.4 – 39.3]	36.7 [34.3 – 39.1]
Economic status of the HRP (%)						
Self-employed	10.0 [9.4 – 10.6]	9.6 [8.6 – 10.7]	8.6 [7.5 – 9.8]	10.7 [9.4 – 12.1]	10.2 [8.7 – 11.9]	11.5 [10.0 – 13.3]
Employed	64.7 [63.8 – 65.6]	71.3 [69.7 – 72.9]	57.1 [55.1 – 59.1]	58.5 [56.4 – 60.5]	66.2 [63.7 – 68.5]	70.7 [68.3 – 72.9]
Unemployed	2.9 [2.5 – 3.2]	1.6 [1.2 – 2.2]	4.6 [3.9 – 5.7]	3.8 [3.1 – 4.8]	1.8 [1.3 – 2.7]	2.4 [1.7 – 3.4]
Retired	10.8 [10.2 – 11.3]	10.2 [9.3 – 11.2]	11.3 [10.1 – 12.6]	14.9 [13.5 – 16.3]	12.3 [10.8 – 13.9]	3.7 [2.9 – 4.8]
Inactive*	11.7 [11.1 – 12.3]	7.3 [6.4 – 8.3]	18.4 [16.9 – 20.1]	12.2 [10.9 – 13.6]	9.6 [8.2 – 11.2]	11.7 [10.1 – 13.4]
Ethnicity of the HRP (%)						
White	89.5 [88.8 – 90.1]	92.3 [91.2 – 93.2]	92.2 [90.1 – 93.3]	82.9 [81.2 – 84.5]	91.6 [89.9 – 93.1]	87.1 [85.1 – 88.8]
Mixed Race	1.2 [1.0 – 1.5]	0.9 [0.6 – 1.4]	0.8 [0.5 – 1.2]	1.8 [1.3 – 2.5]	1.5 [1.0 – 2.3]	1.3 [0.9 – 2.0]
Asian	5.7 [5.2 – 6.2]	4.3 [3.6 – 5.1]	4.3 [3.5 – 5.3]	9.0 [7.9 – 10.3]	4.7 [3.6 – 6.1]	6.6 [5.4 – 8.1]
Black	2.2 [1.9 – 2.6]	1.3 [1.0 – 1.8]	1.6 [1.2 – 2.2]	4.1 [3.3 – 5.2]	1.1 [0.6 – 1.8]	3.3 [2.5 – 4.4]
Other	1.4 [1.2 – 1.7]	1.2 [0.9 – 1.7]	1.0 [0.7 – 2.0]	2.1 [1.6 – 2.8]	1.1 [0.6 – 1.8]	1.7 [1.1 – 2.6]
Rural-dwelling (%)	23.2 [22.4 – 24.0]	25.8 [24.4 – 27.3]	22.5 [20.9 – 24.2]	23.8 [22.1 – 25.5]	23.3 [21.3 – 25.4]	18.0 [16.2 – 20.0]
Sample size	**12,074**	**3, 528**	**2,666**	**2,582**	**1,676**	**1,622**
Percent of sample	**100.0**	**29.2**	**22.1**	**21.4**	**13.9**	**13.4**

* This group includes full-time university students, those occupied with household duties, those who have no need to be employed, and those involved in unpaid or voluntary work (ONS 2016b).

Note: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

Table 6.8: *Characteristics of each cluster [95% confidence intervals], LCFS (2013 – 2015/16), weighted (continued)*

	Sample average	Cluster 1 Most common	Cluster 2 Highly processed	Cluster 3 Fruit & vegetable burden	Cluster 4 Restaurants, cafés, and canteens	Cluster 5 Takeaways
Country (%)						
England	84.3 [83.6 – 85.0]	84.7 [83.4 – 86.0]	82.5 [80.9 – 84.0]	86.2 [84.8 – 87.8]	85.4 [83.6 – 87.1]	82.1 [80.1 – 84.0]
Wales	4.7 [4.3 – 5.1]	4.7 [4.0 – 5.5]	5.1 [4.2 – 6.0]	4.8 [4.0 – 5.7]	4.7 [3.7 – 5.9]	3.9 [3.0 – 5.2]
Scotland	8.4 [7.8 – 8.9]	7.5 [6.6 – 8.5]	10.4 [9.2 – 11.7]	7.2 [6.2 – 8.4]	7.7 [6.4 – 9.1]	9.4 [8.0 – 11.0]
Northern Ireland	2.7 [2.4 – 3.0]	3.0 [2.5 – 3.7]	2.0 [1.6 – 2.7]	1.8 [1.4 – 2.4]	2.2 [1.6 – 3.0]	4.5 [3.6 – 5.6]
Season (%)						
Spring	25.8 [25.0 – 26.7]	25.6 [24.1 – 27.2]	24.3 [22.6 – 26.0]	27.1 [25.3 – 29.0]	27.3 [25.0 – 29.6]	25.2 [23.1 – 27.5]
Summer	23.2 [22.4 – 24.0]	23.1 [21.6 – 24.6]	22.6 [20.9 – 24.4]	23.6 [21.8 – 25.4]	23.8 [21.7 – 26.1]	23.3 [21.2 – 25.5]
Autumn	23.3 [22.5 – 24.1]	22.3 [20.8 – 23.7]	25.7 [24.0 – 27.5]	21.5 [19.8 – 23.3]	23.2 [21.1 – 25.4]	24.6 [22.5 – 26.9]
Winter	27.7 [26.8 – 28.5]	29.1 [27.5 – 30.7]	27.4 [25.7 – 29.2]	27.8 [26.0 – 29.7]	25.8 [23.6 – 28.0]	26.9 [24.6 – 29.2]
Sample size	**12,074**	**3, 528**	**2,666**	**2,582**	**1,676**	**1,622**
Percent of sample	**100.0**	**29.2**	**22.1**	**21.4**	**13.9**	**13.4**

Note: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

6.11.2 Demographic profiles of the clusters

Using the information presented within Tables 6.7 and 6.8, the following subsections build a profile of the households within each of the food expenditure clusters, highlighting their characteristics and how they are distinct from other clusters.

6.11.2.1 Cluster 1: Most common

This cluster is so called as it contains the largest percentage of households in the sample (29.2 per cent) with the proportion of income spent on each food category most closely resembling that of the sample average. The median weekly income is £716.63, and 4.9 per cent of households are fuel poor under the 10 per cent indicator and 8.0 per cent are fuel poor under the AFP indicator. 14.9 per cent of households are income poor.

The majority of households within this cluster consist of two adults (35.1 per cent), but this cluster has the highest percentage of households containing two adults with two children (13.6 per cent) compared to all other clusters. This cluster also has the lowest percentage of households with a female HRP (33.9 per cent), an unemployed HRP (1.6 per cent) and an inactive HRP (7.3 per cent) compared to all other clusters. The majority of HRPs are White (92.3 per cent) and live in England (84.7 per cent). This cluster has the highest percentage of households interviewed in winter (29.1 per cent) compared to all other clusters.

6.11.2.2 Cluster 2: Highly processed

This cluster contains 22.1 per cent of the sample and is characterised by high proportions of the food budget being allocated to *Processed meats* (14.0 per cent) and to *Sugar, cakes, and confectionary* (22.0 per cent), with over a third of the total food budget (36.0 per cent) dedicated to these food groups. This is significantly higher than for all other clusters as shown by the non-overlapping confidence intervals. Households within this cluster also spend the highest proportion of their income on staple food items, with 9.9 per cent of the food budget spent on *Bread, pasta, and rice*. Again, this is significantly higher than for all other clusters.

This suggests that there may be less opportunity for purchasing variety (International Dietary Data Expansion Project 2018), which can contribute to a poor diet quality (Drewnowski et al. 1997). Compared to all other clusters, this cluster contains the highest proportion of households in fuel poverty - 12.5 per cent of households classified as fuel poor under the 10 per cent indicator and 17.4 per cent of households fuel poor under the AFP indicator - and the lowest median weekly income (£497.65), which is statistically significant as indicated by the non-overlapping confidence intervals. This equates to the highest percentage of households in income poverty (33.0 per cent), which is significantly higher than all other clusters as indicated by the non-overlapping confidence intervals. Additionally, this cluster has the highest percentage of single-parent households with two or more children (4.1 per cent), of HRPs who are female (40.9 per cent) unemployed (4.6 per cent), inactive (18.4 per cent) and White (92.2 per cent), and the highest percentage of households living in Wales (5.1 per cent) and Scotland (10.4 per cent) compared to all other clusters, although these are not statistically significant. This cluster has the lowest percentage of households with a degree or equivalent (24.5 per cent) compared to all other clusters and this is statistically significant as indicated by the non-overlapping confidence intervals.

6.11.2.3 Cluster 3: Fruit & vegetable burden

21.4 per cent of households fall into this cluster, which is characterised by almost a fifth (19.6 per cent) of the food budget allocated to *Fresh fruit and vegetables* and 10.7 per cent to *Fresh meats*, which is significantly higher than all other clusters as indicated by the non-overlapping confidence intervals. 11.5 per cent of households are fuel poor under the 10 per cent indicator and 14.0 per cent are fuel poor under the AFP indicator. Households within this cluster have the second to lowest median income per week after households in the *Highly processed* cluster (£543.18) and 27.3 per cent are income poor.

Compared to all other clusters, households within this cluster have the highest percentage of households with a retired HRP (14.9 per cent) and the highest percentage of households living in England (86.0 per cent). This cluster has the lowest percentage of households with a White HRP (82.9 per cent) and this is statistically significant.

6.11.2.4 Cluster 4: Restaurants, cafés, and canteens

This cluster contains 13.9 per cent of the sample. Households within this cluster spend over half (53.0 per cent) of their food budget in restaurants, cafés, and canteens, which is significantly higher than for all other groups. Households within this cluster have the highest median weekly income (£760.73) and the lowest rates of fuel poverty (5.0 per cent under the 10 per cent indicator and 6.3 under the AFP indicator) and of income poverty (12.7 per cent) compared to all other clusters. Furthermore, households within this cluster have the highest percentage of single-adult households (23.3 per cent) and two-adult households (41.6 per cent), which is significantly higher than all other clusters as indicated by the non-overlapping confidence intervals. They also have the highest percentage of households with a degree or equivalent (52.4 per cent), which is statistically significant, the lowest percentage of Black HRPs (1.1 per cent), and the lowest percentage of households interviewed in the winter (25.8 per cent) compared to all other clusters.

6.11.2.5 Cluster 5: Takeaways

13.4 per cent of households fall into this final cluster – the smallest percentage of the sample – and spend around a third (33.7 per cent) of their food budget on takeaways, which is significantly higher than all other clusters as indicated by the non-overlapping confidence intervals. Within this cluster, 8.2 per cent are fuel poor under the 10 per cent indicator and 14.0 per cent are fuel poor under the AFP indicator. These households have the third lowest median weekly income (£617.67), and 26.4 per cent are income poor.

Compared to all other clusters, this cluster contains the highest proportion of households containing two adults with three or more children (5.9 per cent) and households with three or more adults with 1 child (5.3 per cent) and with two or more children (3.7 per cent), although these are not significantly different from other clusters. This cluster also contains the highest percentage of households where the highest qualification is A-level or equivalent (21.5 per cent), and the highest percentage of HRPs who are self-employed (11.5 per cent) and employed (70.7 per cent), although these are not significantly different from other clusters. Furthermore, this cluster has the lowest percentage of rural-dwelling households (18.0 per cent) across all clusters, which is statistically significant as indicated by the non-overlapping confidence intervals, and the highest percentage of households in Northern Ireland (4.5 per cent) – reflecting evidence provided in Table 6.3 that households in Northern Ireland have the highest expenditure on takeaways (ONS 2020b).

6.12 Identifying the relationship between fuel poverty and cluster membership: multinomial regression

Following the creation of the demographic profiles for each cluster in the previous section, it was of interest to explore the relationship between fuel poverty and cluster membership as a way of further understanding how fuel poverty can impact on food purchases. To do this, multinomial regression was used. This type of regression is an extension of binary logistic regression, but instead of a binary dependent variable, the dependent variable is polychotomous and unordered (Hosmer et al. 2013). As the dependent variable was the identified food expenditure patterns, and therefore five unordered levels, multinomial regression was considered the most suitable method to use.

6.12.1 Interpreting multinomial regression: relative risk ratios

The multinomial regression outputs produce Relative Risk Ratios (RRR)[63]. These indicate how the risk of the outcome (i.e. fuel poverty) falling in the comparison group compares to the risk of the outcome falling in the base category changes with the variable in question. An RRR

[63] These are often used interchangeably with ORs (Ranganathan et al. 2015), which were explained in the previous chapter (section 5.4).

over 1 indicates a higher risk of the outcome falling in the comparison group compared to the base category, and an RRR below 1 indicates a lower risk of the outcome falling in the comparison group compared to falling in the base category.

6.12.2 Cluster membership: the results of multinomial regression analysis

The following tables present the results of multinomial regression analyses to determine the effect of fuel poverty on cluster membership, using the largest category – *Most common* – as the base category, i.e. the cluster that all other clusters are compared to. The models were built with the same sets and order of variables as indicated in section 6.9.5 and, again, only the results for fuel poverty are presented, with the full models available in Appendix C (Tables C.9 to C.14 for the whole sample analysis and C.15 to C.20 for the poor sample analysis). As done in section 6.10, in describing the results, the discussion will take a comparative approach between models, drawing attention to similarities and differences in the effect of fuel poverty under two different indicators on food expenditure patterns.

Similar to the approach taken to explore food expenditure and food expenditure patterns, the multinomial regression models were conducted on the whole sample (Table 6.9) and the poor sample (i.e. on all households whose income fell below the poverty line, defined as 60 per cent of the median equivalised household income AHC) (Table 6.10). To reiterate, this was performed to investigate whether fuel poverty has a separate and additional effect on food expenditure patterns specifically among those households who are poor.

Whole sample: Table 6.9 presents the results of multinomial regression analysis, which explores the impact of fuel poverty under the 10 per cent indicator and the AFP indicator on food expenditure patterns in the whole sample.

Table 6.9: *Multinomial regression: The impact of fuel poverty on cluster membership[1](coefficients (robust standard errors)), LCFS (2013 – 2015/16), weighted: the whole sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, & canteens**	**Cluster 5: Takeaways**
10 per cent indicator				
Model 1				
Fuel poverty (ref: No)	2.044 (0.263)***	1.901 (0.255)***	0.859 (0.153)	1.383 (0.209)*
Pseudo R^2 (McFadden adjusted)	**0.017**			
Model 2				
Fuel poverty (ref: No)	1.343 (0.179)*	1.499 (0.214)**	0.880 (0.163)	1.140 (0.171)
Pseudo R^2 (McFadden adjusted)	**0.048**			
Model 3				
Fuel poverty (ref: No)	1.021 (0.147)	1.086 (0.168)	0.907 (0.196)	1.020 (0.171)
Pseudo R^2 (McFadden adjusted)	**0.058**			
AFP indicator				
Model 1				
Fuel poverty (ref: No)	1.950 (0.228)***	1.812 (0.224)***	0.844 (0.130)	1.563 (0.189)***
Pseudo R^2 (McFadden adjusted)	**0.017**			
Model 2				
Fuel poverty (ref: No)	1.388 (0.168)**	1.469 (0.188)**	0.878 (0.140)	1.296 (0.190)*
Pseudo R^2 (McFadden adjusted)	**0.048**			
Model 3				
Fuel poverty (ref: No)	1.071 (0.137)	1.114 (0.148)	1.045 (0.180)	1.171 (0.158)
Pseudo R^2 (McFadden adjusted)	**0.058**			
Sample size	**12,074**			

[1] Model 1 contains fuel poverty and household type as an adjuster variable; model 2 adds the second set of variables: highest qualification in the household, longstanding physical or mental illness in the household, the sex, economic status, and ethnicity of the HRP, country, urban or rural, and season. Model 3 adds the third set of variables: household full income deciles.

*p<0.05 **p<0.01 ***p<0.001

In model 1 where *fuel poverty* is entered with *household type* as an expenditure adjuster, fuel poverty under both the 10 per cent indicator and the AFP indicator is shown to be positively and significantly associated with all clusters apart from *Restaurants, cafés, & canteens,* with the highest RRR observed for *Highly processed* for both fuel poor groups. This finding highlights that the fuel poor have diverse budget allocation patterns and suggests that indicators may capture different experiences of food insecurity.

When adding the second set of variables (*highest qualification in the household, the sex, economic status,* and *ethnicity of the HRP, longstanding physical or mental illness in the household, country, urban or rural,* and *season*), the association between fuel poverty under both indicators and the *Highly processed* and *Fruit & Vegetable burden* clusters remains, although the RRRs are reduced across these clusters, with the greatest reduction observed for the *Highly processed* cluster. The RRRs associated with falling into this cluster are reduced by 34.3 per cent[64] for the fuel poor under the 10 per cent indicator and by 28.8 per cent for the fuel poor under the AFP indicator. This suggests that the addition of this second set of variables has a greater effect on explaining the relationship between fuel poverty and this food expenditure pattern.

Unlike for the fuel poor under the 10 per cent indicator, where the relationship between fuel poverty and the *Takeaways* cluster was explained by the addition of the second set of variables, a weakly significant relationship remains between fuel poverty under the AFP indicator and the *Takeaways* cluster, although with RRRs reduced by 20.6 per cent compared to model 1. This may suggest that the underlying factors that affect the relationship between fuel poverty and *Takeaways* have a different impact under different fuel poverty indicators.

The addition of *household full income deciles* in model 3 shows that fuel poverty under both indicators is now no longer significantly associated with any of the clusters, with income explaining the significant associations between these and fuel poverty. This suggests that fuel poverty is not a direct driver of food expenditure patterns and that other factors may be at play.

[64] The per cent change in RRRs has been calculated as follows: (new RRR - old RRR)/old RRR x100

Poor sample: Table 6.10 overleaf presents the results of multinomial regression analysis, which explores the impact of fuel poverty under the 10 per cent indicator and the AFP indicator on food expenditure patterns in the poor sample. The table shows that fuel poverty does not significantly affect food expenditure patterns amongst the poor.

Table 6.10: *Multinomial regression: The impact of fuel poverty on cluster membership[1](coefficients (robust standard errors)), LCFS (2013 – 2015/16), weighted: the poor sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, & canteens**	**Cluster 5: Takeaways**
10 per cent indicator				
Model 1				
Fuel poverty (ref: No)	1.026 (0.171)	1.138 (0.199)	0.773 (0.192)	0.937 (0.178)
Pseudo R^2 (McFadden adjusted)	**0.025**			
Model 2				
Fuel poverty (ref: No)	0.924 (0.159)	1.063 (0.197)	0.765 (0.198)	0.822 (0.162)
Pseudo R^2 (McFadden adjusted)	**0.085**			
Model 3				
Fuel poverty (ref: No)	0.898 (0.163)	1.028 (0.205)	0.687 (0.193)	0.835 (0.177)
Pseudo R^2 (McFadden adjusted)	**0.093**			
AFP indicator				
Model 1				
Fuel poverty (ref: No)	0.879 (0.134)	1.085 (0.178)	0.854 (0.190)	0.970 (0.157)
Pseudo R^2 (McFadden adjusted)	**0.025**			
Model 2				
Fuel poverty (ref: No)	0.872 (0.132)	1.088 (0.181)	0.864 (0.199)	0.957 (0.158)
Pseudo R^2 (McFadden adjusted)	**0.085**			
Model 3				
Fuel poverty (ref: No)	0.861 (0.129)	1.078 (0.176)	0.845 (0.193)	0.954 (0.157)
Pseudo R^2 (McFadden adjusted)	**0.093**			
Sample size	**2,645**			

[1] Model 1 contains fuel poverty and household type as an adjuster variable; model 2 adds the second set of variables: highest qualification in the household, longstanding physical or mental illness in the household, the sex, economic status, and ethnicity of the HRP, country, urban or rural, and season. Model 3 adds the third set of variables: household full income deciles.

*p<0.05 **p<0.01 ***p<0.001

6.13 Discussion

This chapter has investigated the impact of fuel poverty on food expenditure and food expenditure patterns as a way of further understanding the effect that fuel poverty may have on food insecurity and to further elaborate on the heat or eat dilemma. In particular, the chapter has explored differences in food expenditure, both in absolute and proportionate terms, between fuel poor and non-fuel poor households and has investigated whether variations in these translate to differences in food expenditure patterns. Within this, the analysis was performed on the two different fuel poverty indicators used throughout the thesis – the 10 per cent indicator and the AFP indicator – as a way of investigating whether they captured differences in the experience of food insecurity. Furthermore, the analysis was conducted on the whole sample and the sample restricted to the poor. The purpose of this was to understand whether fuel poverty had a separate and additional effect amongst the poor. The key findings of this chapter are discussed in the following subsections.

6.13.1 Key findings

To synthesise the wealth of information contained within this chapter and to facilitate its discussion, this section is structured in two parts. The first part focuses on the relationship between fuel poverty, food expenditure and food expenditure patterns for the whole sample, and the second focuses on these relationships for the poor sample.

6.13.1.1 The relationship between fuel poverty, food expenditure and food expenditure patterns: the whole sample

When exploring the first objective of the study, which was to determine how fuel poverty impacts on food expenditure both in absolute terms and as a proportion of income, the multiple regression analysis on the whole sample revealed that the fuel poor spent significantly less on food in absolute terms. This aligns with the evidence presented by the literature in section 6.5 that formed the backbone of this study and which suggested that fuel poor households reduce expenditure on food as a way of coping with fuel poverty (Bhattacharya et al. 2003; Anderson et al. 2010; Lambie-Mumford et al. 2015). The analysis presented in model 1 in Table 6.5 found that both fuel poor groups spent less on food in absolute terms than the non-fuel poor. The same analysis was conducted for the proportion of income spent on food and the output showed that fuel poverty under both indicators was significantly associated with a greater proportion of income spent on food (see model 1 in Table 6.6). This suggests that, although spending significantly less in absolute terms than non-fuel poor households, food expenditure places a significantly greater burden on the incomes of the fuel poor, with a greater burden on the incomes of the fuel poor under the 10 per cent indicator, possibly due to this group having the lowest incomes. These findings suggest that food insecurity is present in fuel poor households, but that the experience and extent of food insecurity may differ between both fuel poor groups.

The use of a large-scale, secondary quantitative dataset allowed for this relationship to be explored further by controlling for a range of explanatory variables as a way of understanding factors that may underlie this observed relationship. In selecting appropriate control variables with reference to the literature, the analysis revealed insights into this relationship. Controlling for household characteristics, demographic characteristics of the HRP, dwelling factors, and season as well as income showed that although there was no significant relationship between fuel poverty and absolute food expenditure (see model 3 in Table 6.5), the percentage of income spent on food was significantly greater for the fuel poor under each fuel poverty indicator (see model 3 in Table 6.6). This suggests that food expenditure places a greater burden on the incomes of the fuel poor, further emphasising that elements of food insecurity are likely to exist within fuel poor households. This could be linked to lower incomes in fuel poor households compared to non-fuel poor households (see Tables 5.6 and 5.7 in Chapter 5). However, the reasons behind this finding are unclear and it is not known whether this reflects paying more for food due to the nature of the food environment in which the fuel poor live, for example, food deserts and the poverty premium.

The lack of this type of information in the LCFS meant that this finding could not be explored further.

To fulfil the second objective set for this chapter, the analysis then went on to explore whether differences could be observed between food expenditure patterns of the fuel poor and non-fuel poor. In general, food choices are driven by a variety of factors such as taste, cost, convenience, and health (Glanz et al. 1998). However, for fuel poor households, there may be a more complex set of factors governing food choice, which may be underpinned by additional concerns about the cost of fuel for storing, preparing, and cooking foods (Hernández and Bird 2010). The use of self-disconnection as a way of coping with fuel poverty may hinder the ability to cook (Vyas 2014) and has been linked to the loss of food stored in refrigerators and freezers (O'Sullivan et al. 2011). These factors may influence the types of food purchased.

Following the identification of food expenditure patterns through cluster analysis, multinomial regression analysis was performed to explore whether fuel poverty was associated with different types of food expenditure patterns and whether this could shed light on some of the reasons for the documented existence of health inequalities between the fuel poor and non-fuel poor. The analysis found that, before controlling for other factors, fuel poverty under both indicators was significantly associated with three patterns of food expenditure: *Highly processed*¸ *Fruit & Vegetable burden*, and *Takeaways* (see model 1 Table 6.9). This highlights how diverse the fuel poor are in their food purchases and indicates that the fuel poor may experience food insecurity in different ways within the same fuel poverty indicator. This intra-indicator diversity provides a novel dimension to the notion of heterogeneity, which was identified in the previous chapter, and shows that there are not only compositional differences between the fuel poor under different definitions, but that their experience of disadvantage may also be varied. However, the advantage of being able to explore this further by considering a range of control variables found that these relationships were being driven by income.

6.13.1.2 The relationship between fuel poverty, food expenditure and food expenditure patterns: the poor sample

The analysis on food expenditure and food expenditure patterns was replicated for the poor sample, i.e. all households whose income fell below the poverty line, to determine whether fuel poverty had a separate and additional impact on the poor.

When conditioning on low income by focusing only on the poor, it was found that only the fuel poor under the AFP indicator had significantly higher absolute expenditure on food with no significant relationship found between fuel poverty under the 10 per cent indicator and absolute food expenditure (see model 1 in Table 6.5). However, both fuel poor groups had a greater proportion of income allocated to food compared to their non-fuel poor counterparts, with the fuel poor under the 10 per cent indicator dedicating a greater proportion of their income to food compared to the fuel poor under the AFP indicator (see model 1 in Table 6.6). This suggests that fuel poverty increases food insecurity amongst the poor and this effect is greatest for the fuel poor under the 10 per cent indicator. When controlling for household characteristics, demographic characteristics of the HRP, dwelling factors, season, and income, only the fuel poor under the AFP indicator were found to be associated with significantly higher expenditure on food in absolute terms compared to their non-fuel poor counterparts. However, both fuel poor groups were found to spend a higher proportion of their income on food compared to their non-fuel poor counterparts. This reflects findings for the whole sample, suggesting that the fuel poor experience a greater food expenditure burden and, therefore, greater food insecurity compared to their non-fuel poor counterparts.

In contrast to the whole sample analysis, when conducting multinomial regression analysis on the poor sample to explore the effect of fuel poverty on food expenditure patterns amongst the poor, fuel poverty under each indicator had no additional effect on food expenditure patterns amongst the poor. However, the lack of statistical significance may be linked to a smaller sample size in this analysis, or to greater variation amongst this sample, where expenditure patterns do not reflect those identified based on the whole sample.

6.13.2 Study limitations

Despite these findings and further clarification of the impacts of fuel poverty under two different indicators on food insecurity, there is, of course, a need to acknowledge certain aspects of the study that leave several unknowns. Firstly, although food expenditure patterns have been found to be closely related to food consumption (Fan et al. 2007; Humphries et al. 2017), they are not always equivalent. Given the nature of the study and the reliance on secondary data, it is not clear whether food was consumed from non-purchased means, such as from food banks or through home-grown foods, such as fruit and vegetables grown in the garden or in an allotment. It is also unknown whether food stores purchased outside of the survey period were being consumed and this may influence diet beyond what has been captured in the expenditure patterns.

Food expenditure patterns do not consider whether the quantities of foods purchased are sufficient to avoid hunger or whether some foods go unconsumed. It was also not possible to determine how food is distributed amongst household members, whether food expenditure patterns differ between household members, or whether meals were skipped in response to fuel poverty (Grey et al. 2015b) or rising fuel costs (McHardy 2013). As such, it is not clear whether members of the same fuel poor household experience food insecurity differently.

6.14 Chapter summary and conclusions

This chapter has explored the impact of fuel poverty on food insecurity through its effects on food expenditure, both in absolute and proportionate terms, and food expenditure patterns. Although these aspects do not present a complete picture of food intake and the different ways that food insecurity may be experienced, they extend the literature on how fuel poverty can impact on food expenditure and food purchases and provide an insight into whether food insecurity is present in fuel poor households.

The analysis presented in this chapter shows that fuel poverty under both indicators is associated with a greater proportion of income being spent on food, suggesting that fuel poverty increases food insecurity. The analysis has also helped to build on how the heterogeneous nature of fuel poverty is understood by highlighting inter- and intra-indicator heterogeneity, i.e. how the burden of food expenditure may be different for the fuel poor under different definitions and how the fuel poor have diverse food expenditure patterns. This may suggest that the experience of food insecurity may vary between and within fuel poverty indicators. However, the loss of statistical significance in the models once other variables are added suggests that fuel poverty may not be a direct driver of food poverty and that further studies with different methods may be needed to understand the causal pathways between fuel poverty and food poverty.

In the following chapter, the second research question, which explores the impact of fuel poverty on social isolation, is addressed.

Chapter 7| What are the links between fuel poverty and social isolation?

7.1 Introduction

Social relationships are a fundamental component of human life (Ge et al. 2017) and research has indicated that their absence can have severe impacts on physical and mental health (House et al. 1988; Cacioppo and Hawkley 2003). This absence has predominantly been explored through the concept of social isolation and its associated dimensions.

Within the literature presented in Chapter 3, several studies highlighted the various ways that fuel poverty may contribute to the manifestation of social isolation. It may hinder the ability to form and maintain social relationships through, for example, participating in fewer social activities as a way of diverting limited financial resources to other essentials (Harrington et al. 2005; Anderson et al. 2010; Cotter et al. 2012; Grey et al. 2017b), and feeling reluctant to invite friends and family into a cold and damp home (Department of Trade and Industry 2001; Harrington et al. 2005; Anderson et al. 2010; Grey et al. 2017b). However, these findings have emerged mainly through probing participants on their experiences of living in fuel poverty, where fuel poverty has not been consistently defined, and where social isolation has not been a primary focus of the research (see Harrington et al. 2005; Anderson et al. 2010, for example). Furthermore, only a small number of aspects linked to social isolation have been identified in these studies and, as such, these studies provide only a limited view of how the fuel poor may experience social isolation.

7.2 Chapter aim and objectives

This chapter aims to further investigate the relationship between fuel poverty and social isolation as a way of illuminating this under-explored area. The importance of exploring social isolation amongst the fuel poor is linked to how it can shape the experience of fuel poverty. Social isolation may increase the time spent at home and this may deepen fuel poverty through increasing energy needs. It may also exacerbate the mental and physical health consequences associated with fuel poverty, which were detailed in section 2.8 of Chapter 2, by increasing exposure to a poor internal environment or increasing worry and anxiety about the cost of fuel bills, for example. Furthermore, given that advice and knowledge about switching energy suppliers and energy efficiency upgrades is sought from members of social networks (Wright 2004; Day and Hitchings 2009; Coyne et al. 2018; Middlemiss et al. 2019), social isolation may prolong the experience of fuel poverty by hindering help-seeking behaviours and creating a barrier to accessing advice (Ormandy and Ezratty 2015), thus also increasing the invisibility of fuel poverty. This creates a further obstacle to identifying the fuel poor and to tackling the issue.

The study aims to extend the literature by adding distinct elements to the understanding of the relationship between fuel poverty and social isolation by considering the following two objectives:

1. To explore overall levels of social isolation amongst the fuel poor and the underlying factors that contribute to this;
2. To identify whether there is an association between fuel poverty and social isolation after taking account of the characteristics of the individual and their household.

Through these two objectives, this study aims to identify whether the fuel poor under the 10 per cent indicator and the AFP indicator – the two fuel poverty indicators used throughout the research – experience social isolation when it is conceptualised more completely and explores whether social isolation varies under different fuel poverty indicators.

7.3 Chapter outline

To begin with, this chapter presents an overview of how social isolation has been conceptualised in previous studies as a way of understanding the inherent intricacies in the application of this concept. The links between fuel poverty and social isolation are then traced using evidence offered by the literature, focusing on how fuel poverty may cause or exacerbate aspects of social isolation through a series of pathways, which draw on the tension between a low income and high fuel bills, the impact that fuel poverty can have on the home, and the physical and mental health consequences of living in fuel poverty. Following this, the methods used to construct a scale to identify social isolation in this study are detailed, describing how its components were selected and how it was used to score social isolation. The results of the analyses are then presented and discussed, and, finally, the chapter concludes with a summary of the study.

7.4 Conceptualisations and measurements of social isolation

Social isolation is characterised by a lack of contact with others (Cornwell and Waite 2009) and has been defined in several ways, often focusing on the quantity and quality of relationships (Delisle 1988) together with feelings of loneliness (Hawthorne 2006). However, despite extensive research in this area, there is no established definition or conceptual clarity that allows for a consistent measurement of this concept (Zavaleta et al. 2014; Wang et al. 2017).

Previous studies have explored social isolation in several ways, such as through the lack of contact with individuals and institutions (Wilson 1987), the quantity and quality of relationships (Delisle 1988), and loneliness (Weiss 1973), which has been described as a deficiency in social networks where they fail to achieve the desired degree of intimacy, leading to feeling unfulfilled by social ties (de Jong-Gierveld and Kamphuls 1985; Holt-Lunstad et al. 2010). This acknowledges the importance of objective and subjective social isolation (i.e. loneliness) (House et al. 1988), differentiating between the number, types, and sizes of social networks an individual has and the value placed on them. Within this, various indicators have been used to explore social isolation and these are often driven by the discipline within which the research is conducted and the interests of the researcher (Cornwell and Waite 2009). Commonly used indicators include living alone (Dean et al. 1992), the frequency of participation in social activities (Thoits and Hewitt 2001), neighbourhood cohesion (Kearns et al. 2015), perceived social support (Blazer 1982; Krause 1987; Cornwell and Waite 2009), and loneliness (Cornwell and Waite 2009). This makes it difficult to compare the effects of different indicators and dimensions of social relationships across studies (Valtorta et al. 2016a; Eckhard 2018).

Recently, Zavaleta and colleagues (2014) proposed a new and broader definition of social isolation in which they state that it is "the inadequate quality and quantity of *social relations* with other people at the different levels where human interaction takes place (individual, group, community, and the larger social environment)" (Zavaleta et al. 2014, p.5). This definition provides a much more complete understanding of social isolation, incorporating both its objective and subjective dimensions as well as the different levels in which these can be experienced.

7.5 The health impacts of social isolation

The importance of social relationships is evidenced through the adverse effects that social isolation can have on physical and mental health. Social isolation has been linked to high blood pressure (Hawkley et al. 2010), an increased risk of coronary heart disease and stroke (Thurston and Kubzansky 2009; Valtorta et al. 2016b), cognitive decline and Alzheimer's Disease (Wilson et al. 2007), and depressive symptoms across the lifespan (Cacioppo et al. 2006; Qualter et al. 2010; Matthews et al. 2016). Social isolation has also been found to negatively impact health behaviours (Kobayashi and Steptoe 2018) and to increase the risk of mortality (Berkman and Syme 1979; House et al. 1988; Holt-Lunstad et al. 2010) and the use of health care utilisation (Gerst-Emerson and Jayawardhana 2015). Furthermore, loneliness has been associated with a higher number of in-surgery GP consultations and greater use of hospital emergency departments (Ellaway et al. 1999; Geller et al. 1999). However, it appears that these negative health outcomes are linked not so much to the quantity or type of networks that a person is connected to, but rather to how these networks are perceived and the presence of loneliness, which triggers a series of mechanisms linked to morbidity and mortality (Cacioppo et al. 2011; Ge et al. 2017). This stresses that dimensions of social isolation are not always correlated with each other and that one can have few social connections but not feel lonely while others can feel lonely despite having many (Coyle and Dugan 2012; Perissinotto et al. 2012; Zavaleta et al. 2014).

7.6 The pathways linking fuel poverty and social isolation: a review of the literature

Although empirical research to determine the relationship between fuel poverty and social isolation is sparse, several studies have inadvertently highlighted a multitude of barriers to social connectedness faced by the fuel poor, spanning economic, emotional, and health domains. These barriers may impact on the formation of social networks and the maintenance of meaningful social ties and appear to emerge from three consequences of fuel poverty, which can be illustrated through the following three pathways: (1) constrained finances and high fuel bills; (2) the effects that fuel poverty can have on the home; and (3) the health impacts of living in fuel poverty. These pathways are discussed in turn with reference to the literature within the following three subsections.

7.6.1 Pathway 1: Social isolation as a result of constrained finances and high fuel bills

Fuel poverty is often characterised by disproportionately high fuel costs for the poorest households (Boardman 2010), presenting an economic barrier to social connectedness. Those living in fuel poverty may withdraw from social activities in order to concentrate their available finances on maintaining indoor warmth (Harrington et al. 2005; Day and Hitchings 2009; Cotter et al. 2012). In work by Anderson et al. (2010) it was found that those living in cold homes and on low incomes prioritise bills over less inflexible expenditures, such as socialising and food. Furthermore, fuel poor households have been found to reduce their spending on clothing and transport (McAvoy 2007), which could further limit routes to social connectedness. The impact of a constrained income may become more pronounced in colder weather when domestic fuel requirements increase and where fuel bills may be higher.

7.6.2 Pathway 2: Social isolation as a result of the effects of fuel poverty on the home

This pathway draws on how fuel poverty can affect feelings towards the home. The home and the household can be affected in different ways depending on how fuel poverty is experienced. In part, this may be influenced by the coping behaviours adopted by fuel poor households, as evidenced in Chapter 3. Where fuel poverty manifests as a cold home as a result of being unable to heat the home adequately, damp and mould can develop (Healy and Clinch 2004; Marmot Review Team 2011). This can affect the appearance of the home and may be a source of embarrassment and shame (Ormandy and Ezratty 2015; Longhurst and Hargreaves 2019), which may leave householders feeling reluctant to invite friends and family into the home (Harrington et al. 2005; Anderson et al. 2010; Grey et al. 2017b). In work conducted by Packer et al. (1994), it was found that over a fifth (22.7 per cent) of those living in damp housing felt socially isolated compared to 12.6 per cent living in dry homes. However, it is not clear how social isolation was being measured and whether the aspects considered were open to subjective interpretation.

The literature presented in Chapter 3 indicated that some of the coping strategies adopted by fuel poor households can impact on the meaningful dimension of the home, a place that is supposed to provide refuge in a social and psychological sense (Shaw 2004), and may contribute to feelings of disconnection from the home. This is evidenced with increased time spent away from home through external warmth-seeking behaviours as indicated in Chapter 3 (see section 3.3.1.1), where those living in homes they cannot afford to keep warm spending more time away from the home (Anderson et al. 2010; Grey et al. 2017b) and more time in public spaces (Radcliffe 2010; Cotter et al. 2012; National Energy Action 2018c) or at work (Petrova 2018a). However, this may also provide opportunities for social interactions away from the home. Furthermore, fuel poor households may also reduce their living space through spatial shrinkage, which was outlined in Chapter 3 (see section 3.3.1.1), and this has been linked to overcrowding and a deterioration of familial relationships due to a lack of privacy (McAvoy 2007).

7.6.3 Pathway 3: Social isolation as a consequence of the health impacts of living in fuel poverty

The wide-ranging experiences and effects of fuel poverty can lead to a multitude of physical and mental ailments (Hills 2012) and can occur as a result of cold living conditions, thermal discomfort, the stress and worry of high fuel bills, and having to go without essentials (Harrington et al. 2005; Anderson et al. 2010). These have been discussed in more detail in Chapter 2, section 2.8. These health consequences can contribute to – or exacerbate – social isolation by reducing the desire to invite people into the home and by limiting exposure and accessibility to social networks (Hills 2012).

Children may also experience social isolation by having to take time off school to recover from illness caused by living in fuel poverty (Howden-Chapman et al. 2008) and, as well as impacting on educational attainment (Department of Health 2007; Barnes et al. 2008), it may also have a negative impact on creating social ties with peers (Harker 2006).

7.7 Tackling fuel poverty and its effects on social isolation

In addition to the literature that has been used to pave the links between fuel poverty and social isolation, there is also evidence to suggest that improving the energy efficiency of the home as a way of tackling fuel poverty can have a positive impact on social relationships within and outside the home. This has been shown to occur in three ways: by reducing energy bills and increasing disposable income (Grey et al. 2015b); through improving the indoor environment (Gilbertson et al. 2006); and by ameliorating health conditions caused by living in fuel poverty (Gilbertson et al. 2006; Shortt and Rugkåsa 2007), therefore showing the ability to disrupt the pathways between fuel poverty and social isolation identified in section 7.6.

Increases in disposable income have been documented following energy efficiency improvements (Gilbertson et al. 2006; Howden-Chapman et al. 2007; Grey et al. 2017b) and these have translated into improved health outcomes (Grey et al. 2017b) and greater availability of financial resources for social activities within and outside the home (Gilbertson et al. 2006; Grey et al. 2017b). The installation or improvement of heating systems and the installation of solid or cavity wall insulation has been found to alter heating regimes (Shortt and Rugkåsa 2007; Northern Ireland Housing Executive 2014). This has resulted in greater use of the living space where the householder no longer felt the need to limit heating to just a few rooms in the home, contributing to the home being heated more evenly (Basham et al. 2004; Gilbertson et al. 2006; Shortt and Rugkåsa 2007; Northern Ireland Housing Executive 2014) and therefore reducing the risk of cold stress caused by moving from a warm to a cold room, which can have severe implications for health (Goodwin 2005). The resulting increased use of living space has been found to improve social interactions within the home (Basham et al. 2004; Gilbertson et al. 2006; Shortt and Rugkåsa 2007). Furthermore, improvements in the energy efficiency of the home have resulted in reductions in condensation, mould, and damp and have made householders feel more comfortable about inviting friends and family into the home (Basham et al. 2004; Banks and White 2012; Northern Ireland Housing Executive 2014), thus reducing feelings of social isolation (Grey et al. 2017b). Additionally, householders who received energy efficiency improvements felt that they could go out more often as they knew they could return to a warm home (Shortt and Rugkåsa 2007).

Improvements in thermal comfort have not only been shown to ease physical illness and improve mobility (Gilbertson et al. 2006; Shortt and Rugkåsa 2007), but have also been shown to have beneficial impacts on mental health, such as reducing stress and anxiety (Grey et al. 2017b), which may have previously created barriers to socialising.

7.8 Study hypothesis

Given the links made between fuel poverty and social isolation, it is hypothesised that fuel poverty increases social isolation.

7.9 Data source and methods

This study uses individual-level data from wave 6 of the UKHLS. A brief description of this data source was provided in Chapter 4 (see section 4.5.2), together with the data cleaning procedures used for income and fuel expenditure data (see section 4.7) and the methods used to construct both fuel poverty indicators used throughout the thesis (see section 4.8). Unlike previous chapters where the household has been the unit of analysis, this chapter focuses on the individual, using individual-level response data contained within wave 6 (2014 – 16) of the UKHLS to account for the different experiences of social isolation amongst individuals within the same household. Within this wave, there are two modules – *Social Networks* and *Local Neighbourhood* – that collect information on different aspects of social connectedness at the household survey and this allows for a broad exploration of the concept of social isolation.

7.9.1 Steps in developing a social isolation scale

To fulfil the aim of the chapter through its objectives stated in section 7.2, a scale was developed to understand the relationship between fuel poverty and social isolation and its underlying factors in individuals within fuel poor and non-fuel poor households. Developing a scale was an integral part of identifying social isolation as it is a construct that cannot be identified through a single variable (DeVellis 2003), but one which comprises a myriad of aspects.

In the following subsections, the steps taken for scale development are outlined, beginning with the process of selecting potential variables to be included in the scale and their rationale for inclusion. This is followed by the procedures used to clean the variables, the decisions around which variables to include in the scale, and how the scale was optimised and implemented.

7.9.1.1 Item selection

As emphasised in the literature presented in section 7.6, there is a multitude of conceptualisations and definitions of social isolation that incorporate a wide range of indicators. Although this presents obstacles when attempting to compare the effects of different components and dimensions of social isolation, it does allow the freedom to select indicators appropriate for the research goals. With this in mind, the literature was drawn upon to select suitable variables present within wave 6 of the UKHLS to explore social isolation.

A total of 13 variables that potentially could be used to explore social isolation were identified in the dataset based on their content validity – as determined through previous research – together with aspects of social isolation that may be present in fuel poor households as identified through the pathways detailed in section 7.6. As far as was possible, given the constraints of using secondary data, the different dimensions (objective and subjective) and different levels within which social isolation can be experienced, as indicated by Zavaleta et al. (2014, p.5) (from more intimate networks, such as family and friends, to wider networks, such as volunteering, for example), were used as a guideline to create a robust scale[65]. These identified variables are presented in Table 7.1 overleaf alongside their rationale for inclusion.

[65] Initial attempts of scale construction were focused on developing two different scales: one to identify objective social isolation and the other to identify subjective social isolation (i.e. loneliness). However, when attempting to create two scales it was found that it was not possible to obtain an acceptable alpha coefficient (described in section 7.9.1.3) for the objective social isolation scale without removing several items, which would have reduced the range of aspects that could be considered to reflect social isolation. As such, the decision was taken to compose one scale that incorporated many different aspects of social isolation whilst still producing an acceptable alpha value.

Table 7.1: *Potential variables to be used for creating the social isolation scale and the rationale for their inclusion, UKHLS: wave 6*

Potential social isolation items	Rationale for inclusion
Number of close friends	This variable relates to the *individual* sphere of where social interactions can take place put forward in the definition of social isolation offered by Zavaleta and colleagues (2014, p.5). This variable provides a sense of the size of the friendship network. Having close friends has been shown to reduce social isolation and feelings of loneliness (Hayanga et al. 2020) and has been used previously in the World Bank's survey on measuring social capital (Grootaert et al. 2004).
Do you go out socially or visit friends when you feel like it?	This variable has been used in previous studies to explore social isolation (Hayanga et al. 2020) and provides an indication of accessibility to friendship networks.
Frequency of contact with friends	The frequency of contact made with friends has strong links with well-being and is a proxy for meaningful relationships, with more frequent contact implying stronger ties with network members (Granovetter 1973) and low frequency of contact with friends linked with higher levels of loneliness (Nicolaisen and Thorsen 2017). This variable has also been used in the 2012 Poverty and Social Exclusion Survey (Dermott and Pantazis 2015).
Whether you are a member of not, do you join in the activities of organisations* on a regular basis?	This variable reveals connections to the *group, community, and larger social environment* – three of the levels in which social isolation can be experienced as suggested by Zavaleta and colleagues (2014, p.5). It has been used in previous work to identify social isolation (Steptoe et al. 2013; Schrempft et al. 2019).

*Organisations include: Political party; trade union; environmental group; parents/school association; tenants/residents group or neighbourhood watch; religious group or church organisation; voluntary services group; pensioners group/organisation; scouts/guides organisation; professional organisation; other community or civic group; social club/working men's club; sports club; women's institute/townswomen's guild; women's group/feminist organisation; other group or organisation; none of these.

Table 7.1: *Potential variables to be used for creating the Social Isolation Scale and the rationale for their inclusion, UKHLS: wave 6 (continued)*

<table>
<tr><th>Potential social isolation items</th><th>Rationale for inclusion</th></tr>
<tr><td>Frequency of volunteering in the last 12 months</td><td rowspan="2">These variables have been selected as volunteering provides information on participation in the community and the strength of community ties (Boeck et al. 2009). Volunteering has been shown to help tackle loneliness and social isolation (Warburton 2006; Carr et al. 2018), with loneliness shown to decrease with more time spent volunteering (Carr et al. 2018).</td></tr>
<tr><td>Hours spent volunteering in the last 4 weeks</td></tr>
<tr><td>I feel like I belong to this neighbourhood</td><td rowspan="5">These variables related to the neighbourhood provide information about neighbourhood attachment, which has been found to provide important insights into levels of subjective social isolation. Feelings of belonging to a neighbourhood influence feelings towards the community, and, in turn, this influences feelings of loneliness (Prezza et al. 2001). Those who feel like they belong to their neighbourhood are more likely to receive social support from their neighbours and to reciprocate this support (Stewart et al. 2009), leading to decreased feelings of loneliness (Hombrados-Mendieta et al. 2013). A lack of trust in others in the neighbourhood has been associated with loneliness (Kearns et al. 2015; Matthews et al. 2019), but talking regularly to neighbours has been linked to lower levels of loneliness (Kearns et al. 2015).</td></tr>
<tr><td>People in this neighbourhood can be trusted</td></tr>
<tr><td>The friendships and associations I have with other people in my neighbourhood mean a lot to me</td></tr>
<tr><td>Talk regularly to neighbours</td></tr>
<tr><td>Likes present neighbourhood</td></tr>
<tr><td>Worry about being affected by crime</td><td>This variable also reflects how people feel about their neighbourhood, with those feeling worried about being affected by crime limiting socialising away from the home (Scharf et al. 2002).</td></tr>
<tr><td>Feel safe walking alone at night</td><td>This variable has been used in previous studies exploring loneliness with those feeling unsafe walking alone at night being more likely to report increased levels of loneliness (Kearns et al. 2015).</td></tr>
</table>

The variables presented in Table 7.1 provide a broad and multi-levelled understanding of social isolation and attempt to provide an insight into the diversity of social networks, the frequency of contact with and time allocated to social participation, and neighbourhood cohesion to explore the presence of loneliness.

There were two variables available in the dataset that were not considered for the scale. Firstly, although the UKHLS collects information on loneliness, this was only asked as part of the *Retirement Planning* module, where respondents from the age of 45 who are not retired are asked how worried they are about experiencing loneliness and isolation in retirement, and so was not considered appropriate for this research. Secondly, virtual friendships and connections (i.e. those formed via the internet) were not included as they often lack real-life interaction, which is considered necessary for genuine friendships (Fröding and Peterson 2012).

7.9.1.2 Data cleaning procedures

Before determining whether all variables could be included in the scale, data cleaning procedures were conducted, which involved three steps. Firstly, the missing categories of the potential variables were inspected. For questions where negative values had been assigned to missing answers, where the respondent said they "don't know", or if it was a proxy response, were coded as missing. This ensured that these answers were not included in the construction of the scale. Where a question was "not applicable", often due to question routing, a new category within the variable was created to reflect why the question was not applicable so as not to substantially reduce the sample size. This was particularly relevant for *Frequency of volunteering in the last 12 months* and *Hours spent volunteering in the last 4 weeks*, where almost 66 per cent[66] of the sample were "not applicable", capturing those who do not volunteer. For this 66 per cent of the sample, a new variable category was created: "Does not volunteer". For the variables focused on neighbourhood aspects, around 3 per cent[67] of the

[66] This was equivalent to 26,918 respondents.
[67] This was equivalent to approximately 1,000 respondents for each related variable.

sample responses were placed in the “not applicable” category for each related variable. As it was not clear what exactly was meant by this response category and as it was a very small percentage of the sample, the decision was taken to exclude these individuals from the analysis.

Secondly, the potential variables were re-coded and reverse-scored where necessary so that the direction of variable coding had the same meaning, i.e. higher scores indicated a higher degree of social isolation. The potential variables and how they were coded are presented in Table 7.2.

Table 7.2: *The potential variables selected for the Social Isolation scale and their codings, UKHLS: wave 6*

Selected indicator	Variable coding
Number of close friends	1= "More than 10"; 2= "5-10"; 3= "3-4"; 4= "1-2"; 5= "0"
Do you go out socially or visit friends when you feel like it?	0= "Yes"; 1= "No"
Frequency of contact with friends	1= "Most days"; 2= "At least once a week"; 3= "At least once a month"; 4= "Less than once a month"; 5= "No friends"
Whether you are a member of not, do you join in the activities of organisations* on a regular basis?	0= "Yes"; 1= "No"
Frequency of volunteering in the last 12 months	1= "At least once a week" 2= "Less than once a week but at least once a month"; 3= "Less than once a month"; 4= "Does not volunteer"
Hours spent volunteering in the last 4 weeks	1= "Over 20 hours" 2= "11 – 20 hours"; 3= "1 – 10 hours"; 4= "Zero hours"; 5= "Does not volunteer"
I feel like I belong to this neighbourhood	1= "Strongly agree"; 2= "Agree; 3= "Neither agree nor disagree"; 4= "Disagree"; to 5 = "Strongly disagree"
People in this neighbourhood can be trusted	
Local friends mean a lot	
Talk regularly to neighbours	
Likes present neighbourhood	0= "Yes"; 1= "No"
Worry about being affected by crime	0= "No"; 1= "Yes"
Feel safe walking alone at night	1= "Very safe" 2= "Fairly safe"; 3= "A bit unsafe"; 4= "Very unsafe"; 5= "Never goes out after dark"

*Organisations include: Political party; trade union; environmental group; parents/school association; tenants/residents group or neighbourhood watch; religious group or church organisation; voluntary services group; pensioners group/organisation; scouts/guides organisation; professional organisation; other community or civic group; social club/working men's club; sports club; women's institute/townswomen's guild; women's group/feminist organisation; other group or organisation; none of these.

Thirdly, following recoding, all variables – including binary-coded variables – were standardised. Standardisation rescales a variable so that it has a mean of 0 and a standard deviation of 1, and this ensured that all the variables contributed equal weight to the scale. Following this, the fuel poverty status data computed in the household-level datasets used in previous chapters were then merged with the individual response data so that each individual had a household fuel poverty status.

7.9.1.3 Deciding on scale items: the use of Cronbach's Alpha

Once the data cleaning procedures were complete, it was important to determine whether the identified variables presented in Table 7.2 could be used to construct a scale to measure social isolation. To do this, Cronbach's alpha was used. This provides a measure of internal consistency, or how closely a set of items are related as a group (Tavakol and Dennick 2011). It produces an alpha coefficient that lies between 0 and 1, with a higher alpha coefficient indicating that the items have shared covariance and that they possibly measure the same underlying concept (Tavakol and Dennick 2011). According to George and Mallery (2003), an acceptable alpha coefficient lies between 0.70 and 0.90, a range that is widely regarded as indicating acceptable internal consistency (Taber 2018). However, for exploratory research such as this, an alpha coefficient between 0.60 and 0.70 are considered satisfactory (Nunnally and Bernstein 1994).

The first step of scale construction involved assessing the 13 standardised items for their alpha value. A summary version of the output is presented in Table 7.3. Within this table, two aspects of the output are presented: the item-rest correlations and the alpha value. These are two important measures used for deciding whether items should be retained or discarded. The item-rest correlations show how well an item is correlated with a scale computed from the remaining items and it is important that individual items are correlated with the scale as a whole (Williams 2015). The "alpha if deleted" column, on the other hand, presents the change in the alpha value for the scale if that item were removed. Item-rest correlations of between

0.20 and 0.40 have been stated as minimally required values of item-rest correlations (Piedmont 2014; Zijlmans et al. 2018) and, for the purpose of this research, a minimum correlation of 0.20 has been used to ensure that the scale retained as many of the items as possible whilst still achieving an acceptable alpha value.

Table 7.3: *Item-rest correlations and Cronbach's alpha values for a scale with all 13 standardised items, UKHLS: wave 6*

Items	Item-rest correlation	Alpha if deleted
Number of close friends	0.272	0.643
Do you go out socially or visit friends when you feel like it?	0.190	0.656
Frequency of contact with friends	0.088	0.671
Whether you are a member of not, do you join in the activities of organisations* on a regular basis?	0.232	0.650
Frequency of volunteering in the last 12 months	0.316	0.636
Hours spent volunteering in the last 4 weeks	0.317	0.636
Belong to neighbourhood	0.491	0.607
Local friends mean a lot	0.445	0.615
Talk regularly to neighbours	0.416	0.620
People in this neighbourhood can be trusted	0.416	0.620
Like neighbourhood	0.270	0.644
Worry about being affected by crime	0.119	0.667
Feel safe walking alone at night	0.205	0.654
Test scale alpha value	**0.659**	
Sample size	**25,989**	

*Organisations include: Political party; trade union; environmental group; parents/school association; tenants/residents group or neighbourhood watch; religious group or church organisation; voluntary services group; pensioners group/organisation; scouts/guides organisation; professional organisation; other community or civic group; social club/working men's club; sports club; women's institute/townswomen's guild; women's group/feminist organisation; other group or organisation; none of these.

7.9.1.4 Optimising the scale

Including all 13 standardised items in the scale produced an alpha value of 0.66, which is within the satisfactory range of the alpha values stated above in section 7.9.1.3. However, examining the output further, particularly the item-rest correlations and the "alpha if deleted" column, it was noted that the scale could be refined by removing items with a low item-rest correlation that would increase the alpha coefficient.

As presented in Table 7.3, two items – *Frequency of contact with friends* and *Worry about being affected by crime* – had inter-item correlations considerably below the 0.20 threshold. It was also observed that removing both of these items would result in an increase in the alpha value. As such, the decision was taken to remove both of these items, which resulted in an increased alpha coefficient, from 0.66 to 0.68. Although *Frequency of contact with friends* may be important in the context of fuel poverty, *Number of close friends* and *Do you go out socially or visit friends when you feel like it?* were viewed as providing sufficient insight into friendship networks. The result of removing both of these items and how it affects the remainder of items is shown in the output presented in Table 7.4 overleaf.

Table 7.4: *Cronbach's alpha with 11 standardised items, UKHLS: wave 6*

Items	Item-rest correlation	Alpha if deleted
Number of close friends	0.230	0.676
Do you go out socially or visit friends when you feel like it?	0.175	0.672
Whether you are a member of not, do you join in the activities of organisations* on a regular basis?	0.341	0.657
Frequency of volunteering in the last 12 months	0.341	0.658
Hours spent volunteering in the last 4 weeks	0.344	0.657
Belong to neighbourhood	0.505	0.629
Local friends mean a lot	0.458	0.637
Talk regularly to neighbours	0.439	0.640
People in this neighbourhood can be trusted	0.423	0.643
Like neighbourhood	0.273	0.669
Feel safe walking alone at night	0.182	0.684
Test scale alpha value	**0.681**	
Sample size	**25,989**	

*Organisations include: Political party; trade union; environmental group; parents/school association; tenants/residents group or neighbourhood watch; religious group or church organisation; voluntary services group; pensioners group/organisation; scouts/guides organisation; professional organisation; other community or civic group; social club/working men's club; sports club; women's institute/townswomen's guild; women's group/feminist organisation; other group or organisation; none of these.

Table 7.4 shows that the remaining items all have item-rest correlations ranging from 0.18 to 0.51. Although *Do you go out socially or visit friends when you feel like it?* and *Feel safe walking alone at night* both had item-rest correlations below 0.20, they were deemed to be close enough to the minimum threshold and were retained in order to include as many diverse aspects of social isolation as possible whilst maintaining an acceptable alpha value. Furthermore, their removal would have had a minimal impact on the alpha value, with *Do you go out socially or visit friends when you feel like it?* decreasing the alpha value. The final social isolation scale consisted of 11 items, achieving a Cronbach's alpha value of 0.68, which is considered close enough to the widely accepted value of 0.70, and which falls within the satisfactory range of 0.60 and 0.70 (Nunnally and Bernstein 1994).

7.9.1.5 Scale reliability across age and ethnic groups

As well as achieving an acceptable alpha coefficient overall, it was also important that the alpha coefficient was acceptable across age and ethnic groups. This is to ensure that the scale was representative of social isolation across different characteristics. Table 7.5 below presents the scale reliability across age and ethnic groups.

Table 7.5: The reliability of the scale across age and ethnic groups

Characteristic	Cronbach's Alpha
Age (banded years)	
16-34	0.66
35-54	0.69
55-74	0.69
75 and over	0.70
Ethnic grouping	
White	0.68
Mixed race	0.72
Asian	0.62
Black	0.67
Other	0.65
Sample size	**25,989**

Table 7.5 shows that Cronbach's alpha is within the satisfactory range of 0.60 and 0.70 across all the groups. This suggests that the scale is a reliable measure of social isolation across age and ethnic groups.

7.9.1.6 Implementing the scale: scoring social isolation

Once the decision on whether to retain or discard scale items was made, all individuals were then assigned a score for social isolation. This was calculated by computing the mean of the combined items for individuals with no missing values on any of the items shown in Table 7.4.

The final scale was then composed of the mean values assigned to all individuals for each item, with those with negative values having lower than average levels of social isolation and those with positive values having greater than average levels of social isolation. Those with a score of zero indicated that the mean response for each of the included items was provided.

7.10 Analysis

The analysis presented in this chapter is based on wave 6 only of the UKHLS and includes 25,989 individuals aged 16 and over belonging to 13,929 households. Table 7.6 shows the response percentages for each item used to create the social isolation scale. These are presented for the fuel poor under each fuel poverty indicator and the income poor, as well as for non-fuel poor and non-income poor individuals.

Table 7.6: *Response percentages (%) to each item in the social isolation scale by group, UKHLS: wave 6, weighted*

	10 per cent indicator		AFP indicator		Income poverty		Whole sample
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
Number of close friends							
More than 10	6.3	**4.9**	6.3	**4.8**	6.5***	**4.9*** **	6.2
5 to 10	39.2***	**34.1*** **	39.6***	**31.7*** **	40.4***	**31.2*** **	39.0
3 to 4	31.8	**31.8**	31.7	**33.7**	31.8	**31.9**	31.8
1 to 2	20.1***	**24.8*** **	19.9***	**26.0*** **	18.9***	**27.9*** **	20.4
None	2.6***	**4.4*** **	2.6**	**3.9** **	2.4***	**4.2*** **	2.7
Do you go out socially or visit friends when you feel like it?							
Yes	87.9***	**82.7*****	88.3***	**81.3*****	89.2***	**80.1*****	87.7
No	12.1***	**17.3*** **	11.7***	**18.7*****	10.8***	**19.9*****	12.3
Whether you are a member or not, do you join in the activities of organisations† on a regular basis?							
Yes	55.1***	**42.8*****	56.1***	**36.3*****	58.0***	**36.1*****	54.5
No	45.0***	**57.2*****	43.9***	**63.7*****	42.0***	**63.9*****	45.5
Frequency of volunteering in the last 12 months							
At least once a week	9.9	**11.0**	10.2*	**7.9***	10.0	**9.4**	10.0
Less than once a week but at least once a month	4.8	**4.4**	4.9***	**3.3*** **	5.0***	**2.8*** **	4.8
Less than once a month	6.8	**5.6**	6.9	**5.9**	7.0***	**5.2*** **	6.8
Does not volunteer	78.5	**79.0**	78.1***	**83.0*** **	77.7***	**82.7*** **	78.5
Mean scores[1]	0.016***	**0.088*** **	0.006***	**0.173*** **	-0.014***	**0.194*** **	**0.020**
Sample size	24,760	**1,229**	23,815	**2,174**	21,918	**4,071**	**25,989**

†Organisations include: Political party; trade union; environmental group; parents/school association; tenants/residents group or neighbourhood watch; religious group or church organisation; voluntary services group; pensioners group/organisation; scouts/guides organisation; professional organisation; other community or civic group; social club/working men's club; sports club; women's institute/townswomen's guild; women's group/feminist organisation; other group or organisation; none of these.

Note: Chi-squared tests were used to assess whether there is a statistically significant association between two categorical variables.

[1]ANOVA was used to assess whether there are statistically significant differences between the means of two or more independent (unrelated) groups.

*p<0.05 **p<0.01 ***p<0.001

Table 7.6: *Response percentages (%) to each item in the social isolation scale by group, UKHLS: wave 6, weighted (continued)*

	10 per cent indicator		**AFP indicator**		**Income poverty**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
Hours spent volunteering in the last 4 weeks							
Over 20 hours	3.0***	**4.5*** **	3.1	**2.9**	3.0	**3.5**	3.0
11 – 20 hours	3.2	**3.1**	3.3***	**2.1*** **	3.3*	**2.5***	3.2
1 – 10 hours	9.6	**7.8**	9.9***	**6.2*** **	10.2***	**6.0*** **	9.6
Zero hours	5.8	**5.7**	5.8	**5.8**	5.8	**5.3**	5.8
Does not volunteer	78.5	**79.0**	78.1***	**83.0*** **	77.7***	**82.7*** **	78.5
Belong to neighbourhood							
Strongly agree	20.9*	**23.8***	21.0	**21.5**	21.3	**19.7**	21.0
Agree	49.5	**47.1**	49.9***	**44.3*** **	50.2***	**45.0*** **	49.4
Neither agree nor disagree	23.3	**21.8**	23.0	**25.0**	22.7***	**25.6*** **	23.2
Disagree	4.8	**5.0**	4.6***	**6.5*** **	4.5***	**6.5*** **	4.8
Strongly disagree	1.5	**2.3**	1.5***	**2.7*** **	1.3***	**3.2*** **	1.6
Local friends mean a lot							
Strongly agree	15.6*	**18.3***	15.7	**16.0**	15.9	**14.8**	15.7
Agree	42.2	**44.6**	42.5	**40.7**	42.5	**41.1**	42.3
Neither agree nor disagree	30.7***	**26.0*** **	30.5	**29.9**	30.6	**29.7**	30.5
Disagree	9.2	**8.7**	9.1	**9.9**	9.0*	**10.2***	9.2
Strongly disagree	2.4	**2.3**	2.3***	**3.5*** **	2.0***	**4.1*** **	2.4
Mean scores[1]	0.016***	**0.088*** **	0.006***	**0.173*** **	-0.014***	**0.194*** **	**0.020**
Sample size	24,760	**1,229**	23,815	**2,174**	21,918	**4,071**	**25,989**

Note: Chi-squared tests were used to assess whether there is a statistically significant association between two categorical variables.
[1]ANOVA was used to assess whether there are statistically significant differences between the means of two or more independent (unrelated) groups.
*p<0.05 **p<0.01 ***p<0.001

Table 7.6: *Response percentages (%) to each item in the social isolation scale by group, UKHLS: wave 6, weighted (continued)*

	10 per cent indicator		**AFP indicator**		**Income poverty**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
Talk regularly to neighbours							
Strongly agree	21.5	**22.7**	21.6	**21.1**	21.8	**20.4**	21.6
Agree	48.0	**49.8**	48.4***	**44.8*** **	48.4*	**46.3***	48.1
Neither agree nor disagree	18.0	**17.9**	17.7***	**21.4*** **	17.6***	**19.9*** **	18.0
Disagree	9.3***	**6.7*** **	9.3	**8.3**	9.2	**8.9**	9.2
Strongly disagree	3.3	**2.9**	3.1*	**4.4***	3.0***	**4.7*** **	3.2
People in this neighbourhood can be trusted							
Strongly agree	11.6	**11.2**	11.8***	**9.6*** **	12.2***	**8.5*** **	11.6
Agree	58.8	**56.7**	59.6***	**48.6*** **	60.8***	**48.1*** **	58.7
Neither agree nor disagree	22.6	**21.7**	22.0***	**29.1*** **	21.3***	**29.1*** **	22.5
Disagree	5.6***	**8.9*** **	5.3***	**10.2*** **	4.7***	**11.4*** **	5.7
Strongly disagree	1.4	**1.5**	1.3***	**2.5*** **	1.1***	**3.1*** **	1.4
Like neighbourhood							
Yes	95.6	**94.3**	95.8***	**92.9*** **	96.1***	**92.2*** **	95.5
No	4.4	**5.7**	4.3***	**7.1*** **	3.9***	**7.8*** **	4.5
Feel safe walking alone at night							
Very safe	38.9***	**32.2*** **	39.0***	**34.3*** **	39.6***	**33.3*** **	38.6
Fairly safe	41.3	**38.5**	41.2	**40.5**	41.4	**40.2**	41.2
A bit unsafe	10.0	**10.6**	9.9*	**11.6***	9.5***	**12.6*** **	10.0
Very unsafe	2.7**	**4.2** **	2.6***	**4.7*** **	2.3***	**5.2*** **	2.7
Never goes out after dark	7.2***	**14.5*** **	7.4*	**9.0***	7.3***	**8.7*** **	7.5
Mean scores[1]	0.016***	**0.088*** **	0.006***	**0.173*** **	-0.014***	**0.194*** **	**0.020**
Sample size	24,760	**1,229**	23,815	**2,174**	21,918	**4,071**	**25,989**

Note: Chi-squared tests were used to assess whether there is a statistically significant association between two categorical variables.
[1]ANOVA was used to assess whether there are statistically significant differences between the means of two or more independent (unrelated) groups.
*p<0.05 **p<0.01 ***p<0.001

Table 7.6 shows that, overall, both fuel poor groups score significantly higher on the social isolation scale compared to those who are not fuel poor, with mean scores greater for the fuel poor under the AFP indicator (0.173) compared to the fuel poor under the 10 per cent indicator (0.088). This suggests that the fuel poor under the AFP indicator experience higher levels of social isolation. However, the income poor have the highest mean social isolation score (0.194), suggesting that they experience the highest levels of social isolation compared to all groups. It can also be seen that there are statistically significant differences between the items of the social isolation scale and the fuel poor and non-fuel poor under each indicator and the income poor and non-income poor.

Of particular interest in Table 7.6 is that the fuel poor under the 10 per cent indicator have the highest response percentages across all groups in the sample on volunteering at least once a week (11.0 per cent) and volunteering over 20 hours in the last 4 weeks (4.5 per cent), and have the highest response percentages on the "strongly agree" answer category for *Belong to neighbourhood* (23.8 per cent), *Local friends mean a lot* (18.3 per cent), and *Talk regularly to neighbours* (22.7 per cent), however these are not also statistically different from the non-fuel poor under this indicator. They also have higher response percentages on the "yes" response category for *Whether you are a member or not, do you join in the activities of organisations on a regular basis?* (42.8 per cent) compared to the fuel poor under the AFP indicator (36.3 per cent) and the income poor (36.1 per cent). These responses could be indicative of stronger social ties to the neighbourhood and the community, as indicated by Kearns and colleagues (2015), for the fuel poor under the 10 per cent indicator. This may be linked to a higher likelihood of owner-occupation in this group as identified in Chapter 5 (see Table 5.23), which has been found to be positively associated with neighbourhood cohesion (Macintyre and Ellaway 2000; Kearns et al. 2015).

In comparing the response percentages of both fuel poor groups and the income poor, the fuel poor under the AFP indicator and the income poor appear broadly similar in response percentages across most of the variables. However, the fuel poor under the AFP indicator had the lowest response percentages for volunteering at least once a week (7.9 per cent) and volunteering over 20 hours in the last 4 weeks (2.9 per cent), whilst the income poor had the lowest percentage of individuals responding "yes" to *Do you go out socially or visit friends when you feel like it?* (80.1 per cent), and "strongly agree" to *Belong to neighbourhood* (19.7 per cent), to *Local friends mean a lot* (14.8 per cent), to *Talk regularly to neighbours* (20.4 per cent), and to *People in this neighbourhood can be trusted* (8.5 per cent). These findings suggest that the income poor experience the lowest levels of neighbourhood cohesion and that they may experience the highest levels of loneliness.

7.11 Unpicking the relationship between fuel poverty and social isolation: multiple regression

Although the response percentages presented in Table 7.6 suggest that fuel poor individuals experience higher levels of social isolation overall than those who are not fuel poor, it was of interest to explore the relationship between fuel poverty and social isolation in the presence of other variables. To do so, multiple regression was used. This method has been detailed in Chapter 6 (see section 6.9.4).

7.11.1 Selecting the control variables to explore the relationship between fuel poverty and social isolation

Purposeful selection, which was described in Chapter 5 (see section 5.3.7.2), was used to select the control variables to explore the relationship between fuel poverty and social isolation through multiple regression analysis. The variables selected, along with their rationale, are presented in Table 7.7 overleaf.

Table 7.7: *Control variables for exploring the relationship between fuel poverty and social isolation and their rationale for inclusion, UKHLS: wave 6*

Variable name	Rationale for inclusion
Tenure	Positive associations have been found between owner-occupation and neighbourhood cohesion (Macintyre and Ellaway 2000; Kearns et al. 2015), with higher levels of place attachment and lower levels of loneliness found for owner-occupiers compared to those in the private rented sector or those living in social housing (Franklin and Tranter 2011; Oswald et al. 2011).
Number of cars in the household	This variable represents accessibility, particularly in areas where transport connections are poor – such as in rural areas – or where mobility issues are present, and has been found to be an important aspect of maintaining a social life (Commission for Rural Communities 2012).
Urban or rural	Rural dwellers have reported lower levels of social isolation than those in urban areas, with higher levels of being able to rely on family members, and experiencing lower levels of loneliness compared to urban dwellers (Henning-Smith et al. 2018). Statistics also show that there are differences in the rates of volunteering between urban and rural areas, with 29 per cent of rural dwellers regularly volunteering, compared to 20 per cent of urban dwellers (UK Civil Society Almanac 2020). This may be partly due to the higher proportion of older households in rural areas compared to urban areas (Defra 2019a), as age has been found to be positively associated to the frequency of volunteering (Cornwell et al. 2008).
Household type	This variable provides an indication of household size, as well as providing information on the composition of the household. Higher levels of social isolation and loneliness have been found amongst those living alone (Mullins et al. 1988; Shimada et al. 2014). However, work by Chatters and colleagues (2018) found that those living with others are significantly more likely to be objectively more isolated from their friends.
Sex	Men have been found to have smaller social networks than women, with women reporting higher quality and emotionally intimate relationships compared to men (Vandervoort 2000). However, women tend to require more social support than men and so a lack of meaningful relationships may be perceived more strongly amongst women, leading to higher levels of loneliness among women (Eckhard 2018).

Table 7.7: *Control variables for exploring the relationship between fuel poverty and social isolation and their rationale for inclusion, UKHLS: wave 6 (continued)*

Variable name	Rationale for inclusion
Age	Social isolation may become more pronounced with advancing age due to the thinning of social networks, bereavement and widowhood (Weiss 2005), and illness and disability (Thoits and Hewitt 2001), and older adults may adjust expectations so that low levels of social connectedness do not result in feelings of loneliness or perceived deficiencies in support (Lang and Carstensen 1994). In contrast, retirement may be linked with more free time and increased participation in social activities and volunteering (Cornwell et al. 2008).
Ethnicity	Levels of social isolation have been found to vary by ethnic group. Black African, Black Caribbean, Pakistani, and Indian women have been found to have the highest risks of experiencing objective social isolation (Platt 2009). People belonging to Black and Minority Ethnic groups have been found to be more likely to have fewer close friends and fewer friends that live locally, with possible impacts on the quality and frequency of interactions, and social support (Hayanga et al. 2020). Those belonging to Asian ethnic groups – specifically Pakistani and Bangladeshi men and women – have been found to be less likely to go out socially or to participate in organised activities compared to other groups (Platt 2009).
Highest qualification achieved	Although the relationship between education and social isolation is unclear, there is evidence to suggest that education acts as an important resource in later life and indirectly reduces feelings of loneliness (Bishop and Martin 2007). This is supported by others who found that education plays a significant role in place attachment (Mesch and Manor 1998; Livingston et al. 2008).
Longstanding illness or disability	Disability and illness have been linked to limited contact with family and friends, having fewer visitors, and spending long periods of time alone (Macdonald et al. 2018). There may also be physical barriers to socialisation, such as inaccessibility (Macdonald et al. 2018), which may restrict the types of activities participated in. Disability has also been linked to a desire for more contact with the community and higher levels of loneliness (Macdonald et al. 2018).
Household income	A low income may present an economic barrier to social activities. It may hinder the ability to afford the costs associated with certain social activities and may lower the ability to socialise with networks (Durcan and Bell 2015). A low income has also been linked to higher levels of social isolation and a lower sense of belonging (Stewart et al. 2009; Menec et al. 2019), and lower income groups have been found to have a lower number of friends (Hjalmarsson and Mood 2015).

7.11.2 Social isolation scores by control variables

Before presenting the multiple regression analysis, it was important to explore how social isolation scores varied by the control variables presented in Table 7.7. The following table (Table 7.8) presents the mean social isolation score, as well as the range of social isolation scores, for each control variable.

Table 7.8: *Mean social isolation scores [95% confidence intervals] by demographic and accessibility characteristics and household income, weighted*

Variable	Mean social isolation score	Range (min, max)
Tenure		
Owner-occupied	-0.060 [-0.066 – -0.532]	-1.449, 2.093
Private rented	0.174 [0.154 – 0.194]	-1.263, 2.086
Social housing	0.246 [0.230 – 0.262]	-1.352, 2.381
Number of cars in the household		
None	0.214 [0.196 – 0.232]	-1.352, 2.381
One or more	-0.013 [-0.020 – -0.007]	-1.449, 2.300
Urban or rural		
Urban	0.065 [0.058 – 0.072]	-1.449, 2.381
Rural	-0.117 [-0.128 – - 0.106]	-1.449, 1.926
Household type		
Single adult	0.027 [0.010 – 0.043]	-1.368, 2.284
Single adult, 1 child	0.162 [0.112 – 0.213]	-1.261, 1.926
Single adult, 2+ children	0.238 [0.186 – 0.291]	-1.352, 2.184
2 adults	-0.048 [-0.058 – -0.038]	-1.449, 2.093
2 adults, 1 child	0.092 [0.071 – 0.112]	-1.255, 2.300
2 adults, 2 children	-0.004 [-0.021 – 0.014]	-1.368, 1.965
2 adults, 3+ children	0.040 [0.011 – 0.069]	-1.261, 1.820
3+ adults	0.047 [0.032 – 0.063]	-1.358, 2.381
3+ adults, 1 child	0.089 [0.069 – 0.109]	-1.342, 1.971
3+ adults, 2+ children	0.139 [-0.081 – 0.359]	-0.786, 1.018
Sex		
Male	0.010 [0.002 – 0.019]	-1.449, 2.284
Female	0.289 [0.020 – 0.037]	-1.368, 2.381
Age		
16 - 24	0.161 [0.142 – 0.179]	-1.271, 2.300

Note: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

Table 7.8: *Mean social isolation scores [95% confidence intervals] by demographic and accessibility characteristics and household income, weighted (continued)*

Variable	Mean social isolation score (standard deviation)	Range (min, max)
Age		
25 - 34	0.168 [0.152 – 0.185]	-1.352, 2.122
35 - 44	0.039 [0.025 – 0.053]	-1.368, 2.184
45 - 54	-0.001 [-0.015 – 0.012]	-1.352, 2.191
55 - 64	-0.063 [-0.077 – -0.049]	-1.449, 2.381
65 - 74	-0.141 [-0.156 – -0.126]	-1.368, 2.284
75 - 84	-0.044 [-0.067 – -0.021]	-1.449, 1.982
85 and over	0.151 [0.104 – 0.198]	-1.332, 2.061
Ethnicity		
White	0.012 [0.005 – 0.018]	-1.449, 2.381
Mixed Race	0.138 [0.083 – 0.193]	-1.064, 1.896
Asian	0.120 [0.099 – 0.141]	-1.241, 1.997
Black	0.141 [0.102 – 0.179]	-1.255, 1.982
Other	0.112 [0.024 – 0.199]	-0.901, 1.701
Highest qualification achieved		
Degree level or equivalent	-0.099 [-0.110 – -0.087]	-1.449, 2.184
Other higher qualification	-0.052 [-0.070 – -0.035]	-1.368, 2.220
A-level or equivalent	0.051 [0.038 – 0.063]	-1.449, 2.300
GCSE or equivalent	0.091 [0.078 – 0.104]	-1.449, 2.191
Other below degree level	0.080 [0.060 – 0.100]	-1.271, 2.284
No formal qualifications	0.119 [0.102 – 0.137]	-1.358, 2.381
Longstanding illness or disability		
No	0.004 [-0.005 – 0.010]	-1.368, 2.300
Yes	0.051 [0.040 – 0.061]	-1.449, 2.381
Household full income (deciles)		
1st (lowest)	0.104 [0.085 – 0.124]	-1.352, 2.220
2nd	0.087 [0.067 – 0.107]	-1.368, 2.300
3rd	0.090 [0.070 – 0.109]	-1.449, 2.184
4th	0.071 [0.052 – 0.091]	-1.352, 2.122
5th	0.026 [0.007 – 0.045]	-1.368, 1.989
6th	0.028 [0.009 – 0.047]	-1.368, 2.381
7th	-0.017 [-0.036 – 0.001]	-1.449, 2.284
8th	-0.034 [-0.053 – -0.016]	-1.449, 1.999
9th	-0.052 [-0.070 – -0.033]	-1.358, 2.037
10th (highest)	-0.111 [-0.129 – -0.094]	-1.358, 1.633
Sample size	**25,989**	

Note: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

Table 7.8 shows that levels of social isolation are significantly higher amongst individuals in social housing (0.246), households with no cars (0.214), urban dwellers (0.065), single adult households with two or more children (0.238), and females (0.289) as indicated by the non-overlapping confidence intervals within each category.

It is also noted that social isolation decreases with age until the age of 75 when it begins to rise again. This may be linked to a higher incidence of illness and disability amongst older age groups, which may limit the ability and desire to participate in social activities (Macdonald et al. 2018), or to the loss of network members (Weiss 2005), as suggested in Table 7.7. Individuals belonging to Black ethnic groups have the highest scores for social isolation and this is significantly higher than individuals belonging to a White ethnic group. This is followed by those belonging to Mixed Race groups (0.138) and Asian ethnic groups (0.120) and this may be linked to having fewer close friends and going out less frequently (Platt 2009; Hayanga et al. 2020). Social isolation generally increases as the level of highest qualification decreases, with those with a *Degree or equivalent* having significantly lower social isolation scores (-0.099) compared to all other qualification types. *Having* a longstanding illness or disability has a significant association with social isolation scores compared to those without a longstanding illness of disability, and, overall, social isolation decreases with increasing income, with individuals in the lowest decile of household income having the highest levels of social isolation (0.104) and those in the highest decile of household income having significantly lower levels of social isolation (-0.111) compared to all other income deciles. This could be linked to the role of financial resources in the ability to participate in social activities (Durcan and Bell 2015).

7.11.3 Building the models: selecting the groupings and order of variables

As in previous chapters, the multiple regression models have been built up sequentially through the addition of variable sets, which are shown overleaf. In this way, the effect of each set of variables on the relationship between fuel poverty and social isolation can be determined.

Set 1: *Fuel poverty* is entered into the model first as a way of identifying its relationship with social isolation before controlling for other sets of variables.

Set 2: Dwelling characteristics and accessibility (*tenure, the presence of a car in the household,* and *urban or rural*) constitute the second set of variables.

Set 3: Demographic characteristics (*household type, sex, age, ethnicity, the highest qualification achieved,* and *longstanding illness or disability*), constitute the third set of variables.

Set 4: *Household full income,* as unequivalised income deciles, is entered last to identify its effect after controlling for all other variables. The purpose of entering it last is to disentangle the effect of income from other variables already in the model and to investigate whether the effect of fuel poverty is simply a low-income effect. Income was considered at the household level as this provides an overall measure of resources available to the individual (Menec et al. 2019). However, it is acknowledged that access to this collective income may not be equal across household members.

7.12 The results of multiple regression

Within this section, the results of multiple regression analysis are presented. Like in the previous chapter, the analysis was performed on the whole sample and on those who are poor, i.e. individuals whose household income falls below the poverty line (defined as 60 per cent of the median equivalised household income AHC) whether they are fuel poor or not. To reiterate, the purpose of restricting the sample to the poor is to investigate whether fuel poverty has a separate and additional effect on social isolation amongst the poor. When discussing the results, a comparative approach is taken, highlighting differences in the relationship between social isolation and fuel poverty under the 10 per cent indicator and the AFP indicator, and describing how this is altered by the addition of the sets of control variables presented in section 7.11.3. Additional analysis, which explores the relationship between fuel poverty and the individual items within the social isolation scale, is presented in Appendix D (see Tables D.1 and D.2).

7.12.1 The relationship between fuel poverty and social isolation: the whole sample

Tables 7.9 and 7.10 present the results of the multiple regression analysis, which explores the effects of fuel poverty under the 10 per cent indicator and the AFP indicator, respectively, on social isolation for the whole sample. The reference category used for each variable, i.e. the characteristic that all others are compared to, is shown in brackets alongside each variable.

Table 7.9: *Multiple regression: The effects of fuel poverty under the 10 per cent indicator on social isolation (coefficients (robust standard errors)), UKHLS: wave 6, weighted: the whole sample*

	Model 1	Model 2	Model 3	Model 4
In fuel poverty (ref: No)	0.072 (0.016)***	0.033 (0.016)*	0.031 (0.016)*	-0.009 (0.018)
Tenure (ref: Owner-occupied)				
Social housing		0.265 (0.010)***	0.191 (0.011)***	0.175 (0.011)***
Private rented		0.207 (0.012)***	0.145 (0.012)***	0.129 (0.012)***
Urban or rural (ref: Urban)		-0.155 (0.007)***	-0.137 (0.007)***	-0.134 (0.007)***
Number of cars in household (ref: None)				
One or more		-0.088 (0.012)***	-0.076 (0.012)***	-0.067 (0.012)***
Household type (ref: Two adults)				
Single adult			-0.020 (0.011)	-0.053 (0.012)***
Single adult, 1 child			-0.031 (0.028)	-0.059 (0.028)*
Single adult, 2+ children			-0.001 (0.031)	-0.081 (0.031)
Two adults, 1 child			0.023 (0.013)	0.031 (0.013)*
Two adults, 2 children			-0.040 (0.012)**	-0.027 (0.012)*
Two adults, 3+ children			-0.056 (0.018)**	-0.042 (0.018)*
Three or more adults			0.026 (0.011)*	0.065 (0.011)***
Three or more adults, 1 child			0.003 (0.014)	0.040 (0.014)**
Three or more adults, 2+ children			-0.062 (0.137)	0.027 (0.137)
Sex (ref: Male)			0.007 (0.006)	0.006 (0.006)
Age group (years) (ref: 16-24)				
25-34			0.026 (0.015)	0.022 (0.015)
35-44			-0.066 (0.014)***	-0.064 (0.014)***
45-54			-0.129 (0.013)***	-0.127 (0.013)***
55-64			-0.204 (0.014)***	-0.206 (0.014)***
65-74			-0.298 (0.015)***	-0.306 (0.015)***
75-84			-0.237 (0.018)***	-0.249 (0.018)***
85 and over			-0.084 (0.029)**	-0.093 (0.029)**
Ethnicity (ref: White)				
Mixed Race			0.020 (0.031)	0.019 (0.031)
Asian			0.059 (0.014)***	0.047 (0.014)**
Black			-0.010 (0.024)	-0.011 (0.024)

Table 7.9: *Multiple regression: The effects of fuel poverty under the 10 per cent indicator on social isolation (coefficients (robust standard errors)), UKHLS: wave 6, weighted: the whole sample (continued)*

	Model 1	Model 2	Model 3	Model 4
Ethnicity (ref: White)				
Other			0.047 (0.056)	0.032 (0.055)
Highest qualification achieved (ref: Degree level)				
Other higher qualification			0.066 (0.011)***	0.053 (0.011)***
A-Level or equivalent			0.112 (0.010)***	0.092 (0.010)***
GCSE or equivalent			0.159 (0.010)***	0.134 (0.010)***
Other qualification			0.201 (0.013)***	0.171 (0.013)***
No formal qualification			0.233 (0.013)***	0.200 (0.013)***
Longstanding illness or disability (ref: No)			0.064 (0.007)***	0.060 (0.007)***
Household full income decile (£/week) (ref: 10th (Highest)				
1st (lowest)				0.168 (0.019)***
2nd				0.152 (0.017)***
3rd				0.148 (0.016)***
4th				0.136 (0.015)***
5th				0.093 (0.014)***
6th				0.105 (0.014)***
7th				0.073 (0.014)***
8th				0.051 (0.014)***
9th				0.051 (0.014)***
Constant	**0.016 (0.004)*** **	**0.063 (0.012)*** **	**0.057 (0.019)** **	**-0.027 (0.021)**
Adjusted R^2	**0.001**	**0.090**	**0.145**	**0.151**
Sample size	**25,989**			

*p<0.05 **p<0.01 ***p<0.001

Table 7.10: *Multiple regression: The effects of fuel poverty under the AFP indicator on social isolation (coefficients (robust standard errors)), UKHLS: wave 6, weighted: the whole sample*

	Model 1	Model 2	Model 3	Model 4
In fuel poverty (ref: No)	0.167 (0.013)***	0.076 (0.013)***	0.044 (0.013)**	0.005 (0.014)
Tenure (ref: Owner-occupied)				
Social housing		0.257 (0.011)***	0.189 (0.011)***	0.175 (0.011)***
Private rented		0.201 (0.012)***	0.143 (0.012)***	0.129 (0.013)***
Urban or rural (ref: Urban)		-0.154 (0.007)***	-0.137 (0.007)***	-0.134 (0.007)***
Number of cars in household (ref: None)				
One or more		-0.087 (0.012)***	-0.075 (0.012)***	-0.067 (0.012)***
Household type (ref: Two adults)				
Single adult			-0.019 (0.011)	-0.052 (0.012)***
Single adult, 1 child			-0.031 (0.028)	-0.058 (0.028)*
Single adult, 2+ children			-0.003 (0.031)	-0.019 (0.031)
Two adults, 1 child			0.021 (0.014)	0.031 (0.013)*
Two adults, 2 children			-0.041 (0.012)**	-0.028 (0.012)*
Two adults, 3+ children			-0.060 (0.018)**	-0.043 (0.018)*
Three or more adults			0.026 (0.011)*	0.064 (0.011)***
Three or more adults, 1 child			-0.002 (0.014)	0.039 (0.014)**
Three or more adults, 2+ children			-0.064 (0.137)	0.026 (0.138)
Sex (ref: Male)			0.007 (0.006)	0.006 (0.006)
Age group (years) (ref: 16-24)				
25-34			0.028 (0.015)	0.023 (0.015)
35-44			-0.065 (0.014)***	-0.064 (0.014)***
45-54			-0.128 (0.013)***	-0.127 (0.013)***
55-64			-0.203 (0.014)***	-0.206 (0.014)***
65-74			-0.298 (0.015)***	-0.306 (0.015)***
75-84			-0.236 (0.018)***	-0.249 (0.018)***
85 and over			-0.083 (0.029)**	-0.092 (0.029)**
Ethnicity (ref: White)				
Mixed Race			0.019 (0.031)	0.019 (0.031)
Asian			0.057 (0.014)***	0.047 (0.014)**
Black			-0.010 (0.024)	-0.012 (0.024)
Other			0.046 (0.055)	0.03 (0.055)

Table 7.10: *Multiple regression: The effects of fuel poverty under the AFP indicator on social isolation (coefficients (robust standard errors)), UKHLS: wave 6, weighted: the whole sample (continued)*

	Model 1	Model 2	Model 3	Model 4
Highest qualification achieved (ref: degree level)				
Other higher qualification			0.065 (0.011)***	0.053 (0.011)***
A-Level or equivalent			0.111 (0.010)***	0.092 (0.010)***
GCSE or equivalent			0.157 (0.010)***	0.134 (0.010)***
Other qualification			0.200 (0.013)***	0.171 (0.013)***
No formal qualification			0.232 (0.013)***	0.201 (0.013)***
Longstanding illness or disability (ref: no)			0.064 (0.007)***	0.060 (0.007)***
Household full income decile (£/week) (ref: 10^{th} (highest)				
1^{st} (lowest)				0.163 (0.018)***
2^{nd}				0.149 (0.017)***
3^{rd}				0.147 (0.016)***
4^{th}				0.135 (0.015)***
5^{th}				0.093 (0.014)***
6^{th}				0.104 (0.014)***
7^{th}				0.073 (0.014)***
8^{th}				0.051 (0.014)***
9^{th}				0.051 (0.013)***
Constant	**0.006 (0.004)**	**0.059 (0.012)*** **	**0.056 (0.019)** **	**-0.027 (0.021)**
Adjusted R^2	**0.009**	**0.091**	**0.146**	**0.151**
Sample size	**25,989**			

*p<0.05 **p<0.01 ***p<0.001

Model 1 in Table 7.10 presents the relationship between fuel poverty and social isolation only and shows that fuel poverty under both fuel poverty indicators significantly increases social isolation. However, this increase is greater for the fuel poor under the AFP indicator, suggesting that they experience higher levels of social isolation compared to the fuel poor under the 10 per cent indicator. This reinforces the inter-indicator heterogeneity of fuel poverty that was found in the previous chapter, as the level of social isolation varies by the fuel poverty indicator used.

To explore whether the observed relationship between fuel poverty and social isolation in model 1 is underlain by other factors, model 2 incorporates the second set of variables: dwelling characteristics and accessibility (*tenure, urban or rural,* and *the number of cars in the household*). The addition of this set of variables reduces the effect of fuel poverty under both indicators on social isolation, with the greatest decrease observed for the fuel poor under the AFP indicator. This not only suggests that different degrees of social isolation are captured by each fuel poverty indicator, but that the relationship between fuel poverty and social isolation is affected differently by the addition of this set of control factors. This further builds on the understanding of the inter-indicator heterogeneity of fuel poverty. However, fuel poverty under both indicators remains positively and significantly associated with social isolation, with the fuel poor under the AFP indicator continuing to experience higher levels of social isolation compared to the fuel poor under the 10 per cent indicator.

Of interest in this model is the strong relationship between *tenure*, *urban or rural*, and social isolation. In particular, individuals in owner-occupied dwellings and those living in rural areas have significantly lower levels of social isolation compared to those in the private rented sector and in social housing, and in urban areas, respectively. These findings are of importance as these factors were identified as key characteristics of the fuel poor based on the UKHLS data through the analysis conducted in Chapter 5 and these may affect the experience of social isolation amongst the fuel poor. More specifically, the significantly lower levels of social isolation amongst individuals living in owner-occupied dwellings and in rural areas may suggest that the fuel poor under the 10 per cent indicator, despite these factors being associated with a higher likelihood of fuel poverty under this indicator (as shown Table 5.23 in Chapter 5), may experience lower levels of social isolation. In contrast, individuals in the private rented sector - a factor that was associated with a higher likelihood of fuel poverty under the AFP indicator (see Chapter 5, Table 5.23) - have significantly higher levels of social isolation compared to those living in owner-occupied dwellings and this may increase social isolation for the fuel poor under this indicator.

To explore the relationship between fuel poverty and social isolation further, model 3 adds the demographic characteristics (*household type, sex, age, ethnicity, the highest qualification achieved,* and *longstanding illness or disability*). This set of variables only marginally reduces the effect of fuel poverty on social isolation for the fuel poor under the 10 per cent indicator, with greater decreases in social isolation for the fuel poor under the AFP indicator. This, again, suggests that these variables bear a greater influence on the experience of social isolation for the fuel poor under the AFP indicator compared to the fuel poor under the 10 per cent indicator, further emphasising the inter-indicator heterogeneity of fuel poverty under the two fuel poverty indicators. This model also shows that individuals belonging to Asian ethnic groups have significantly higher levels of social isolation compared to individuals belonging to White ethnic groups. Belonging to an Asian ethnic group was identified as being a factor related to a higher likelihood of fuel poverty under the AFP indicator using the UKHLS dataset (see Table 5.23 in Chapter 5) and this suggests that this could increase social isolation for the fuel poor under this indicator. It is noted that, although adding this set of variables reduces the effect of *tenure* and *urban or rural* on social isolation, these factors remain highly significant.

Household full income deciles constitutes the last set of variables to be added and is presented in model 4. This addition further reduces the impact of fuel poverty on social isolation and this relationship is now non-significant under both fuel poverty indicators. This suggests that, although the fuel poor experience higher levels of social isolation compared to non-fuel poor individuals, this is driven by income rather than fuel poverty itself. However, within this model, it is again observed that characteristics associated with the highest likelihood of fuel poverty identified in Table 5.23 influence levels of social isolation. This includes the statistically significant relationship between social isolation and owner-occupation and rural-dwelling, which may decrease social isolation amongst the fuel poor under the 10 per cent indicator; or living in the private rented sector and belonging to an Asian ethnic group, which may increase social isolation amongst fuel poor under the AFP indicator.

These factors may moderate how the fuel poor under different fuel poverty indicators experience social isolation.

7.12.2 The relationship between fuel poverty and social isolation: the poor sample

In the following two tables (Table 7.11 and 7.12), the multiple regression analyses performed in the previous section are replicated for the poor sample. To reiterate, the purpose of this is to investigate whether, amongst the poor, fuel poverty has an additional and separate effect on social isolation. For this sample, only individuals whose household income falls below the poverty line (i.e. below 60 per cent of the median equivalised household income AHC) are included.

Table 7.11: *Multiple regression: The effects of fuel poverty under the 10 per cent indicator on social isolation (coefficients (robust standard errors)), UKHLS: wave 6, weighted: the poor sample*

	Model 1	Model 2	Model 3	Model 4
In fuel poverty (ref: No)	-0.097 (0.022)***	-0.051 (0.021)*	-0.020 (0.022)	-0.033 (0.024)
Tenure (ref: Owner-occupied)				
Social housing		0.187 (0.022)***	0.145 (0.023)***	0.153 (0.023)***
Private rented		0.130 (0.024)***	0.101 (0.026)***	0.106 (0.026)***
Urban or rural (ref: Urban)		-0.159 (0.023)***	-0.144 (0.023)***	-0.143 (0.023)***
Number of cars in household (ref: None)				
One or more		-0.028 (0.022)	-0.030 (0.023)	-0.028 (0.023)
Household type (ref: Two adults)				
Single adult			0.008 (0.028)	-0.004 (0.031)
Single adult, 1 child			-0.015 (0.053)	-0.022 (0.054)
Single adult, 2+ children			-0.038 (0.048)	-0.034 (0.051)
Two adults, 1 child			0.042 (0.038)	0.051 (0.044)
Two adults, 2 children			0.083 (0.039)*	0.088 (0.043)*
Two adults, 3+ children			-0.033 (0.041)	-0.025 (0.048)
Three or more adults			0.100 (0.050)*	0.108 (0.051)*
Three or more adults, 1 child			0.022 (0.038)	0.037 (0.045)
Three or more adults, 2+ children			-0.108 (0.132)	-0.075 (0.139)
Sex (ref: Male)			0.009 (0.019)	0.009 (0.019)
Age group (years) (ref: 16-24)				
25-34			-0.034 (0.038)	-0.033 (0.038)
35-44			-0.076 (0.034)*	-0.075 (0.034)*
45-54			-0.164 (0.034)***	-0.165 (0.034)***
55-64			-0.262 (0.039)***	-0.267 (0.039)***
65-74			-0.300 (0.044)***	-0.298 (0.044)***
75-84			-0.238 (0.051)***	-0.241 (0.052)***
85 and over			-0.229 (0.071)**	-0.235 (0.071)**
Ethnicity (ref: White)				
Mixed Race			0.035 (0.077)	0.040 (0.077)
Asian			-0.061 (0.029)*	-0.060 (0.029)*
Black			-0.090 (0.042)*	-0.093 (0.041)*
Other			-0.036 (0.119)	-0.037 (0.119)

*p<0.05 **p<0.01 ***p<0.001

Table 7.11: *Multiple regression: The effects of fuel poverty under the 10 per cent indicator on social isolation (coefficients (robust standard errors)), UKHLS: wave 6, weighted: the poor sample (continued)*

	Model 1	Model 2	Model 3	Model 4
Highest qualification achieved (ref: degree level)				
Other higher qualification			0.081 (0.041)	0.079 (0.041)
A-Level or equivalent			0.112 (0.032)**	0.111 (0.032)**
GCSE or equivalent			0.142 (0.031)***	0.142 (0.031)***
Other qualification			0.194 (0.040)***	0.195 (0.040)***
No formal qualification			0.201 (0.036)***	0.202 (0.036)***
Longstanding illness or disability (ref: No)			0.056 (0.020)**	0.058 (0.020)**
Household income decile BHC (£/week) (ref: 10th (highest)				
1st (lowest)				0.093 (0.059)
2nd				0.028 (0.055)
3rd				-0.006 (0.054)
4th				0.076 (0.052)
5th				0.032 (0.052)
6th				0.006 (0.051)
7th				0.020 (0.049)
8th				0.038 (0.045)
9th				0.022 (0.045)
Constant	**0.214 (0.011)*** **	**0.147 (0.024)*** **	**0.128 (0.049)** **	**0.092 (0.064)**
Adjusted R^2	**0.006**	**0.050**	**0.096**	**0.099**
Sample size	**4,071**			

*p<0.05 **p<0.01 ***p<0.001

Table 7.12: *Multiple regression: The effects of fuel poverty under the AFP indicator on social isolation (coefficients (robust standard errors)), UKHLS: wave 6, weighted: the poor sample*

	Model 1	Model 2	Model 3	Model 4
In fuel poverty (ref: No)	0.002 (0.019)	0.021 (0.019)	0.002 (0.019)	0.005 (0.019)
Tenure (ref: Owner-occupied)				
Social housing		0.197 (0.021)***	0.148 (0.022)***	0.156 (0.023)***
Private rented		0.140 (0.024)***	0.104 (0.026)***	0.108 (0.026)***
Urban or rural (ref: Urban)		-0.162 (0.023)***	-0.145 (0.023)***	-0.144 (0.023)***
Number of cars in household (ref: None)				
One or more		-0.027 (0.022)	-0.030 (0.023)	-0.030 (0.023)
Household type (ref: Two adults)				
Single adult			0.006 (0.028)	0.002 (0.031)
Single adult, 1 child			-0.015 (0.053)	-0.022 (0.054)
Single adult, 2+ children			-0.037 (0.048)	-0.038 (0.050)
Two adults, 1 child			0.043 (0.038)	0.047 (0.040)
Two adults, 2 children			0.086 (0.039)*	0.085 (0.042)*
Two adults, 3+ children			-0.030 (0.041)	-0.030 (0.048)
Three or more adults			0.103 (0.050)*	0.102 (0.052)*
Three or more adults, 1 child			0.025 (0.038)	0.032 (0.045)
Three or more adults, 2+ children			-0.101 (0.133)	-0.079 (0.139)
Age group (years) (ref: 16-24)				
25-34			-0.034 (0.038)	-0.033 (0.038)
35-44			-0.076 (0.034)*	-0.075 (0.034)*
45-54			-0.164 (0.034)***	-0.165 (0.034)***
55-64			-0.263 (0.039)***	-0.267 (0.039)***
65-74			-0.301 (0.044)***	-0.299 (0.044)***
75-84			-0.237 (0.051)***	-0.240 (0.052)***
85 and over			-0.229 (0.071)**	-0.235 (0.071)**
Ethnicity (ref: White)				
Mixed Race			0.035 (0.077)	0.040 (0.077)
Asian			-0.060 (0.029)*	-0.059 (0.029)*
Black			-0.092 (0.042)*	-0.095 (0.041)*
Other			-0.035 (0.119)	-0.033 (0.119)

Table 7.12: *Multiple regression: The effects of fuel poverty under the AFP indicator on social isolation (coefficients (robust standard errors)), UKHLS: wave 6, weighted: the poor sample (continued)*

	Model 1	Model 2	Model 3	Model 4
Highest qualification achieved (ref: degree level)				
Other higher qualification			0.081 (0.041)	0.079 (0.041)
A-Level or equivalent			0.112 (0.032)**	0.111 (0.032)**
GCSE or equivalent			0.141 (0.031)***	0.141 (0.031)***
Other qualification			0.194 (0.040)***	0.195 (0.040)***
No formal qualification			0.200 (0.036)***	0.202 (0.036)***
Longstanding illness or disability (ref: No)			0.056 (0.020)**	0.058 (0.020)**
Household income decile BHC (£/week) (ref: 10th (highest)				
1st (lowest)				0.065 (0.055)
2nd				0.006 (0.052)
3rd				-0.022 (0.053)
4th				0.065 (0.051)
5th				0.023 (0.051)
6th				0.000 (0.051)
7th				0.015 (0.048)
8th				0.037 (0.045)
9th				0.022 (0.045)
Constant	**0.193 (0.013)*** **	**0.120 (0.024)*** **	**0.121 (0.049)***	**0.094 (0.064)**
Adjusted R^2	0.000	0.049	0.096	0.098
Sample size	**4,071**			

*p<0.05 **p<0.01 ***p<0.001

In contrast to the whole sample analysis presented in Tables 7.9 and 7.10, the analysis on the poor sample shows that fuel poverty under the 10 per cent indicator is associated with significantly lower levels of social isolation compared to their non-fuel poor counterparts, but no significant relationship is observed between fuel poverty under the AFP indicator and social isolation. This suggests that fuel poverty under the AFP indicator has no additional effect on social isolation amongst the poor. These findings, again, emphasise the inter-indicator heterogeneity of fuel poverty and suggest that fuel poverty is not always associated with greater levels of disadvantage.

Adding the second set of variables (*tenure, urban or rural, and the number of cars in the household*) increases the levels of social isolation amongst the fuel poor and this reduces the statistical significance for the fuel poor under the 10 per cent indicator, with the relationship between fuel poverty under the AFP indicator and social isolation remaining non-significant. Reflecting the findings from the whole sample analysis, living in an owner-occupied dwelling and in a rural area is associated with significantly lower levels of social isolation, whilst living in the private rented sector is associated with significantly higher levels of social isolation. This could suggest that these factors may moderate the relationship between social isolation under the 10 per cent indicator and the AFP indicator, respectively, as these were shown to be characteristics of the fuel poor associated with the highest likelihood of fuel poverty under these indicators (see Table 5.23).

Model 3 adds the demographic characteristics (*household type, sex, age, ethnicity, the highest qualification achieved,* and *longstanding illness or disability*), and the relationship between fuel poverty under the 10 per cent definition and social isolation is no longer significant. However, the strong relationship between *tenure* and *urban or rural* remains in this sample, with individuals living in owner-occupied dwellings and those living in rural areas associated with significantly lower levels of social isolation, whilst those in the private rented sector are associated with significantly higher levels of social isolation.

Adding *household full income deciles*[68] in model 4 has no substantial effect on the relationship between fuel poverty and social isolation. However, the relationship between social isolation, *tenure,* and *urban or rural* remain highly significant in this model, with significantly lower levels of social isolation amongst owner-occupiers and those living in rural areas, and significantly higher levels of social isolation amongst those living in the private rented sector. This may, again, suggest that these factors play an important role in moderating the relationship between social isolation and fuel poverty under the two different indicators.

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[68] Household full income deciles were created for the poor sample.

7.13 Discussion

This chapter has explored the relationship between fuel poverty and social isolation as a way of gaining further insights into the experiences of the fuel poor and how this relationship may vary under different fuel poverty indicators and the factors that underlie this. To explore this relationship, an original and unique social isolation scale was constructed, which combined multiple items that have been shown to be related to social isolation in the literature. This incorporated indicators of both objective and subjective dimensions of social isolation and the different levels within which social isolation may take place – from more intimate networks (for example, *Number of close friends*) to wider aspects (for example, *Frequency of volunteering*) – as defined by Zavaleta and colleagues (2014, p.5). This has provided an extended perspective of how the fuel poor may experience social isolation and reflects a much more comprehensive understanding of this concept in contrast to the limited elements that have emerged through the exploration of the lived experience of fuel poverty, such as avoiding inviting visitors into the home (Harrington et al. 2005; Anderson et al. 2010; Ormandy and Ezratty 2015; Grey et al. 2017b).

7.13.1 Key findings

The findings within this chapter are discussed within the following two subsections, which focus on the relationship between fuel poverty and social isolation and the factors that underlie this for the whole and poor sample, drawing attention to how the findings build on the heterogeneous nature of fuel poverty that was identified and discussed in Chapters 5 and 6.

7.13.1.1 The relationship between fuel poverty and social isolation and its underlying factors: the whole sample

The response percentages presented in Table 7.6 showed that the fuel poor experience higher levels of social isolation compared to both non-fuel poor groups, with the fuel poor under the AFP indicator experiencing higher levels compared to the fuel poor under the 10 per cent indicator. To explore this further, multiple regression analysis was used to investigate this relationship in the presence of other variables. Without controlling for other factors, the multiple regression analyses showed that fuel poverty under both indicators was significantly associated with higher levels of social isolation as indicated by their higher scores, but that the fuel poor under the AFP indicator experience higher levels of social isolation compared to the fuel poor under the 10 per cent indicator (see model 1 in Tables 7.9 and 7.10). This finding builds on the notion of heterogeneity of fuel poverty identified and discussed in the previous chapters. Where Chapter 5 highlighted compositional heterogeneity, Chapter 6 showed that the indicators of fuel poverty captured differences in food expenditure, both in absolute and proportionate terms. Like in Chapter 6, this chapter reinforces that the degree of disadvantage (i.e. social isolation) associated with fuel poverty is dependent on the fuel poverty indicator used, further emphasising the inter-indicator heterogeneity of fuel poverty. Furthermore, when adding the sets of control variables in models 2 and 3, it was noted that their addition had a greater effect on the fuel poor under the AFP indicator. This indicates that it is not only the degree of social isolation that varies between both fuel poor groups, but that underlying factors differentially affect the relationship between fuel poverty and social isolation. This suggests that the compositional differences that exist between both fuel poor groups, which were identified in Chapter 5 (see Table 5.23) influence the relationship between fuel poverty and social isolation. This helps to further develop the understanding of the inter-indicator heterogeneity of fuel poverty, which was found in the previous chapter.

In inspecting the outputs when controlling for other factors, it is noteworthy that significant relationships were found between social isolation and some of the control variables that could reveal further insights into how the relationship between social isolation and fuel poverty under the two different fuel poverty indicators may vary. In particular, there were three factors (tenure, urban- or rural-dwelling, and ethnicity), which had been identified as having a higher likelihood of fuel poverty in Chapter 5 (see Table 5.23), that were found to have a significant relationship with social isolation, even after controlling for income. These may help to understand how compositional differences amongst the fuel poor under the different indicators may have consequences for their experience of other forms of disadvantage.

Firstly, the analysis in Tables 7.9 and 7.10 revealed that owner-occupation was strongly associated with significantly lower levels of social isolation compared to those in the private rented sector and those living in social housing. This reflects the findings of previous work (Franklin and Tranter 2011; Oswald et al. 2011) and may be linked to the importance of home ownership for neighbourhood attachment (Oh 2004; Livingston et al. 2008), which embodies the emotional connection to physical and social environments, shaping how people interact with their local environment and connect with others (Comstock et al. 2010). Although increasing the likelihood of fuel poverty under the 10 per cent indicator, as shown in Table 5.23 in Chapter 5, owner-occupation may decrease the vulnerability to social isolation and feelings of loneliness amongst the fuel poor under this indicator. In contrast, the strong positive relationship between those in the private rented sector (a factor associated with the highest likelihood of fuel poverty under the AFP indicator (see Table 5.23) and social isolation may suggest that the fuel poor under the AFP indicator may experience increased levels of social isolation. This may be linked to a lack of a sense of belonging to a community (ONS 2018d), and to a high turnover of residents often associated with this tenure (Kearns et al. 2015), which may make it difficult to form connections and build friendships.

Secondly, the analysis presented in Tables 7.9 and 7.10 also revealed that living in a rural area is associated with lower levels of social isolation. This has also been found elsewhere (Henning-Smith et al. 2018) and has been linked to having a larger number of close friends and relatives and higher levels of being able to rely of family and friends compared to urban dwellers (Henning-Smith et al. 2018). Living in a rural area was one of the key determinants of fuel poverty under the 10 per cent indicator (see Table 5.23) and could suggest that living in a rural area may mitigate the experience of social isolation amongst the fuel poor under the 10 per cent indicator.

Thirdly, belonging to an Asian ethnic group – a characteristic associated with a higher likelihood of fuel poverty under the AFP indicator constructed using fuel expenditure data from the UKHLS (see Table 5.23) – was found to be associated with significantly higher levels of social isolation (see model 3 in Tables 7.9 and 7.10). Although the reasons for this are not explored within this chapter, work by Platt found that some groups within the Asian ethnic category (Pakistani and Bangladeshi men and women) were less likely to go out socially or participate in organised activities (Platt 2009), which are two components included in the scale.

When controlling for income the relationship between fuel poverty and social isolation was no longer significant. This suggests that it is not fuel poverty itself that is linked to higher levels of social isolation within these fuel poor groups, but the low levels of income within these households, which may create an economic barrier to connecting with social networks and participating in social activities. This finding supports the literature presented in pathway 1 in section 7.6.1. Socialising, especially where financial costs are involved, may be avoided as a response to fuel poverty in order to divert resources to keeping the home warm and to be able to afford other energy services, especially where these may be prioritised (see Harrington 2005 and Day and Hitchings 2009, for example). Socialising may also be actively avoided as a way of evading social comparisons (Eckhard 2018), which may provoke feelings of inferiority and anxiety (Mills et al. 2014; Eckhard 2018). This may lead to feelings of disconnection from friends, family, and wider networks.

7.13.1.2 The relationship between fuel poverty and social isolation and its underlying factors: the poor sample

In conducting the same analysis on the sample restricted to the poor as a way of understanding whether fuel poverty has a separate and additional effect amongst the poor, the results show that the fuel poor under the 10 per cent indicator have significantly lower levels of social isolation compared to their non-fuel poor counterparts (see model 1 in Table 7.11), suggesting that fuel poverty is not always associated with higher levels of disadvantage. In contrast, no significant relationship was observed between the fuel poor under the AFP indicator in this sample, suggesting that fuel poverty under the AFP indicator has no influence on the degree of social isolation experienced amongst the poor. These findings further emphasise the inter-indicator heterogeneity of fuel poverty, where the level of disadvantage differs under the two different fuel poverty indicators.

It was also observed that some factors that were significant in the whole sample analysis were also significant in the analysis for the poor and this may help to understand how factors may mitigate or enhance the degree of social isolation experienced by the poor. In particular, the strong relationship that was identified in the whole sample analysis between social isolation and tenure and urban- or rural-living is similarly observed amongst the poor, with individuals in owner-occupied properties and living in a rural area associated with significantly lower levels of social isolation, further emphasising its importance in the relationship between social isolation and fuel poverty under the 10 per cent indicator. It was also observed, like in the whole sample analysis, that those in the private rented sector had significantly higher levels of social isolation and this may moderate the relationship between social isolation and fuel poverty under the AFP indicator.

7.13.2 Study limitations

Although exploring social isolation in this way has extended the understanding of some of the factors that may increase or decrease the degree of social isolation experienced by fuel poor individuals, the social isolation scale only included some aspects of a very broad concept due to the boundaries imposed by secondary data. Being reliant on the variables within the UKHLS may not have entirely incorporated the various ways that the fuel poor may experience social isolation. For example, despite a significant relationship between social isolation and individuals within households containing three or more adults with children, the research was not able to consider family interactions within the home, which have been found to be affected by fuel poverty, both positively (Harrington et al. 2005) and negatively (McAvoy 2007). As such, it is not clear whether these individuals, despite being socially isolated, as measured by the scale, are socially fulfilled in other aspects. Given that there is no set definition of social isolation and no consensus on which variables should be used to explore this concept, it is possible that the inclusion of different variables in the social isolation scale may have revealed different insights into the relationship between fuel poverty and social isolation.

7.14 Chapter summary and conclusions

This chapter has sought to gain a better understanding of the relationship between fuel poverty and social isolation and the underlying components of this through the construction of a social isolation scale composed of a range of items evidenced to be linked with this concept. In doing so, the study provides a more nuanced and distinct contribution to the study of fuel poverty and its relationship with social isolation.

Within this chapter, the relationship between fuel poverty and social isolation was found to be driven by a low income. This suggests that fuel poverty may not be a direct driver of social isolation and that further studies and different methods may be needed to understand the causal pathways between fuel poverty and social isolation. However, the ability to control for a range of factors through the use of a large-scale quantitative dataset has unveiled some characteristics of the fuel poor that may alter the relationship between fuel poverty and social isolation, such as home ownership and living in a rural area. This can help to further understand the relationship between social isolation and fuel poverty using different indicators.

As well as helping to better understand the relationship between fuel poverty and social isolation using two different fuel poverty indicators, this chapter has also helped to illuminate the heterogeneous nature of fuel poverty that was identified in the previous two chapters. Like in Chapter 6, the analysis within this chapter revealed that levels of disadvantage (i.e. social isolation, in this case) vary using different fuel poverty indicators. Furthermore, the analysis also showed that the control factors had different effects on the relationship between fuel poverty and social isolation depending on the fuel poverty indicator used and this has helped to add further layers to the understanding of the inter-indicator heterogeneity of fuel poverty.

The following chapter addresses the final research question set for the thesis, which asks whether the order of curtailment of material deprivation items differs between the fuel poor and non-fuel poor as a way of understanding whether differences exist in how fuel poverty under the 10 per cent indicator and the AFP indicator impact on the living standards of the fuel poor.

Chapter 8| Is there a difference in the order of curtailment of material deprivation items between fuel poor and non-fuel poor households?

8.1 Introduction

As emphasised in Chapter 2 (see section 2.4.1), fuel poverty is often associated with fuel bills that consume a disproportionate share of income, with low-income households being particularly affected. This is widely supported by the literature (Isherwood and Hancock 1979; Boardman 2010; Hinson and Bolton 2020) and it is this conceptualisation of fuel poverty that is used throughout the analysis chapters. The burden of fuel bills may leave households with a limited residual income, which may force them to juggle competing expenditures and, at times, cut back on essential items (Bhattacharya et al. 2003; Harrington et al. 2005; Anderson et al. 2010; Powell-Hoyland et al. 2016). This has been documented predominantly through the heat or eat trade-off (Bhattacharya et al. 2003; Beatty et al. 2014a; Lambie-Mumford et al. 2015), which has been discussed in Chapter 3 (section 3.3.2). However, the literature that contributed to the conceptual framework presented in Chapter 3 indicated that fuel poor households also curb expenditure on other essential items, such as clothing, holidays, new furniture, and social activities to afford fuel (Bhattacharya et al. 2003; Anderson et al. 2010). This curbing of essential expenditures identifies a distinct set of coping strategies and provides an insight into how the living standards of the fuel poor may be affected, which may help to understand the wider implications of fuel poverty and can help to broaden the understanding of the experiences of the fuel poor.

8.2 Chapter aim and objectives

To extend the literature on the types of essential expenditures that are curbed by fuel poor households, this study focuses on expenditures that are currently considered essential by the majority of society. These are contained within deprivation suites and are discussed later in the chapter (see sections 8.4 and 8.7.1). In particular, the study explores differences in the rates of material deprivation and the order in which essential expenditures are curtailed in fuel poor and non-fuel poor households. The purpose of this is to gain novel insights into how living standards may vary between these groups and to further understand the experiences of the fuel poor. Moreover, using material deprivation suites for adult and pensioner households, the order of curtailment of essential expenditures is explored within working-age adult households with and without children, and in pensioner households. The purpose of this is to investigate whether being fuel poor within different household types has a different bearing on the order in which expenditures are curtailed and, therefore, whether differing impacts on standards of living are observed in different household types using the same definition of fuel poverty. The following three objectives have been set for the study:

1. To explore whether rates of material deprivation differ between fuel poor and non-fuel poor groups within different household types
2. To determine whether the sequence of curtailment of essential expenditures differs between the fuel poor and non-fuel poor across different household types
3. To investigate whether the order of curtailment of essential expenditures differs between the fuel poor and income poor across different household types

These objectives aim to add further dimensions to understanding of the effects of fuel poverty using different indicators and within different household types, and to help better understand differences in these experiences between the fuel poor and income poor.

8.3 Chapter outline

In the following section, a brief background to material deprivation is provided, focusing on its origins and the types of essential expenditures that are used to identify material deprivation. This is followed by a review of the literature that reveals the types of essential expenditures curbed by the fuel poor and how some essential expenditures are prioritised over others. The data source and the process of variable selection are described, and the methods used for the analysis conducted within this chapter are outlined. The results of the analysis are then presented, and a discussion of the results is provided thereafter. The chapter is drawn to a close with a summary of the study and the conclusions.

8.4 The origins and evolution of material deprivation

Associated with the early work of Townsend (1979), who viewed poverty beyond simply a low income, material deprivation is a concept that refers to the lack of items that are considered necessities in society at a given point in time (Willitts 2006), with the degree of deprivation increasing with the number of items lacking (Townsend 1979; Mack and Lansley 1985; Desai and Shah 1988; Nolan and Whelan 1996). Townsend provided the following definition of material deprivation:

> Individuals, families and groups in the population can be said to be in poverty when they lack the resources to obtain the type of diet, participate in the activities and have the living conditions and amenities which are customary, or at least widely encouraged, or approved, in the societies to which they belong. Their resources are so seriously below those commanded by the average individual or family that they are, in effect, excluded from ordinary living patterns, customs and activities (Townsend 1979, p.31).

In this way, material deprivation provides an insight into how people are living rather than just focusing on their level of income. Townsend developed a list of sixty indicators of the population's *style of living* for a survey into standards of living in the United Kingdom carried out in 1968/69 (Townsend 1979). These covered the following areas: diet; clothing; fuel and light; home amenities; housing and housing facilities; the immediate environment of the home; the general conditions and security of work; family support; recreation; education; health; and social relations (Townsend 1979). A full list is provided in Townsend (1979, p.1173) and, from this, a summary index was compiled, which is shown in Table E.1 in Appendix E.

However, Townsend's indicators were criticised for being arbitrary and for not allowing for differences in how people lived and the choices they made (Mack et al. 2013). As a way of overcoming the criticisms of Townsend's indicators, Mack and Lansley (1985) pioneered a consensual approach to determining material deprivation in their *Breadline Britain* survey conducted in 1983. This approach used public opinion, rather than expert views and defined poverty as the "enforced lack of socially perceived necessities" (Mack and Lansley 1985, p.9). However, Fahmy and colleagues (2015) have highlighted some issues with this approach, which include the diverse understanding of "necessity" and perhaps this being more a "majoritarian" approach, rather than a consensual one (Fahmy et al. 2015, p.606). Despite the limitations of this approach, these consensual indicators have been included in the Family Resources Survey (FRS) since 2004/05 (PSE [no date]) and those in the most recent FRS are presented in Tables E.2 to E.4 in Appendix E.

8.5 Fuel poverty and its links with material deprivation

The ways in which fuel poverty can impact on essential expenditures is predominantly concentrated on the heat or eat trade-off, which has often been interpreted as having to choose between heating or eating. However, the literature presented in Chapter 6 (see section 6.5) did not support the conclusion that this choice was strictly binary, but instead suggested that behaviours are employed to avoid this choice having to be made, such as buying cheaper foods (Anderson et al. 2010).

In contrast, knowledge of the ways in which households manage other types of essential expenditures in the context of fuel poverty is scarce and, to the author's knowledge, only one study has explored this within the framework of material deprivation. Within this study, Anderson and colleagues (2010) used a set of material deprivation indicators developed for the FRS by McKay and Collard (2003). These, along with the percentage of households who went without each item are shown in Table E.5 in Appendix E. Overall, they found that 68 per cent of fuel poor households – identified through the overlap of income poverty and the difficulty of keeping the home warm – had gone without one or more essential items. Households cut back on heating to afford fuel bills, with 42 per cent stating that fuel bills were a “heavy financial burden” and only 21 per cent stating that they were “not a problem at all” (Anderson et al. 2010, p.26). Households forwent holidays in favour of regular expenditures, they prioritised bills to avoid falling into debt, and they expressed difficulties in being able to visit family members who live outside of their area due to expenses associated with travelling. They also found that some respondents would buy clothes from charity shops meaning that their clothing choices were dependent on the donations of others. This could mean that they may be ill-equipped for the weather.

Beyond this study, only a few studies have identified other essential expenditures affected in fuel poor households, but these have not been explored within the context of material deprivation. As there is currently a dearth of literature in this area, the available evidence has been grouped into similar items, which correspond to the most recent items used to identify material deprivation in the FRS (see Tables E.2 to E.4 in Appendix E).

8.5.1 Holidays, socialising, and visiting family and friends

In contrast to Anderson et al. (2010) who found that fuel poor householders forwent holidays to be able to afford warmth, Harrington and colleagues (2005) found that some fuel poor households curbed their expenditure on heating in order to save for a holiday and spent time in other peoples’ homes as a way of keeping warm whilst keeping their fuel costs low. Deller and colleagues (2021) found 29.5 per cent of households who spent more than 10 per cent of their income on fuel stated that they could not afford a holiday.

The ways in which fuel poverty can hinder social interactions have been described in detail in the previous chapter, but – in brief – this includes concentrating available resources on keeping the home warm (Harrington et al. 2005; Anderson et al. 2010; Cotter et al. 2012), living in a cold home and feelings of embarrassment and shame about the appearance of the internal environment, which may be impaired by the presence of damp and mould (Harrington et al. 2005; Anderson et al. 2010; Ormandy and Ezratty 2015; Grey et al. 2017a), and the mental and physical health impacts associated with living in fuel poverty (Marmot Review Team 2011; Hills 2012; Liddell and Guiney 2015). Furthermore, some fuel poor households have been found to cut back on travel costs (McAvoy 2007; Anderson et al. 2010), which may reduce opportunities to visit family and friends.

8.5.2 Keeping the home warm and damp-free

The presence of damp and mould is common in fuel poor homes (Platt et al. 1989; Healy and Clinch 2004; Gilbertson et al. 2006) and is caused by inadequate heating regimes, which often occur as a response to high fuel costs or as a consequence of poor energy efficiency (Boardman 2010; Jones et al. 2016). Some fuel poor households have been found to prioritise heating at the expense of other essentials, such as food (O'Neill et al. 2006), whilst others have found that lighting, cooking, and hot water are viewed as more important than heating (Lambie-Mumford et al. 2015). This could have implications for keeping the home warm and damp-free.

8.5.3 Adequate winter clothing

The use of appropriate and adequate winter clothing is essential to protect against the negative health impacts of cold weather. There is evidence to suggest that those who live in cold homes are more likely to wear inadequate outdoor clothing in the winter compared to those who live in warm homes (The Eurowinter Group 1997). This could be linked to the purchasing of second-hand clothes by fuel poor households, which was identified by Anderson et al. (2010). Additionally, studies by Bhattacharya et al. (2003) and Cotter and colleagues (2012) showed that clothing expenditure was reduced during colder months in order to accommodate increased heating requirements. Although the authors do not comment on how this may have affected the provision of winter clothing, it may suggest that those living in cold homes are less able to afford suitable winter clothing due to the increased financial burden of heating requirements in colder months. Furthermore, for those living in fuel poverty, winter clothing may have additional importance as Harrington and colleagues (2005) and others (Cotter et al. 2012; Middlemiss and Gillard 2015; Chard and Walker 2016) have found that outdoor clothing is used indoors as a way of keeping warm.

8.5.4 Repairing or replacing major electrical goods, replacing worn-out furniture, and savings

The second-hand purchasing behaviours associated with fuel poor households also extends to the replacement or repair of electrical goods and the replacement of worn-out furniture. According to work conducted by Brunner and colleagues (2012), fuel poor householders purchased second-hand goods, asked friends for used and unwanted furniture and appliances, and repaired broken objects instead of replacing them. Boardman and colleagues (1997) also found that low-income households purchased second-hand appliances and would keep them for longer. Although viewed as a money-saving option, purchasing second-hand electrical goods or taking on unwanted appliances may inadvertently worsen fuel poverty as these may be older and less energy efficient (Boardman et al. 1997; Boardman 2010), thereby increasing fuel usage and fuel costs. Deller and colleagues (2021) also found that 15.2 per cent those spending 10 per cent or more of their income on fuel were unable to afford to replace furniture.

The second-hand purchasing behaviours of fuel poor households and not being able to replace worn-out goods has been linked to low incomes and difficulties around savings (Anderson et al. 2010). Lower income households are less likely to have a savings account compared to wealthier households (Kempson and Finney 2009; Boardman 2010) and they may experience higher levels of debt (Williams et al. 2015; Adam and Monaghan 2016). This may prohibit the fuel poor from purchasing essential items, especially those that require large sums of money to be paid, such as furniture or major electrical goods.

8.5.5 Keeping up with bills and regular debt repayments

The literature presents contrasting accounts of how the fuel poor manage their bills, with a particular focus on fuel bills. For example, Anderson and colleagues (2010), and Harrington et al. (2005) suggest fuel bills are prioritised despite them being a burden and are often paid at the expense of other essentials due to worry about falling into debt. This may restrict the availability of financial resources for other essential expenditures and, therefore, may have implications for material deprivation. However, others have found that households fall into energy debt and other types of debt to be able to keep the home warm (Harrington et al. 2005; Anderson et al. 2010; Adam and Monaghan 2016). These contrasting behaviours appear to be influenced by the presence of children in the household, with parents prioritising warmth to protect the health of their children.

8.6 Study hypothesis

Despite the limited research in this area, the studies referred to herein suggest that fuel poor households cut back on essential expenditures and that living in fuel poverty may not only be associated with higher levels of material deprivation, but that it may influence the types of expenditures that are affected. Given that the fuel poor in this thesis are defined as those who are spending a disproportionate amount of income on fuel, this may restrict the availability of financial resources for other types of essential expenditures. As such, it is hypothesised that the fuel poor experience higher rates of material deprivation compared to non-fuel poor households and that they curb expenditures on essential items that are associated with higher costs first, such as replacing worn-out furniture or repairing or replacing major electrical goods.

8.7 Data source and methods

To fulfil the objectives set for this study presented in section 8.2, data from the UKHLS were used. A brief description of this data source has been provided in Chapter 4 (see section 4.5.2), together with the data cleaning procedures used for income and fuel expenditure data (see section 4.7) and the methods used to construct both fuel poverty indicators used throughout the thesis (see section 4.8). In the following subsections, the relevant variables available in the UKHLS and their selection for the analysis is detailed, and the two methods that allow the research objectives to be addressed – *prevalence weighting* and *Item Response Theory* – are described.

8.7.1 Material deprivation variables available in the UKHLS

Before embarking on the methods used to conduct the analysis, it was firstly important to identify and select relevant variables to be used in the analysis. The UKHLS contains information on material deprivation items for working-age adult households and pensioner households sourced from the FRS[69]. The items included in the UKHLS, along with the waves within which they are present and their possible response categories, are shown in Tables 8.1 and 8.2 for working-age adult households and pensioner households, respectively.

[69] Preliminary analysis included child-specific items, but due to small sample sizes, these were not used in the final analysis.

Table 8.1: *Material deprivation items* for working-age adult households, UKHLS: waves 2 – 6*

<table>
<tr><th>Variable label</th><th>Waves present</th><th>Response categories</th></tr>
<tr><td colspan="3">Do you and your family/partner …?</td></tr>
<tr><td>Have a holiday away from home for at least one week a year, whilst not staying with relatives at their home?</td><td>2, 4, 6</td><td rowspan="10">(1) “I/We have this”

(2) “I/We would like to have this but can’t afford this”

(3) “I/We do not want/need this at the moment”

(4) “Does not apply”</td></tr>
<tr><td>Have friends/family around for a drink or meal at least once a month?</td><td>2</td></tr>
<tr><td>Have two pairs of all-weather shoes for all adult members of the family?</td><td>2</td></tr>
<tr><td>Have enough money to keep your house in a decent state of repair?</td><td>2, 4, 6</td></tr>
<tr><td>Have household contents insurance?</td><td>2, 4, 6</td></tr>
<tr><td>Have enough money to make regular savings of £10 a month or more for rainy days or retirement?</td><td>2, 4, 6</td></tr>
<tr><td>Have enough money to replace any worn-out furniture?</td><td>2, 4, 6</td></tr>
<tr><td>Have enough money to replace or repair major electrical goods such as a refrigerator of washing machine, when broken?</td><td>2, 4, 6</td></tr>
<tr><td>Have a small amount of money to spend each week on yourself (not on your family)?</td><td>4, 6</td></tr>
<tr><td>Keep up with bills and regular debt repayments?</td><td>4, 6</td></tr>
</table>

* Items are asked of households that either contain only working-age adults or working-age adults with one or more children aged 0 to 15 years. No persons of pensionable age are in these households.

In work by McKay (2008), it was found that the items and response categories used for assessing material deprivation in working-age adult households were not appropriate for older adults. This is because their responses were shown to differ significantly from younger adults, with older people being more likely to state that they do not want or need an item, rather than being unable to afford it (McKay 2008). In light of this, a wider set of indicators were developed and since 2008, additional response categories for pensioner deprivation items were extended to cover financial and non-financial reasons for why deprivation of an item may occur, including ill-health or disability, not having anyone to help them, and being too much trouble or too tiring (McKay 2008; Mckay 2010). The full set of variables for the pensioner suite of material deprivation available in the UKHLS are presented in Table 8.2 below, along with their possible response categories and the waves within which they are present.

Table 8.2: *Pensioner material deprivation items*, UKHLS, waves 4 & 6*

Variable label	Waves present	Response categories
Do you take a holiday away from home for a week or more at least once a year?	4, 6	(1) "Yes" (2) "No, no money for this" (3) "No, not a priority" (4) "No, health/disability prevents this" (5) "No, too much trouble/too tiring" (6) "No, no company/help" (7) "No, not wanted" (8) "No, not relevant" (97) "Spontaneous: no, other"
Do you go out socially either alone or with other people, at least once a month?	4, 6	
Do you see friends and family at least once a month?	4, 6	
Do you eat at least one filling meal a day?	4, 6	
Would the cooker be able to be replaced if it broke down?	4, 6	
Is your home kept in a good state of repair?	4, 6	
Are your heating, electrics, plumbing and drains kept in good working order?	4, 6	
Do you have a damp-free home?	4, 6	
Is your home kept adequately warm?	4, 6	
Do you have a telephone to use, whenever one is needed?	4, 6	
Do you have access to a car or taxi whenever one is needed?	4, 6	
Do you have your hair done or cut regularly?	4, 6	
Do you have a warm waterproof coat?	4, 6	
Would you be able to pay an unexpected expense of £200?	4, 6	

* Items are only asked of households where there are no children aged 0 to 15 and where there is one or more adults of pensionable age.

8.7.1.1 Variable selection

As questions regarding deprivation are part of a rotating module (Carpenter 2016), they are not asked at each wave of the UKHLS and are – most often – asked at two-wave intervals.

This can be seen in Tables 8.1 and 8.2. Furthermore, some items that are present in earlier waves are not present in later waves and this reflects changing opinions on what is viewed as necessities (Berthoud et al. 2004).

Although the items in the pensioner deprivation suite were consistent in waves 4 and 6, this was not the case for adult material deprivation indicators, where some items were present only in wave 2[70], others in waves 4 and 6[71], while the remainder were consistent in waves 2, 4, and 6, as shown in Table 8.1. Essentially, this meant that a decision had to be made between items in wave 2 and items in waves 4 and 6. After consulting the literature, the items in waves 4 and 6 were selected, which included having a small amount of money to spend each week on oneself and keeping up with bills and regular debt repayments. Although not specific to fuel bills or energy debt, this item was of particular interest in the context of fuel poverty as the literature provides contrasting evidence for how the fuel poor manage their bills, specifically fuel bills, as evidenced in section 8.5.5. As a result of this decision, all analyses within this chapter were based on waves 4 and 6[72] of the UKHLS. The final set of selected items for working-age adult and pensioner households have been presented in Table 8.3 overleaf and, for simplicity, have been abbreviated for the purpose of the analysis.

[70] "Have friends/family around for a drink or meal at least once a month?" and "Have two pairs of all-weather shoes for all adult members of the family?".
[71] "Have a small amount of money to spend each week on yourself (not on your family)?" and "Keep up with bills and regular debt repayments?".
[72] Wave 4 spans 2012 to 2014, and wave 6 spans 2014 to 2016.

Table 8.3: *The final selection of items to identify working-age adult material deprivation* and pensioner material deprivation**, and their abbreviations, UKHLS: waves 4 & 6*

Working-age adult items[73]	**Abbreviation**
Do you and your family/partner …?	
Have a holiday away from home for at least one week a year, whilst not staying with relatives at their home?	Holiday
Have enough money to keep your house in a decent state of repair?	House
Have household contents insurance?	Contents insurance
Have enough money to make regular savings of £10 a month or more for rainy days or retirement?	Regular savings
Have enough money to replace any worn-out furniture?	Furniture
Have enough money to replace or repair major electrical goods such as a refrigerator or washing machine, when broken?	Electrical goods
Have a small amount of money to spend each week on yourself (not on your family)?	Money for self
Keep up with bills and regular debt repayments?	Bills
Pensioner items[74]	**Abbreviation**
Do you take a holiday away from home for a week or more at least once a year?	Holiday
Do you eat at least one filling meal a day?	Filling meal
Do you go out socially either alone or with other people, at least once a month?	Go out socially
Do you see friends and family at least once a month?	Friends & family
Would the cooker be able to be replaced if it broke down?	Replace cooker
Is your home kept in a good state of repair?	House
Are your heating, electrics, plumbing and drains kept in good working order?	Working order
Do you have a damp-free home?	Damp-free home
Is your home kept adequately warm?	Warm home
Do you have a telephone to use, whenever one is needed?	Phone
Do you have access to a car or taxi whenever one is needed?	Access to car/taxi
Do you have your hair done or cut regularly?	Haircut
Do you have a warm waterproof coat?	Coat
Would you be able to pay an unexpected expense of £200?	Unexpected expense

* Items are asked of households that either contain only working-age adults or working-age adults with one or more children aged 0 to 15 years. No persons of pensionable age are in these households.
**Items are only asked of households where there are no children aged 0 to 15 and where there is one or more adults of pensionable age.

[73] The reliability of the material deprivation scale overall: 0.841; for working-age adult households without children: 0.852; for working-age adult households with children: 0.825.
[74] The reliability of the material deprivation scale for pensioner households: 0.709.

8.7.2 Scoring material deprivation: Prevalence weighting

The first objective set for this study was to identify whether variations in material deprivation exist between fuel poor and non-fuel poor groups in the household population. To do this, *prevalence weighting* was used. This was first introduced by Desai and Shah (1988) and is the method used to produce statistics on material deprivation by the DWP for their reports on *Households Below Average Income* (DWP 2018b). Prevalence weighting is a technique of scoring material deprivation in which more weight, and therefore more importance, is given to items that are more widely possessed in society (DWP 2018b). As such, it is based on the idea that, as item weight increases, so does the severity of deprivation (DWP 2011).

To conduct prevalence weighting, it was firstly important to binary code the selected variables presented in Table 8.3 so that enforced lack, and therefore deprivation, could be identified. In line with the published documentation on identifying enforced lack (DWP 2018b), the items contained within the working-age adult material deprivation suite were binary coded, with "1" allocated to "I/We would like to have this but can't afford this" to identify enforced lack and, therefore, deprivation of that item, and "0" allocated to all other response categories (i.e. "I/We have this"; "I/We do not want/need this at the moment"; and "Does not apply") to indicate not being deprived of that item. For some items, such as *Furniture* or *House*, the "Does not apply" category captured households living in the private rented sector where the costs associated with these items may come under the responsibility of the landlord and so was coded as "0" to indicate not being deprived of these items. For pensioners, only those who selected "Yes", "No, not wanted", or "No, not relevant" are considered not deprived of that item and therefore coded as "0", with all other remaining response categories[75] identifying enforced lack and, therefore, being coded as "1". These binary coding decisions follow the methods used by the DWP in their reports on *Households Below Average Income* (2018b, pp.29–32).

[75] The remaining responses include: "No, no money for this"; "No, not a priority"; "No, health/disability prevents this"; "No, too much trouble/too tiring"; "No, no company/help"; and "Spontaneous: no, other".

Following binary coding of the selected variables shown in Table 8.3, material deprivation scores were calculated. Firstly, each score of 1 was weighted by the proportion of the population not being deprived of that item so that each score of 1 has a weight based on how widely possessed that item is. The weights of each item were then summed to produce a total weight. The relative prevalence of each item was then divided by this total weight and the sum was then multiplied by 100 to ease interpretation. In theory, prevalence weighting produces a continuous scale of scores ranging from 0 (where no items are lacked) to 100 (where all items are lacked) (DWP 2013). The weights and final scores assigned to each item for each household type is shown in Tables E.6 to E.8 in Appendix E.

8.7.2.1 Scoring material deprivation

Using prevalence weighting, different thresholds are used to classify households as materially deprived. For working-age adults with and without children who are living within a household that has a final score of 25 or more and an equivalised household income BHC below 70 per cent of median equivalised income are considered to be living in *low income and material deprivation* (DWP 2018b, p.29)[76]. Working-age adult households with and without children with a final score of 25 or more and an equivalised household income BHC below 50 per cent of median equivalised income are considered to be living in *severe low income and material deprivation* (DWP 2018b, p.30). For pensioners, a final score of 20 or more is used as the threshold for identifying material deprivation in these households. In contrast to working-age adult households with and without children where material deprivation is presented alongside a low-income threshold, material deprivation for pensioners is presented as a separate measure (DWP 2018b). This is due to the concept of material deprivation for pensioners being broader and very different from low income (DWP 2018b).

[76] For equivalising income BHC, the modified OECD scale is used. This allocates a score of 0.67 to the first adult and 0.33 to all other adults and any children aged 14 and over. Any children under the age of 14 are allocated a score of 0.20. A two adult household with no children is used as the reference point with a score of 1.0 (DWP 2018b, p.23).

8.7.3 Determining the order of curtailment: Item Response Theory

To determine the order of curtailment of material deprivation items and, therefore, address the second and third objectives set for this chapter in section 8.2, Item Response Theory (IRT) was employed. Also known as Latent Trait Analysis, IRT is used to explain the relationship between an unobservable characteristic, or latent trait, that cannot be measured directly – such as ability (Borgatto et al. 2015), quality of life (Borges et al. 2017), or material deprivation (Szeles and Fusco 2013; Deutsch et al. 2015; Najera Catalan 2017) – and responses to each item (Deutsch et al. 2015; Columbia University 2022). The application of this approach in this study draws on work conducted by Deutsch and colleagues (2015) who used IRT to identify the order of curtailment of material deprivation items in countries belonging to the European Union.

For the purpose of this research, a 2-parameter logistic (2PL) model was used[77] to explore the curtailment of material deprivation items presented in Table 8.3. This reflects the method used by others who have applied IRT to the study of material deprivation (Szeles and Fusco 2013; Deutsch et al. 2015; Najera Catalan 2017). Like the 1-parameter logistic (1PL) model, the 2PL model includes a *difficulty* (or *severity*) parameter. This parameter indicates the position on the latent trait variable (x-axis) – in this case, material deprivation – which is measured in standard deviation units, and is determined at the point of median probability (y-axis), i.e. the ability at which 50 per cent of respondents endorse a positive response, which, in this case, is those exhibiting enforced lack (or deprivation) of an item (Columbia University 2022). This is calculated using maximum likelihood estimation, which provides expected scores for each individual (Deutsch et al. 2015; Columbia University 2022) and creates the

[77] Before deciding on the 2-parameter logistic model, a 1-parameter logistic model and 2-parameter logistic model were conducted for the samples within each household type. Using a likelihood ratio test to determine the goodness of fit for each model, the 2-parameter logistic model was found to fit the data better with a significance level less than 0.001 across all three household types.

item characteristic curves, which visually represent the relationship between the latent trait and the item. An example of this is shown in Figure E.1 in Appendix E.

Unlike the 1PL model, the 2PL model also includes a *discrimination* parameter. Although not a key focus in this analysis, the discrimination parameter represents how well an item distinguishes between those who are deprived and those who are not (Deutsch et al. 2015; Najera Catalan 2017) and alters the steepness of the item characteristic curves, as shown in Figure E.1 in Appendix E. Whereas the 1PL model assumes the same discrimination across all items, the 2PL model does not, with this parameter reflecting the power of the items to discriminate between individuals whose latent scores of deprivation are below and above the item difficulty. As such, the discrimination parameter provides additional information as it influences the IRT estimation (Deutsch et al. 2015).

Using IRT to explore expenditure-curbing within the context of fuel poverty may further the understanding of the types of essential expenditures that fuel poor households forgo first and this may shed light on the differences in living standards of fuel poor and non-fuel poor households.

8.8 Analysis

The cross-sectional analysis presented in this section is based on pooled data from waves 4 and 6 of the UKHLS. Within these waves, there were 14,162 working-age adult households without children, 11,066 working-age adult households with children, and 13,195 pensioner households. The unit of analysis throughout this chapter is the household as the answers to items within deprivation suites are based on household responses. Households that have missing responses on any of the material deprivation items and those without a fuel poverty status have been excluded from the analysis. These households comprised less than 2 per cent of the sample and so re-weighting of the sample was not necessary. The characteristics associated with the highest likelihood of fuel poverty under each indicator using the UKHLS datasets are shown in Chapter 5 (see Table 5.23).

8.8.1 Descriptive analysis

In the following tables, the rates of fuel poverty, expenditure on fuel, and full household income, as well as the rates of material deprivation, are presented for each fuel poor and non-fuel poor group and the income poor in working-age adult households without children (Table 8.4), working-age adult households with children (Table 8.5), and pensioner households (Table 8.6). A comparison of the tables is provided, drawing on similarities and differences between the households. The rates of being deprived of each item for each household are presented in Tables E.9 to E.11 in Appendix E.

Table 8.4: *Descriptive analysis for working-age adult households without children [95% confidence intervals], UKHLS: waves 4 & 6, weighted*

	10 per cent indicator		**AFP indicator**		**Income poverty**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
Rate of fuel poverty (%)	-	**7.4 [6.9 – 7.9]**	-	**8.6 [8.0 – 9.1]**	-	-	
Median fuel expenditure (£/week)	21.14 [20.87 – 21.42]	**28.31 [27.05 – 29.56]**	20.90 [20.64 – 21.17]	**28.46 [27.89 – 29.04]**	22.36 [21.96 – 22.76]	**18.73 [18.13 – 19.32]**	21.78 [21.62 – 21.93]
Median household full income (£/week)	659.13 [647.98 – 670.27]	**193.08 [183.47 – 202.69]**	663.39 [651.72 – 675.06]	**257.13 [247.45 – 266.80]**	735.72 [724.40 – 747.05]	**235.46 [229.01 – 241.91]**	612.93 [603.04 – 622.83]
Low income and material deprivation (%)†[1]	7.7***	**43.6*** **	7.1***	**45.0*** **	1.3***	**48.9*** **	10.3 [9.6 – 11.1
Severe low income and material deprivation (%)† [2]	2.6***	**29.2*** **	3.2***	**19.5*** **	0.2***	**24.0*** **	4.6 [4.2 – 5.1]
Sample size	**13,112**	**1,050**	**12,966**	**1,196**	**11,646**	**2,516**	**14,162**

Note 1: The median values within the table are taken directly from the dataset. As the distributions of full income and fuel expenditure are skewed, this means that the median percentage of full income spent on fuel cannot be calculated from the median values of full income and fuel expenditure presented in the table.

Note 2: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

† Chi-squared tests were used to assess whether there is a statistically significant association between two categorical variables.

*p<0.05 **p<0.01 ***p<0.001

[1]A final prevalence weighting score of 25 or more and an equivalised household income BHC below 70 per cent of median equivalised income.

[2]A final prevalence weighting score of 25 or more and an equivalised household income BHC below 50 per cent of median equivalised income.

Table 8.4 presents descriptive analysis for working-age adult households without children. 7.4 per cent are fuel poor under the 10 per cent indicator and 8.6 per cent are fuel poor under the AFP indicator. The rates of fuel poverty under the two fuel poverty indicators are significantly different from each other given their non-overlapping confidence intervals. It is also observed that there is a statistically significant difference between the fuel expenditures and incomes of the fuel poor and non-fuel poor under each indicator as well as between the income poor and non-income poor. Mirroring findings in Chapter 5 (see Table 5.6), the fuel poor are shown to spend more on fuel than the non-fuel poor and income poor, with both fuel poor groups spending similar median weekly amounts (£28.31 for the fuel poor under the 10 per cent indicator and £28.46 for the fuel poor under the AFP indicator), and the income poor spending the least (£18.73). Both fuel poor groups have statistically significantly lower incomes than their non-fuel poor counterparts, with the fuel poor under the 10 per cent indicator having the lowest weekly full income (£193.08), followed by the income poor (£235.46) and the fuel poor under the AFP indicator (£257.13).

It is also observed that there is a statistically significant difference between measures of low income and material deprivation between the fuel poor and non-fuel poor groups under each fuel poverty indicator and between the income poor and non-income poor. The rates of low income and material deprivation are broadly similar across the fuel poor and income poor groups, with the income poor having the highest rates (48.9 per cent), followed by the fuel poor under the AFP indicator (45.0 per cent) and the fuel poor under the 10 per cent indicator (43.6 per cent). These rates do not follow levels of income, with the fuel poor under the 10 per cent indicator having the lowest income but not the highest rates of low income and material deprivation. This has also been found elsewhere (Berthoud et al. 2004; Whelan et al. 2004; Hick 2015) and may be linked to current income only capturing a temporary period of low income, which may not fully explain differences in the rates of material deprivation amongst different groups. It may also be linked to the use of full income, which may not reflect the true income that is available for households to spend freely. For example, as supported by analysis shown in Chapter 5 (see Table 5.23), households living in the private rented sector have higher likelihoods of fuel poverty under the AFP indicator and may use a significant proportion of income to pay for rent, potentially leaving a restricted amount of income available for other essential expenditures.

In contrast, levels of severe low income and material deprivation do follow levels of income, with the highest levels amongst the fuel poor under the 10 per cent indicator (29.2 per cent), followed by the income poor (24.0 per cent) and the fuel poor under the AFP indicator (19.5 per cent). A strong relationship has also been found between material deprivation and persistent low income[78], with the time spent in low income increasing the severity of disadvantage (Berthoud et al. 2004). This may suggest that the fuel poor under the 10 per cent indicator, who have the highest levels of severe low income and material deprivation, have experienced a low income for longer periods than other groups.

[78] This is defined as "at least three years out of four below thresholds of 60 or 70 per cent of median income" (DWP 2013b, p.247).

Table 8.5: *Descriptive analysis for working-age adult households with children [95% confidence intervals], UKHLS: waves 4 & 6, weighted*

	10 per cent indicator		**AFP indicator**		**Income poverty**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
Rate of fuel poverty (%)	-	**4.4 [4.0 – 4.8]**	-	**11.9 [11.2 – 12.6]**	-	-	-
Median fuel expenditure (£/week)	26.13 [24.62 – 28.34]	**40.46 [39.26 - 41.65]**	24.93 [24.46 – 25.40]	**37.06 [36.32 – 37.81]**	26.43 [26.10 – 26.76]	**26.04 [25.51 – 26.58]**	26.30 [26.15 – 26.44]
Median household full income (£/week)	755.35 [744.79 – 765.91]	**299.04 [282.66 – 315.42]**	785.93 [774.53 – 797.33]	**466.89 [455.84 – 477.95]**	854.76 [845.05 – 864.47]	**432.70 [423.77 – 441.64]**	734.91 [724.87 – 744.94]
Low income and material deprivation (%)[1]	13.0***	**59.4*** **	10.1***	**51.2*** **	1.9***	**54.7*** **	15.0 [14.1 – 15.9]
Severe low income and material deprivation (%)[2]	2.8***	**38.5*** **	3.0***	**14.8*** **	0.4***	**17.6*** **	4.4 [3.9 – 4.9]
Sample size	**10,542**	**524**	**9,656**	**1,410**	**8,298**	**2,768**	**11,066**

Note 1: The median values within the table are taken directly from the dataset. As the distributions of full income and fuel expenditure are skewed, this means that the median percentage of full income spent on fuel cannot be calculated from the median values of full income and fuel expenditure presented in the table.

Note 2: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.

† Chi-squared tests were used to assess whether there is a statistically significant association between two categorical variables.

*p<0.05 **p<0.01 ***p<0.001

[1]A final prevalence weighting score of 25 or more and an equivalised household income BHC below 70 per cent of median equivalised income.

[2]A final prevalence weighting score of 25 or more and an equivalised household income BHC below 50 per cent of median equivalised income.

Table 8.5 presents descriptive analysis for working-age adult households with children. In contrast to working-age adult households without children (Table 8.4), the rates of fuel poverty under the 10 per cent indicator are 3 percentage points lower at 4.4 per cent for working-age adult households with children. This is significantly lower than households without children as indicated by the non- overlapping confidence intervals.

However, the rates of fuel poverty under the AFP indicator are 3.3 percentage points higher at 11.9 per cent. This is significantly higher than households without children as indicated by the non-overlapping confidence intervals. These differences in fuel poverty rates between working-age adult households with and without children are linked to the behaviour of the fuel poverty indicators, where the AFP indicator has a higher propensity for capturing larger households and those containing children, while the 10 per cent indicator tends to capture single-adult households (see model 1 in Tables 5.19 and 5.20 in Chapter 5), further demonstrating the compositional heterogeneity of the fuel poverty indicators that was first highlighted in Chapter 5.

It is again observed that there is a statistically significant difference between the fuel expenditures and incomes of the fuel poor and non-fuel poor under each indicator as well as between the income poor and non-income poor. Median weekly fuel expenditure is higher across all groups compared to working-age adult households without children (Table 8.4) and, again, it can be seen that fuel poor households have higher fuel expenditures compared to non-fuel poor households and income poor households, with the fuel poor under the 10 per cent indicator having the highest median weekly fuel expenditure (£40.46). Although income is higher across households in this sample, both fuel poor groups have lower incomes than their non-fuel poor counterparts. The fuel poor under the 10 per cent indicator have the lowest levels of median weekly income (£299.04), followed by the income poor (£432.70), and the fuel poor under the AFP indicator (£466.89) and this reflects the order of income observed for working-age adult households without children in Table 8.4.

Like in table 8.4, it is observed that there is a statistically significant difference between the fuel poor and non-fuel poor under each fuel poverty indicator and the income poor and non-income poor in measures of low income and material deprivation. The rates of low income and material deprivation are higher in working-age adult households with children compared to those without children. However, in contrast to working-age adult households without children where the rates of low income and material deprivation do not follow levels of income, the opposite is observed here, with rates of low income and material deprivation increasing with decreasing levels of income. The fuel poor under the 10 per cent indicator have the lowest income and the highest rates of low income and material deprivation (59.4 per cent). This is followed by the income poor (54.7 per cent) and the fuel poor under the AFP indicator (51.2 per cent).

For the fuel poor under the AFP indicator and the income poor, the rates of severe low income and material deprivation are lower compared to those in working-age adult households without children. The fuel poor under the AFP indicator have severe low income and material deprivation rates that are 4.7 percentage points lower than those in working-age adult households without children at 14.8 per cent, and the income poor have severe low income and material deprivation rates that are 6.4 percentage points lower than those in working-age adult households without children at 17.6 per cent. Similar to working-age adults without children, the fuel poor under the 10 per cent indicator have the highest rates of severe low income and material deprivation at 38.5 per cent, which is 9.3 percentage points higher for working-age adult households with children.

Table 8.6: *Descriptive analysis for pensioner households [95% confidence intervals], UKHLS: waves 4 & 6, weighted*

	10 per cent indicator		**AFP indicator**		**Income poverty**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
Rate of fuel poverty (%)	-	**9.1 [8.6 – 9.6]**	-	**7.4 [6.9 – 7.8]**	-	**-**	-
Median fuel expenditure (£/week)	21.78 [21.62 – 21.93]	**29.64 [29.04 – 30.24]**	21.78 [21.74 – 21.81]	**28.20 [27.60 – 28.80]**	22.93 [22.45 – 23.41]	**19.16 [18.57 – 18.75]**	22.25 [22.02 – 22.49]
Median household full income (£/week)	481.08 [474.84 – 487.31]	**225.67 [219.82 – 231.51]**	475.00 [469.10 – 480.91]	**253.86 [244.47 – 263.24]**	495.86 [489.28 – 502.44]	**243.45 [236.97 – 248.93]**	451.35 [444.68 – 458.02]
Materially deprived (%)†[1]	5.2**	**9.8****	4.9***	**14.7*****	4.6***	**12.5*****	5.6 [5.1 – 6.1]
Sample size	**11,885**	**1,310**	**12,188**	**1,007**	**11,565**	**1,630**	**13,195**

Note 1: The median values within the table are taken directly from the dataset. As the distributions of full income and fuel expenditure are skewed, this means that the median percentage of full income spent on fuel cannot be calculated from the median values of full income and fuel expenditure presented in the table.
Note 2: Non-overlapping confidence intervals indicate that differences between groups are statistically significance.
† Chi-squared tests were used to assess whether there is a statistically significant association between two categorical variables.
*p<0.05 **p<0.01 ***p<0.001
[1]A final prevalence weighting score of 25 or more and an equivalised household income BHC below 70 per cent of median equivalised income.
[2]A final prevalence weighting score of 25 or more and an equivalised household income BHC below 50 per cent of median equivalised income.

Table 8.6 presents descriptive analysis for pensioner households. In contrast to working-age adult households with and without children, the rates of fuel poverty under the 10 per cent indicator are highest for pensioner households, at 9.1 per cent, and lowest under the AFP indicator at 7.4 per cent. As previously mentioned, this draws attention to the behaviour of the indicators, where older households have higher rates of fuel poverty under the 10 per cent indicator (see Table 5.17 in Chapter 5). It is also noted that rates of fuel poverty for pensioner households under the two indicators are significantly different to those for households with and without children as indicated by the non-overlapping confidence intervals. Again, like for households with and without children, expenditure on fuel and household incomes are significantly different between the fuel poor and non-fuel poor under each fuel poverty indicator and the income poor and non-income poor. As shown for working-age adults with and without children, the fuel poor are spending consistently more on fuel compared to non-fuel poor and income poor groups. The fuel poor under the 10 per cent indicator have the highest median weekly expenditure on fuel (£29.64) and this is followed by the fuel poor under the AFP indicator (£28.20) and the income poor (£19.16). These values are similar to those for working-age adult households without children (Table 8.4), but lower than fuel expenditure values for working-age adult households with children (Table 8.5).

Again, it is observed that the fuel poor under the 10 per cent indicator have significantly the lowest weekly incomes overall (£225.67), followed by the income poor (£243.45) and the fuel poor under the AFP indicator (£253.86), which is a consistent pattern across all three household types. However, as observed for working-age adult households without children, levels of income do not follow patterns of material deprivation as the fuel poor under the 10 per cent indicator are shown to have the lowest rates of material deprivation (9.8 per cent), followed by the income poor (12.5 per cent), with the highest rates for the fuel poor under the AFP indicator (14.7 per cent).

8.8.2 The order of curtailment of essential items: Results from Item Response Theory

To fulfil the second and third objectives set for this study (see section 8.2), IRT was conducted to determine the order of curtailment of essential items contained in working-age adult and pensioner material deprivation suites. This method was described in section 8.7.3.

In the following tables, the results of the 2PL IRT models for working-age adult households with and without children and for pensioner households are presented, identifying the order of curtailment for material deprivation items for these households. Using a 2PL model produced difficulty and discrimination parameters for each item, as described in section 8.7.3. The difficulty parameter, presented as standard deviation units, is the main focus here as this is the parameter that determines the order in which items are curtailed and is used to identify differences between groups that forgo items at the same position in the order of curtailment.

In the context of this research, the difficulty parameter indicates the severity of deprivation for a given item (Najera Catalan 2017), with positive standard deviation values indicating that expenditures are more difficult to curtail and are curtailed later (and higher levels of material deprivation), and negative standard deviation values indicating expenditures that are easier to curtail and are curtailed first (and lower levels of material deprivation). Standard deviation values around zero suggest a situation in which people are equally likely (50 per cent) to be deprived of a given item (Najera Catalan 2017). The discrimination parameter values for each item within each household type of focus is provided in Table E.12 to Table E.14 in Appendix E.

To facilitate interpretation of the data and following the approach adopted by Deutsch and colleagues (2015), the order of curtailment for each suite of material deprivation items is presented as a heatmap, with red indicating the first item to be curtailed and green the last. Only items that have a statistically significant difficulty parameter will be discussed. The results are interpreted from a fuel poverty perspective, drawing on the literature provided earlier in section 8.5 and the broader literature provided in Chapters 2 and 3.

8.8.2.1 Working-age adult households without children

Table 8.7 presents the values of the difficulty parameters for each of the material deprivation items for working-age adult households without children. These have been used to create the curtailment order of items, which is presented as a heatmap in Table 8.8.

Table 8.7: *Difficulty parameter values from 2PL models for material deprivation items in working-age adult households without children, UKHLS: waves 4 & 6, weighted*

Item	Coefficient (clustered robust standard errors)						
	10 per cent indicator		**AFP indicator**		**Below the poverty line**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Holiday"	0.984 (0.017)***	**0.229 (0.052)*** **	1.013 (0.018)***	**0.047 (0.054)**	1.158 (0.023)***	**0.553 (0.041)**	0.923 (0.016)***
"House"	1.734 (0.035)***	**1.116 (0.089)*** **	1.751 (0.036)***	**1.090 (0.084)*** **	1.783 (0.040)***	**1.261 (0.067)*** **	1.667 (0.031)***
"Contents insurance"	1.609 (0.030)***	**0.864 (0.072)*** **	1.664 (0.032)***	**0.690 (0.063)*** **	1.906 (0.047)***	**0.747 (0.050)*** **	1.527 (0.027)***
"Regular savings"	0.921 (0.013)***	**0.046 (0.046)**	0.941 (0.014)***	**-0.015 (0.043)**	1.092 (0.018)***	**-0.017 (0.052)**	0.852 (0.012)***
"Furniture"	0.738 (0.010)***	**0.044 (0.032)**	0.757 (0.010)***	**-0.067 (0.032)* **	0.855 (0.012)***	**-0.045 (0.025)**	0.688 (0.009)***
"Electrical goods	0.885 (0.011)***	**0.233 (0.036)*** **	0.906 (0.012)***	**0.115 (0.034)** **	1.027 (0.014)***	**0.082 (0.027)** **	0.836 (0.011)***
"Money for self"	1.234 (0.019)***	**0.505 (0.050)*** **	1.266 (0.020)***	**0.366 (0.049)*** **	1.376 (0.024)***	**0.475 (0.040)*** **	1.167 (0.017)***
"Bills"	2.004 (0.042)***	**1.272 (0.088)*** **	2.016 (0.043)***	**1.307 (0.094)*** **	2.181 (0.056)***	**1.411 (0.074)*** **	1.904 (0.036)***
Sample size	**13,112**	**1,050**	**12,966**	**1,196**	**11,646**	**2,516**	**14,162**

Note: The standard errors were clustered to account for changes in the HRP across the waves.
*p<0.05 **p<0.01 ***p<0.001

Table 8.8: *The order of curtailment for adult material deprivation items in working-age adult households without children, UKHLS: waves 4 & 6*

Item	10 per cent indicator		AFP indicator		Income poverty		Whole sample
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Furniture"	1	**1**NS	1	**1**	1	**1** NS	1
"Electrical goods"	2	**4**	2	**4**	2	**4**	2
"Regular savings"	3	**2**NS	3	**2** NS	3	**2** NS	3
"Holiday"	4	**3**	4	**3** NS	4	**3** NS	4
"Money for self"	5	**5**	5	**5**	5	**5**	5
"Contents insurance"	6	**6**	6	**6**	7	**6**	6
"House"	7	**7**	7	**7**	6	**7**	7
"Bills"	8	**8**	8	**8**	8	**8**	8
Sample size	**13,112**	**1,050**	**12,966**	**1,196**	**11,646**	**2,516**	**14,162**

NS: Non-significant

In working-age adult households without children, *Furniture* is the first item to be curtailed across all groups, although for the fuel poor under the 10 per cent indicator and the income poor, this is not statistically significant. Compared to both non-fuel poor groups and the non-income poor group, the fuel poor under the AFP indicator forgo this item earliest, as shown by their lowest difficulty parameter (-0.067) (see Table 8.7).

Although *Electrical goods* is the next item to be curtailed for both non-fuel poor groups, it is in the 4th position for both fuel poor groups and the income poor, although it is forgone first by the income poor (0.082) and latest by the fuel poor under the 10 per cent indicator (0.233). This finding appears to support the literature, which suggests that fuel poor households are less likely to replace electrical goods (Boardman et al. 1997; Brunner et al. 2012) and is a factor that may contribute to higher fuel expenditure in fuel poor households as older appliances tend to be less energy efficient. Alternatively, the results could suggest that *Electrical goods* are considered more essential and are prioritised amongst the fuel poor. All groups curtail *Money for self* at the 5th position, with the fuel poor under the AFP indicator forgoing this first (0.366), followed by the income poor (0.475), and the fuel poor under the 10 per cent indicator (0.505). Interestingly, this does not follow levels of income shown in Table 8.4, where the fuel poor under the AFP indicator have the highest incomes. As mentioned above, the analysis in Chapter 5 showed that those who are fuel poor under the AFP indicator are most likely to live in the private rented sector (see Table 5.23) and those in the private rented sector have the highest housing costs compared to other tenures and the largest difference between income BHC and AHC (Department for Communities and Local Government 2017). This may mean that the fuel poor under the AFP indicator have more burdensome housing costs that leave them with lower amounts of disposable income.

Apart from the non-income poor, all groups curtail *Contents insurance* at the 6th position, with the fuel poor under the AFP indicator forgoing this first (0.690), followed by the income poor (0.747), and the fuel poor under the 10 per cent indicator (0.864). Similarly, the fuel poor under the AFP indicator are the first to forgo *House* (7th position) (1.090), followed by the fuel poor under the 10 per cent indicator (1.116) and the income poor (1.268). This may suggest that the fuel poor under the AFP indicator have the worst housing conditions overall.

Bills is the last item to be curtailed across all groups and this could reflect that bills are viewed as an inflexible expenditure that is prioritised, as shown in some of the literature (Harrington et al. 2005; Anderson et al. 2010). However, the fuel poor curtail this earlier than all other groups as shown by their lower difficulty parameter values. The fuel poor under the 10 per cent indicator curtail this item earliest (1.272), followed by the fuel poor under the AFP indicator (1.307), and the income poor (1.441). These findings may be indicative of the burden that bills place on household resources, particularly for the fuel poor under the 10 per cent indicator who have the lowest incomes overall (see Table 8.6).

8.8.2.2 Working-age adult households with children

Table 8.9 presents the difficulty parameter values for material deprivation items for working-age adult households with children, and these have been used to produce the heatmap of curtailment order shown in Table 8.10.

Table 8.9: *Difficulty parameter values from IRT 2PL models for material deprivation items in working-age households containing children, UKHLS: waves 4 & 6, weighted*

Item	Coefficient (clustered robust standard errors)						
	10 per cent indicator		**AFP indicator**		**Below the poverty line**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Holiday"	0.752 (0.022)***	**-0.293 (0.102)****	0.832 (0.024)***	**-0.230 (0.068)****	1.045 (0.032)***	**-0.219 (0.052)*****	0.701 (0.021)***
"House"	1.749 (0.046)***	**1.123 (0.160)*****	1.774 (0.049)***	**1.346 (0.114)*****	1.797 (0.054)***	**1.478 (0.092)*****	1.705 (0.044)***
"Contents insurance"	1.477 (0.035)***	**0.633 (0.115)*****	1.548 (0.039)***	**0.802 (0.084)*****	1.866 (0.059)***	**0.726 (0.057)*****	1.420 (0.033)***
"Regular savings"	0.698 (0.017)***	**-0.077 (0.076)**	0.766 (0.019)***	**-0.038 (0.048)**	0.903 (0.023)***	**0.013 (0.037)**	0.660 (0.016)***
"Furniture"	0.423 (0.012)***	**-0.138 (0.060)***	0.472 (0.013)***	**-0.157 (0.037)*****	0.576 (0.015)***	**-0.150 (0.028)*****	0.400 (0.012)***
"Electrical goods"	0.618 (0.014)***	**-0.063 (0.062)**	0.677 (0.015)***	**-0.063 (0.041)**	0.817 (0.018)***	**-0.045 (0.030)**	0.586 (0.013)***
"Money for self"	0.789 (0.019)***	**0.039 (0.084)**	0.848 (0.020)***	**0.099 (0.054)**	0.995 (0.025)***	**0.112 (0.040)****	0.752 (0.018)***
"Bills"	1.791 (0.043)***	**1.127 (0.145)*****	1.903 (0.051)***	**1.121 (0.083)*****	2.067 (0.066)***	**1.286 (0.072)*****	1.740 (0.040)***
Sample size	**10,542**	**524**	**9,656**	**1,410**	**8,298**	**2,768**	**11,066**

Note: The standard errors were clustered to account for changes in the HRP across the waves.
*p<0.05 **p<0.01 ***p<0.001

Table 8.10: *The order of curtailment for material deprivation items in working-age adult households with children, UKHLS: waves 4 & 6*

Item	10 per cent indicator		AFP indicator		Income poverty		Whole sample
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Furniture"	1	**2**	1	**2**	1	**2**	1
"Electrical goods"	2	**4** NS	2	**3** NS	2	**3** NS	2
"Regular savings"	3	**3** NS	3	**4** NS	3	**4** NS	3
"Holiday"	4	**1**	4	**1**	5	**1**	4
"Money for self"	5	**5** NS	5	**5** NS	4	**5**	5
"Contents insurance"	6	**6**	6	**6**	7	**6**	6
"House"	7	**7**	7	**8**	6	**8**	7
"Bills"	8	**8**	8	**7**	8	**7**	8
Sample size	**10,542**	**524**	**9,656**	**1,410**	**8,298**	**2,768**	**11,066**

NS: Non-significant

In contrast to working-age adult households without children (Table 8.8), fuel poor working-age adult households with children forgo *Holiday* first along with the income poor. Conversely, this is forgone at the 4th position for both non-fuel poor groups and at the 5th position for non-income poor households. The fuel poor under the 10 per cent indicator forgo this item earliest (-0.293) and this may be linked to having the lowest incomes (see Table 8.5), followed by the fuel poor under the AFP indicator (-0.230), and the income poor (-0.219). This may demonstrate a prioritisation for more immediate expenditures, which may be influenced by the presence of children within the household. However, it may also be driven by the higher costs associated with taking children on holiday and the restrictions in times within which families with children can take holidays, often corresponding to the school holiday period, where travel costs are often higher. As such, holidays for households with children may consume significantly more of the household budget compared to households without children and may, therefore, be an essential expenditure that is not prioritised as highly as within working-age adult households without children.

Similar to working-age adult households without children, the non-fuel poor and non-income poor forgo *Furniture* first. However, the fuel poor and income poor forgo this second, with the fuel poor under the AFP indicator forgoing this earliest (-0.157), followed by the income poor (-0.150) and the fuel poor under the 10 per cent indicator (-0.138).

Similar to households without children (Table 8.8) *Contents insurance* is forgone at the 6th position across all groups except for the non-income poor, who forgo this at the 7th position, with the fuel poor under the 10 per cent indicator forgoing this first (0.633), followed by the income poor (0.726), and the fuel poor under the AFP indicator (0.802). Where *Bills* was consistently forgone last (8th position) in working-age adult households without children, this is forgone in the 7th position for the fuel poor under the AFP indicator and the income poor in working-age adult households with children, with the fuel poor under the AFP indicator forging this first (1.121). Instead, for both of these groups, *House* is the last item to be curtailed with the fuel poor under the AFP indicator forgoing this first (1.346 vs. 1.478). This could possibly indicate a higher importance placed on the conditions of the home, which may have an immediate impact on the child's health. This could also suggest that the fuel poor under the 10 per cent indicator have worse housing conditions compared to the fuel poor under the AFP indicator and the income poor in these households.

8.8.2.3 Pensioner households

Table 8.11 presents the difficulty parameter values for pensioner material deprivation items and these correspond to the order of curtailment of these items presented in Table 8.12. The items used to determine pensioner material deprivation are perhaps more interesting from a fuel poverty perspective compared to items for working-age adult households with and without children. This is because they include items that have traditionally been closely linked with fuel poverty, such as the ability to keep the home warm and damp-free (Boardman 2010; Thomson and Snell 2013; Grey et al. 2017a).

Table 8.11: *Difficulty parameter values from 2PL IRT models for pensioner material deprivation items, UKHLS: waves 4 & 6, weighted*

Item	Coefficient (clustered robust standard errors)						
	10 per cent indicator		**AFP indicator**		**Below the poverty line**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Holiday"	1.141 (0.036)***	**0.764 (0.081)*** **	1.147 (0.037)***	**0.605 (0.085)*** **	1.170 (0.041)***	**0.702 (0.072)*** **	1.101 (0.033)***
"Filling meal"	3.353 (0.184)***	**4.142 (0.753)*** **	3.321 (0.176)***	**4.212 (1.325)** **	3.206 (0.174)***	**4.738 (1.226)*** **	3.422 (0.178)***
"Go out socially"	1.908 (0.059)***	**1.771 (0.172)*** **	1.922 (0.060)***	**1.550 (0.158)*** **	1.833 (0.062)***	**1.893 (0.178)*** **	1.890 (0.055)***
"Friends & family"	3.642 (0.218)***	**3.612 (0.544)*** **	3.588 (0.210)***	**4.605 (1.021)*** **	3.554 (0.226)***	**4.529 (0.820)*** **	3.648 (0.202)***
"Replace cooker"	1.838 (0.041)***	**1.459 (0.076)*** **	1.898 (0.045)***	**1.185 (0.062)*** **	1.925 (0.051)***	**1.309 (0.062)*** **	1.792 (0.036)***
"House"	2.976 (0.126)***	**2.372 (0.204)*** **	2.922 (0.121)***	**2.632 (0.290)*** **	2.980 (0.134)***	**2.669 (0.261)*** **	2.875 (0.108)***
"Working order"	3.255 (0.158)***	**2.842 (0.342)*** **	3.150 (0.145)***	**3.374 (0.537)*** **	3.265 (0.161)***	**2.904 (0.285)*** **	3.183 (0.140)***
"Damp-free"	3.916 (0.279)***	**3.837 (0.731)*** **	3.866 (0.268)***	**4.314 (1.173)*** **	3.982 (0.316)***	**3.719 (0.610)*** **	3.895 (0.256)***
"Warm home"	3.205 (0.139)***	**2.489 (0.245)*** **	3.112 (0.148)***	**2.169 (0.208)*** **	3.090 (0.160)***	**2.522 (0.217)*** **	2.931 (0.118)***
"Telephone"	3.838 (0.242)***	**4.290 (1.486)** **	3.954 (0.290)***	**3.555 (0.863)*** **	4.031 (0.335)***	**3.583 (0.553)*** **	3.884 (0.270)***
"Access to car/taxi"	2.556 (0.089)***	**2.426 (0.255)*** **	2.539 (0.087)***	**2.552 (0.318)*** **	2.580 (0.096)***	**2.474 (0.258)*** **	2.536 (0.083)***
"Haircut"	2.426 (0.075)***	**2.074 (0.161)*** **	2.507 (0.080)***	**1.711 (0.134)*** **	2.512 (0.085)***	**1.953 (0.130)*** **	2.377 (0.067)***
"Coat"	3.154 (0.173)***	**4.669 (1.379)** **	3.184 (0.168)***	**4.011 (1.268)** **	3.241 (0.192)***	**3.435 (0.594)*** **	3.261 (0.179)***
"Unexpected expense"	1.632 (0.037)***	**1.316 (0.063)*** **	1.716 (0.042)***	**0.900 (0.044)*** **	1.761 (0.049)***	**1.017 (0.051)*** **	1.595 (0.032)***
Sample size	**11,885**	**1,310**	**12,188**	**1,007**	**11,565**	**1,630**	**13,195**

Note: The standard errors were clustered to account for changes in the HRP across the waves.
*p<0.05 **p<0.01 ***p<0.001

Table 8.12: *The order of curtailment for material deprivation items in pensioner households, UKHLS, waves 4 & 6*

Item	10 per cent indicator		AFP indicator		Income poverty		Whole sample
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Holiday"	1	**1**	1	**1**	1	**1**	1
"Unexpected expense"	2	**2**	2	**2**	2	**2**	2
"Replace cooker"	3	**3**	3	**3**	4	**3**	3
"Go out socially"	4	**4**	4	**4**	3	**4**	4
"Haircut"	5	**5**	5	**5**	5	**5**	5
"Access to car/taxi"	6	**7**	6	**7**	6	**6**	6
"House"	7	**6**	7	**8**	7	**8**	7
"Warm home"	8	**8**	8	**6**	8	**7**	8
"Working order"	10	**9**	9	**9**	11	**9**	9
"Coat"	9	**14**	10	**11**	10	**10**	10
"Filling meal"	11	**12**	11	**12**	9	**14**	11
"Friends & family"	12	**10**	12	**14**	12	**13**	12
"Telephone"	13	**13**	14	**10**	14	**11**	13
"Damp-free"	14	**11**	13	**13**	13	**12**	14
Sample size	**11,885**	**1,310**	**12,188**	**1,007**	**11,565**	**1,630**	**13,195**

Table 8.12 shows that, for pensioner households, the order of curtailment for the first five items is the same across all groups, except for the non-income poor: *Holiday, Unexpected expense*, *Replace cooker*, *Go out socially*, and *Haircut*. This order appears to represent a gradient of expenses, beginning with forgoing items that are typically more expensive (*Holiday*) to those that are less expensive (*Haircut*). However, by inspecting the difficulty parameters in Table 8.11, it can be observed that different groups forgo items at different speeds, with the fuel poor under the AFP indicator forgoing all these items earliest. This is followed by the income poor for *Holiday, Replace cooker*, *Haircut*, and *Unexpected expense*, and then the fuel poor under the 10 per cent indicator for *Go out socially*.

Of interest in the context of fuel poverty is the position in the curtailment order of *Damp-free* and *Warm home*. The fuel poor under the 10 per cent indicator and the income poor forgo *Damp-free* at the 11th position and 12th position, respectively. The fuel poor under the AFP indicator forgo this later at the 13th position. This could indicate prioritisation of keeping the home damp-free for this group. However, *Warm home* is curtailed earliest for the fuel poor under the AFP indicator (6th position), followed by the income poor (7th position) and the fuel poor under the 10 per cent indicator (8th position). This may reflect the burden of fuel bills and the presence of a cold home for the fuel poor under the AFP indicator, despite their weekly fuel expenditure being lower than the fuel poor under the 10 per cent indicator (see Table 8.6), and could indicate the prioritisation of a warm home for the fuel poor under the 10 per cent indicator who are shown to have higher fuel expenditures (see Table 8.6).

Of further interest is that both fuel poor groups within pensioner households forgo *Coat* later than their non-fuel poor counterparts and the income poor, with the fuel poor under the 10 per cent indicator forgoing this at the 14th position and the fuel poor under the AFP indicator forgoing this at the 11th position. This could suggest that both fuel poor groups have an acute sense of the cold and may rely on warm clothing – including outdoor clothing – to stay warm indoors, as has been shown in other studies (Harrington et al. 2005; Cotter et al. 2012; Middlemiss and Gillard 2015; Chard and Walker 2016).

There are also three items within the pensioner material deprivation suite that could provide further insights into aspects of socialisation: *Go out socially*, *Family & friends,* and *Telephone*. *Go out socially* is curtailed earlier for both fuel poor groups, with the fuel poor under the AFP indicator forgoing this first (1.550). This is a rather subjective item that may have different meanings for different groups. It may be useful at this point, however, to draw upon the characteristics associated with the highest likelihood of fuel poverty under each indicator, which was identified in Chapter 5 (see Table 5.23) and which may help to understand the ordering behind the curtailment of these items. Of particular importance here is that there is a higher likelihood of fuel poverty under the 10 per cent indicator for those living in rural areas. In contrast, those living in urban areas have a higher likelihood of fuel poverty under the AFP indicator (given their concentration in the private rented sector). Social activities may be more costly in urban areas and this may provide an explanation for why the fuel poor under the AFP indicator curtail *Go out socially* before the fuel poor under the 10 per cent indicator. However, *Friends & family* is curtailed earliest by the fuel poor under the 10 per cent indicator, at the 10th position, whereas *Telephone* is forgone later for this group, at the 13th position. This may indicate different preferences or abilities for maintaining social contact, particularly for the fuel poor under the 10 per cent indicator who may be limited by a lack of frequent and reliable public transport in rural areas, which may limit their ability to visit friends and family.

This analysis also provides insight into the housing conditions of the groups. *House* is forgone earliest for the fuel poor under the 10 per cent definition at the 6th position, while for the fuel poor under the AFP indicator and the income poor this was at the 8th position, with the fuel poor under the AFP indicator forgoing this earlier (2.632 vs. 2.669). This may suggest that the fuel poor under the 10 per cent indicator have the worst housing conditions overall amongst pensioner households. *Working order* is curtailed earliest at the 9th position for the fuel poor under the 10 per cent indicator, the fuel poor and the non-fuel poor under the AFP indicator, and the income poor. This is curtailed earliest by the fuel poor under the 10 per cent indicator (2.842), followed by the income poor (2.904), and the fuel poor under the AFP indicator (3.374).

8.9 Discussion

This chapter has aimed to expand the literature on expenditure-curbing of essential items contained within material deprivation suites for the fuel poor in working-age adult households and pensioner households. More specifically, this chapter has explored the order of curtailment of essential expenditures in working-age adult households, with and without children, and in pensioner households as a way of understanding the effects of differing patterns of curtailment on the living standards of the fuel poor and non-fuel poor in different household types, but also as a way of highlighting differences in living standards between the fuel poor and income poor.

8.9.1 Key findings

Using prevalence weighting to identify rates of material deprivation amongst the fuel poor using different indicators within different household types, it was noted that in working age-adult households with and without children, the fuel poor under the 10 per cent indicator had the lowest living standards, as indicated by their highest rates of severe low income and material deprivation. However, for pensioner households, it was the fuel poor under the AFP indicator that had the highest levels of material deprivation. This suggests that disadvantage varies by the fuel poverty indicator used and the household type it is used in, reinforcing the inter- and intra-indicator heterogeneity of fuel poverty found in Chapters 6 and 7.

The following two subsections draw attention to the key findings that have emerged from this chapter, focusing specifically on the sequence of curtailment for the fuel poor and both non-fuel poor groups, and how differences in the order of curtailment between the fuel poor and income poor can shed light on differences in the living standards between these groups, aligning with the objectives set for this chapter in section 8.2 with novel insights into the heterogeneous nature of fuel poverty interwoven throughout these sections.

8.9.1.1 How do the fuel poor and non-fuel poor differ in their orders of curtailment?

Although prevalence weighting revealed differences in material deprivation rates between groups within the three different household types of focus, it was not clear whether standards of living were affected in the same way amongst both fuel poor and non-fuel poor groups. To explore this further, IRT was employed to determine the order in which essential expenditures were curtailed within these groups as a way of providing further insights into the types of essential expenditures that are curtailed or prioritised within households, and how this affects standards of living between the fuel poor and non-fuel poor. This fulfilled the second objective set for this chapter.

In general, the results of IRT showed that, where the location of items was the same in the order of curtailment across fuel poor and non-fuel poor groups, it was the fuel poor that forwent items earlier, as indicated by the values of the difficulty parameter. This was found across all three household types, suggesting that that the fuel poor experience material deprivation earlier.

Despite suites of material deprivation for working-age adult and pensioner households not being comparable due to their different items, similarities can still be drawn between the different household types. Across all households, it is the expenditures that often represent the largest sums of money – and possibly place the greatest burden on income – that are curtailed first. For example, *Furniture* and *Holiday* are two of the first items to be curtailed in working-age adult households, with and without children, and in pensioner households. Similar findings have been demonstrated by Deutsch and colleagues (2015) who found that these items were two of the first items to be curtailed in households across the European Union.

Of particular interest in comparing the fuel poor and non-fuel poor was the finding that both fuel poor groups in working-age adult households without children curtailed *Electrical* *goods* later in the order compared to non-fuel poor groups and the income poor (Table 8.8). This may support the evidence that suggests that fuel poor households are less likely to replace electrical goods (Boardman et al. 1997; Brunner et al. 2012) and this could contribute to higher fuel costs as older appliances tend to be less energy efficient, which may increase fuel expenditure and emphasise the burden of fuel bills.

In contrast to working-age adult households with and without children, the order of curtailment of essential expenditures in pensioner households revealed broader insights into how fuel poverty may be experienced under different indicators. For example, *Warm home* was curtailed earliest by the fuel poor under the AFP indicator (see Table 8.12). This may suggest that fuel bills place a significant burden on income and that these households may be less able to keep their homes adequately warm and, therefore, may be more likely to experience a cold home. However, this is a subjective item that relies on reaching a perceived level of thermal comfort, and the temperature at which this is achieved can vary widely from person to person and, as a result, the burden of fuel costs may also vary. As such, this does not account for the myriad of experiences that can occur within items.

Of further interest in pensioner households is that *Coat* is forgone later for fuel poor groups compared to both non-fuel poor groups, with the fuel poor under the 10 per cent indicator forgoing this last, suggesting that this may be a prioritised expenditure for this group. This is of interest in the context of fuel poverty, where the literature has shown that fuel poor householders use outdoor clothing indoors as a way of keeping warm (Harrington et al. 2005; Anderson et al. 2010; Cotter et al. 2012; Middlemiss and Gillard 2015). However, the analysis was not able to provide reasons for why this essential expenditure may be prioritised in fuel poor households.

8.9.1.2 How do the fuel poor and income poor differ in their orders of curtailment?

The third and final objective set for this chapter focused on identifying whether differences existed in the order of curtailment of essential expenditures between the fuel poor and the income poor as a way of determining differences between these groups. In identifying that rates of material deprivation were, at times, higher for the fuel poor (see Table 8.5, for example), this was explored further using IRT.

Of particular interest here were the items that shed light on the housing conditions of these groups. For example, in working-age adult households without children, *House* – although occupying the same position in the order of curtailment (7th position) – was forgone earlier for both fuel poor groups compared to the income poor, with the fuel poor under the AFP indicator forgoing this earliest as indicated by the value of its discrimination parameter (see Table 8.8). This may indicate that the fuel poor are exposed to poorer housing conditions compared to the income poor and that this may be more pronounced for the fuel poor under the AFP indicator. In working-age adult households with children, *House* is forgone last (8th position) for the fuel poor under the AFP indicator and the income poor but is forgone earlier (7th position) for the fuel poor under the 10 per cent indicator (see Table 8.10). This could suggest that the fuel poor under the 10 per cent indicator experience poorer housing conditions in these households compared to the income poor and the fuel poor under the AFP indicator.

Similarly, the pensioner suite of indicators contains items that provide an insight into the internal environment of the home. The fuel poor under both indicators forgo *House* at an earlier position compared to the income poor, with the fuel poor under the 10 per cent indicator forgoing this first. Furthermore, although being curtailed at the same location, *Working order* is forgone earliest for the fuel poor under the 10 per cent indicator. These items suggest that the fuel poor under the 10 per cent indicator have the poorest housing conditions, at least in pensioner households. This contrasts with the finding that the fuel poor under the AFP indicator are worse off in terms of housing conditions in working-age adult households with and without children, reinforcing the inter-indicator heterogeneity of fuel poverty that emerged in the previous two chapters.

8.10 Chapter summary and conclusions

Using material deprivation suites contained within the UKHLS, this chapter has further explored the types of essential expenditures that are curbed in working-age adult households, with and without children, and pensioner households. In particular, the chapter has explored the order in which these expenditures are curtailed amongst the fuel poor and non-fuel poor within these three household types. The purpose of this was to determine whether this could provide further insights into the experience of material deprivation within different household types under different indicators of fuel poverty.

The chapter found that, in general, the fuel poor forgo essential expenditures earlier than their non-fuel poor counterparts and, at times, the income poor, helping to further differentiate the fuel poor from the income poor. Furthermore, the chapter found that the order in which essential expenditures are curtailed differs between the fuel poverty indicators and amongst different household types under the same fuel poverty indicator, indicating that standards of living in different household types can be affected differently under the same definition of fuel poverty. This has reinforced the inter-indicator heterogeneity of fuel poverty and has helped to build on how the intra-indicator heterogeneity of fuel poverty, which was identified in Chapter 6, can be understood. Like in Chapter 6, where the fuel poor were found to have different experiences of food insecurity, as evidenced by their differing food expenditure patterns, the findings within this chapter suggest that material deprivation can also be experienced in various ways, as indicated by differing curtailment patterns of essential expenditures in different household types under the same fuel poverty indicator.

In the final chapter that follows, a discussion of all the analysis conducted within the thesis is presented, placing the findings within the broader context and highlighting their implications.

Chapter 9| Concluding discussion

9.1 Introduction

The research presented in this thesis has investigated the relationships that exist between fuel poverty and other forms of disadvantage through quantitative means and has explored whether identified relationships are moderated by the fuel poverty indicator used. The motivation underpinning this direction of research was to further understanding of fuel poverty and, in so doing, the experiences of the fuel poor, together with providing further insights into how the experience of disadvantage can vary under different fuel poverty indicators.

This final chapter of the thesis now focuses on the entirety of the research presented herein, collating the results from the analysis performed in Chapters 5 to 8 as a way of making sense of them collectively. In doing so, this chapter emphasises the novel contributions offered by the research, highlighting the implications of these contributions from a policy perspective, and proposes avenues for future research to further advance knowledge of fuel poverty, whilst critically reflecting on the thesis throughout. To begin with, the following section provides a summary of the thesis and recaps on the key results that have emerged from the research.

9.2 A summary of the thesis

In exploring the literature presented in Chapter 3, it was noted that previous research had highlighted aspects of food insecurity, social isolation, and material deprivation amongst those living in fuel poverty. Most often, these aspects were found to emerge as a consequence of the coping behaviours and strategies adopted by fuel poor households as a way of alleviating their experience of fuel poverty, but also from the impact that fuel poverty can have on the home through inadequate heating and lighting, and rationing the use of appliances and hot water as a way of keeping fuel bills affordable. Being dominated by qualitative inquiry, this area of the literature has helped to expose the lived experience of the fuel poor and has revealed the various methods that households use to cope with fuel poverty, which are influenced by a range of different factors, such as the presence of children within the home, and age and illness, for example. However, these studies used different ways of identifying fuel poverty – primarily a low income or an inability to keep the home adequately warm. This made it difficult to understand whether all elements of fuel poverty are consistently linked with other forms of disadvantage, or whether this relationship varies based upon different aspects, understandings, and definitions of fuel poverty.

In attempting to fill this research gap, the thesis aimed to further understand whether links between fuel poverty and other forms of disadvantage exist in fuel poor households using consistent fuel poverty indicators based on expenditure-based equivalents of official definitions of fuel poverty currently used in the UK, and whether identified relationships were moderated by the indicator used. The following three research questions were proposed:

1. How does fuel poverty impact on food insecurity?
2. What are the links between fuel poverty and social isolation?
3. Is there a difference in the order of curtailment of material deprivation items between fuel poor and non-fuel poor households?

9.2.1 The research approach

Given the nature of the proposed research questions and the various areas of disadvantage to be explored, analysis of secondary quantitative data was deemed to be the most appropriate methodological approach. This provided access to large-scale, nationally representative datasets, which allowed for the exploration of relationships between fuel poverty and the different areas of disadvantage stated in the research questions. The LCFS and UKHLS datasets were selected as, between them, they contained information that could be used to explore all three of the proposed research questions and, unlike qualitative research, these data sources allowed for the disentangling of identified relationships through controlling for a range of factors.

9.2.1.1 Conceptualising and identifying fuel poverty

Throughout the thesis, fuel poverty was conceptualised as spending a disproportionate amount of income on domestic fuel, adopting the original conceptualisation of fuel poverty put forward by Isherwood and Hancock (1979) and later reinforced by Boardman (1991; 2010). Using income and actual fuel expenditure data from the LCFS and the UKHLS, two expenditure-based fuel poverty indicators were constructed based on the two official fuel poverty indicators used in the UK at the time of writing. As already mentioned, the purpose of using two fuel poverty indicators served to explore whether any relationships identified were moderated by different ways of defining fuel poverty. The literature shows that different characteristics are captured by different fuel poverty definitions, as noted in Chapter 2 (see section 2.7), but it is so far unclear whether different definitions impact on the relationship between fuel poverty and other forms of disadvantage.

The created indicators reflected the two official fuel poverty definitions used in the UK at the time of writing – the 10 per cent definition and the Low Income High Costs (LIHC) indicator – and represented actual expenditure-based equivalents of these. These were termed the 10 per cent indicator and the Alternative Fuel Poverty (AFP) indicator, respectively, and those who were spending to the stated thresholds within these indicators, and were therefore considered to have disproportionate fuel costs, were classified as fuel poor, aligning with the conceptualisation of fuel poverty used throughout the thesis. As noted in Chapter 2, whilst actual fuel expenditure has traditionally been viewed as a poor indicator of fuel poverty (Hirsch et al. 2011; Moore 2012), using actual – rather than modelled – fuel expenditure has the advantage of capturing some of the challenges faced by the fuel poor, which may not be adequately represented by modelled fuel costs (Middlemiss 2016). Actual fuel expenditure incorporates those who have additional energy needs associated with physical vulnerabilities to the cold (such as a longstanding illness or disability), those who have higher fuel costs due to being on an energy tariff that is not appropriate for their needs, or those whose cultural practices and habits increase energy usage, factors that are not considered in modelling fuel costs[79]. However, it was acknowledged that using actual fuel expenditure excludes those who are not spending to the necessary thresholds to be classified as fuel poor, despite potentially experiencing aspects of fuel poverty. This includes those who are purposely rationing their fuel use as a way of curbing fuel expenditure to avoid high fuel bills and the incurrence of debt. As such, the findings within the thesis are only relevant to those who *are* spending to the thresholds within the created actual expenditure-based fuel poverty indicators used, which may also include those with preferences for warmer homes and the capability to fulfil those preferences, and those who are wasteful. A closer look at actual fuel expenditure and how it compares with modelled fuel costs was taken in Chapter 5 and a summary of this chapter is provided in section 9.3.1 below.

9.3 A recap of the key findings

The research questions stated in section 9.2 were addressed in Chapters 6, 7, and 8 of the thesis, with an in-depth examination of the two fuel poverty indicators used throughout the research – the 10 per cent indicator and the AFP indicator – presented in Chapter 5. The findings from each analysis chapter are detailed in the following four subsections.

9.3.1 Who are the fuel poor? A look back at Chapter 5

Before addressing the proposed research questions stated in section 9.2, Chapter 5 provided a broad and comprehensive examination of both the constructed fuel poverty indicators – the 10 per cent indicator and the AFP indicator. The chapter compared differences between actual fuel expenditure contained within the LCFS and the UKHLS datasets with modelled fuel expenditure provided by the *Fuel Poverty datasets*, which are produced from data collected

[79] Apart from in Scotland, where a higher temperature of 23˚C in the main living area is recommended for households with individuals aged 60 and over or with someone with a longstanding illness or disability (Scottish Government 2018a).

through the EHS. It also compared fuel poverty rates produced by the constructed indicators with official fuel poverty statistics and detailed how the diverse components of the indicators change who is classified as fuel poor.

In comparing actual and modelled fuel costs across income deciles, the chapter showed that these aligned relatively well for the LCFS data, but less so for the UKHLS data, which found a consistent under-spending across income deciles. This was suggested to be linked to differences in the period for which fuel expenditure data are collected within the surveys, with the UKHLS covering a longer period of time, which may make keeping track of more sporadic payments, such as those related to PPMs, more difficult. There were also differences identified between the rates of fuel poverty produced by the constructed indicators and official fuel poverty statistics and it was acknowledged that the constructed indicators were perhaps capturing different households to those within official fuel poverty statistics due to differences in methodologies. For example, a household whose actual expenditure is above the threshold in expenditure-based indicators may have modelled fuel costs that are below the threshold, and so a household may be fuel poor using actual expenditure but not modelled fuel costs, and vice versa.

A particular focus in this chapter was given to the contrast observed between the actual expenditure-based 10 per cent indicator used in the thesis and Boardman's 10 per cent definition. Unlike Boardman's 10 per cent definition, the 10 per cent indicator used in the thesis captured high absolute fuel expenditures, which were found to be greater than for households that were neither fuel poor nor income poor. It was noted that similar findings have been observed elsewhere (Palmer et al. 2008; Waddams Price et al. 2012; Deller et al. 2021) and this finding was linked to the literature on the poverty premium and how it can lead to higher fuel costs. However, this conflict was attributed to differences in how the 10 per cent threshold had been applied, with Boardman defining this threshold based on dividing the sample in the 1988 *Family Expenditure Survey* into households with the lowest three income deciles and the remaining seven income deciles. Boardman found that households in the lowest three income deciles were spending 10 per cent of their income on fuel and this formed the basis of the 10 per cent definition. In contrast, the 10 per cent threshold was applied across the whole sample in this thesis and this is where the conflict had arisen.

This chapter also noted differences between fuel poverty rates produced by the constructed fuel poverty indicators from each dataset and this was attributed to differences in levels of income between the surveys, with households in the UKHLS having higher levels of income and indicators produced using this dataset showing consistently lower rates of fuel poverty compared to those produced with the LCFS dataset, where incomes were lower.

Logistic regression analysis was then used to identify the determinants of fuel poverty under the 10 per cent indicator and the AFP indicator. In doing so, the characteristics of the fuel poor under each indicator from both datasets that had the highest likelihoods of fuel poverty after controlling for other factors were identified and provided a point of reference for the remainder of the analysis chapters (see Table 5.23 in Chapter 5). This analysis emphasised how different components within indicators can change the characteristics of those classified as fuel poor. In agreement with existing evidence (see Boardman 2010; Moore 2012, for example), the use of a full income measure under the 10 per cent indicator captured owner-occupied households, whereas an equivalised household income AHC used in the AFP indicator captured those in the private rented sector. Furthermore, the 10 per cent indicator captured households in rural areas and, although no significant relationship was found between fuel poverty under the AFP indicator and urban or rural areas, the predominance of private rented accommodation in urban areas skews fuel poverty under this indicator towards these areas. These contrasting characteristics contributed to the understanding of the *compositional heterogeneity* of fuel poverty, which not only meant that the fuel poverty indicators captured two different groups, but also that this impacted on the spatial distribution of fuel poverty.

As well as these differences, some similarities were found between the fuel poor under the two different fuel poverty indicators. Households within the lowest income decile and those using PPMs to pay for fuel were found to have a higher likelihood of fuel poverty under both fuel poverty indicators and across both surveys.

9.3.2 Research question 1: How does fuel poverty impact on food insecurity?

In Chapter 6, the first of the proposed research questions was addressed. Using household-level data from the LCFS spanning the years of 2013 to 2015/16, this chapter explored the impact of fuel poverty on food insecurity using absolute food expenditure, the proportion of income spent on food, and food expenditure patterns to further understand the ways in which fuel poverty can affect food purchases and, therefore, dietary intake, with the potential to shed light on the root causes of health inequalities that exist between the fuel poor and non-fuel poor.

Mirroring the results of other studies that have explored the impact of fuel poverty on food expenditure (see Bhattacharya et al. (2003) and Beatty and colleagues (2014a), for example), this study also found that the fuel poor spend less on food in absolute terms, but that this consumed a larger percentage of their income (see Table 6.2), suggesting the presence of food insecurity amongst the fuel poor. However, the greater percentage of income spent on food by the fuel poor under the 10 per cent indicator suggests that food insecurity is most pronounced amongst those under this fuel poverty indicator. This indicates that the level of food insecurity experienced is different for both fuel poor groups and this finding was termed *inter-indicator heterogeneity*. This relationship was explored further, given the wide range of control variables offered by the use of a large-scale quantitative dataset. Controlling for a range of sociodemographic characteristics, including the economic status of the HRP to partially account for life-cycle effects in spending, as well as income, the analysis found that fuel poverty was not significantly associated with higher absolute expenditure on food when controlling for all other factors, but that a significantly greater percentage of income was allocated to food. The fuel poor under the 10 per cent indicator were found to spend a greater percentage of their income on food, which may suggest that the fuel poor under this indicator experience the greatest food burden.

This same analysis was performed on the poor sample to determine whether fuel poverty had a separate and additional impact on the poor. In this analysis, the fuel poor under the AFP indicator were spending significantly more on food in absolute terms than their non-fuel poor counterparts after controlling for all other factors, but no significant relationship was found between absolute food expenditure and the fuel poor under the 10 per cent indicator (see Table 6.5). However, both fuel poor groups were spending a greater percentage of income on food compared to their non-fuel poor counterparts (see Table 6.6). This suggests that fuel poverty increases food insecurity amongst the poor.

The analysis then turned to investigate the relationship between fuel poverty and food expenditure patterns, which had been identified through cluster analysis. The fuel poor under both indicators were significantly associated with three clusters (*Highly processed, Fruit & Vegetable burden*, and *Takeaways*) (see model 1 in Table 6.9), demonstrating their varied expenditure patterns and highlighting how the experience of food insecurity in fuel poor households is not uniform, but may be experienced in a variety of ways. This finding was termed *intra-indicator heterogeneity*. However, the relationship between fuel poverty and these food expenditure patterns were explained by income (see model 3 in Table 6.9). Amongst the poor, neither fuel poverty indicator had a relationship with any of the food expenditure patterns (see Table 6.10), suggesting that fuel poverty has no additional effect on food expenditure patterns amongst the poor. However, it was suggested that the lack of association may have been linked to a smaller sample size or that the food expenditure patterns identified for the whole sample may not necessarily reflect those of the poor.

In summary, these findings suggest that food insecurity is more pronounced amongst the fuel poor, with food expenditure placing a greater burden on the incomes of both fuel poor groups compared to their non-fuel poor counterparts. Of key interest in this chapter was the finding of inter- and intra-indicator heterogeneity, which showed that levels of food insecurity can vary between both fuel poor groups and that it can be experienced in a variety of ways, as indicated by the analysis on food expenditure patterns.

9.3.3 Research question 2: What are the links between fuel poverty and social isolation?

Chapter 7 focused on the second of the research questions, which investigated the links between fuel poverty and social isolation. Using individual-level data from wave 6 of the UKHLS, a social isolation scale was constructed using variables that had been shown to have a relationship with social isolation in the literature, and multiple regression was used to investigate the relationship between fuel poverty and social isolation, as measured by the scale.

The analysis found that fuel poverty under both indicators was significantly associated with social isolation, with the fuel poor under the AFP indicator being affected to a greater extent (see model 1 in Tables 7.9 and 7.10). This reinforced the notion of inter-indicator heterogeneity, which was identified in Chapter 6, by demonstrating that the relationship between fuel poverty and social isolation is altered by the fuel poverty indicator used. It was also found that, because of the compositional differences between both fuel poor groups, the addition of control variables had different effects on the relationship between fuel poverty and social isolation depending on the indicator used, adding further understandings to the inter-indicator heterogeneity of fuel poverty. However, when exploring this relationship further by controlling for other factors, including age to account for life-cycle effects in social isolation, this association was found to be driven by a low income (see model 4 in Tables 7.9 and 7.10), suggesting that those who are fuel poor through spending a disproportionate amount of their income on fuel experience social isolation because of their low income.

In addition, the analysis found that factors that had been identified as characteristics with the highest likelihoods of fuel poverty in Chapter 5 (see Table 5.23) may alter the relationship between fuel poverty and social isolation. In particular, it was noted that owner-occupation and living in a rural area were significantly associated with lower levels of social isolation and these factors may decrease social isolation amongst the fuel poor under the 10 per cent indicator, considering that these were found to be characteristics associated with a higher likelihood of fuel poverty under this indicator (see Table 5.23). In contrast, a significant positive relationship was found between living in the private rented sector and amongst those belonging to an Asian ethnic group, which could suggest that these factors increase social isolation for the fuel poor under the AFP indicator, given that these characteristics were found to be associated with a higher likelihood of fuel poverty under this indicator using the UKHLS dataset (see Table 5.23).

Like in Chapter 6, the analysis was also performed on the poor sample as a way of understanding whether fuel poverty has a particular impact on the poor in terms of social isolation. This analysis showed that amongst the poor, the fuel poor under the 10 per cent indicator were less socially isolated than their non-fuel poor counterparts (see model 1 in Table 7.11), suggesting that fuel poverty, at least under the constructed 10 per cent indicator, is not always associated with higher levels of social isolation. In contrast, fuel poverty under the AFP indicator had no additional effect on the poor in terms of social isolation (see model 1 in Table 7.12). The relationship between social isolation, tenure and living in an urban or rural area, which was found in the whole sample analysis, was also found amongst the poor, and this could suggest that these factors may mediate the relationship between fuel poverty and social isolation.

In summary, these findings suggest that fuel poverty is not always associated with greater levels of disadvantage and that the experience of social isolation is dependent on the fuel poverty indicator used and can be influenced by different characteristics of the fuel poor, further supporting the notion of inter-indicator heterogeneity.

9.3.4 Research question 3: Is there a difference in the order of curtailment of material deprivation items between fuel poor and non-fuel poor households?

Chapter 8 addressed the last of the research questions, exploring the rates of material deprivation and the order that essential items are curtailed in fuel poor and non-fuel poor households as a way of gaining an insight into the living standards of the fuel poor under the two different indicators, but also amongst different household types under the same indicator of fuel poverty.

Using household-level data from waves 4 and 6 of the UKHLS, prevalence weighting was conducted to determine the rates of material deprivation amongst fuel poor and non-fuel poor groups for working-age adult households, with and without children, and pensioner households. Working-age adult households with and without children under the 10 per cent indicator were found to have the highest rates of severe low income and material deprivation compared to the fuel poor under the AFP indicator and the income poor, suggesting that these groups have the most severe levels of material deprivation. This, again, highlights how the level of disadvantage is dependent on the fuel poverty indicator used, reinforcing the inter-indicator heterogeneity found in Chapters 6 and 7. However, rates of severe low income and material deprivation were highest under the 10 per cent indicator in working-age adult households with children, suggesting that households under the same indicator of fuel poverty can experience disadvantage differently, again building on the intra-indicator heterogeneity of fuel poverty found in the previous chapters. In contrast, pensioner households under the AFP indicator had the highest rates of material deprivation, again demonstrating how levels of disadvantage can vary between the fuel poor under different indicators. However, these household types are not directly comparable due to differences in material deprivation suites.

Item Response Theory was then conducted to determine the order of curtailment of essential expenditures contained within deprivation suites. The results showed that expenditure-curbing patterns differed between the fuel poor under different indicators, but also between household types under the same indicator of fuel poverty. This suggests that it is not only the level of disadvantage that can vary between and within indicators, but that different household types under the same indicator of fuel poverty can have different experiences of material deprivation based on their differing patterns of curtailment. This builds on the inter- and intra-indicator heterogeneity of fuel poverty identified in earlier analysis chapters.

Of additional interest in this chapter, was the analysis on the pensioner deprivation items, which included items that are more relevant to fuel poverty and provided an insight into how the experience of fuel poverty can differ under two different indicators of fuel poverty. The findings revealed that both fuel poor households forgo *warm home* first, compared to the non-fuel poor and the income poor, as indicated by their difficulty parameter values (see Table 8.11), with the fuel poor under the AFP indicator forgoing this earlier. This may suggest that the fuel poor may struggle to achieve thermal comfort, despite paying disproportionate fuel costs, and that this struggle may be greater for the fuel poor under the AFP indicator. It was also of interest in the context of fuel poverty that *Coat* was forgone later by both fuel poor groups, with the fuel poor under the 10 per cent indicator forgoing this last. This could suggest that this expenditure is prioritised in fuel poor households and there is some literature that shows that fuel poor householders use outdoor clothing to keep warm indoors (Harrington et al. 2005; Anderson et al. 2010; Cotter et al. 2012; Middlemiss and Gillard 2015). However, the reasons behind forgoing *Coat* later could not be explored further due to the nature of the data.

The findings also revealed that the fuel poor may have worse housing conditions compared to the income poor, helping to differentiate these groups further. In working-age adult households without children, the fuel poor under the AFP indicator forgo *House* earlier, and in working-age adult households with children and in pensioner households, the fuel poor under the 10 per cent indicator forgo this item earlier.

In summary, this chapter has revealed novel insights into the levels of material deprivation amongst fuel poor households, how essential expenditures are curbed and how this may impact on the living standards of the fuel poor. It was also noted that patterns of curtailment varied, not only under the different indicators of fuel poverty, but between different household types under the same indicator of fuel poverty, adding a further dimension to how the inter- and intra-indicator heterogeneity of fuel poverty can be understood.

9.4 Original contributions to knowledge

To the author's knowledge, this thesis presents a unique account of the relationship between those who are fuel poor – through spending a disproportionate amount of their income on fuel – and other forms of disadvantage, offering a detailed portrait of those considered fuel poor under two different indicators and how these different indicators capture experiences of other forms of disadvantage. In collating and scrutinising the findings that have emerged, three novel contributions to knowledge are identified, which are addressed in the following three subsections.

9.4.1 Expanding the understanding of the heterogeneous nature of fuel poverty

The findings within this thesis have helped to build a comprehensive and multifaceted account of the heterogeneous nature of fuel poverty, with the analysis chapters adding different dimensions to how this can be understood. This is perhaps the most important finding that has emerged from the thesis.

Reinforcing existing evidence (see Boardman (2010), Hills (2011), and Moore (2012), for example), Chapter 5 showed that the two fuel poverty indicators were essentially capturing two distinct groups. This was termed *compositional heterogeneity* and emphasised how fuel poverty indicators and their components can change who is classified as fuel poor, as well as changing the rates and the spatial distribution of fuel poverty.

Chapters 6 and 7 helped to develop the understanding of the heterogeneous nature of fuel poverty by finding that this heterogeneity extended to differences in how the fuel poor experienced other forms of disadvantage. In exploring the relationship between fuel poverty and food insecurity in Chapter 6, two further dimensions of the heterogeneous nature of fuel poverty were unveiled. Not only did the fuel poverty indicators capture differences in absolute expenditure and the proportion of income spent on food between the two fuel poor groups, but they also found that fuel poverty was related to different food expenditure patterns. This showed that as well as inter-indicator heterogeneity, as evidenced by differences in food expenditure between both fuel poor groups, the different food expenditure patterns associated with the fuel poor highlighted the myriad of ways that the fuel poor may experience food insecurity, forming the basis of intra-indicator heterogeneity. Chapter 7 reinforced the notion of inter-indicator heterogeneity by demonstrating that levels of social isolation vary for the fuel poor under the different fuel poverty indicators and that they are affected differently by the added control variables, showing how the compositional heterogeneity affects not only the characteristics of the fuel poor, but also the experience of other forms of disadvantage.

In the final analysis chapter, Chapter 8 offered evidence for a further way of how the inter-indicator and intra-indicator heterogeneity of fuel poverty can be understood. Within this chapter, the analysis provided evidence to suggest that the experience of material deprivation does not only vary under different fuel poverty indicators (inter-indicator heterogeneity), but that, in addition, it varies by different household types classified as fuel poor under the same fuel poverty indicator. This suggests that households that are fuel poor under the same definition have different experiences of disadvantage, which may be altered by the make-up of the household. This builds on how the intra-indicator heterogeneity of fuel poverty is understood, as the experience of disadvantage not only differs by the indicator used, but that fuel poverty has different symptoms for households in different circumstances.

9.4.2 A greater understanding of the relationship between fuel poverty and other forms of disadvantage

The findings that have emerged from the analysis chapters have extended the quantitative literature on the relationship between fuel poverty and food insecurity, social isolation, and material deprivation. Given the use of large-scale national survey data, it has been possible to control for a range of variables, which has helped to gain a better understanding of the factors that underlie some of these relationships, specifically for food insecurity and social isolation. This has been a strength in this study and has facilitated a greater understanding of the experiences of the fuel poor under the fuel poverty indicators used and the role of underlying factors, which can alter the experience of disadvantage. At times, the identified relationships were explained by low income, such as in Chapter 7, where the relationship between fuel poverty and social isolation was explored. However, this was not the case in Chapter 6, where fuel poverty remained significantly associated with a higher proportion of income spent on food after controlling for income. This may mean that although low income may be driving some experiences of disadvantage amongst the fuel poor, not all relationships between fuel poverty and disadvantage may be explained by a low income.

9.4.3 Insights into the relationship between fuel poverty and ethnicity

The relationship between ethnicity and fuel poverty has been relatively overlooked by the research community, despite knowledge of minority ethnic groups experiencing higher levels of housing deprivation (De Noronha 2019), being less engaged with the energy market (Finlay 2013), and having higher energy needs (Todd and Steele 2006; Lawrence et al. 2007). This may be because minority ethnic groups are considered “hard to reach” (Rockliffe et al. 2018; Liljas et al. 2019), suggesting that it is difficult to incorporate these groups into research. However, studies that have included minority ethnic groups in their work have used broad ethnic categorisations, such as “non-white” (Anderson et al. 2010), “ethnic minority” (see BEIS 2018a, for example), and “Black and Minority Ethnic” (Todd and Steele 2006). In homogenising fundamentally diverse groups in this way, the myriad of experiences that may occur within this amalgamation may be overlooked.

Unlike the few existing studies and published data that provide some insight into the relationship between fuel poverty and ethnicity, the use of large-scale quantitative datasets used in the research presented herein has allowed for the consideration of more detailed ethnicity classifications. In doing so, Chapter 5 showed that the likelihood of experiencing fuel poverty differs by the ethnic group of the HRP and, for some, this relationship remained highly significant even after controlling for income under both indicators and across both datasets (see Table 5.23). This has provided novel insights into this under-explored relationship and this finding could indicate that fuel poverty – for some – may be entrenched in a wider web of disadvantage that is not explained fully by a low income, and that fuel poverty may arise through the complex interaction of a multitude of disadvantages beyond the main three drivers of fuel poverty, and that the effects of these may vary for different ethnic groups. Acknowledging this may help to understand some of the difficulties in tackling fuel poverty as those belonging to minority ethnic groups may experience additional barriers to accessing help and this may highlight deficiencies in current fuel poverty policy. This may have implications for the types of fuel poverty advice and assistance made available to minority ethnic groups.

9.5 Policy implications and recommendations

In examining the findings more closely and describing how they further the understanding of fuel poverty, two implications for policy have become apparent. These are addressed in the following two subsections.

9.5.1 Increasing efforts to ease the burden of prepayment meters

As summarised in section 9.3.2, the analysis in Chapter 5 showed that paying for fuel using PPM significantly increased the likelihood of experiencing fuel poverty (see Table 5.23). Despite the heterogeneous nature of fuel poverty under the applied fuel poverty indicators, this was a consistent finding under both fuel poverty indicators and across both datasets. At present, fuel poverty alleviation predominantly focuses on improving the energy efficiency of the home. This often includes insulation measures or the replacement of an old boiler, such as in the current phase of the Energy Companies Obligation (ECO3), which was discussed in more detail in Chapter 2 (see section 2.12.1). However, as noted therein, there are often barriers to accessing and installing measures, such as not fulfilling the eligibility criteria and concerns about the perceived disruption of these types of measures (Armstrong et al. 2006), which may discourage uptake. Although an important part of the fuel poverty problem, overly focusing on increasing energy efficiency to eradicate fuel poverty may mean that other factors that play an important role in its manifestation are overlooked.

Using PPMs to pay for fuel has received considerable attention in the context of fuel poverty, with PPM users traditionally having the highest unit costs and the highest rates of fuel poverty compared to other payment methods (Boardman 2010; Hills 2012), with fewer options for reducing fuel bills due to the lack of competitive tariffs available for this payment method (Boardman 2010; Competitions & Markets Authority 2016). The significant relationship between fuel poverty and PPMs found in Chapter 5 suggests that more attention needs to focus on the inequality of fuel prices, which would remain an important factor even in an energy efficient home and could potentially tip a household into fuel poverty. Easing the burden of high fuel costs caused by PPMs would also present a less disruptive approach for attempting to remove a household from fuel poverty compared to energy efficiency upgrades, and a greater focus on removing PPMs may help to target a larger number of households in fuel poverty.

There are already significant efforts being made to ease the disadvantage experienced by PPM customers, with Ofgem (the government regulator for gas and electricity markets in Great Britain) making proposals to reinforce protection for customers, which includes offering additional support to vulnerable customers, such as “friendly hours credit” on public holidays when top-up points may be closed, and “additional support credit” for customers in vulnerable circumstances. However, this credit has to be paid back and so this support may only temporarily displace fuel poverty. In addition to these forms of credit, the level of energy debt a household can have when switching has also recently been increased, from £200 to £500, which may help those in debt to switch to a more suitable energy tariff or supplier, reducing the risk of further debt (Ofgem 2020c). However, given that the benefits of switching are normally temporary (Lomax and Wedderburn 2009; Boardman 2010), the need to keep switching to find the best deal may be off-putting and may discourage switching.

Although these changes show greater acknowledgment of the struggles that households face when using PPMs to pay for fuel, what appears to be lacking in these proposals are efforts for a better relationship between the energy supplier and the customer. Given the complexity of the energy market and the onus of finding a better energy deal placed on the customer, there is a need for energy suppliers to be proactive in informing customers when they are able to switch to a better deal or that their payment method can be changed once any debts are paid off, reassuring customers that they can be helped on to other payment types, if their situation permits, ultimately ensuring that customers are on the best energy tariff and best payment method for their needs.

Easing the burden of fuel costs associated with PPMs requires a multifaceted approach and focusing on this uncovers several other areas where more attention is needed and where help can be offered. Chapter 2 identified that reasons for preferring PPM include being able to budget limited finances (Boardman 2010), distrust of 'invisible' payment methods, such as Direct Debit (Tod et al. 2012), and being financially excluded (Collard 2001; Boardman 2010). This could highlight a need for improving financial literacy and financial education as a way of promoting financial inclusion, and for raising awareness of available financial assistance and facilitating access to this.

9.5.2 Improving fuel poverty modelling procedures: A focus on ethnicity

In defending the use of actual fuel expenditure in Chapter 5, it was emphasised that, although this does not account for the fuel poor who are under-spending as a way of curbing fuel bills and therefore potentially fuel poor under other definitions, it does capture those who have disproportionate fuel expenditures, which is the conceptualisation of fuel poverty used throughout the research. The reasons behind these high fuel expenditures can be due to a multitude of reasons, such as increased needs due to physical vulnerabilities to the cold associated with disability and longstanding illness, the use of PPMs, being on a costly energy tariff, preference, beliefs, or wastefulness. Table 5.23 highlighted that households with a HRP belonging to a minority ethnic group, specifically a Black or Asian ethnic group, had a significantly higher likelihood of experiencing fuel poverty compared to households with a White HRP, even after controlling for income. This finding may be associated with differences in how these households use energy, which may be linked to culturally entrenched practices that are sometimes attached to different ethnic groups, such as religious and cooking practices (Todd and Steele 2006; Lawrence et al. 2007), or to differences in how they use their home and the temperature at which they achieve thermal comfort (Todd and Steele 2006). Although extended time at home due to unemployment or retirement may alter energy usage, other needs that may contribute to higher energy costs are not taken into consideration[80]. This could suggest that fuel poverty amongst households with HRPs belonging to a minority ethnic group is misestimated.

Although the LIHC indicator has consistently shown higher rates of fuel poverty amongst households with HRPs belonging to minority ethnic groups compared to households with a White HRP (BEIS 2019a, p.36), the fuel poverty gap (i.e. the amounts by which required fuel costs exceed the median threshold (Hills 2012)) is smaller amongst households with a HRP belonging to a minority ethnic group. Given that the fuel poverty gap is used to prioritise the targeting of measures, with households with the largest fuel poverty gaps being prioritised (Hills 2012; Middlemiss 2016; Committee on Fuel Poverty 2018), this could mean that households with a HRP belonging to a minority ethnic group may miss out on fuel poverty assistance. Moreover, in reality, fuel poverty rates amongst households with a HRP belonging to a minority ethnic group may be much higher and the fuel poverty gap may be

[80] Apart from in Scotland, where a higher temperature of 23˚C in the main living area is recommended for households with individuals aged 60 and over or with someone with a longstanding illness or disability (Scottish Government 2018a).

much larger. This is because modelling required energy costs does not consider how ethnic minority households use their homes and their energy services, and the assumptions within modelling may not always reflect energy needs in reality.

Compounding their higher fuel needs, minority ethnic groups are less likely to switch energy suppliers or energy tariff (Ipsos MORI 2013) and have lower levels of accessing financial assistance (Kenway and Palmer 2007), which may hinder self-identification of fuel poverty and, in turn, prevent access to fuel poverty assistance. This may, therefore, prevent minority ethnic households from being able to remove themselves from fuel poverty through not fulfilling the necessary eligibility criteria to access measures that may help them change their fuel poverty status. This may indicate that fuel poverty in ethnic households is more persistent.

Further information on the energy practices of different minority ethnic groups needs to be integrated into modelling procedures so that fuel poverty status reflects not only the characteristics of the dwelling and occupancy during the day, but also how ethnicity may shape energy usage and the use of the dwelling. This could help avoid underestimating the numbers in fuel poverty and the depth of fuel poverty, especially for those who may already be disadvantaged in other aspects and who may face barriers in removing themselves from fuel poverty through not fulfilling eligibility criteria and not being able to self-identify as fuel poor because of this.

9.6 Avenues for future research

The research contained within the thesis has made valuable and novel contributions to the understanding of the relationship between fuel poverty – experienced through disproportionate spending on fuel – and other forms of disadvantage, as well as fuel poverty itself. In doing so, the thesis has unveiled potential new avenues of research that could enhance the understanding of these links and provide further understandings of the complex issue of fuel poverty. The following three subsections outline these avenues of research and their importance for furthering the understanding of fuel poverty.

9.6.1 Fuel poverty and disadvantage: A transient issue?

This first avenue of research draws on the limitations of the use of a cross-sectional approach taken throughout the thesis. Using cross-sectional analysis to explore the research questions has neglected the fact that both fuel poverty and other forms of disadvantage may be transient. This was acknowledged as one of the limitations of the research in Chapter 5. Evidence suggesting that fuel poverty is transient has been provided by Cavanaugh (2018) and Kearns (2019), with households moving into and out of fuel poverty with changes to employment, household type, and ill health (Kearns et al. 2019). However, findings from Chapter 8 (see section 8.8.1) also suggested that there may be a link between fuel poverty under the 10 per cent indicator and persistent poverty, given that this group had the highest levels of severe low income and material deprivation, which has been linked to persistent poverty in previous research (Berthoud et al. 2004).

Although research questions 2 and 3 could have been explored longitudinally using the UKHLS dataset, the purpose of the thesis was to highlight connections between fuel poverty and other forms of disadvantage, rather than to investigate how these connections may change and vary over time. However, applying a longitudinal approach to these research questions would allow for the mechanics of the relationships to be better delineated and to understand whether the experience of other forms of disadvantage changes with the presence and absence of fuel poverty, and vice versa, or whether they simply coexist. It could also help to uncover whether these findings reflect long-term experiences or short-term adaptations, whether the research has captured households in a temporary period of fuel poverty simply because a household's financial income cycle and payment cycle do not align (Lomax and Wedderburn 2009), whether households were interviewed in a period of temporary low income, which impacted on their fuel poverty status, or whether these households experience persistent poverty.

9.6.2 Further understanding fuel poverty under different measurements: working towards an improved measure of fuel poverty

In expanding the evidence regarding the heterogeneous nature of fuel poverty, as detailed in section 9.4.1, wider debates about the adequacy of strict and technical definitions for capturing the entirety of the fuel poor and their experiences gain further importance because “who is fuel poor depends on the definition” (Boardman 2010, p.21), and understanding fuel poverty is fundamental for good policy design and more accurate policy targeting. As such, this second avenue of research emphasises the need to explore how fuel poverty indicators can be improved so that they better capture those in need, rather than just those whose expenditure on fuel reaches thresholds within definitions to be classified as fuel poor.

The first research gap identified in section 3.4 highlighted the difficulty of comparing the results of fuel poverty studies, given the multitude of ways used to identify the fuel poor, with a range of objective and subjective assessments being used. This made it difficult to understand the relationship between fuel poverty and other forms of disadvantage in a consistent way given that a disconnect exists between objective and subjective measurements of fuel poverty, where those who are fuel poor through spending to expenditure thresholds do not necessarily feel fuel poor or have experiences commonly associated with fuel poverty, such as a cold and damp home (Devalière et al. 2011; Waddams Price et al. 2012; Phimister et al. 2015). Furthermore, there is a paucity of knowledge of how objective and subjective assessments align with official definitions of fuel poverty and it is unclear whether the experiences of the fuel poor are being captured within these. As such, national statistics could be underestimating the scale of the problem by overlooking households who are experiencing fuel poverty, despite not being defined as such under the official definitions used.

Given the heterogeneous nature of fuel poverty and the disconnect between objective and subjective assessments of fuel poverty, there is a need for a better understanding of the relationships between the different ways of identifying the fuel poor. This requires a concerted research effort by qualitative and quantitative domains to understand the range of experiences of the fuel poor, whether objective measures are capturing these experiences, and whether households who are fuel poor under subjective and objective measures are captured under official definitions of fuel poverty. This could lead to a more consistent understanding of fuel poverty and a more comprehensive understanding of the characteristics and experiences of the fuel poor, which could better reflect the scale of the problem. In addition, exploring how these indicators align with each other could facilitate the fine-tuning of proxy indicators, which could be used to broaden eligibility criteria for access to policy measures, so that fuel poor households are targeted more effectively and the risk of being overlooked is lowered.

9.6.2.1 Integrating a better measure of available income into fuel poverty indicators

Together with investigating the overlap between objective and subjective indicators of fuel poverty to refine fuel poverty indicators and to provide a more consistent understanding of fuel poverty, there may also be scope for re-considering how disposable income is understood within fuel poverty indicators.

During the writing of the thesis, the Social Metrics Commission (2019) proposed a new measure of income poverty, one that considers available income by removing "inescapable costs" such as those related to childcare and disability, as well as housing costs (Social Metrics Commission 2019, p.17). This provides an improved estimate of income compared to current measures. As such, this avenue for future research suggests that, in order to improve indicators of fuel poverty, it is important to have a better understanding of the income that households have available to them and that a more accurate measure of disposable income be incorporated into indicators.

9.6.3 Developing understanding of the experience of fuel poverty amongst minority ethnic groups

Building upon the novel contribution provided by the thesis detailed in section 9.4.3 and tying into the recommendation presented in section 9.5.2, the third avenue of research calls for the acknowledgement of diversity between ethnic groups in fuel poverty research and for further inquiry into how experiences of fuel poverty, and the driving factors behind these, may vary amongst different minority ethnic groups.

As evidenced in Chapter 5, the likelihood of experiencing fuel poverty varied amongst households with HRPs belonging to different minority ethnic groups, a finding that was not explained by income. This may suggest that there are factors that are not contained within the three main drivers of fuel poverty that may increase the likelihood of fuel poverty amongst certain ethnic groups. This warrants greater research attention to investigate whether focusing on the three main drivers of fuel poverty sufficiently capture the drivers behind fuel poverty amongst minority ethnic groups. Given the range of challenges faced by these groups in society, a more pronounced focus may be needed on understanding the accumulation of factors that disadvantage these households, such as racism, housing deprivation, financial exclusion, barriers to accessing information and policy measures, and higher energy needs, as well as the interactions between them. This may reveal new insights into driving factors that may be more relevant to the experience of fuel poverty amongst minority ethnic groups.

A final point here is that the analysis presented in Chapter 5 only focused on the ethnicity of the HRP, but it is acknowledged that this may not represent the ethnic identities of other occupants in the household and so greater attention is needed to understand how ethnically diverse households may experience fuel poverty and the factors that influence this.

9.7 Final remarks and conclusions

The research presented in this thesis has provided a unique perspective on fuel poverty and, in the process, has contributed novel information to the area of fuel poverty, expanding knowledge of how those spending a disproportionate amount of their income on domestic fuel experience other forms of disadvantage, and how the measurement of fuel poverty can change the level of disadvantage and how it is experienced. In doing so, a broader picture of the heterogeneous nature of fuel poverty has been painted, and further avenues of research have been suggested as a way of advancing the understanding of fuel poverty. In evaluating the findings from the thesis as a whole, it has become more evident that fuel poverty is a complex and nuanced issue, which is altered by how it is measured, and this requires acknowledgement in policy.

On a concluding note, writing the final words of this chapter in the midst of the coronavirus pandemic, a sense of uncertainty and worry, and much financial strain have become prominent themes of the present day. Where some have called this "the great equaliser", others have stated that it has shone a brighter light on the inequalities that exist in society (Mein 2020), emphasising that the consequences of this crisis are not borne equally. DWP have revealed that, between 16th March to 12th April 2020, 1.8 million new applications for Universal Credit have been submitted – five times higher than the number of applications received for the same period in the previous year (DWP 2020). This suggests that households are requiring more financial support in difficult times.

There have been considerable rises in fuel costs driven by the demand of gas during the pandemic and, more recently, Russia's invasion of Ukraine has threatened gas supplies from Russia (Karjalainen and Levell 2022). The latest price cap has risen by 54 per cent on 1st April 2022 and it has been estimated that those on default tariffs paying by direct debit will see an increase of around £693, from £1,277 to £1,971 per year, and that customers who use PPMs will see an increase of around £708, from £1,309 to £2,017 per year (Ofgem 2022). The increased costs for those using PPMs is of particular concern as this method of payment is used predominantly by the poorest households (Competitions & Markets Authority 2016; ONS 2022). In recent analysis conducted by the Joseph Rowntree Foundation (2022) it was found that families on low incomes will spend 16 per cent of their income (AHC) on fuel compared to 5 per cent for middle-income families following the new energy price cap. With these rises in fuel costs, it is estimated that the number of households in fuel poverty has doubled: from 3.16 in 2019 to 6.32 following April's price cap rise (End Fuel Poverty Coalition 2022). This is estimated to rise to 8.5 million households by the end of 2022 (End Fuel Poverty Coalition 2022).

While energy companies are making billions of pounds in profits (Meierhans 2022), households are struggling to afford their fuel bills as well as other living costs that have continued to rise (Harari et al. 2022). Incomes and benefits have not risen in line with inflation (Harari et al. 2022) and there have been increases in income tax and National Insurance contributions from April 2022 (Harari et al. 2022), squeezing incomes further. In addition, rising inflation rates are hitting the poorest households hardest (Karjalainen and Levell 2022). Although the Cost of Living Support package has been announced by the government to help with rises in fuel bills and other living costs (HM Treasury 2022), not all support is well-targeted. For example, a £150 Council Tax rebate offered in May 2022 to all those living in Council Tax bands A to D to help towards rising fuel costs was found to be highly mistargeted, with around three-quarters of people eligible for this discount not living in poverty (Department for Levelling Up Housing & Communities 2022; Joseph Rowntree Foundation 2022). This is a further example of a poorly designed solution to the current situation, where help could have been better directed to those in need.

At this time, it becomes of paramount importance that short-term fixes, rather than solely focusing on the long-term gains of energy efficiency improvements, are made available and that there is some malleability in how fuel poverty is understood, beyond the rigidity of current definitions, measures, and eligibility criteria, in order to incorporate a potentially new spectrum of characteristics that have been drawn into fuel poverty by this crisis. Without this, available assistance that does not consider the diverse experiences and characteristics of the fuel poor will continue to overlook those in genuine need, making it impossible to eradicate fuel poverty.

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Appendix A| Catalogue of variables

The following tables provide the components of all the variables from the *Living Costs and Food Survey* (LCFS) and *Understanding Society: The UK Household Longitudinal Study* (UKHLS) that were constructed or re-categorised for the research in this thesis. One table is presented for each survey and the variables have been organised alphabetically.

Table A.1: *Created and re-categorised variables, LCFS (2013 – 2015/16)*

Variable name	Variable levels	Components
Central heating fuel	"Electricity"	Central heating by electricity
	"Gas"	Central heating by gas
	"Oil"	Central heating by oil
	"Other fuel"	Central heating by solid fuel
		Central heating by solid fuel and oil
		Central heating by calor gas
		Other gas central heating
	"No central heating"	None of the above
Dwelling type	"Detached"	Whole house, bungalow - detached
	"Semi-detached"	Whole house, bungalow – semi-detached
	"Terraced"	Whole house, bungalow - terraced
	"Other"	Purpose built flat/maisonette
		Part of a house converted flat
		Others
Economic activity status of HRP	"Self-employed"	Self-employed
	"In paid employment"	Full-time employee
		Part-time employee
		Work-related government training programme
	"Unemployed"	Unemployed
	"Retired"	Retired
	"Inactive"	Unoccupied

Table A.1: *Created and re-categorised variables, LCFS (2013 – 2015/16) (continued)*

Variable name	Variable levels	Components
Ethnicity of HRP	"White"	British/English/Scottish/Welsh/Northern Irish (White)
		Irish (White)
		Gypsy or Irish traveller (White)
		Any other white background (White)
	"Mixed race"	White and Black Caribbean (Mixed)
		White and Black African (Mixed)
		White and Asian (Mixed)
		Any other mixed background (Mixed)
	"Asian"	Indian (Asian or Asian British)
		Pakistani (Asian or Asian British)
		Bangladeshi (Asian or Asian British)
		Chinese (Asian or Asian British)
		Any other Asian background (Asian or Asian British)
	"Black"	Caribbean (Black or Black British)
		African (Black or Black British)
		Any other Black background (Black or Black British)
	"Other"	Arab (other ethnic group)
		Any other ethnic group (other ethnic group)
Method of payment for gas and electricity	"Direct Debit (DD)"	Direct Debit
	"Prepayment meter (PPM)"	Prepayment meter
	"Other"	Budgeting scheme
		Included in rent
		Frequent cash payments (i.e. more frequent than once a month)
		Fuel direct from benefits
		Fixed annual bill
		DSS pay whole of the bill
		DSS pay part of the bill
		Paid direct from someone outside the household
		Other

Table A.1: *Created and re-categorised variables, LCFS (2013 – 2015/16) (continued)*

Variable name	Variable levels	Components
Method of payment for gas and electricity	“Combined	DD and PPM
		DD and Other
		PPM and Other
Tenure	“Owned”	Owned with mortgage
		Owned by rental purchase
		Owned outright
	“Private rented”	Private rented (unfurnished)
		Private rented (furnished)
	“Social housing”	Local authority (furnished/unfurnished)
		Housing association (furnished/unfurnished)
		Rent free

Table A.2: *Created and re-categorised variables, UKHLS (waves 3 – 7)*

Variable name	Created categories	Components
Dwelling type	"Detached"	Detached house/bungalow
	"Semi-detached"	Semi-detached house/bungalow
	"Terraced"	End terraced house/bungalow
	"Other"	Purpose built flat/maisonette (under 10 dwellings)
		Purpose built flat/maisonette (10^+ dwellings)
		Converted flat/maisonette (under 10 dwellings)
		Converted flat/maisonette (10^+ dwellings)
		Dwelling with business premises
		Bedsitter in multiple occupation (under 10 dwellings)
		Bedsitter in multiple occupation (10^+ dwellings)
		Bedsitter/single occupation
		Sheltered accommodation
		Other
Economic activity status of HRP	"Self-employed"	Self-employed
	"In paid employment"	In paid employment (full- or part-time)
		On maternity leave
		On apprenticeship
	"Unemployed"	Unemployed
	"Retired"	Retired
	"Inactive"	Looking after family
		Full-time student
		Long-term sick or disabled
		Unpaid worker in family business
		Doing something else
Ethnicity of HRP	"White"	British/English/Scottish/Welsh/Northern Irish (White)
		Irish (White)
		Gypsy or Irish traveller (White)
		Any other white background (White)
	"Mixed race"	White and Black Caribbean (Mixed)
		White and Black African (Mixed)
		White and Asian (Mixed)
		Any other mixed background (Mixed)

Table A.2: *Created and re-categorised variables, UKHLS (waves 3 – 7) (continued)*

Variable name	Created categories	Components
Ethnicity of HRP	"Asian"	Indian (Asian or Asian British)
		Pakistani (Asian or Asian British)
		Bangladeshi (Asian or Asian British)
		Chinese (Asian or Asian British)
		Any other Asian background (Asian or Asian British)
	"Black"	Caribbean (Black or Black British)
		African (Black or Black British)
		Any other Black background (Black or Black British)
	"Other"	Arab (other ethnic group)
		Any other ethnic group (other ethnic group)
Method of payment for gas and electricity	"Fixed monthly Standing Order"	Fixed monthly Standing Order
	"Monthly bill"	Monthly bill
	"Quarterly bill"	Quarterly bill
	"PPM"	PPM
	"Other"	Other
		Frequent cash payments (i.e. more frequent than once a month)
		Fuel Direct scheme or direct from benefits
		Staywarm scheme
		Annual bill
		Other
	"Combined"	Any combinations from the above
	"Not applicable – Oil or Solid fuel"	Not applicable on all the above
Tenure	"Owned"	Owned outright
		Owned with mortgage
	"Social housing"	Local authority rented
		Housing association rented
	"Private rented"	Rented private (unfurnished)
		Rented private (furnished)
		Rented from employer

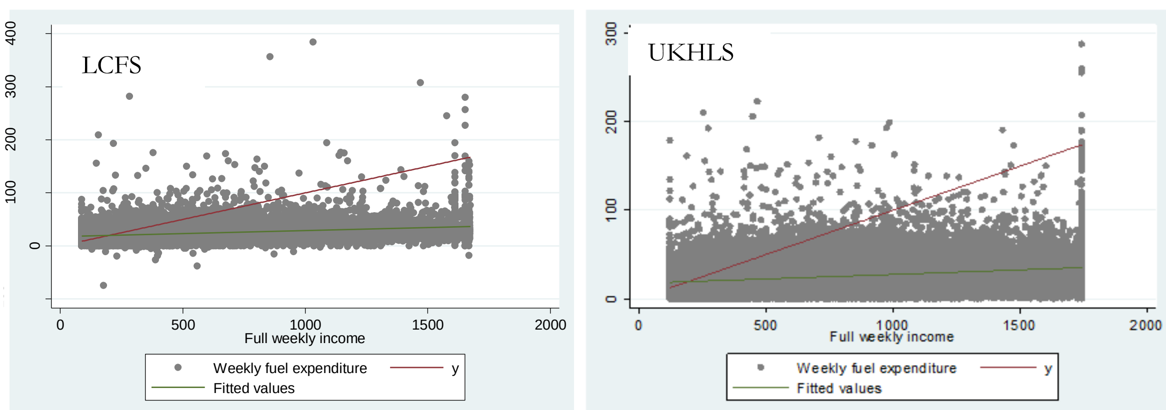
Table A.2: *Created and re-categorised variables, UKHLS (waves 3 – 7) (continued)*

Variable name	Created categories	Components
Types of fuels used in the home	"Electricity only"	Electricity
	"Gas only"	Gas (including Calor Gas)
	"Gas & Electricity"	Electricity and Gas (including Calor Gas)
	"Oil & Other fuel"	Oil
		Other fuel (including solid fuel)
	All fuels	Electricity, gas, oil, other fuel (including solid fuel)
	Other combinations	Electricity and oil; Electricity and other fuel; Gas (including Calor Gas) and oil; other fuel

Appendix B| Additional analysis for Chapter 5: A focus on the fuel poverty gap

This appendix firstly illustrates the relationship between income and absolute fuel expenditure using unwinsorised absolute fuel expenditure data and then provides information on the characteristics and determinants of the fuel poverty gap. The fuel poverty gap was calculated for the fuel poor under the AFP indicator to understand the depth of fuel poverty for different characteristics, and to offer further understandings of the AFP indicator.

Figure B.1: *Scatterplots showing the relationship between income and absolute fuel expenditure presented with the 10 per cent threshold and the regression line, LCFS (2013 – 2015/16) and UKHLS (waves 3 - 7)*



B.1 Re-creating the fuel poverty gap: assessing the depth of fuel poverty

As mentioned in Chapter 2, section 2.4.2, the LIHC indicator also calculates the *fuel poverty gap* – the amount by which the required fuel costs of a fuel poor household exceed median required fuel costs, i.e. the threshold for reasonable costs (Hills 2012). This is the amount by which a fuel poor household would need to reduce their fuel expenditure by in order to no longer be classified as fuel poor (BEIS 2020b) and as such, the fuel poverty gap presents the depth of fuel poverty.

B.1.1 Method for calculating the fuel poverty gap

To calculate the fuel poverty gap for the fuel poor under the AFP indicator, the guidance provided by BEIS in their methodological information was followed (BEIS 2020b, p.64). As instructed, the fuel poverty gap was determined by calculating the difference between equivalised fuel costs and equivalised median fuel costs for the fuel poor, i.e. the gap. However, as this difference is based on equivalised values, the gap did not represent an actual value in pounds (£). To achieve an actual value, the difference was unequivalised by multiplying the gap by the fuel equivalisation factors shown in Table 4.1 in Chapter 4. This produced an absolute value, which represents – in pounds (£) – the amount a household would need to reduce their fuel costs by to no longer be classified as fuel poor under the AFP indicator.

B.2 Mean annual fuel poverty gap for selected characteristics

Table B.1 presents the mean annual fuel poverty gap for 2016 for the control variables selected for the logistic regression models presented in Chapter 5 (see Tables 5.13 and 5.14). Although normally only produced for England, as this is the only nation of the UK using the LIHC indicator, the fuel poverty gap has been produced for households within the whole of the UK for the purpose of this exploration. The fuel poverty gap for each characteristic is presented as a mean value, reflecting how it is presented in fuel poverty reports and so allows for a comparison between those calculated for the analysis and those produced for national statistics. To facilitate comparisons between the surveys, the highest fuel poverty gap is shown in bold for each variable.

Table B.1: *The mean annual fuel poverty gap (2016) for the fuel poor under the AFP indicator, LCFS (2013 – 2015/16) and UKHLS (waves 3 – 7), weighted*

	LCFS	**UKHLS**
Country		
England	530.85	425.78
Wales	568.66	462.50
Scotland	531.84	477.36
Northern Ireland	**787.24**	**645.08**
Urban or rural		
Urban	518.50	417.29
Rural	**658.23**	**532.68**
Dwelling type		
Detached property	**739.31**	**607.36**
Semi-detached property	543.36	428.70
Terraced property	511.39	420.60
Other	484.33	355.66
Tenure		
Owned	**583.62**	**471.31**
Private rented	502.04	452.37
Social housing	540.96	409.29
Fuel used for heating		
Electricity	530.09	-
Gas	508.46	-
Oil	898.21	-
Other fuel	**1,017.77**	-
No central heating	491.22	-
All types of fuels used		
Electricity only	-	364.78
Gas only	-	416.54
Oil & Other fuel	-	368.99
All fuels	-	**877.89**
Other combinations	-	628.51

Table B.1: *The mean annual fuel poverty gap (2016) for the fuel poor under the AFP indicator, LCFS (2013 – 2015/16) and UKHLS (waves 3 – 7), weighted (continued)*

	LCFS	**UKHLS**
Method of fuel payment for gas & electricity		
Direct Debit (DD)	467.02	-
Prepayment meter (PPM)	**618.49**	-
Other	595.25	-
Combined	491.00	-
Method of fuel payment for gas & electricity		
Fixed monthly standing order	-	409.17
Monthly bill	-	409.57
Quarterly bill	-	478.23
PPM	-	458.11
Other	-	479.31
Combined	-	**494.33**
No gas or electricity	-	368.99
Household type		
Single adult	442.35	388.22
Single adult, 1 child	605.31	404.06
Single adult, 2+ children	547.66	481.99
2 adults	572.33	408.09
2 adults, 1 child	622.60	452.69
2 adults, 2 children	516.76	475.26
2, 3+ children	625.33	502.59
3+ adults	619.83	538.21
3+ adults, 1 child	**730.41**	559.67
3+ adults, 2+ children	576.50	**626.58**
Sex of the HRP		
Male	541.68	**449.47**
Female	**551.41**	439.25
Ethnicity of the HRP		
White	548.37	439.12

Table B.1: *The mean annual fuel poverty gap (2016) for the fuel poor under the AFP indicator, LCFS (2013 – 2015/16) and UKHLS (waves 3 – 7), weighted (continued)*

	LCFS	**UKHLS**
Ethnicity of the HRP		
Mixed Race	645.09	**540.21**
Asian	447.09	484.35
Black	**620.40**	471.36
Other	545.61	455.93
Employment status of HRP		
Self-employed	**669.80**	**529.68**
In paid employment	522.51	442.84
Unemployed	503.01	424.27
Retired	529.68	412.26
Inactive	558.38	454.52
Longstanding illness or disability in the household		
No	**553.78**	**455.01**
Yes	541.55	430.40
Household income decile (full income)		
1st (lowest)	505.49	396.34
2nd	509.65	400.12
3rd	587.64	458.72
4th	566.01	474.56
5th	633.15	472.79
6th	496.98	556.87
7th	616.46	559.40
8th	624.37	680.89
9th	777.20	852.61
10th	**791.45**	**1111.02**
Mean fuel poverty gap (£/year)	*546.47*	*443.92*
Mean fuel poverty gap (England only) (£/year)	*530.85*	*425.78*
National estimate (2016) (England only) (£/year)	*334.00*	
Sample size	**1,754**	**8,780**

As indicated by BEIS (2020a, p.40), although fuel poverty rates tend to be lower for higher income households, the fuel poverty gap does not reflect the same pattern. Higher income households tend to have a higher fuel poverty gap, and this is demonstrated in Table B.1. According to the most recent *Annual Fuel Poverty Statistics* report (Department for Business Energy & Industrial Strategy 2020b), this is linked to higher income households being more likely to live in larger dwellings. As dwelling size increases, energy efficiency tends to decrease, which increases fuel requirements (Department for Business Energy & Industrial Strategy 2020b).

By examining the remaining characteristics, some further similarities can be observed between the surveys. Households in Northern Ireland, rural-dwelling households, those living in detached properties, owner-occupiers, households with a self-employed HRP, and households where there is no longstanding illness or disability are all shown to have the highest fuel poverty gap. There are also some differences with households with three adults and once child having the highest fuel poverty gap in the LCFS and households with three adults and two or more children having the highest fuel poverty gap in the UKHLS. Although information on the fuel poverty gap is not available for all the characteristics presented in the table, the evidence that is available allows us to understand why some characteristics have the highest fuel poverty gap.

According to analysis conducted by BEIS (2020b), households using oil and solid fuel have the highest fuel poverty gap. This is also demonstrated in Table B.1 under *Other fuel* for the LCFS dataset and *All fuels* for the UKHLS dataset, both of which include oil and solid fuel. This could explain the higher fuel poverty gap in Northern Ireland and in rural areas, where connection to the gas network is low and where more expensive heating fuels are used (Baker et al. 2008; Boardman 2010; Preston et al. 2014). Additionally, detached properties are more common in rural areas (Ministry of Housing Communities & Local Government 2018) and are more likely to be larger and less energy efficient compared to other dwelling types (Baker et al. 2008; Boardman 2010; Wilson et al. 2012) and this could explain the higher fuel poverty gap for these dwellings.

As presented in Table B.1, BEIS (2020b) also shows that owner-occupiers have the highest fuel poverty gap, reflecting the nature of the housing stock where owner-occupiers tend to have one of the lowest energy efficient dwellings, but higher incomes than those in the private rented sector and in social housing, which makes them less likely to be fuel poor. HRPs belonging to a Black ethnic group in the LCFS data and those belonging to a Mixed

Race ethnic group in the UKHLS data have the highest fuel poverty gaps. This may be linked to lower incomes (Kenway and Palmer 2007) and greater housing deprivation (De Noronha 2019) amongst minority ethnic groups, and being less likely to switch energy suppliers or tariffs (Ipsos MORI 2013).

Overall, households in the LCFS dataset have a higher fuel poverty gap on average (£536.40), compared to households in the UKHLS (£496.51). This far-exceeds the estimated fuel poverty gap for England (£326.00) provided by BEIS (2018a) for the same year, with households in the LCFS exceeding the estimated fuel poverty gap for England by £210.40 and those in the UKHLS exceeding this by £170.51. This suggests that the modelled and actual fuel gap are not comparable. This could be related to over-spending or could suggest that modelling may not capture peoples' energy needs and costs in reality.

B.3 Identifying the determinants of the fuel poverty gap: Multiple regression

Although Table B.1 has offered some understanding of how the fuel poverty gap can vary between the characteristics presented, it is not clear what the unique effect of each variable is in the presence of others. To further understand this relationship, multiple regression was conducted to understand the relative contribution of each variable. This method was described in Chapter 6 (see section 6.9.2).

In contrast to the block method used for building regression models in earlier chapters, the same variables used in the analysis in section 5.3.7.3 are entered simultaneously to gain an overall understanding of the relationship between the characteristics explored and the fuel poverty gap. Using a logarithmically transformed[81] fuel poverty gap variable to account for any outliers and fulfil this assumption of multiple regression, the outputs of this are shown in Table B.2.

[81] The natural logarithm of a number is its logarithm to the base of *e*, which is equal to (approximately) 2.718.

Table B.2: *Multiple regression: Identifying the determinants of the fuel poverty gap, LCFS (2013 –2015/16) (coefficient (robust standard error)) and UKHLS (waves 3 – 7) coefficient (clustered robust standard error)*[82]*, weighted*

	LCFS	UKHLS
Country (ref: England)		
Wales	-0.014 (0.159)	0.103 (0.052)*
Scotland	-0.065 (0.118)	0.194 (0.050)***
Northern Ireland	-0.222 (0.149)	0.165 (0.052)**
Urban or rural (ref: Urban)	-0.068 (0.094)	0.015 (0.042)
Dwelling type (ref: Semi-detached)		
Detached	-0.348 (0.101)**	0.344 (0.043)***
Terraced	-0.030 (0.078)	-0.077 (0.035)*
Other	-0.211 (0.105)	-0.218 (0.054)***
Tenure (ref: Owned)		
Private rented	-0.258 (0.095)**	-0.077 (0.044)
Social housing	-0.126 (0.092)	-0.209 (0.042)***
Fuel used for heating (ref: Gas)		
Electricity	0.031 (0.174)	-
Oil	0.810 (0.132)***	-
Other fuel	0.969 (0.200)***	-
No central heating	-0.112 (0.199)	-
Fuel used for heating (ref: Gas)		
Electricity only	-	-0.091 (0.079)
Oil & other fuel	-	-0.268 (0.221)
All fuels	-	0.576 (0.125)***
Other combinations	-	0.368 (0.051)***
Method used to pay for gas and/or electricity (ref: DD)		
PPM	0.467 (0.094)***	-
Other	0.425 (0.080)***	-
Combined	0.328 (0.124)*	-
Method used to pay for gas and/or electricity (ref: Fixed monthly standing order)		
Monthly bill	-	-0.045 (0.047)
Quarterly bill	-	0.185 (0.054)**
PPM	-	0.380 (0.051)***
Other	-	0.209 (0.105)*
Combined	-	0.190 (0.070)*
No gas or electricity	-	.

[82] Robust standard errors were clustered by HRP to account for unobserved changes to the HRP over time.

Table B.2: *Multiple regression: Identifying the determinants of the fuel poverty gap, LCFS (2013 –2015/16) (coefficient (robust standard error)) and UKHLS (waves 3 – 7) coefficient (clustered robust standard error), weighted*

	LCFS	UKHLS
Household composition (ref: Two adults)		
Single adult	-0.329 (0.108)**	0.155 (0.052)**
Single adult, 1 child	0.149 (0.155)	0.026 (0.081)
Single adult, 2+ children	-0.146 (0/163)	0.191 (0.069)**
2 adults, 1 child	0.010(0.160)	0.164 (0.066)*
2 adults, 2 children	-0.123 (0.142)	0.145 (0.068)*
2 adults, 3+ children	0.118 (0.161)	0.047 (0.091)
3+ adults	0.020 (0.158)	0.236 (0.067)***
3+ adults, 1 child	0.300 (0.197)	0.195 (0.081)*
3+ adults, 2+ children	0.034 (0.187)	0.205 (0.107)
Sex HRP (ref: Male)	0.054 (0.078)	0.039 (0.033)
Ethnicity of HRP (ref: White)		
Mixed Race	0.504 (0.199)*	0.197 (0.136)
Asian	-0.040 (0.124)	0.118 (0.056)*
Black	0.182 (0.193)	0.245 (0.066)***
Other	0.325 (0.210)	0.267 (0.162)
Economic status of HRP (ref: Employed)		
Self-employed	0.178 (0.116)	0.104 (0.054)
Unemployed	-0.091 (0.139)	-0.036 (0.057)
Retired	-0.043 (0.099)	-0.031 (0.045)
Inactive	0.037 (0.089)	0.063 (0.044)
Longstanding illness or disability (in the household) (ref: No)	0.010 (0.069)	0.005 (0.032)
Full income deciles (ref: 10th, highest)		
1st (lowest)	-1.239 (0.278)***	-1.602 (0.290)***
2nd	-1.359 (0.268)***	-1.571 (0.289)***
3rd	-1.202 (0.262)***	-1.397 (0.287)***
4th	-1.235 (0.255)***	-1.392 (0.286)**
5th	-1.070 (0.250)***	-1.385 (0.286)***
6th	-1.192 (0.260)***	-1.195 (0.287)***
7th	-1.059 (0.288)***	-1.277 (0.295)***
8th	-1.176 (0.369)**	-0.893 (0.295)**
9th	-0.625 (0.367)	-0.674 (0.300)***
Constant	**6.731 (0.269)*** **	**6.714 (0.296)*** **
Adjusted R^2	**0.097**	**0.087**
Sample size	**1,754**	**8,780**

*p<0.05 **p<0.01 ***p<0.001

The analysis of the fuel poverty gap using multiple regression presented in Table B.2 shows that only a few similarities exist between the surveys. Both surveys show that the highest fuel gap exists for those using PPM and for *Other fuel* (LCFS) and *Oil & other fuel* (UKHLS) compared to their reference groups. Both surveys show no significant relationship between the fuel poverty gap and urban- or rural-living, sex and economic status of the HRP, and longstanding illness or disability in the household.

In contrast to findings for the LCFS where no significant relationship between *Country* and the fuel poverty gap was found, the UKHLS shows that households living in Scotland have a significantly higher fuel poverty compared to those in England. Analysis of the LCFS also found that households in detached dwellings have a significantly lower fuel poverty gap compared to those in semi-detached dwellings. However, the UKHLS data shows that those in detached dwellings have a significantly higher fuel poverty gap compared to those in semi-detached dwellings. A further contrast is that the fuel poverty gap is significantly lower for those in the private rented sector and in single-adult households in the LCFS, whereas for the UKHLS data, it is lowest in the social housing sector and in two-adult households. Although households with a HRP belonging to certain minority ethnic groups have a higher fuel poverty gap, the groups with the highest fuel poverty gap are different between the surveys. Households with a Mixed Race HRP have a higher fuel poverty gap in the LCFS, whilst in the UKHLS it is households with a Black HRP compared to their reference group. A final difference between the surveys is that households in the second decile of income have the lowest fuel poverty gap in the LCFS, whilst it is those in the lowest (first) income decile that have the lowest fuel poverty compared to households in the highest (tenth) decile.

This analysis of the fuel poverty gap has helped offer some important insights into fuel poverty under the AFP indicator. It has helped to isolate the types of characteristics that were associated with paying above reasonable costs (the median threshold), and as such has helped to identify the types of characteristics that are associated with the deepest levels of fuel poverty.

These findings have implications for tackling fuel poverty. At present, policy measures are targeted based on the *worst first* principle whereby those with the deepest levels of fuel poverty, as identified by the fuel poverty gap, are prioritised (Hills 2012; Middlemiss 2016; Committee on Fuel Poverty 2018). However, those who have the highest fuel poverty gap, as shown by the analysis based on actual expenditure, may be most able to remove themselves from fuel poverty and this brings into question the adequacy of the fuel poverty gap to identify the most vulnerable households who would benefit most from policy measures, at least from an expenditure perspective.

Appendix C| Supplementary material for Chapter 6

Within this appendix, the full outputs of the multiple regression and multinomial regression analyses are presented, summary versions of which are shown and discussed in Chapter 6.

C.1 The relationship between fuel poverty and food expenditure: the full multiple regression models

The following tables provide for the full multiple regression models for the relationship between fuel poverty and absolute food expenditure under the 10 per cent indicator and the LIHC indicator for the whole sample and the poor sample. Tables C.1 to C.4 present the full models for the analysis between fuel poverty and absolute expenditure for the whole sample (C.1 and C.2) and the poor sample (C.3 and C.4), and this corresponds to Table 6.5. Tables C.5 to C.8 present the full models for the analysis between fuel poverty and the proportion of income spent on food for the whole sample (C.5 and C.6) and the poor sample (C.7 and C.8), and this corresponds to Table 6.6.

Table C.1: *Multiple regression: The impact of fuel poverty (10 per cent indicator) on absolute food expenditure (natural log), LCFS (2013 – 2015/16), weighted: the whole sample*

	Model 1	Model 2	Model 3
Fuel poverty (ref: No)	-0.239 (0.030)***	-0.117 (0.028)***	0.061 (0.032)
Household type (ref: Two adults)			
Single adult	-0.739 (0.020)***	-0.687 (0.020)***	-0.504 (0.022)***
Single adult, 1 child	-0.435 (0.037)***	-0.324 (0.038)***	-0.166 (0.039)***
Single adult, 2+ children	-0.111 (0.035)**	0.029 (0.036)	0.097 (0.035)**
2 adults, 1 child	0.101 (0.024)***	0.113 (0.023)***	0.114 (0.022)***
2 adults, 2 children	0.306 (0.020)***	0.295 (0.020)***	0.260 (0.019)***
2 adults, 3+ children	0.362 (0.031)***	0.416 (0.030)***	0.357 (0.029)***
3+ adults	0.262 (0.040)***	0.291 (0.037)***	0.198 (0.034)***
3+ adults, 1 child	0.404 (0.040)***	0.452 (0.041)***	0.339 (0.042)***
3+ adults, 2+ children	0.558 (0.061)***	0.656 (0.060)***	0.542 (0.058)***
Highest qualification in the household (ref: Degree level or equivalent)			
Other higher qualification		-0.093 (0.023)***	-0.029 (0.022)
A-level or equivalent		-0.177 (0.019)***	-0.066 (0.022)**
GCSE or equivalent		-0.255 (0.021)***	-0.129 (0.021)***
Other below degree level		-0.258 (0.027)***	-0.134 (0.026)***
No formal qualifications		-0.171 (0.054)**	-0.037 (0.050)
Longstanding illness or disability (ref: No)		-0.014 (0.016)	-0.001 (0.015)
Sex of HRP (ref: Male)		-0.033 (0.016)*	-0.010 (0.015)
Economic status of HRP (ref: In paid employment)			
Self-employed		0.026 (0.032)	0.062 (0.031)*
Unemployed		-0.319 (0.050)***	-0.187 (0.050)***
Retired		0.018 (0.024)	0.106 (0.023)***
Inactive		-0.160 (0.025)***	-0.045 (0.025)
Ethnicity of HRP (ref: White)			
Mixed Race		-0.238 (0.086)**	-0.167 (0.080)*
Asian		-0.296 (0.042)***	-0.239 (0.036)***
Black		-0.384 (0.059)***	-0.331 (0.056)***
Other		-0.068 (0.064)	-0.045 (0.061)
Country (ref: England)			

Wales		-0.106 (0.045)*	-0.088 (0.043)*
Scotland		-0.079 (0.028)**	-0.055 (0.027)*
Northern Ireland		0.179 (0.031)***	0.219 (0.029)***
Urban or rural (ref: Urban)		0.070 (0.018)***	0.038 (0.017)*
Season (ref: Winter)			
Spring		-0.010 (0.020)	-0.005 (0.019)
Summer		-0.017 (0.021)	-0.011 (0.020)
Autumn		-0.022 (0.021)	-0.025 (0.020)
Full income deciles (ref: 10th, Highest)			
1st (Lowest)			-0.807 (0.045)***
2nd			-0.631 (0.036)***
3rd			-0.568 (0.035)***
4th			-0.492 (0.034)***
5th			-0.410 (0.032)***
6th			-0.346 (0.032)***
7th			-0.290 (0.031)***
8th			-0.215 (0.035)***
9th			-0.185 (0.037)***
Constant	4.335 (0.012)***	4.495 (0.022)***	4.740 (0.033)***
Adjusted R^2	**0.321**	**0.370**	**0.415**
Sample size	**12,074**		

*p<0.05 **p<0.01 ***p<0.001

Table C.2: *Multiple regression: The impact of fuel poverty (AFP indicator) on absolute food expenditure (natural log), LCFS (2013 – 2015/16), weighted: the whole sample*

	Model 1	**Model 2**	**Model 3**
Fuel poverty (ref: No)	-0.242 (0.026)***	-0.136 (0.025)***	0.025 (0.027)
Household type (ref: Two adults)			
Single adult	-0.758 (0.020)***	-0.696 (0.020)***	-0.503 (0.022)***
Single adult, 1 child	-0.430 (0.037)***	-0.321 (0.039)***	-0.166 (0.039)***
Single adult, 2+ children	-0.074 (0.036)*	0.049 (0.036)	0.095 (0.035)**
2 adults, 1 child	0.117 (0.024)***	0.122 (0.023)***	0.112 (0.022)***
2 adults, 2 children	0.324 (0.020)***	0.305 (0.020)***	0.258 (0.019)***
2 adults, 3+ children	0.398 (0.032)***	0.436 (0.031)***	0.353 (0.029)***
3+ adults	0.279 (0.039)***	0.300 (0.036)***	0.194 (0.034)***
3+ adults, 1 child	0.430 (0.040)***	0.465 (0.041)***	0.336 (0.042)***
3+ adults, 2+ children	0.617 (0.059)***	0.690 (0.059)***	0.536 (0.059)***
Highest qualification in the household (ref: Degree level or equivalent)			
Other higher qualification		-0.092 (0.023)***	-0.029 (0.022
A-level or equivalent		-0.173 (0.023)***	-0.067 (0.022)**
GCSE or equivalent		-0.250 (0.021)***	-0.129 (0.021)***
Other below degree level		-0.253 (0.027)***	-0.134 (0.026)***
No formal qualifications		-0.167 (0.053)***	-0.036 (0.051)
Longstanding illness or disability (ref: No)		-0.015 (0.015)	-0.000 (0.015)
Sex of HRP (ref: Male)		-0.031 (0.016)	-0.010 (0.015)
Economic status of HRP (ref: In paid employment)			
Self-employed		0.027 (0.032)	0.062 (0.031)*
Unemployed		-0.326 (0.050)***	-0.181 (0.049)***
Retired		0.018 (0.024)	0.107 (0.023)***
Inactive		-0.163 (0.025)***	-0.041 (0.025)
Ethnicity of HRP (ref: White)			
Mixed Race		-0.234 (0.082)**	-0.164 (0.081)*
Asian		-0.292 (0.041)***	-0.239 (0.036)***
Black		-0.376 (0.059)***	-0.331 (0.056)***
Other		-0.071 (0.064)	-0.043 (0.061)
Country (ref: England)			
Wales		-0.105 (0.045)*	-0.088 (0.043)*
Scotland		-0.077 (0.028)**	-0.055 (0.028)*
Northern Ireland		0.174 (0.031)***	0.225 (0.029)***
Urban or rural (ref: Urban)		0.068 (0.018)***	0.039 (0.017)*

Season (ref: Winter)			
Spring		-0.009 (0.020)	-0.005 (0.019)
Summer		-0.017 (0.021)	-0.013 (0.020)
Autumn		-0.024 (0.021)	0.025 (0.020)
Full income deciles (ref: 10th, Highest)			
1st (Lowest)			-0.790 (0.044)***
2nd			-0.629 (0.036)***
3rd			-0.569 (0.035)***
4th			-0.494 (0.035)***
5th			-0.412 (0.033)***
6th			-0.348 (0.033)***
7th			-0.291 (0.031)***
8th			-0.216 (0.035)***
9th			-0.185 (0.037)***
Constant	4.338 (0.012)***	4.495 (0.022)***	4.742 (0.033)***
Adjusted R^2	**0.323**	**0.371**	**0.414**
Sample size	**12,074**		

*p<0.05 **p<0.01 ***p<0.001

Table C.3: *Multiple regression: The impact of fuel poverty (10 per cent indicator) on absolute food expenditure (natural log), LCFS (2013 – 2015/16), weighted: the poor sample*

	Model 1	**Model 2**	**Model 3**
Fuel poverty (ref: No)	0.001 (0.040)	0.028 (0.037)	0.059 (0.041)
Household type (ref: Two adults)			
Single adult	-0.817 (0.051)***	-0.741 (0.047)***	-0.684 (0.054)***
Single adult, 1 child	-0.353 (0.062)***	-0.229 (0.067)**	-.0225 (0.066)**
Single adult, 2+ children	0.014 (0.057)	0.146 (0.060)*	0.104 (0.062)
2 adults, 1 child	0.100 (0.064)	0.175 (0.060)**	0.147 (0.061)*
2 adults, 2 children	0.257 (0.053)***	0.301 (0.053)***	0.225 (0.060)***
2 adults, 3+ children	0.430 (0.058)***	0.509 (0.059)***	0.331 (0.072)***
3+ adults	0.098 (0.089)	0.124 (0.083)	0.039 (0.088)
3+ adults, 1 child	0.490 (0.085)***	0.549 (0.093)***	0.408 (0.101)***
3+ adults, 2+ children	0.631 (0.073)***	0.758 (0.073)***	0.549 (0.086)***
Highest qualification in the household (ref: Degree level or equivalent)			
Other higher qualification		-0.043 (0.063)	-0.048 (0.061)
A-level or equivalent		-0.206 (0.053)***	-0.190 (0.052)***
GCSE or equivalent		-0.250 (0.049)***	-0.236 (0.048)***
Other below degree level		-0.244 (0.054)***	-0.227 (0.054)***
No formal qualifications		-0.050 (0.097)	-0.059 (0.092)
Longstanding illness or disability (ref: No)		-0.066 (0.035)	-0.066 (0.034)
Sex of HRP (ref: Male)		-0.029 (0.035)	-0.025 (0.034)
Economic status of HRP (ref: In paid employment)			
Self-employed		0.085 (0.053)	0.115 (0.051)*
Unemployed		-0.241 (0.063)***	-0.220 (0.062)***
Retired		0.167 (0.059)**	0.179 (0.057)**
Inactive		-0.084 (0.041)*	-0.072 (0.042)
Ethnicity of HRP (ref: White)			
Mixed Race		-0.253 (0.144)	-0.236 (0.144)
Asian		-0.172 (0.076)*	-0.161 (0.071)*
Black		-0.313 (0.087)***	-0.314 (0.078)***
Other		0.034 (0.094)	0.024 (0.092)
Country (ref: England)			
Wales		0.067 (0.066)	0.076 (0.068)
Scotland		-0.072 (0.062)	-0.065 (0.062)
Northern Ireland		0.299 (0.054)***	0.287 (0.058)***
Urban or rural (ref: Urban)		0.063 (0.044)	0.065 (0.044)

Season (ref: Winter)			
Spring		-0.012 (0.044)	-0.012 (0.043)
Summer		-0.031 (0.048)	-0.026 (0.047)
Autumn		-0.094 (0.045)*	-0.084 (0.043)
Full income deciles (ref: 10^{th}, Highest)			
1^{st} (Lowest)			-0.288 (0.103)**
2^{nd}			-0.569 (0.106)***
3^{rd}			-0.386 (0.091)***
4^{th}			-0.324 (0.088)***
5^{th}			-0.379 (0.079)***
6^{th}			-0.292 (0.077)***
7^{th}			-0.333 (0.072)***
8^{th}			-0.309 (0.071)***
9^{th}			-0.244 (0.068)***
Constant	**4.047 (0.036)*** **	**4.254 (0.065)*** **	**4.561 (0.089)*** **
Adjusted R^2	**0.314**	**0.368**	**0.384**
Sample size	**2,645**		

*$p<0.05$ **$p<0.01$ ***$p<0.001$

Table C.4: *Multiple regression: The impact of fuel poverty (AFP indicator) on absolute food expenditure (natural log), LCFS (2013 – 2015/16), weighted: the poor sample*

	Model 1	**Model 2**	**Model 3**
Fuel poverty (ref: No)	0.083 (0.034)*	0.072 (0.033)*	0.076 (0.032)*
Household type (ref: Two adults)			
Single adult	-0.808 (0.049)***	-0.731 (0.046)***	-0.684 (0.054)***
Single adult, 1 child	-0.348 (0.062)***	-0.225 (0.067)**	-0.222 (0.065)**
Single adult, 2+ children	0.011 (0.057)	0.141 (0.061)*	0.101 (0.062)
2 adults, 1 child	0.104 (0.064)	0.173 (0.060)**	0.146 (0.061)*
2 adults, 2 children	0.259 (0.053)***	0.296 (0.053)***	0.223 (0.060)***
2 adults, 3+ children	0.432 (0.057)***	0.503 (0.059)***	0.330 (0.072)***
3+ adults	0.101 (0.089)	0.120 (0.083)	0.035 (0.088)
3+ adults, 1 child	0.473 (0.089)***	0.531 (0.096)***	0.396 (0.105)***
3+ adults, 2+ children	0.620 (0.074)***	0.739 (0.074)***	0.534 (0.087)***
Highest qualification in the household (ref: Degree level or equivalent)			
Other higher qualification		-0.045 (0.063)	-0.048 (0.061)
A-level or equivalent		-0.206 (0.053)***	-0.190 (0.052)***
GCSE or equivalent		-0.253 (0.049)***	-0.237 (0.048)***
Other below degree level		-0.245 (0.054)***	-0.226 (0.053)***
No formal qualifications		-0.048 (0.097)	-0.055 (0.092)
Longstanding illness or disability (ref: No)		-0.066 (0.036)	-0.066 (0.034)
Sex of HRP (ref: Male)		-0.033 (0.035)	-0.028 (0.034)
Economic status of HRP (ref: In paid employment)			
Self-employed		0.087 (0.053)	0.117 (0.051)*
Unemployed		-0.235 (0.063)***	-0.213 (0.062)**
Retired		0.164 (0.058)**	0.176 (0.057)**
Inactive		-0.079 (0.041)	-0.067 (0.042)
Ethnicity of HRP (ref: White)			
Mixed Race		-0.257 (0.147)	-0.234 (0.146)
Asian		-0.172 (0.075)*	-0.162 (0.070)*
Black		-0.316 (0.087)***	-0.315 (0.079)***
Other		0.042 (0.094)	0.033 (0.092)
Country (ref: England)			
Wales		0.060 (0.066)	0.070 (0.068)
Scotland		-0.073 (0.063)	-0.066 (0.062)
Northern Ireland		0.292 (0.054)***	0.284 (0.059)***
Urban or rural (ref: Urban)		0.058 (0.045)	0.059 (0.044)

Season (ref: Winter)			
Spring		-0.011 (0.044)	-0.011 (0.097)
Summer		-0.025 (0.049)	-0.022 (0.047)
Autumn		-0.087 (0.044)*	-0.078 (0.043)
Full income deciles (ref: 10th, Highest)			
1st (Lowest)			-0.249 (0.097)*
2nd			-0.535 (0.096)***
3rd			-0.359 (0.090)***
4th			-0.305 (0.086)***
5th			-0.368 (0.079)***
6th			-0.283 (0.078)***
7th			-0.326 (0.073)***
8th			-0.301 (0.072)***
9th			-0.236 (0.068)**
Constant	**4.009 (0.037)*** **	**4.230 (0.065)*** **	**4.529 (0.090)*** **
Adjusted R^2	**0.317**	**0.370**	**0.385**
Sample size	**2,645**		

*p<0.05 **p<0.01 ***p<0.001

Table C.5: *Multiple regression: The impact of fuel poverty (10 per cent indicator) on the percentage of income spent on food, LCFS (2013 – 2015/16), weighted: the whole sample*

	Model 1	**Model 2**	**Model 3**
Fuel poverty (ref: No)	14.152 (1.657)***	12.964 (1.731)***	6.629 (1.280)***
Household type (ref: Two adults)			
Single adult	-2.989 (0.633)***	-2.594 (0.546)***	-7.888 (0.804)***
Single adult, 1 child	-0.952 (0.870)	-0.251 (0.771)	-4.220 (0.828)***
Single adult, 2+ children	0.643 (0.763)	1.136 (0.685)	0.138 (0.616)
2 adults, 1 child	0.202 (0.571)	1.113 (0.497)*	1.125 (0.464)*
2 adults, 2 children	0.976 (0.489)*	2.059 (0.418)***	2.805 (0.380)***
2 adults, 3+ children	2.020 (0.595)**	2.859 (0.540)***	4.252 (0.503)***
3+ adults	0.866 (0.654)	0.505 (0.703)	2.598 (0.687)***
3+ adults, 1 child	0.879 (0.728)	1.238 (0.886)	3.854 (0.812)***
3+ adults, 2+ children	3.846 (1.310)**	4.492 (1.400)**	7.122 (1.266)***
Highest qualification in the household (ref: Degree level or equivalent)			
Other higher qualification		1.107 (0.915)	-0.167 (0.910)
A-level or equivalent		0.620 (0.518)	-1.784 (0.560)**
GCSE or equivalent		-0.516 (0.557)	-3.370 (0.621)***
Other below degree level		-0.628 (0.664)	-3.544 (0.727)***
No formal qualifications		1.109 (1.080)	-1.889 (1.126)
Longstanding illness or disability (ref: No)		-0.687 (0.444)	-0.941 (0.422)*
Sex of HRP (ref: Male)		0.180 (0.430)	-0.393 (0.404)
Economic status of HRP (ref: In paid employment)			
Self-employed		3.245 (0.541)***	2.066 (0.508)***
Unemployed		1.583 (1.330)	-3.012 (1.421)*
Retired		3.831 (0.724)***	1.650 (0.637)*
Inactive		3.421 (0.702)***	-0.122 (0.738)
Ethnicity of HRP (ref: White)			
Mixed Race		4.140 (5.711)	2.632 (5.629)
Asian		-0.993 (1.027)	-2.403 (1.085)*
Black		-3.783 (0.824)***	-4.885 (0.818)***
Other		0.335 (1.947)	-0.215 (1.829)
Country (ref: England)			
Wales		-0.774 (0.624)	-1.040 (0.555)
Scotland		-0.460 (0.511)	-1.064 (0.483)*
Northern Ireland		3.665 (0.957)***	2.853 (0.905)**
Urban or rural (ref: Urban)		-0.548 (0.337)	0.166 (0.339)

Season (ref: Winter)			
Spring		-0.421 (0.498)	-0.507 (0.478)
Summer		-0.033 (0.612)	-0.203 (0.587)
Autumn		-0.963 (0.498)	-0.874 (0.469)
Full income deciles (ref: 10th, Highest)			
1st (Lowest)			22.006 (1.605)***
2nd			12.605 (0.684)***
3rd			10.584 (0.563)***
4th			8.531 (0.512)***
5th			7.417 (0.459)***
6th			6.264 (0.449)***
7th			4.652 (0.376)***
8th			3.101 (0.415)***
9th			1.484 (0.393)***
Constant	**14.000 (0.336)*** **	**13.024 (0.642)*** **	**9.349 (0.607)*** **
Adjusted R^2	**0.097**	**0.119**	**0.215**
Sample size	**12,074**		

*p<0.05 **p<0.01 ***p<0.001

Table C.6: *Multiple regression: The impact of fuel poverty (AFP indicator) on the percentage of income spent on food, LCFS (2013 – 2015/16), weighted: the whole sample*

	Model 1	Model 2	Model 3
Fuel poverty (ref: No)	9.762 (1.364)***	8.601 (0.952)***	3.507 (1.088)**
Household type (ref: Two adults)			
Single adult	-1.743 (0.559)**	-1.577 (0.476)**	-7.776 (0.769)***
Single adult, 1 child	0.500 (0.878)	0.051 (0.770)	-4.183 (0.821)***
Single adult, 2+ children	-0.420 (0.893)	0.025 (0.784)	-0.136 (0.658)
2 adults, 1 child	-0.448 (0.622)	0.639 (0.533)	0.949 (0.487)
2 adults, 2 children	0.161 (0.567)	1.456 (0.479)**	2.561 (0.426)***
2 adults, 3+ children	0.523 (0.755)	1.500 (0.675)*	3.751 (0.584)***
3+ adults	0.003 (0.740)	-0.343 (0.794)	2.206 (0.753)**
3+ adults, 1 child	-0.278 (0.873)	0.252 (1.006)	3.455 (0.905)***
3+ adults, 2+ children	1.368 (1.501)	2.256 (1.552)	6.205 (1.352)***
Highest qualification in the household (ref: Degree level or equivalent)			
Other higher qualification		1.174 (0.929)	-0.091 (0.917)
A-level or equivalent		0.508 (0.543)	-1.804 (0.569)**
GCSE or equivalent		-0.485 (0.573)	-3.342 (0.626)***
Other below degree level		-0.480 (0.670)	-3.495 (0.729)***
No formal qualifications		1.318 (1.087)	-1.792 (1.143)
Longstanding illness or disability (ref: No)		-0.663 (0.454)	-0.913 (0.424)*
Sex of HRP (ref: Male)		0.084 (0.440)	-0.431 (0.408)
Economic status of HRP (ref: In paid employment)			
Self-employed		3.516 (0.562)***	2.105 (0.517)***
Unemployed		3.849 (1.235)**	-2.371 (1.378)
Retired		4.150 (0.763)***	1.759 (0.658)**
Inactive		4.797 (0.689)***	0.282 (0.718)
Ethnicity of HRP (ref: White)			
Mixed Race		4.613 (5.841)	2.935 (5.680)
Asian		-1.015 (1.056)	-2.446 (1.105)*
Black		-4.091 (0.818)***	-4.978 (0.818)***
Other		0.810 (1.897)	0.014 (1.780)
Country (ref: England)			
Wales		-0.837 (0.626)	-1.032 (0.559)
Scotland		-0.473 (0.536)	-1.083 (0.491)*
Northern Ireland		4.820 (0.957)***	3.441 (0.895)***
Urban or rural (ref: Urban)		-0.346 (0.375)	0.250 (0.338)

Season (ref: Winter)			
Spring		-0.520 (0.518)	-0.550 (0.486)
Summer		-0.275 (0.631)	-0.331 (0.594)
Autumn		-0.932 (0.499)	-0.870 (0.465)
Full income deciles (ref: 10^{th}, Highest)			
1^{st} (Lowest)			23.539 (1.704)***
2^{nd}			12.549 (0.701)***
3^{rd}			10.363 (0.571)***
4^{th}			8.212 (0.520)***
5^{th}			7.109 (0.456)***
6^{th}			6.021 (0.460)***
7^{th}			4.487 (0.377)***
8^{th}			3.066 (0.416)***
9^{th}			1.438 (0.396)***
Constant	**14.220 (0.348)*** **	**12.971 (0.653)*** **	**9.509 (0.645)*** **
Adjusted R^2	**0.059**	**0.089**	**0.206**
Sample size	**12,074**		

*p<0.05 **p<0.01 ***p<0.001

Table C.7: *Multiple regression: The impact of fuel poverty (10 per cent indicator) on the percentage of income spent on food, LCFS (2013 – 2015/16), weighted: the poor sample*

	Model 1	**Model 2**	**Model 3**
Fuel poverty (ref: No)	11.647 (2.042)***	11.242 (1.889)***	2.923 (1.023)**
Household type (ref: Two adults)			
Single adult	-10.058 (3.224)**	-8.959 (2.294)***	-21.881 (3.503)***
Single adult, 1 child	-10.262 (3.078)**	-6.888 (1.969)***	-6.114 (1.577)***
Single adult, 2+ children	-8.842 (2.800)**	-5.883 (1.818)**	1.074 (1.525)
2 adults, 1 child	-4.606 (2.965)	-2.428 (2.091)	2.773 (1.871)
2 adults, 2 children	-4.428 (2.818)	-3.183 (1.963)	4.704 (1.868)*
2 adults, 3+ children	-5.594 (2.680)*	-4.086 (1.913)*	6.158 (2.108)**
3+ adults	-4.120 (3.422)	-5.184 (3.826)	1.234 (3.435)
3+ adults, 1 child	-4.969 (3.070)	-3.851 (2.898)	7.435 (2.600)**
3+ adults, 2+ children	-1.546 (3.649)	0.836 (3.141)	11.632 (3.238)***
Highest qualification in the household (ref: Degree level or equivalent)			
Other higher qualification		-1.104 (4.444)	-0.232 (3.885)
A-level or equivalent		-7.035 (2.622)**	-5.900 (2.133)**
GCSE or equivalent		-9.442 (2.701)***	-6.930 (2.115)**
Other below degree level		-9.656 (3.117)**	-7.840 (2.410)**
No formal qualifications		-7.499 (3.920)	-6.278 (3.373)
Longstanding illness or disability (ref: No)		-4.166 (1.535)**	-2.395 (1.316)
Sex of HRP (ref: Male)		-1.242 (1.532)	-1.329 (1.329)
Economic status of HRP (ref: In paid employment)			
Self-employed		5.607 (1.681)**	3.754 (1.405)**
Unemployed		0.095 (1.695)	-4.909 (1.697)**
Retired		7.649 (3.822)*	6.070 (3.269)
Inactive		3.302 (1.321)*	-1.455 (1.191)
Ethnicity of HRP (ref: White)			
Mixed Race		4.855 (12.115)	5.973 (11.137)
Asian		-2.064 (2.676)	-4.628 (2.395)
Black		-9.939 (1.907)***	-7.011 (1.595)***
Other		-1.691 (4.280)	0.593 (3.428)
Country (ref: England)			
Wales		0.267 (1.732)	0.039 (1.619)
Scotland		-2.136 (1.862)	-2.212 (1.594)
Northern Ireland		7.101 (2.428)**	4.904 (1.961)*
Urban or rural (ref: Urban)		0.755 (1.603)	-0.505 (1.505)

Season (ref: Winter)			
Spring		-2.368 (1.823)	-1.520 (1.508)
Summer		-1.412 (2.204)	-1.577 (1.913)
Autumn		-3.656 (1.798)*	-2.762 (1.457)
Full income deciles (ref: 10th, Highest)			
1st (Lowest)			52.790 (6.006)***
2nd			24.969 (3.129)**
3rd			20.441 (2.405)***
4th			15.661 (2.382)***
5th			9.661 (1.937)***
6th			6.174 (2.249)**
7th			3.905 (1.611)*
8th			2.059 (1.299)
9th			0.466 (1.155)
Constant	**24.288 (2.297)*** **	**31.673 (3.491)*** **	**19.891 (2.981)*** **
Adjusted R^2	**0.069**	**0.126**	**0.333**
Sample size	**2,645**		

*p<0.05 **p<0.01 ***p<0.001

Table C.8: *Multiple regression: The impact of fuel poverty (AFP indicator) on the percentage of income spent on food, LCFS (2013 – 2015/16), weighted: the poor sample*

	Model 1	**Model 2**	**Model 3**
Fuel poverty (ref: No)	4.578 (1.551)**	4.089 (1.374)**	3.255 (1.104)**
Household type (ref: Two adults)			
Single adult	-7.932 (2.970)**	-7.439 (2.160)**	-21.908 (3.457)***
Single adult, 1 child	-9.824 (3.028)**	-6.921 (1.943)***	-5.968 (1.566)***
Single adult, 2+ children	-10.161 (3.032)**	-7.527 (1.989)***	0.941 (1.523)
2 adults, 1 child	-6.174 (3.162)	-3.908 (2.229)	2.717 (1.865)
2 adults, 2 children	-6.333 (3.103)*	-4.956 (2.168)*	4.605 (1.888)*
2 adults, 3+ children	-7.808 (3.023)*	-6.324 (2.167)**	6.138 (2.131)**
3+ adults	-6.701 (3.775)	-7.747 (4.202)	1.011 (3.505)
3+ adults, 1 child	-7.168 (3.699)	-5.761 (3.517)	6.976 (2.822)*
3+ adults, 2+ children	-4.997 (4.079)	-2.553 (3.452)	11.024 (3.328)**
Highest qualification in the household (ref: Degree level or equivalent)			
Other higher qualification		-0.653 (4.519)	-0.195 (3.850)
A-level or equivalent		-7.041 (2.719)*	-5.888 (2.136)**
GCSE or equivalent		-9.137 (2.771)**	-6.931 (2.113)**
Other below degree level		-9.122 (3.150)**	-7.770 (2.392)**
No formal qualifications		-7.198 (3.845)	-6.096 (3.350)
Longstanding illness or disability (ref: No)		-4.449 (1.573)***	2.394 (1.317)
Sex of HRP (ref: Male)		-1.268 (1.570)	-1.455 (1.338)
Economic status of HRP (ref: In paid employment)			
Self-employed		6.148 (1.793)**	3.816 (1.411)**
Unemployed		2.544 (1.652)	-4.571 (1.684)**
Retired		8.015 (3.916)*	5.947 (3.226)
Inactive		4.960 (1.362)***	-1.233 (1.177)
Ethnicity of HRP (ref: White)			
Mixed Race		7.003 (12.417)	5.940 (11.082)
Asian		-1.732 (2.723)	-4.656 (2.384)
Black		-10.135 (1.846)***	-7.044 (1.614)***
Other		-1.173 (4.048)	1.014 (3.376)
Country (ref: England)			
Wales		0.050 (1.748)	-0.249 (1.632)
Scotland		-1.819 (1.812)	-2.212 (1.597)
Northern Ireland		8.819 (2.607)**	4.852 (2.003)*
Urban or rural (ref: Urban)		0.740 (1.681)	-0.751 (1.559)

Season (ref: Winter)			
Spring		-2.617 (1.893)	-1.487 (1.497)
Summer		-2.100 (2.266)	-1.439 (1.929)
Autumn		-3.819 (1.819)*	-2.525 (1.434)
Full income deciles (ref: 10th, Highest)			
1st (Lowest)			54.769 (6.111)***
2nd			26.666 (3.149)***
3rd			21.779 (2.438)***
4th			16.594 (2.336)***
5th			10.242 (1.969)***
6th			6.635 (2.280)**
7th			4.243 (1.616)**
8th			2.431 (1.343)
9th			0.885 (1.171)
Constant	**26.287 (2.410)*** **	**33.159 (3.705)*** **	**18.524 (2.802)*** **
Adjusted R^2	**0.030**	**0.091**	**0.335**
Sample size	**2,645**		

*p<0.05 **p<0.01 ***p<0.001

C.2 Cluster membership: the full multinomial regression analysis

The following tables present the full outputs of the multinomial regression analysis exploring the relationship between fuel poverty and food expenditure patterns. Tables C.9 to C.14 presents the analysis between fuel poverty and food expenditure patterns for the whole sample and this corresponds to Table 6.9. Tables C.15 to C.20 present the analysis between fuel poverty and food expenditure patterns for the poor sample and corresponds to Table 6.10.

Table C.9: *Multinomial regression: Model 1: The impact of fuel poverty (10 per cent indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the whole sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, canteens**	**Cluster 5: Takeaways**
Fuel poverty (ref: No)	2.044 (0.263)***	1.901 (0.255)***	0.859 (0.153)	1.383 (0.209)*
Household type (ref: Two adults)				
Single adult	1.845 (0.187)***	1.446 (0.141)***	1.543 (0.159)***	2.014 (0.234)***
Single adult, 1 child	1.818 (0.317)**	1.123 (0.184)	0.543 (0.125)**	2.268 (0.407)***
Single adult, 2+ children	2.337 (0.379)***	0.955 (0.176)	0.651 (0.149)	2.388 (0.454)***
2 adults, 1 child	1.086 (0.130)	0.754 (0.094)*	0.660 (0.081)**	1.864 (0.247)***
2 adults, 2 children	1.053 (0.117)	0.651 (0.069)***	0.460 (0.056)***	1.304 (0.156)*
2 adults, 3+ children	1.620 (0.233)**	0.769 (0.125)	0.384 (0.080)***	2.328 (0.371)***
3+ adults	1.461 (0.315)	1.445 (0.298)	0.733 (0.177)	1.303 (0.334)
3+ adults, 1 child	1.105 (0.330)	1.021 (0.406)	0.505 (0.123)**	2.428 (0.590)***
3+ adults, 2+ children	2.810 (1.028)**	1.034 (0.353)	0.491 (0.103)	4.516 (1.306)***
Constant	**0.597 (0.043)***	**0.787 (0.052)***	**0.573 (0.038)***	**0.315 (0.026)***
Pseudo R^2 (McFadden adjusted)	**0.017**			
Sample size	**12,074**			

*p<0.05 **p<0.01 ***p<0.001

Table C.10: *Multinomial regression: Model 1: The impact of fuel poverty (AFP indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the whole sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, canteens**	**Cluster 5: Takeaways**
Fuel poverty (ref: No)	1.950 (0.228)***	1.812 (0.224)***	0.844 (0.130)	1.563 (0.189)***
Household type (ref: Two adults)				
Single adult	1.953 (0.196)***	1.520 (0.146)***	1.531 (0.155)***	1.563 (0.189)***
Single adult, 1 child	1.812 (0.314)**	1.120 (0.183)	0.545 (0.126)**	2.051 (0.237)***
Single adult, 2+ children	2.132 (0.352)***	0.882 (0.164)	0.664 (0.153)**	2.216 (0.398)***
2 adults, 1 child	1.041 (0.125)	0.727 (0.091)*	0.664 (0.082)**	2.225 (0.428)***
2 adults, 2 children	1.003 (0.112)	0.624 (0.066)***	0.464 (0.056)***	1.820 (0.240)***
2 adults, 3+ children	1.470 (0.211)**	0.707 (0.116)*	0.391 (0.081)***	1.271 (0.151)*
3+ adults	1.396 (0.300)	1.389 (0.288)	0.738 (0.179)	2.197 (0.352)***
3+ adults, 1 child	1.029 (0.314)	0.960 (0.388)	0.511 (0.124)**	1.278 (0.329)**
3+ adults, 2+ children	2.413 (0.902)*	0.906 (0.315)	0.505 (0.199)	4.130 (1.197)***
Constant	**0.685 (0.036)*** **	**0.786 (0.052)*** **	**0.627 (0.036)*** **	**0.311 (0.026)*** **
Pseudo R^2 (McFadden adjusted)	**0.017**			
Sample size	**12,074**			

*p<0.05 **p<0.01 ***p<0.001

Table C.11: *Multinomial regression: Model 2: The impact of fuel poverty (10 per cent indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the whole sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, canteens**	**Cluster 5: Takeaways**
Fuel poverty (ref: No)	1.343 (0.179)*	1.499 (0.214)**	0.880 (0.163)	1.140 (0.171)
Household type (ref: Two adults)				
Single adult	1.891 (0.189)***	1.572 (0.156)***	1.475 (0.152)***	1.677 (0.195)***
Single adult, 1 child	1.671 (0.291)**	1.304 (0.232)	0.533 (0.128)**	1.593 (0.303)*
Single adult, 2+ children	2.044 (0.362)***	0.999 (0.196)	0.632 (0.152)	1.675 (0.344)*
2 adults, 1 child	1.321 (0.160)*	0.885 (0.111)	0.629 (0.078)***	1.637 (0.233)**
2 adults, 2 children	1.455 (0.167)**	0.791 (0.086)*	0.436 (0.054)***	1.201 (0.151)
2 adults, 3+ children	1.914 (0.279)***	0.825 (0.139)	0.363 (0.076)***	1.941 (0.322)***
3+ adults	1.336 (0.287)	1.238 (0.252)	0.749 (0.178)	1.302 (0.329)
3+ adults, 1 child	1.262 (0.418)	0.893 (0.294)	0.476 (0.120)**	2.190 (0.551)**
3+ adults, 2+ children	3.185 (1.230)**	0.788 (0.271)	0.460 (0.185)	3.699 (1.125)***
Highest qualification in the household (ref: Degree level or equivalent)				
Other higher qualification	1.455 (0.186)**	0.892 (0.124)	0.920 (0.119)	1.378 (0.175)*
A-level or equivalent	2.105 (0.259)***	0.972 (0.188)	0.805 (0.099)	2.093 (0.242)***
GCSE or equivalent	2.388 (0.285)***	1.009 (0.128)	0.696 (0.101)*	1.879 (0.214)***
Other below degree level	2.799 (0.419)***	1.171 (0.167)	0.828 (0.131)	2.209 (0.442)***
No formal qualifications	2.896 (0.968)**	1.680 (0.696)	0.721 (0.267)	1.890 (0.807)
Longstanding illness or disability (ref: No)	1.344 (0.101)***	1.142 (0.089)	0.872 (0.073)	1.062 (0.083)
Female HRP (ref: Male)	1.146 (0.098)	1.053 (0.091)	1.063 (0.095)	1.009 (0.096)
Economic status of HRP (ref: In paid employment)				
Self-employed	1.375 (0.228)	1.417 (0.169)**	1.287 (0.204)	1.198 (0.153)
Unemployed	2.419 (0.579)***	2.096 (0.513)**	1.160 (0.374)	1.069 (0.288)
Retired	1.314 (0.191)	1.818 (0.259)***	1.040 (0.154)	0.565 (0.130)*
Inactive	1.985 (0.225)***	1.653 (0.224)***	1.300 (0.191)	1.156 (0.155)
Ethnicity of HRP (ref: White)				
Mixed Race	0.834 (0.337)	2.142 (0.889)	1.379 (0.522)	1.286 (0.487)
Asian	1.177 (0.279)	2.514 (0.451)***	1.211 (0.252)	1.393 (0.262)
Black	1.144 (0.380)	3.034 (0.984)**	0.601 (0.234)	2.014 (0.614)*
Other	0.873 (0.266)	2.002 (0.503)**	1.087 (0.365)	1.281 (0.402)
Country (ref: England)				

Wales	1.240 (0.275)	1.133 (0.252)	1.115 (0.215)	1.031 (0.213)
Scotland	1.714 (0.250)***	1.074 (0.147)	1.045 (0.156)	1.849 (0.345)**
Northern Ireland	0.558 (0.145)*	0.490 (0.134)**	0.716 (0.180)	1.464 (0.280)*
Urban or rural (ref: Urban)	1.047 (0.107)	1.097 (0.110)	0.962 (0.105)	0.612 (0.067)***
Season (ref: Winter)				
Spring	0.965 (0.110)	0.963 (0.105)	1.064 (0.105)	1.061 (0.129)
Summer	0.957 (0.109)	1.104 (0.129)	1.082 (0.125)	0.973 (0.107)
Autumn	1.178 (0.136)	0.904 (0.110)	1.242 (0.152)	1.192 (0.149)
Constant	**0.215 (0.025)*** **	**0.495 (0.060)*** **	**0.600 (0.072)*** **	**0.228 (0.034)*** **
Pseudo R^2 (McFadden adjusted)	**0.048**			
Sample size	**12,074**			

*p<0.05 **p<0.01 ***p<0.001

Table C.12: *Multinomial regression: Model 2: The impact of fuel poverty (AFP indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the whole sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, canteens**	**Cluster 5: Takeaways**
Fuel poverty (ref: No)	1.388 (0.168)**	1.469 (0.188)**	0.878 (0.140)	1.296 (0.190)*
Household type (ref: Two adults)				
Single adult	1.932 (0.192)***	1.620 (0.159)***	1.466 (0.149)***	1.689 (0.196)***
Single adult, 1 child	1.663 (0.289)**	1.303 (0.232)	0.534 (0.128)**	1.572 (0.299)*
Single adult, 2^+ children	1.955 (0.349)***	0.948 (0.187)	0.643 (0.155)	1.614 (0.335)*
2 adults, 1 child	1.295 (0.157)*	0.866 (0.109)	0.631 (0.079)***	1.612 (0.230)***
2 adults, 2 children	1.420 (0.163)**	0.771 (0.085)*	0.438 (0.054)***	1.180 (0.149)
2 adults, 3^+ children	1.824 (0.265)***	0.783 (0.133)	0.366 (0.778)***	1.876 (0.315)***
3^+ adults	1.312 (0.282)	1.206 (0.246)	0.753 (0.179)	1.292 (0.327)
3^+ adults, 1 child	1.224 (0.408)	0.858 (0.287)	0.480 (0.121)**	2.141 (0.543)**
3^+ adults, 2^+ children	2.978 (0.169)**	0.734 (0.253)	0.468 (0.189)	3.543 (1.091)***
Highest qualification in the household (ref: Degree level or equivalent)				
Other higher qualification	1.447 (0.185)**	0.891 (0.124)	0.918 (0.119)	1.367 (0.174)*
A-level or equivalent	2.081 (0.256)***	0.964 (0.117)	0.805 (0.099)	2.067 (0.240)***
GCSE or equivalent	2.359 (0.282)***	1.001 (0.127)	0.694 (0.102)*	1.849 (0.211)***
Other below degree level	2.766 (0.412)***	1.164 (0.167)	0.826 (0.131)	2.171 (0.440)***
No formal qualifications	2.874 (0.951)**	1.676 (0.693)	0.722 (0.268)	1.864 (0.795)
Longstanding illness or disability (ref: No)	1.344 (0.101)***	1.142 (0.089)	0.873 (0.073)	1.061 (0.083)
Female HRP (ref: Male)	1.139 (0.972)	1.046 (0.090)	1.064 (0.094)	1.002 (0.095)
Economic status of HRP (ref: In paid employment)				
Self-employed	1.374 (0.228)	1.419 (0.169)**	1.286 (0.204)	1.189 (0.152)
Unemployed	2.468 (0.585)***	2.190 (0.530)**	1.128 (0.358)	1.052 (0.282)
Retired	1.315 (0.191)	1.827 (0.261)***	1.036 (0.154)	0.563 (0.129)*
Inactive	2.002 (0.228)***	1.695 (0.228)***	1.285 (0.190)	1.139 (0.153)
Ethnicity of HRP (ref: White)				
Mixed Race	0.828 (0.332)	2.123 (0.873)	1.378 (0.525)	1.260 (0.474)
Asian	1.167 (0.279)	2.487 (0.441)***	1.214 (0.252)	1.375 (0.259)
Black	1.127 (0.374)	2.985 (0.966)**	0.604 (0.236)	1.985 (0.604)*
Other	0.881 (0.269)	2.024 (0.508)**	1.086 (0.365)	1.281 (0.402)
Country (ref: England)				
Wales	1.234 (0.275)	1.130 (0.252)	1.115 (0.215)	1.025 (0.213)

Scotland	1.708 (0.248)***	1.070 (0.146)	1.045 (0.156)	1.841(0.343)**
Northern Ireland	0.565 (0.148)*	0.506 (0.136)*	0.705 (0.117)	1.454 (0.277)*
Urban or rural (ref: Urban)	1.054 (0.107)	1.103 (0.110)	0.961 (0.104)	0.614 (0.068)***
Season (ref: Winter)				
Spring	0.963 (0.110)	0.961 (0.105)	1.064 (0.123)	1.061 (0.129)
Summer	0.956 (0.109)	1.098 (0.129)	1.083 (0.125)	0.977 (0.108)
Autumn	1.184 (0.136)	0.909 (0.111)	1.240 (0.152)	1.199 (0.149)
Constant	**0.216 (0.025)*** **	**0.495 (0.060)*** **	**0.602 (0.072)*** **	**0.228 (0.034)*** **
Pseudo R^2 (McFadden adjusted)	**0.048**			
Sample size	**12,074**			

*p<0.05 **p<0.01 ***p<0.001

Table C.13: *Multinomial regression: Model 3: The impact of fuel poverty (10 per cent indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the whole sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, canteens**	**Cluster 5: Takeaways**
Fuel poverty (ref: No)	1.021 (0.147)	1.086 (0.168)	0.907 (0.196)	1.020 (0.171)
Household type (ref: Two adults)				
Single adult	1.428 (0.157)**	1.187 (0.132)	1.783 (0.213)***	1.505 (0.195)**
Single adult, 1 child	1.320 (0.234)	1.025 (0.189)	0.661 (0.165)	1.428 (0.281)
Single adult, 2^{+} children	1.864 (0.333)***	0.919 (0.183)	0.759 (0.186)	1.571 (0.329)*
2 adults, 1 child	1.336 (0.162)*	0.894 (0.112)	0.630 (0.079)***	1.632 (0.232)*
2 adults, 2 children	1.580 (0.183)***	0.837 (0.092)	0.414 (0.051)***	1.240 (0.157)
2 adults, 3^{+} children	2.202 (0.328)***	0.902 (0.152)	0.338 (0.071)**	2.038 (0.341)***
3^{+} adults	1.601 (0.346)*	1.483 (0.291)	0.664 (0.161)	1.380 (0.341)
3^{+} adults, 1 child	1.532 (0.504)	1.064 (0.353)	0.411 (0.105)***	2.383 (0.608)**
3^{+} adults, 2^{+} children	4.018 (1.520)***	0.924 (0.316)	0.389 (0.158)*	4.038 (1.233)***
Highest qualification in the household (ref: Degree level or equivalent)				
Other higher qualification	1.293 (0.167)*	0.834 (0.120)	1.014 (0.133)	1.315 (0.170)*
A-level or equivalent	1.754 (0.213)***	0.856 (0.106)	0.937 (0.120)	1.951 (0.236)***
GCSE or equivalent	1.951 (0.239)***	0.867 (0.112)	0.819 (0.123)	1.728 (0.206)***
Other below degree level	2.313 (0.352)***	1.010 (0.149)	0.959 (0.157)	2.033 (0.418)**
No formal qualifications	2.266 (0.763)*	1.412 (0.571)	0.886 (0.330)	1.729 (0.740)
Longstanding illness or disability (ref: No)	1.325 (0.099)***	1.128 (0.088)	0.904 (0.076)	1.055 (0.083)
Female HRP (ref: Male)	1.110 (0.096)***	1.018 (0.088)	1.091 (0.098)	0.994 (0.095)
Economic status of HRP (ref: In paid employment)				
Self-employed	1.308 (0.214)	1.324 (0.156)*	1.284 (0.207)	1.174 (0.150)
Unemployed	1.989 (0.474)**	1.718 (0.424)*	1.218 (0.400)	1.001 (0.273)
Retired	1.146 (0.169)	1.611 (0.231)**	1.163 (0.172)	0.533 (0.124)**
Inactive	1.662 (0.195)***	1.377 (0.193)*	1.424 (0.219)*	1.080 (0.149)
Ethnicity of HRP (ref: White)				
Mixed Race	0.755 (0.305)	1.949 (0.800)	1.453 (0.554)	1.240 (0.467)
Asian	1.063 (0.251)	2.357 (0.409)***	1.243 (0.261)	1.356 (0.257)
Black	1.052 (0.343)	2.853 (0.885)**	0.662 (0.261)	1.953 (0.589)*
Other	0.849 (0.258)	1.975 (0.499)**	1.119 (0.382)	1.268 (0.401)
Country (ref: England)				
Wales	1.194 (0.259)	1.118 (0.237)	1.159 (0.220)	1.004 (0.207)

Scotland	1.671 (0.243)***	1.043 (0.143)	1.085 (0.164)	1.829 (0.340)**
Northern Ireland	0.513 (0.131)**	0.463 (0.125)**	0.769 (0.190)	1.412 (0.270)
Urban or rural (ref: Urban)	1.100 (0.111)	1.151 (0.115)	0.917 (0.101)	0.627 (0.070)***
Season (ref: Summer)				
Spring	0.950 (0.109)	0.955 (0.103)	1.070 (0.124)	1.060 (0.128)
Autumn	0.937 (0.108)	1.085 (0.128)	1.081 (0.125)	0.975 (0.108)
Winter	1.175 (0.136)	0.902 (0.109)	1.222 (0.151)	1.192 (0.149)
Full income deciles (ref: 10th, Highest)				
1st (Lowest)	5.183 (1.348)***	2.585 (0.547)***	0.535 (0.139)*	1.681 (0.396)*
2nd	4.589 (1.130)***	2.104 (0.405)***	0.413 (0.084)***	1.578 (0.326)*
3rd	3.230 (0.787)***	1.759 (0.324)**	0.552 (0.110)*	1.623 (0.313)*
4th	3.227 (0.822)***	1.246 (0.247)	0.348 (0.067)***	1.414 (0.277)
5th	3.021 (0.701)***	1.349 (0.274)	0.470 (0.084)***	1.470 (0.324)
6th	2.415 (0.562)***	1.150 (0.224)	0.651 (0.125)*	1.110 (0.198)
7th	2.561 (0.625)***	1.327 (0.261)	0.728 (0.128)	1.398 (0.255)
8th	1.727 (0.449)*	0.922 (0.190)	0.790 (0.138)	1.246 (0.257)
9th	2.512 (0.647)***	0.874 (0.159)	0.722 (0.110)*	1.172 (0.199)
Constant	**0.097 (0.021)*** **	**0.449 (0.078)*** **	**0.831 (0.134)**	**0.185 (0.036)*** **
Pseudo R^2 (McFadden adjusted)	**0.058**			
Sample size	**12,074**			

*p<0.05 **p<0.01 ***p<0.001

Table C.14: *Multinomial regression: Model 3: The impact of fuel poverty (AFP indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the whole sample*

	Cluster 2: Highly processed	Cluster 3: Fruit & vegetable burden	Cluster 4: Restaurants, cafés, canteens	Cluster 5: Takeaways
Fuel poverty (ref: No)	1.071 (0.137)	1.114 (0.148)	1.045 (0.180)	1.171 (0.158)
Household type (ref: Two adults)				
Single adult	1.143 (0.161)**	1.198 (0.135)	1.799 (0.217)***	1.535 (0.201)**
Single adult, 1 child	1.322 (0.234)	1.026 (0.189)	0.661 (0.165)	1.433 (0.282)
Single adult, 2^+ children	1.849 (0.331)**	0.908 (0.181)	0.753 (0.185)	1.539 (0.324)*
2 adults, 1 child	1.331 (0.162)*	0.888 (0.112)	0.628 (0.079)***	1.614 (0.229)**
2 adults, 2 children	1.572 (0.183)***	0.830 (0.091)	0.412 (0.051)***	1.220 (0.156)
2 adults, 3^+ children	2.178 (0.327)***	0.888 (0.151)	0.335 (0.071)***	1.981 (0.337)***
3^+ adults	1.594 (0.345)*	1.425 (0.290)	0.663 (0.061)	1.364 (0.338)
3^+ adults, 1 child	1.519 (0.501)	1.049 (0.350)	0.409 (0.104)***	2.327 (0.599)**
3^+ adults, 2^+ children	3.971 (1.517)***	0.904 (0.311)	0.386 (0.158)*	3.881 (1.201)***
Highest qualification in the household (ref: Degree level or equivalent)				
Other higher qualification	1.293 (0.167)*	0.835 (0.120)	1.012 (0.133)	1.313 (0.170)*
A-level or equivalent	1.753 (0.213)***	0.856 (0.106)	0.937 (0.120)	1.949 (0.236)***
GCSE or equivalent	1.949 (0.239)***	0.867 (0.112)	0.818 (0.123)	1.724 (0.205)***
Other below degree level	2.312 (0.351)***	1.010 (0.148)	0.957 (0.156)	2.026 (0.418)**
No formal qualifications	2.266 (0.763)*	1.413 (0.571)	0.884 (0.329)	1.726 (0.739)
Longstanding illness or disability (ref: No)	1.326 (0.100)***	1.129 (0.088)	0.904 (0.076)	1.056 (0.083)
Female HRP (ref: Male)	1.109 (0.095)	1.017 (0.088)	1.090 (0.098)	0.992 (0.095)
Economic status of HRP (ref: In paid employment)				
Self-employed	1.306 (0.214)	1.323 (0.156)*	1.283 (0.207)	1.170 (0.150)
Unemployed	1.983 (0.469)**	1.723 (0.423)*	1.195 (0.389)	0.990 (0.269)
Retired	1.147 (0.169)	1.615 (0.231)**	1.162 (0.171)	0.534 (0.124)**
Inactive	1.660 (0.196)***	1.381 (0.194)*	1.411 (0.219)*	1.073 (0.149)
Ethnicity of HRP (ref: White)				
Mixed Race	0.753 (0.304)	1.948 (0.801)	1.436 (0.549)	1.233 (0.463)
Asian	1.061 (0.251)	2.352 (0.407)***	1.240 (0.261)	1.352 (0.256)
Black	1.050 (0.342)	2.843 (0.881)**	0.659 (0.261)	1.938 (0.584)*
Other	0.849 (0.258)	1.980 (0.499)**	1.117 (0.382)	1.269 (0.401)
Country (ref: England)				
Wales	1.193 (0.259)	1.118 (0.238)	1.158 (0.220)	1.001 (0.207)
Scotland	1.670 (0.242)***	1.042 (0.143)	1.085 (0.164)	1.828 (0.339)**
Northern Ireland	0.513 (0.132)*	0.466 (0.125)**	0.760 (0.188)	1.405 (0.269)

Urban or rural (ref: Urban)	1.100 (0.111)	1.152 (0.115)	0.916 (0.101)	0.627 (0.070)***
Season (ref: Summer)				
Spring	0.951 (0.109)	0.956 (0.103)	1.071 (0.124)	1.061 (0.128)
Autumn	0.938 (0.108)	1.085 (0.128)	1.084 (0.125)	0.980 (0.108)
Winter	1.177 (0.136)	0.904 (0.110)	1.224 (0.151)	1.197 (0.149)
Full income deciles (ref: 10th, Highest)				
1st (Lowest)	5.084 (1.328)***	2.564 (0.533)**	0.504 (0.125)**	1.580 (0.364)*
2nd	4.508 (1.137)***	2.061 (0.402)***	0.402 (0.083)***	1.502 (0.318)
3rd	3.192 (0.789)***	1.732 (0.323)**	0.543 (0.110)***	1.567 (0.307)*
4th	3.196 (0.822)***	1.229 (0.247)	0.345 (0.067)***	1.374 (0.271)
5th	3.003 (0.700)***	1.335 (0.273)	0.467 (0.084)***	1.443 (0.322)
6th	2.406 (0.562)***	1.143 (0.223)	0.649 (0.125)*	1.096 (0.196)
7th	2.645 (0.624)***	1.322 (0.261)	0.727 (0.128)	1.385 (0.253)
8th	1.727 (0.448)*	0.921 (0.190)	0.790 (0.138)	1.244 (0.256)
9th	2.511 (0.647)***	0.873 (0.159)	0.722 (0.110)*	1.170 (0.199)
Constant	**0.097 (0.022)*** **	**0.451 (0.079)*** **	**0.833 (0.134)**	**0.187 (0.037)*** **
Pseudo R^2 (McFadden adjusted)	**0.058**			
Sample size	**12,074**			

*p<0.05 **p<0.01 ***p<0.001

Table C.15: *Multinomial regression: Model 1: The impact of fuel poverty (10 per cent indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the poor sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, canteens**	**Cluster 5: Takeaways**
Fuel poverty (ref: No)	1.026 (0.171)	1.138 (0.199)	0.773 (0.192)	0.937 (0.178)
Household type (ref: Two adults)				
Single adult	2.387 (0.606)**	1.817 (0.456)*	1.778 (0.571)	2.464 (0.712)**
Single adult, 1 child	1.914 (0.592)*	1.080 (0.319)	0.391 (0.183)*	2.570 (0.853)**
Single adult, 2^+ children	1.823 (0.523)*	0.979 (0.289)	0.454 (0.201)	2.683 (0.882)**
2 adults, 1 child	1.429 (0.397)	0.966 (0.284)	0.348 (0.146)*	3.707 (1.166)***
2 adults, 2 children	1.288 (0.330)	0.804 (0.214)	0.317 (0.126)**	1.978 (0.592)
2 adults, 3^+ children	1.642 (0.463)	0.494 (0.154)*	0.168 (0.087)**	2.926 (0.937)**
3^+ adults	2.058 (0.825)	1.373 (0.602)	0.903 (0.412)	2.056 (0.789)
3^+ adults, 1 child	0.685 (0.380)	0.409 (0.340)	0.650 (0.398)	2.995 (1.586)*
3^+ adults, 2^+ children	1.058 (0.219)	0.797 (0.374)	0.530 (0.432)	7.134 (3.153)***
Constant	**1.058 (0.219)**	**1.259 (0.241)**	**0.581 (0.149)***	**0.379 (0.090)****
Pseudo R^2 (McFadden adjusted)	**0.025**			
Sample size	**2,645**			

**p*<0.05 ***p*<0.01 ****p*<0.001

Table C.16: *Multinomial regression: Model 1: The impact of fuel poverty (AFP indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the poor sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, canteens**	**Cluster 5: Takeaways**
Fuel poverty (ref: No)	0.879 (0.134)	1.085 (0.178)	0.854 (0.190)	0.970 (0.157)
Household type (ref: Two adults)				
Single adult	2.362 (0.597)**	1.867 (0.462)*	1.689 (0.534)	2.434 (0.708)**
Single adult, 1 child	1.902 (0.585)*	1.087 (0.320)	0.387 (0.181)*	2.564 (0.853)**
Single adult, 2^+ children	1.826 (0.525)*	0.963 (0.287)	0.468 (0.208)	2.704 (0.887)**
2 adults, 1 child	1.413 (0.391)	0.951 (0.281)	0.358 (0.151)*	3.738 (1.172)***
2 adults, 2 children	1.297 (0.326)	0.787 (0.211)	0.330 (0.131)**	1.999 (0.592)*
2 adults, 3^+ children	1.629 (0.457)	0.482 (0.151)*	0.176 (0.091)**	2.961 (0.933)**
3^+ adults	2.037 (0.816)	1.334 (0.587)	0.950 (0.433)	2.085 (0.781)
3^+ adults, 1 child	0.701 (0.385)	0.397 (0.328)	0.688 (0.419)	3.033 (1.598)*
3^+ adults, 2^+ children	1.990 (0.834)	0.763 (0.359)	0.573 (0.467)	7.274 (3.184)***
Constant	**1.133 (0.237)**	**1.269 (0.254)**	**0.575 (0.154)***	**0.376 (0.134)*****
Pseudo R^2 (McFadden adjusted)	**0.025**			
Sample size	**2,645**			

*p<0.05 **p<0.01 ***p<0.001

Table C.17: *Multinomial regression: Model 2: The impact of fuel poverty (10 per cent indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the poor sample*

	Cluster 2: Highly processed	Cluster 3: Fruit & vegetable burden	Cluster 4: Restaurants, cafés, canteens	Cluster 5: Takeaways
Fuel poverty (ref: No)	0.924 (0.159)	1.063 (0.197)	0.765 (0.198)	0.822 (0.162)
Household type (ref: Two adults)				
Single adult	2.287 (0.533)***	1.831 (0.437)*	1.686 (0.516)	2.206 (0.618)***
Single adult, 1 child	1.860 (0.550)*	1.205 (0.381)	0.326 (0.152)*	2.331 (0.801)*
Single adult, 2^+ children	1.900 (0.573)*	0.953 (0.301)	0.421 (0.195)	2.503 (0.887)*
2 adults, 1 child	1.791 (0.492)*	1.091 (0.307)	0.324 (0.136)**	3.590 (1.217)***
2 adults, 2 children	1.757 (0.452)*	0.938 (0.262)	0.273 (0.108)**	1.877 (0.598)*
2 adults, 3^+ children	2.027 (0.594)*	0.442 (0.147)*	0.142 (0.075)***	2.615 (0.898)**
3^+ adults	2.822 (1.088)**	1.099 (0.397)	0.857 (0.411)	2.480 (0.998)*
3^+ adults, 1 child	1.014 (0.556)	0.324 (0.268)	0.609 (0.406)	2.799 (1.540)
3^+ adults, 2^+ children	2.499 (1.067)*	0.571 (0.276)	0.506 (0.426)	6.509 (2.956)***
Highest qualification in the household (ref: Degree level or equivalent)				
Other higher qualification	1.762 (0.483)*	0.840 (0.250)	0.812 (0.281)	1.827 (0.550)*
A-level or equivalent	1.689 (0.382)*	0.792 (0.189)	0.591 (0.188)	1.936 (0.488)**
GCSE or equivalent	3.255 (0.719)***	1.053 (0.249)	0.532 (0.172)	2.651 (0.655)***
Other below degree level	3.141 (0.871)***	1.206 (0.334)	0.761 (0.278)	2.659 (0.806)**
No formal qualifications	2.584 (1.405)	0.909 (0.536)	0.479 (0.423)	2.052 (1.762)
Longstanding illness or disability (ref: No)	1.660 (0.245)**	1.234 (0.205)	0.675 (0.169)	1.590 (0.267)**
Female HRP (ref: Male)	1.057 (0.174)	1.155 (0.195)	1.170 (0.277)	0.809 (0.148)
Economic status of HRP (ref: In paid employment)				
Self-employed	1.657 (0.386)*	1.592 (0.403)	1.243 (0.438)	1.473 (0.366)
Unemployed	1.842 (0.554)*	1.722 (0.531)	1.181 (0.552)	1.036 (0.352)
Retired	1.124 (0.326)	1.704 (0.498)	1.142 (0.447)	0.535 (0.220)
Inactive	1.816 (0.331)**	1.813 (0.365)**	0.973 (0.294)	1.228 (0.258)
Ethnicity of HRP (ref: White)				
Mixed Race	0.915 (0.539)	2.182 (1.278)	1.338 (0.863)	1.603 (0.915)
Asian	0.687 (0.242)	3.320 (1.145)**	1.190 (0.655)	0.879 (0.292)
Black	2.195 (0.910)	6.044 (2.502)***	0.352 (0.255)	2.425 (1.062)*
Other	0.849 (0.375)	2.127 (0.807)*	1.106 (0.733)	1.093 (0.532)
Country (ref: England)				
Wales	0.843 (0.273)	1.230 (0.387)	2.004 (0.853)	0.868 (0.323)

Scotland	1.980 (0.557)*	0.918 (0.267)	0.898 (0.343)	2.402 (0.726)**
Northern Ireland	1.006 (0.386)	0.890 (0.344)	2.417 (1.068)*	3.568 (1.254)***
Urban or rural (ref: Urban)	1.101 (0.221)	1.348 (0.267)	1.209 (0.346)	0.547 (0.125)**
Season (ref: Winter)				
Spring	1.055 (0.212)	1.089 (0.236)	0.521 (0.152)*	0.890 (0.200)
Summer	1.411 (0.305)	1.402 (0.323)	0.765 (0.248)	1.022 (0.237)
Autumn	1.656 (0.358)*	1.121 (0.255)	1.071 (0.310)	1.147 (0.266)
Constant	**0.195 (0.060)***	**0.500 (0.157)***	**0.975 (0.372)**	**0.162 (0.61)***
Pseudo R^2 (McFadden adjusted)	**0.085**			
Sample size	**2,645**			

*p<0.05 **p<0.01 ***p<0.001

Table C.18: *Multinomial regression: Model 2: The impact of fuel poverty (AFP indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the poor sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, canteens**	**Cluster 5: Takeaways**
Fuel poverty (ref: No)	0.872 (0.132)	1.088 (0.181)	0.864 (0.199)	0.957 (0.158)
Household type (ref: Two adults)				
Single adult	2.235 (0.524)**	1.854 (0.441)***	1.618 (0.492)	2.145 (0.606)**
Single adult, 1 child	1.844 (0.546)*	1.206 (0.382)	0.322 (0.150)*	2.323 (0.802)*
Single adult, 2^{+} children	1.921 (0.575)*	0.941 (0.298)	0.435 (0.201)	2.561 (0.903)**
2 adults, 1 child	1.803 (0.493)*	1.085 (0.305)	0.334 (0.140)**	3.666 (0.124)***
2 adults, 2 children	1.780 (0.456)*	0.930 (0.260)	0.283 (0.112)**	1.932 (0.610)*
2 adults, 3^{+} children	2.063 (0.604)*	0.438 (0.145)*	0.148 (0.078)***	2.705 (0.918)**
3^{+} adults	2.859 (1.104)**	1.075 (0.390)	0.908 (0.432)	2.575 (1.022)*
3^{+} adults, 1 child	1.047 (0.572)	0.313 (0.256)	0.654 (0.429)	2.869 (1.580)
3^{+} adults, 2^{+} children	2.608 (1.110)*	0.552 (0.268)	0.549 (0.460)	6.843 (3.086)***
Highest qualification in the household (ref: Degree level or equivalent)				
Other higher qualification	1.766 (0.483)*	0.842 (0.251)	0.808 (0.280)	1.816 (0.547)*
A-level or equivalent	1.696 (0.384)*	0.794 (0.189)	0.596 (0.190)	1.931 (0.488)**
GCSE or equivalent	3.269 (0.723)***	1.050 (0.248)	0.531 (0.172)	2.631 (0.651)***
Other below degree level	3.149 (0.873)***	1.208 (0.335)	0.759 (0.277)	2.627 (0.799)**
No formal qualifications	2.575 (1.397)	0.911 (0.537)	0.478 (0.426)	2.037 (1.748)
Longstanding illness or disability (ref: No)	1.663 (0.245)**	1.233 (0.204)	0.683 (0.171)	1.594 (0.267)**
Female HRP (ref: Male)	1.065 (0.175)	1.152 (0.196)	1.175 (0.278)	0.807 (0.148)
Economic status of HRP (ref: In paid employment)				
Self-employed	1.647 (0.383)*	1.595 (0.403)	1.228 (0.432)	1.455 (0.362)
Unemployed	1.808 (0.529)*	1.741 (0.523)	1.106 (0.501)	0.995 (0.332)
Retired	1.125 (0.325)	1.702 (0.496)	1.124 (0.441)	0.534 (0.220)
Inactive	1.794 (0.326)**	1.834 (0.368)**	0.926 (0.277)	1.195 (0.251)
Ethnicity of HRP (ref: White)				
Mixed Race	0.916 (0.549)	2.183 (1.277)	1.291 (0.839)	1.532 (0.883)
Asian	0.683 (0.241)	3.324 (1.150)**	1.194 (0.662)	0.870 (0.291)
Black	2.198 (0.912)	6.009 (2.486)***	0.350 (0.255)	2.420 (1.059)*
Other	0.838 (0.369)	2.138 (0.810)*	1.094 (0.732)	1.079 (0.524)
Country (ref: England)				
Wales	0.857 (0.278)	1.226 (0.386)	2.034 (0.872)	0.866 (0.323)
Scotland	1.985 (0.558)*	0.920 (0.268)	0.889 (0.339)	2.390 (0.721)**
Northern Ireland	1.014 (0.388)	0.890 (0.342)	2.329 (1.025)	3.439 (1.190)***

Urban or rural (ref: Urban)	1.109 (0.223)	1.336 (0.266)	1.210 (0.351)	0.545 (0.124)**
Season (ref: Winter)				
Spring	1.052 (0.212)	1.090 (0.237)	0.523 (0.152)*	0.898 (0.201)
Summer	1.395 (0.298)	1.402 (0.324)	0.773 (0.252)	1.041 (0.239)
Autumn	1.636 (0.352)*	1.126 (0.256)	1.073 (0.312)	1.157 (0.267)
Constant	**0.202 (0.063)*** **	**0.491 (0.154)***	**0.963 (0.377)**	**0.157 (0.060)*** **
Pseudo R^2 (McFadden adjusted)	**0.085**			
Sample size	**2,645**			

*p<0.05 **p<0.01 ***p<0.001

Table C.19: *Multinomial regression: Model 3: The impact of fuel poverty (10 per cent indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the poor sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, canteens**	**Cluster 5: Takeaways**
Fuel poverty (ref: No)	0.898 (0.163)	1.028 (0.205)	0.687 (0.193)	0.835 (0.177)
Household type (ref: Two adults)				
Single adult	2.250 (0.587)**	1.780 (0.475)*	1.605 (0.538)	2.557 (0.828)**
Single adult, 1 child	1.828 (0.546)*	1.133 (0.361)	0.323 (0.152)*	2.318 (0.801)*
Single adult, 2^+ children	2.050 (0.650)*	1.099 (0.365)	0.515 (0.241)	2.499 (0.912)*
2 adults, 1 child	1.863 (0.528)*	1.262 (0.370)	0.377 (0.161)*	3.561 (1.228)***
2 adults, 2 children	2.105 (0.602)**	1.246 (0.393)	0.360 (0.162)*	2.074 (0.705)*
2 adults, 3^+ children	3.070 (1.061)**	0.642 (0.255)	0.181 (0.111)**	3.859 (1.525)**
3^+ adults	3.521 (1.313)**	1.419 (0.550)	1.090 (0.574)	2.884 (1.143)**
3^+ adults, 1 child	1.468 (0.894)	0.465 (0.408)	0.914 (0.711)	3.596 (2.200)
3^+ adults, 2^+ children	3.970 (1.948)**	0.815 (0.446)	0.574 (0.539)	10.546 (5.467)***
Highest qualification in the household (ref: Degree level or equivalent)				
Other higher qualification	1.765 (0.481)*	0.838 (0.244)	0.794 (0.281)	1.803 (0.539)*
A-level or equivalent	1.604 (0.360)*	0.744 (0.175)	0.576 (0.187)	1.855 (0.469)*
GCSE or equivalent	3.145 (0.689)***	1.007 (0.235)	0.525 (0.164)*	2.595 (0.637)***
Other below degree level	3.016 (0.832)***	1.153 (0.315)	0.717 (0.262)	2.560 (0.771)**
No formal qualifications	2.574 (1.416)	0.896 (0.528)	0.485 (0.427)	2.127 (1.798)
Longstanding illness or disability (ref: No)	1.672 (0.248)**	1.254 (0.206)	0.702 (0.172)	1.594 (0.270)**
Female HRP (ref: Male)	1.040 (0.170)	1.154 (0.195)	1.157 (0.272)	0.796 (0.146)
Economic status of HRP (ref: In paid employment)				
Self-employed	1.541 (0.362)	1.489 (0.374)	1.237 (0.428)	1.401 (0.351)
Unemployed	1.798 (0.558)	1.680 (0.532)	1.155 (0.529)	1.054 (0.371)
Retired	1.070 (0.313)	1.582 (0.455)	1.015 (0.389)	0.508 (0.212)
Inactive	1.803 (0.336)**	1.772 (0.361)**	0.877 (0.263)	1.240 (0.268)
Ethnicity of HRP (ref: White)				
Mixed Race	0.884 (0.517)	2.111 (1.214)	1.397 (0.905)	1.522 (0.863)
Asian	0.655 (0.228)	3.151 (1.036)***	1.043 (0.579)	0.839 (0.276)
Black	2.187 (0.899)	6.180 (2.589)***	0.406 (0.296)	2.450 (1.055)*
Other	0.887 (0.401)	2.314 (0.891)*	1.309 (0.884)	1.112 (0.540)
Country (ref: England)				

Wales	0.812 (0.266)	1.184 (0.372)	1.842 (0.805)	0.806 (0.306)
Scotland	1.967 (0.549)*	0.904 (0.263)	0.878 (0.341)	2.399 (0.729)**
Northern Ireland	1.051 (0.415)	0.869 (0.334)	2.133 (0.948)	3.683 (1.328)***
Urban or rural (ref: Urban)	1.089 (0.216)	1.326 (0.261)	1.193 (0.337)	0.553 (0.125)**
Season (ref: Winter)				
Spring	1.058 (0.211)	1.081 (0.233)	0.540 (0.156)*	0.894 (0.201)
Summer	1.399 (0.301)	1.380 (0.317)	0.763 (0.244)	1.023 (0.238)
Autumn	1.637 (0.352)*	1.121 (0.254)	1.151 (0.331)	1.139 (0.266)
Full income deciles (ref: 10th, Highest)				
1st (Lowest)	1.402 (0.611)	1.235 (0.597)	1.366 (0.893)	1.365 (0.691)
2nd	2.964 (1.289)*	2.007 (0.980)	1.157 (0.780)	2.348 (1.194)
3rd	2.078 (0.851)	1.598 (0.721)	0.733 (0.465)	2.144 (1.023)
4th	1.846 (0.708)	1.767 (0.793)	1.976 (1.224)	1.800 (0.775)
5th	2.499 (0.948)*	1.990 (0.871)	1.147 (0.699)	2.770 (1.153)*
6th	1.963 (0.701)	1.471 (0.597)	0.917 (0.522)	2.450 (0.954)*
7th	2.039 (0.721)*	1.344 (0.549)	0.981 (0.566)	2.677 (1.011)**
8th	2.292 (0.778)*	1.280 (0.456)	0.999 (0.525)	2.394 (0.840)*
9th	1.304 (0.438)	0.778 (0.281)	0.308 (0.171)*	2.012 (0.656)*
Constant	**0.103 (0.043)***	**0.346 (0.161)***	**0.920 (0.544)**	**0.075 (0.035)*****
Pseudo R^2 (McFadden adjusted)	**0.093**			
Sample size	**2,645**			

*p<0.05 **p<0.01 ***p<0.001

Table C.20: *Multinomial regression: Model 3: The impact of fuel poverty (AFP indicator) on cluster membership, LCFS (2013 – 2015/16) weighted: the poor sample*

	Cluster 2: Highly processed	**Cluster 3: Fruit & vegetable burden**	**Cluster 4: Restaurants, cafés, canteens**	**Cluster 5: Takeaways**
Fuel poverty (ref: No)	0.861 (0.129)	1.078 (0.176)	0.845 (0.193)	0.954 (0.157)
Household type (ref: Two adults)				
Single adult	2.246 (0.588)**	1.789 (0.418)*	1.652 (0.553)	2.595 (0.843)**
Single adult, 1 child	1.182 (0.542)*	1.334 (0.361)	0.314 (0.147)*	2.309 (0.801)*
Single adult, 2^+ children	2.056 (0.647)*	1.091 (0.362)	0.511 (0.238)	2.493 (0.908)*
2 adults, 1 child	1.865 (0.528)*	1.261 (0.369)	0.376 (0.161)*	3.563 (1.233)***
2 adults, 2 children	2.114 (0.604)**	1.243 (0.392)	0.358 (0.161)*	2.069 (0.704)*
2 adults, 3^+ children	3.088 (1.068)**	0.642 (0.255)	0.179 (0.109)**	3.817 (1.507)**
3^+ adults	3.547 (1.324)**	1.399 (0.543)	1.118 (0.592)	2.906 (1.151)**
3^+ adults, 1 child	1.498 (0.909)	0.453 (0.394)	0.927 (0.717)	3.549 (2.177)*
3^+ adults, 2^+ children	4.110 (2.014)**	0.800 (0.441)	0.593 (0.557)	10.604 (5.501)***
Highest qualification in the household (ref: Degree level or equivalent)				
Other higher qualification	1.766 (0.480)*	0.840 (0.246)	0.783 (0.278)	1.792 (0.536)
A-level or equivalent	1.610 (0.362)*	0.746 (0.176)	0.580 (0.187)	1.853 (0.469)*
GCSE or equivalent	3.155 (0.690)***	1.005 (0.234)	0.521 (0.162)*	2.574 (0.632)***
Other below degree level	3.022 (0,835)***	1.154 (0.315)	0.715 (0.260)	2.534 (0.766)**
No formal qualifications	2.560 (1.404)	0.898 (0.528)	0.475 (0.424)	2.108 (1.784)
Longstanding illness or disability (ref: No)	1.673 (0.248)**	1.255 (0.206)	0.709 (0.173)	1.591 (0.269)**
Female HRP (ref: Male)	1.047 (0.171)	1.151 (0.195)	1.168 (0.274)	0.794 (0.146)
Economic status of HRP (ref: In paid employment)				
Self-employed	1.536 (0.359)	1.489 (0.374)	1.241 (0.430)	1.397 (0.350)
Unemployed	1.775 (0.547)	1.685 (0.53)	1.111 (0.507)	1.035 (0.364)
Retired	1.074 (0.313)	1.575 (0.452)	1.008 (0.385)	0.508 (0.211)
Inactive	1.790 (0.333)**	1.782 (0.364)**	0.856 (0.255)	1.227 (0.266)
Ethnicity of HRP (ref: White)				
Mixed Race	0.882 (0.524)	2.106 (1.210)	1.348 (0.876)	1.471 (0.841)
Asian	0.653 (0.226)	3.153 (1.039)***	1.058 (0.593)	0.837 (0.276)
Black	2.184 (0.898)	6.151 (2.577)***	0.391 (0.287)	2.435 (1.047)*
Other	0.874 (0.384)	2.328 (0.896)*	1.287 (0.881)	1.092 (0.531)

Country (ref: England)				
Wales	0.826 (0.271)	1.182 (0.371)	1.348 (0.826)	0.805 (0.308)
Scotland	1.973 (0.551)*	0.905 (0.264)	0.868 (0.336)	2.394 (0.726)**
Northern Ireland	1.059 (0.418)	0.864 (0.331)	2.062 (0.913)	3.598 (1.285)***
Urban or rural (ref: Urban)	1.101 (0.219)	1.316 (0.260)	1.201 (0.344)	0.553 (0.126)**
Season (ref: Winter)				
Spring	1.054 (0.210)	1.083 (0.234)	0.540 (0.156)*	0.899 (0.201)
Summer	1.382 (0.294)	1.383 (0.317)	0.777 (0.250)	1.037 (0.239)
Autumn	1.615 (0.345)*	1.127 (0.255)	1.155 (0.332)	1.146 (0.266)
Full income deciles (ref: 10^{th}, Highest)				
1^{st} (Lowest)	1.301 (0.542)	1.244 (0.571)	1.045 (0.640)	1.189 (0.567)
2^{nd}	2.790 (1.173)*	2.026 (0.944)	0.928 (0.598)	2.092 (1.013)
3^{rd}	1.979 (0.796)	1.617 (0.713)	0.631 (0.393)	1.977 (0.917)
4^{th}	1.779 (0.670)	1.781 (0.777)	1.768 (1.074)	1.696 (0.711)
5^{th}	2.460 (0.932)*	1.992 (0.867)	1.057 (0.638)	2.642 (1.091)*
6^{th}	1.936 (0.689)	1.471 (0.591)	0.878 (0.495)	2.356 (0.906)*
7^{th}	2.022 (0.711)*	1.346 (0.550)	0.941 (0.541)	2.608 (0.978)*
8^{th}	2.265 (0.774)*	1.285 (0.457)	0.973 (0.507)	2.349 (0.823)*
9^{th}	1.284 (0.429)	0.785 (0.282)	0.301 (0.166)*	1.977 (0.646)*
Constant	**0.109 (0.046)*** **	**0.336 (0.156)***	**0.972 (0.580)**	**0.077 (0.037)*** **
Pseudo R^2 (McFadden adjusted)	**0.093**			
Sample size	**2,645**			

*p<0.05 **p<0.01 ***p<0.001

Appendix D| Supplementary analysis for Chapter 7

This appendix presents additional analysis exploring the relationship between fuel poverty and social isolation. The created social isolation scale was dismantled into its individual items in order to investigate whether a relationship existed between them and fuel poverty. Although the relationship between fuel poverty and social isolation explored in Chapter 7 was explained by income, it was of interest to explore whether any relationships existed between fuel poverty and the individual items included in the social isolation scale given that some items may be experienced more strongly than others amongst different groups.

D.1 The relationship between fuel poverty and the individual items in the social isolation scale

Tables D.1 and D.2 present the results of multiple regression analysis on each of the items included within the social isolation scale. All four sets of control variables presented in section 7.11.3 in Chapter 7 were added into the model simultaneously. The purpose of this was to gain an overall understanding of the effects of fuel poverty on each of the items of the scale. Again, this analysis was performed on the whole sample (Table D.1) and the poor sample (Table D.2) and only the results for fuel poverty are presented.

Table D.1: *Multiple regression: The effect of fuel poverty on the items of the social isolation scale (coefficients (robust standard errors))[1], UKHLS: wave 6, weighted: the whole sample*

	Number of close friends	Do you go out socially or visit friends when you feel like it?	Whether you are a member of not, do you join in the activities of organisations on a regular basis?	Frequency of volunteering in the last 12 months	Hours of volunteering in the last 4 weeks	Belong to neighbourhood
10 per cent indicator (ref: Not in fuel poverty)						
	0.013 (0.039)	0.007 (0.044)	0.018 (0.034)	-0.083 (0.037)*	-0.091 (0.036)*	0.012 (0.040)
Adjusted R^2	0.046	0.064	0.133	0.049	0.050	0.072
AFP indicator (ref: Not in fuel poverty)						
	0.006 (0.029)	0.031 (0.034)	0.056 (0.026)*	-0.001 (0.025)	-0.009 (0.025)	-0.002 (0.031)
Adjusted R^2	0.046	0.064	0.133	0.049	0.049	0.072
	Local friends mean a lot	Talk regularly to neighbours	People in this neighbourhood can be trusted	Like neighbourhood	Feel safe walking alone at night	
10 per cent indicator (ref: Not in fuel poverty)						
	0.011 (0.037)	0.029 (0.036)	-0.028 (0.038)	0.025 (0.045)	-0.009 (0.039)	
Adjusted R^2	0.079	0.105	0.125	0.030	0.229	
AFP indicator (ref: Not in fuel poverty)						
	0.017 (0.029)	0.011 (0.029)	0.000 (0.031)	-0.003 (0.037)	-0.054 (0.027)*	
Adjusted R^2	0.079	0.105	0.125	0.030	0.229	
Sample size: 25,989						

[1]Controlled for tenure, urban or rural, number of cars in the household, household type, sex, economic status, ethnicity, highest qualification achieved, longstanding illness or disability, and household full income deciles
*p<0.05 **p<0.01 ***p<0.001

Table D.1 shows that, when conducting multiple regression on the individual items of the scale found that, under the 10 per cent definition, the fuel poor were found to have a significant negative association with *Frequency of volunteering in the last 12 months* and *Hours spent volunteering in the last 4 weeks*, suggesting that this group have a higher frequency of volunteering and spend more hours volunteering than those who are not fuel poor. This could further reflect strong connections to the neighbourhood or local community through home ownership, which has been shown to enhance participation in community organisations and voluntary activities (Rohe et al. 2002) and to increase levels of volunteering (Dallimore et al. 2018). However, this could not be explored further given the lack of variables relevant to these aspects in the UKHLS. Conversely, the fuel poor under the AFP indicator had a significant positive association with participating in the activities of organisations on a regular basis and this suggests that the fuel poor under this definition, participate less in these types of activities and experience higher levels of social isolation in this component.

Table D.2: *Multiple regression: The effect of fuel poverty on the items of the social isolation scale (coefficients (robust standard errors))*[1]*, UKHLS: wave 6, weighted: the poor sample*

	Number of close friends	Do you go out socially or visit friends when you feel like it?	Whether you are a member of not, do you join in the activities of organisations on a regular basis?	Frequency of volunteering in the last 12 months	Hours of volunteering in the last 4 weeks	Belong to neighbourhood
10 per cent indicator (ref: Not in fuel poverty)						
	-0.067 (0.054)	-0.009 (0.062)	-0.007 (0.045)	-0.072 (0.047)	-0.055 (0.044)	-0.016 (0.055)
Adjusted R^2	0.037	0.060	0.098	0.044	0.039	0.073
AFP indicator (ref: Not in fuel poverty)						
	-0.050 (0.039)	-0.017 (0.046)	0.034 (0.034)	0.073 (0.034)*	0.079 (0.035)*	-0.033 (0.041)
Adjusted R^2	0.037	0.060	0.098	0.044	0.040	0.073
	Local friends mean a lot	Talk regularly to neighbours	People in this neighbourhood can be trusted	Like neighbourhood	Feel safe walking alone at night	
10 per cent indicator (ref: Not in fuel poverty)						
	0.015 (0.050)	0.027 (0.050)	-0.075 (0.054)	-0.055 (0.063)	-0.054 (0.050)	
Adjusted R^2	0.096	0.107	0.139	0.032	0.168	
AFP indicator (ref: Not in fuel poverty)						
	-0.008 (0.038)	0.020 (0.039)	-0.017 (0.043)	0.002 (0.051)	-0.039 (0.036)	
Adjusted R^2	0.096	0.107	0.139	0.032	0.168	
Sample size: 4,071						

[1]Controlled for tenure, urban or rural, number of cars in the household, household type, sex, economic status, ethnicity, highest qualification achieved, longstanding illness or disability, and household full income deciles
*p<0.05 **p<0.01 ***p<0.001

Table D.2 shows that, when performing the same analysis on the poor sample, the fuel poor under the 10 per cent indicator were not significantly different from their non-fuel poor counterparts on any of the items. However, the fuel poor under the AFP indicator had significantly higher levels of social isolation on *Frequency of volunteering in the past 12 months* and *Hours of volunteering in the last 4 weeks* compared to their non-fuel poor counterparts, suggesting that the fuel poor volunteer less frequently compared to their non-fuel poor counterparts. The reasons behind this finding are unclear and may be related to aspects that could not be explored further, such as the availability of time, which has been found to be important for volunteering in other studies (Southby and South 2016).

D.1.1 Exploring the relationship between fuel poverty and the excluded items

When deciding on items to include in the scale, two items were discarded: *Frequency of contact with friends* and *Worry about being affected by crime* (see section 7.9.1.4). To investigate whether a relationship existed between fuel poverty and these items, multiple regression was performed. In the same way as in the previous section, all four sets of control variables presented in section 7.11.3 in Chapter 7 were added into the model simultaneously to gain an overall understanding of the effects of fuel poverty on each of the discarded items. Again, this analysis was performed on the whole sample and the poor sample and only the results for fuel poverty are presented, as shown in Table D.3 overleaf.

Table D.3: *Multiple regression: The impact of fuel poverty on items excluded from the scale*[1] *for the whole sample and poor sample, UKHLS: wave 6, weighted*

	Whole sample		**Poor sample**	
	Frequency of contact with friends	Worry about being affected by crime	Frequency of contact with friends	Worry about being affected by crime
10 per cent indicator (ref: Not in fuel poverty)				
	-0.007 (0.042)	0.034 (0.037)	-0.015 (0.060)	0.066 (0.050)
Adjusted R^2	0.089	0.032	0.083	0.046
AFP indicator (ref: Not in fuel poverty)				
	-0.023 (0.029)	-0.033 (0.027)	-0.050 (0.041)	0.016 (0.036)
Adjusted R^2	0.089	0.032	0.084	0.046
Sample size	**25,989**		**4,071**	

[1]Controlled for tenure, urban or rural, number of cars in the household, household composition, sex, economic status, ethnicity, level of qualifications, longstanding illness or disability, and household full income deciles
*p<0.05 **p<0.01 ***p<0.001

In exploring the relationship between the excluded items and fuel poverty in Table D.3, no significant relationships were observed between fuel poverty and *Frequency of contact with friends* and *Worry about being affected by crime* in the whole sample or the poor sample when controlling for all other factors, suggesting that the fuel poor do not experience higher levels of social isolation on these items compared to individuals who are not fuel poor.

Appendix E| Supplementary material for Chapter 8

This appendix provides additional information for Chapter 8: The order of curtailment of material deprivation items in fuel poor and non-fuel poor households.

Table E.1: *A summary index of Townsend's indicators*

Level	Deprivation items
Household	Has not had a week's holiday away from home in the last 12 months
	Has not had an afternoon or evening out for entertainments in the last two weeks
	Does not have fresh meat (including meals out) as many as four days a week
	Has gone through one or more days in the past fortnight without a cooked meal
	Has not had a cooked breakfast most days of the week
	Household does not have a refrigerator
	Household does not usually have a Sunday joint (3 in 4 times)
	Household does not have sole use of four amenities indoors (flush WC; sink or washbasin and cold-water tap; fixed bath or shower; and gas or electric cooker)
Adult only	Has not had a relative or friend to the home for a meal or snack in the last 4 weeks
	Has not been out in the last 4 weeks to a relative or friend for a meal or snack
Children only (under 15 years)	Has not had a friend to play or to tea in the last 4 weeks
	Did not have a party on last birthday

Source: Townsend 1979, p.250

Table E.2: *Adult social deprivation and household deprivation items used in the most recent Family Resources Survey (2017/18)*

<table>
<tr><th>Variable label</th><th>Response categories</th></tr>
<tr><th colspan="2">Do you and your family/and your partner…</th></tr>
<tr><td>Have a holiday away from home for at least one week a year, whilst not staying with relatives at their home?</td><td rowspan="10">(1) “I/We have this”

(2) “I/We would like to have this but can’t afford this”

(3) “I/We do not want/need this at the moment”

(4) “Does not apply”</td></tr>
<tr><td>Have enough money to keep your home in a decent state of decoration?</td></tr>
<tr><td>Have household contents insurance?</td></tr>
<tr><td>Make regular savings of £10 a month or more for rainy days or retirement?</td></tr>
<tr><td>Replace any worn out furniture?</td></tr>
<tr><td>Have two pairs of all-weather shoes for all adult members of the family?</td></tr>
<tr><td>Replace or repair major electrical goods such as a refrigerator of washing machine, when broken?</td></tr>
<tr><td>Have a small amount of money to spend each week on yourself (not on your family)?</td></tr>
<tr><td>Keep up with bills and regular debt repayments? (yes or no only)</td></tr>
<tr><td>In winter, are you able to keep this accommodation warm enough? Yes, no, does not apply</td></tr>
</table>

Source: DWP et al. 2017, pp.283–286

Table E.3: *Child social deprivation and household items used in the most recent Family Resources Survey (2017/18)*

Variable label	Response categories
Does your child have/do your children…	
A warm winter coat?	(1) "Child(ren) has/have this" (2) "Child(ren) would like to have this but can't afford this" (3) "Child(ren) do not want/need this at the moment" (4) "Does not apply"
Eat fresh fruit and/or vegetables every day	
Have a holiday away from home for at least one week a year?	
Are there enough bedrooms for every child of 10 or over of a different sex to have their own bedroom?	
Leisure equipment such as sports equipment or a bicycle?	
Celebrations on special occasions such as birthdays, Christmas or other religious festivals?	
Attend at least one regular organised activity a week outside school, such as sport or a youth group?	
Do a hobby or leisure activity?	
Have friends round for tea or a snack once a fortnight?	
For children under 6 who do not attend primary or private school: Go to toddler group / nursery / playgroup at least once a week?	
Go on school trips?	
An outdoor space or facilities nearby where they can play safely	YES or NO

Source: DWP et al. 2017, pp.295–298

Table E.4: *Pensioner deprivation items used in the most recent Family Resources Survey (2017/18)*

Variable label	Response categories
Do you eat at least one filling meal a day?	(1) “Yes” (2) “No, no money for this” (3) “No, not a priority” (4) “No, health/disability prevents this” (5) “No, too much trouble/too tiring” (6) “No, no company/help” (7) “No, not wanted” (8) “No, not relevant” (97) “Spontaneous: no, other”
Do you go out socially either alone or with other people, at least once a month?	
Do you see friends and family at least once a month?	
Do you take a holiday away from home for a week or more at least once a year?	
Would the cooker be able to be replaced if it broke down?	
Is your home kept in a good state of repair?	
Are your heating, electrics, plumbing and drains kept in good working order?	
Do you have a damp-free home?	
Is your home kept adequately warm?	
Without cutting back on essentials, are you able to pay regular bills like electricity, gas or Council Tax (GB) / Rent (NI)?	
Do you have a telephone (landline) to use, whenever one is needed?	
Do you have access to a car or taxi whenever one is needed?	
Do you have your hair done or cut regularly?	
Do you have a warm waterproof coat?	
Would you be able to pay an unexpected expense of £200?	

Source: DWP et al. 2017, pp.286–294

Table E.5: *Items households went without in the previous 12 months due to a lack of money*

Material deprivation items	Per cent of all low-income households
A week's annual holiday away from home	40%
Going out or socialising	37%
Putting away £10 each month for a rainy day	32%
Replacing worn out furniture	22%
A hobby or leisure activity	21%
Buying new, rather than second-hand clothes	19%
Keeping your home adequately warm in winter	18%
Having friends or family for a drink or meal once a month	17%
Household contents insurance	16%
Keeping your home in a decent state of decoration	13%
Replacing a major electrical appliance such as a fridge	12%
Two pairs of all-weather shoes for each adult	10%
None	32%
Unweighted base	**699**

Source: Anderson et al. 2010, p.22

E.1 Prevalence weighting

In the following tables (Tables E.6 to E.8), the prevalence weight for each item within the deprivation suites in use has been calculated using the method described in Chapter 8 (see section 8.7.3) for each household type examined in the analysis. All weights were calculated based on households who had no missing values on any of the items.

Table E.6: *Prevalence weights and final scores for items in the Adult Material Deprivation suite for working-age adult households without children*

Item	Weight	Final scores*
“Holiday”	0.764	11.53
“House”	0.901	13.59
“Insurance”	0.894	13.49
“Regular savings”	0.768	11.59
“Furniture”	0.738	11.13
“Electrical goods”	0.780	11.77
“Money for self”	0.839	12.66
“Bills”	0.945	14.26
Sum of all weights	**6.629**	**100.0**

* **Calculation:** Weight/sum of all weights x 100

Table E.7: *Prevalence weights and final scores for items in the Adult Material Deprivation suite for working-age adult households with children*

Item	Weight	Final scores*
“Holiday”	0.685	11.27
“House”	0.874	14.37
“Insurance”	0.854	14.04
“Regular savings”	0.699	11.49
“Furniture”	0.637	10.47
“Electrical goods”	0.699	11.49
“Money for self”	0.720	11.84
“Bills”	0.914	15.03
Sum of all weights	**6.082**	**100.0**

* **Calculation:** Weight/sum of all weights x 100

Table E.8: *Prevalence weights and final scores for items in the pensioner deprivation suite*

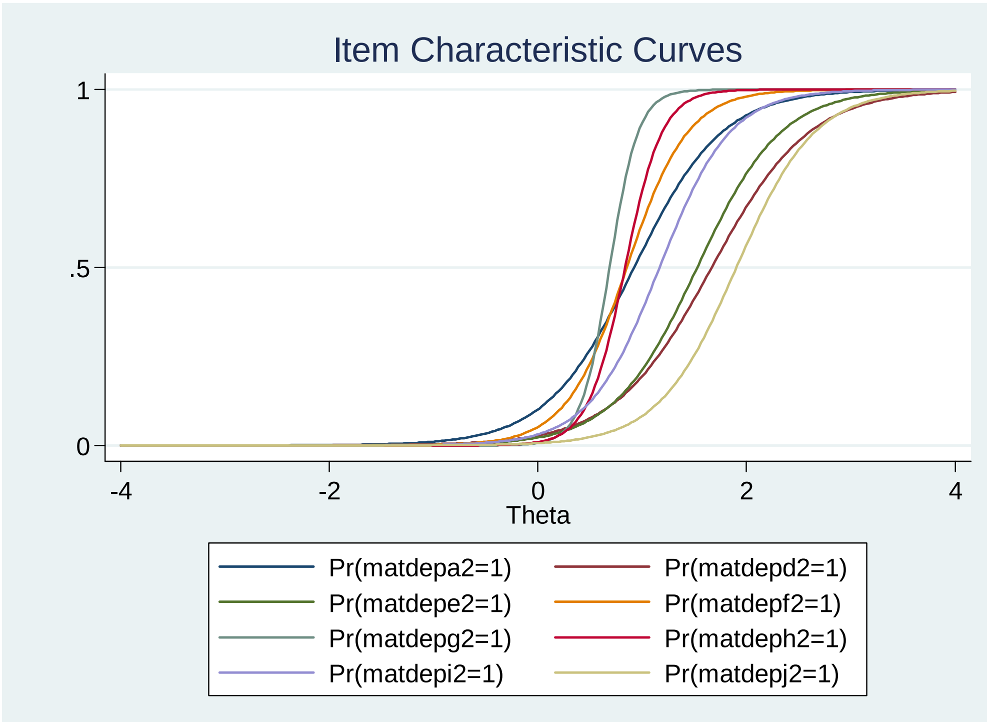
Item	Weight	Final scores*
"Holiday"	0.764	5.74
"Filling meal"	0.996	7.48
"Go out socially"	0.895	6.72
"Friends & family"	0.978	7.34
"Replace cooker"	0.949	7.13
"House"	0.975	7.32
"Working order"	0.991	7.44
"Damp-free home"	0.965	7.25
"Warm home"	0.976	7.33
"Telephone"	0.997	7.49
"Access to car/taxi"	0.953	7.16
"Hair cut"	0.963	7.23
"Warm coat"	0.994	7.46
"Unexpected expense"	0.921	6.92
Sum of all weights	**13.317**	**100.0**

* **Calculation:** Weight/sum of all weights x 100

E.2 An example of a visual representation of IRT: Item Characteristic Curves

Figure E.1 overleaf presents the Item Characteristic Curves for the order of curtailment of material deprivation items for the whole sample of working-age adult households without children (sample size = 14,162). This shows the location of the *difficulty* parameter and the steepness of the *discrimination* parameter.

Figure E.1: *An example of Item Characteristic Curves*



Source: Author's own analysis

<u>Key:</u> **Matdepa2**=Holiday; **Matdepd2**=House; **Matdepe2**=Contents insurance; **Matdepf2**=Regular savings; **Matdepg2**=Furniture; **Matdeph2**=Electrical goods; **Matdepi2**=Money for self; **Matdepj2**=Bills.

Theta, the household's trait score, is presented as standard deviations on the x-axis. In the context of this research, the difficulty parameter indicates the severity of deprivation for a given item, specifically when the probability reaches 0.5 on the y-axis (Deutsch et al. 2015; Najera Catalan 2017). A difficulty parameter towards the right of the scale indicates that expenditures are more difficult to curtail and are curtailed later (and higher material deprivation), with those to the left being easier to curtail and are curtailed earlier (and lower material deprivation). As can be observed in Figure E.1, *Replace worn-out furniture* is the first item to be curtailed and *Keep up with bills* is the last item to be curtailed. Figure E.1 also shows how the difficulty parameter is shaped by the discrimination parameters. As mentioned in Chapter 8 (section 8.7.4), the discrimination parameter represents how well an item distinguishes between those who are deprived and those who are not (Deutsch et al. 2015;

Najera Catalan 2017) and reflects the power of the items to discriminate between individuals whose latent scores of deprivation are below and above the item difficulty, with a highly discriminatory item differentiating better, around its difficulty value, between those with similar levels of material deprivation. The steepest discrimination parameter, indicating the most discriminatory item, is for *Furniture*, with a higher ability to discriminate between those who are and are not deprived, and the lowest is for *House* with a lower ability to discriminate between those who are and are not deprived.

E.3 Rates of enforced lack by household type

The following tables present the rates of enforced lack for each item contained with material deprivation suites for working-age adult households with (Table E.9) and without children (Table E.10), and pensioner households (Table E.11).

Table E.9: *Rates of enforced lack for each deprivation item included in the Adult Material Deprivation suite for working-age adult households without children, UKHLS: waves 4 & 6, weighted*

	10 per cent indicator		**Alternative fuel poverty indicator**		**Income poverty**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Holiday"	22.0	**44.3**	21.2	**49.6**	17.6	**49.2**	23.6
"Decent"	9.0	**21.7**	8.7	**22.9**	7.7	**19.5**	9.9
"Insurance"	9.4	**26.5**	8.7	**31.2**	6.0	**30.3**	10.7
"Regular savings"	21.1	**50.1**	20.6	**51.9**	16.6	**51.6**	23.2
"Furniture"	24.2	**50.5**	23.5	**54.6**	19.8	**53.3**	26.2
"Electrical goods"	20.3	**43.1**	19.6	**47.3**	15.8	**48.2**	22.0
"Money for self"	14.6	**34.9**	13.9	**39.5**	11.3	**36.6**	16.1
"Bills"	4.7	**15.9**	4.4	**17.0**	3.0	**16.1**	5.5
Sample size	**13,112**	**1,050**	**12,966**	**1,196**	**11,646**	**2,516**	**14,162**

Table E.10: *Rates of enforced lack for each deprivation item included in the Adult Material Deprivation suite for working-age adult households with children, UKHLS: waves 4 & 6, weighted*

	10 per cent indicator		**Alternative fuel poverty indicator**		**Income poverty**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Holiday"	30.3	**57.4**	28.3	**55.4**	23.7	**55.1**	31.5
"House"	12.1	**23.6**	11.5	**20.3**	10.4	**19.0**	12.6
"Insurance"	13.7	**34.0**	12.3	**31.4**	8.7	**32.4**	14.6
"Regular savings"	29.0	**52.8**	27.2	**51.5**	23.5	**49.9**	30.1
"Furniture"	35.4	**55.9**	33.6	**56.5**	29.7	**56.4**	36.3
"Electrical goods"	29.0	**52.9**	27.0	**52.7**	22.7	**52.2**	30.1
"Money for self"	27.0	**49.1**	25.3	**47.3**	21.6	**47.2**	28.0
"Bills"	8.0	**21.5**	7.0	**20.4**	5.5	**17.9**	8.6
Sample size	**10,542**	**524**	**9,656**	**1,410**	**8,298**	**2,768**	**11,066**

Table E.11: *Rates of enforced lack for each item included in the Pensioner Deprivation suite, UKHLS: waves 4 & 6, weighted*

	10 per cent indicator		**Alternative fuel poverty indicator**		**Income poverty**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Holiday"	22.8	**31.8**	22.6	**36.1**	22.1	**33.5**	23.6
"Filling meal"	0.3	**0.6**	0.4	**0.4**	0.4	**0.4**	0.4
"Go out socially"	10.0	**15.6**	10.0	**18.0**	9.6	**16.5**	10.5
"Friends & family"	2.2	**2.5**	2.1	**3.5**	2.0	**3.8**	2.2
"Replace cooker"	4.7	**9.2**	4.4	**13.3**	4.1	**11.6**	5.1
"House"	2.3	**3.9**	2.3	**4.6**	2.2	**4.6**	2.5
"Working order"	0.8	**1.7**	0.9	**1.2**	0.8	**1.4**	0.9
"Damp-free home"	3.4	**4.3**	3.4	**5.3**	3.3	**5.0**	3.5
"Warm home"	2.1	**4.7**	2.1	**5.6**	2.0	**4.7**	2.4
"Telephone"	0.3	**0.8**	0.3	**0.5**	0.3	**0.6**	0.3
"Access to car/taxi"	4.4	**7.5**	4.4	**8.1**	4.0	**9.4**	4.7
"Hair cut"	3.5	**6.2**	3.3	**8.8**	3.2	**7.2**	3.7
"Warm coat"	0.6	**0.8**	0.6	**0.7**	0.5	**1.3**	0.6
"Unexpected expense"	7.6	**11.0**	7.0	**19.4**	6.6	**16.8**	8.0
Sample size	**11,885**	**1,310**	**12,188**	**1,007**	**11,565**	**1,630**	**13,195**

E.4 The order of curtailment: Discrimination parameters

The following tables show the discrimination parameter values for working-age adult households without children (Table E.12), for working-age adult households with children (Table E.13), and pensioner households (Table E.14).

Table E.12: *Discrimination parameter values from 2PL models for material deprivation items in working-age adult households without children, UKHLS: waves 4 & 6, weighted*

Item	Coefficient (clustered robust standard errors)						
	10 per cent indicator		**AFP indicator**		**Below the poverty line**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Holiday"	2.337 (0.073)***	**2.044 (0.191)*** **	2.339 (0.075)***	**1.835 (0.167)*** **	2.284 (0.085)***	**1.646 (0.100)*** **	2.367 (0.068)***
"House"	2.120 (0.072)***	**1.762 (0.171)*** **	2.125 (0.079)***	**1.636 (0.157)*** **	2.225 (0.090)***	**1.619 (0.108)*** **	2.135 (0.073)***
"Insurance"	2.462 (0.090)***	**1.973 (0.218)*** **	2.398 (0.097)***	**1.960 (0.189)*** **	2.331 (0.105)***	**1.694 (0.115)*** **	2.488 (0.086)***
"Regular savings"	3.406 (0.116)***	**2.573 (0.244)*** **	3.349 (0.116)***	**2.761 (0.265)*** **	3.174 (0.124)***	**2.579 (0.160)*** **	3.415 (0.110)***
"Furniture"	7.119 (0.336)***	**7.103 (1.332)*** **	7.073 (0.339)***	**6.111 (1.021)*** **	7.347 (0.333)***	**6.419 (0.964)*** **	7.282 (0.328)***
"Electrical goods"	5.538 (0.217)***	**5.147 (0.664)*** **	5.463 (0.216)***	**5.034 (0.675)*** **	5.440 (0.232)***	**4.141 (0.338)*** **	5.592 (0.209)***
"Money for self"	2.903 (0.094)***	**2.577 (0.233)*** **	2.892 (0.094)***	**2.194 (0.211)*** **	2.963 (0.114)***	**1.975 (0.118)*** **	2.955 (0.090)***
"Bills"	2.602 (0.113)***	**2.299 (0.274)*** **	2.665 (0.118)***	**1.825 (0.222)*** **	2.747 (0.150)***	**1.718 (0.127)*** **	2.666 (0.108)***
Sample size	**13,112**	**1,050**	**12,966**	**1,196**	**11,646**	**2,516**	**14,162**

Note: The standard errors were clustered to account for changes in the HRP across the waves.
*p<0.05 **p<0.01 ***p<0.001

Table E.12 shows that, for working-age adult households without children, the most discriminatory item is *Furniture* across all groups, with a discrimination parameter value of 7.282. The least discriminatory item overall is *House*, with a discrimination parameter value of 2.135. For both fuel poor groups and the income poor, the most discriminatory item is *Furniture*, with the highest parameter value for the fuel poor under the 10 per cent indicator (7.103), followed by the income poor (6.419) and the fuel poor under the AFP indicator (6.111). For both fuel poor groups and the income poor, the least discriminatory item is *House*, with a discrimination parameter value of 1.762 for the fuel poor under the 10 per cent indicator, 1.636 for the fuel poor under the AFP indicator, and 1.619 for the income poor.

Table E.13: *Discrimination parameter values from IRT 2PL models for material deprivation items in working-age adult households containing children, UKHLS: waves 4 & 6, weighted*

Item	Coefficient (clustered robust standard errors)						
	10 per cent indicator		**AFP indicator**		**Below the poverty line**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Holiday"	1.672 (0.054)***	**1.314 (0.190)*** **	1.680 (0.057)***	**1.162 (0.113)*** **	1.627 (0.064)***	**1.141 (0.079)*** **	**1.687 (0.053)*** **
"House"	1.565 (0.058)***	**1.424 (0.232)*** **	1.589 (0.061)***	**1.335 (0.139)*** **	1.694 (0.075)***	**1.254 (0.096)*** **	**1.577 (0.056)*** **
"Insurance"	1.917 (0.071)***	**1.475 (0.220)*** **	1.959 (0.078)***	**1.288 (0.124)*** **	1.840 (0.091)***	**1.379 (0.090)*** **	**1.930 (0.069)*** **
"Regular savings"	2.417 (0.078)***	**2.176 (0.315)*** **	2.385 (0.082)***	**2.117 (0.191)*** **	2.379 (0.096)***	**1.900 (0.117)*** **	**2.442 (0.077)*** **
"Furniture"	5.346 (0.314)***	**4.768 (1.207)*** **	5.367 (0.334)***	**4.852 (0.833)*** **	5.633 (0.423)***	**4.797 (0.556)*** **	**5.261 (0.295)*** **
"Electrical goods"	4.389 (0.182)***	**4.029 (0.762)*** **	4.486 (0.196)***	**3.289 (0.359)*** **	4.290 (0.205)***	**3.652 (0.292)*** **	**4.410 (0.179)*** **
"Money for self"	2.261 (0.074)***	**1.778 (0.242)*** **	2.274 (0.079)***	**1.698 (0.144)*** **	2.269 (0.091)***	**1.633 (0.100)*** **	**2.268 (0.072)*** **
"Bills"	2.198 (0.097)***	**1.680 (0.268)*** **	2.133 (0.102)***	**1.876 (0.186)*** **	2.108 (0.117)***	**1.762 (0.139)*** **	**2.204 (0.092)*** **
Sample size	**10,542**	**524**	**9,656**	**1,410**	**8,298**	**2,768**	**11,066**

Note: The standard errors were clustered to account for changes in the HRP across the waves.
*p<0.05 **p<0.01 ***p<0.001

Table E.13 shows that, for working-age adult households with children, the most discriminatory item is *Furniture* across all groups, with a discrimination parameter value of 5.261. The least discriminatory item overall is *House*, with a discrimination parameter value of 1.557. For both fuel poor groups and the income poor, the most discriminatory item is *Furniture*, with the highest parameter value for the fuel poor under the AFP indicator (4.852), followed by the fuel poor under the 10 per cent indicator (4.768) and the income poor (4.797). For both fuel poor groups, the least discriminatory item is *Holiday*, with a discrimination parameter value of 1.314 for the fuel poor under the 10 per cent indicator and 1.162 for the fuel poor under the AFP indicator. For the income poor, the least discriminatory item is *House*, with a discrimination parameter value of 1.141.

Table E.14: *Discrimination parameter values from 2PL IRT models for pensioner material deprivation items, UKHLS: waves 4 & 6, weighted*

Item	**Coefficient (clustered robust standard errors)**						
	10 per cent indicator		**AFP indicator**		**Below the poverty line**		**Whole sample**
	Not fuel poor	**Fuel poor**	Not fuel poor	**Fuel poor**	Not income poor	**Income poor**	
"Holiday"	1.464 (0.067)***	**1.319 (0.154)*** **	1.473 (0.069)***	**1.201 (0.147)*** **	1.479 (0.076)***	**1.259 (0.122)*** **	1.459 (0.062)***
"Filling meal"	2.454 (0.240)***	**1.469 (0.344)*** **	2.475 (0.235)***	**1.565 (0.726)* **	2.690 (0.278)***	**1.327 (0.466)** **	2.304 (0.202)***
"Go out socially"	1.568 (0.074)***	**1.182 (0.150)*** **	1.561 (0.076)***	**1.232 (0.158)*** **	1.667 (0.087)***	**1.009 (0.118)*** **	1.529 (0.067)***
"Friends & family"	1.227 (0.097)***	**1.177 (0.230)*** **	1.268 (0.100)***	**0.780 (0.198)*** **	1.314 (0.114)***	**0.772 (0.159)*** **	1.218 (0.089)***
"Replace cooker"	3.749 (0.310)***	**3.817 (0.708)*** **	3.482 (0.287)***	**4.367 (0.717)*** **	3.595 (0.334)***	**3.639 (0.491)*** **	3.781 (0.286)***
"House"	1.628 (0.110)***	**1.940 (0.281)*** **	1.692 (0.115)***	**1.461 (0.228)*** **	1.678 (0.122)***	**1.437 (0.214)*** **	1.686 (0.103)***
"Working order"	2.024 (0.169)***	**1.979 (0.402)*** **	2.111 (0.174)***	**1.672 (0.403)*** **	2.004 (0.172)***	**2.093 (0.340)*** **	2.043 (0.156)***
"Damp-free home"	0.952 (0.082)***	**0.896 (0.206)*** **	0.975 (0.083)***	**0.716 (0.222)** **	0.946 (0.090)***	**0.880 (0.177)*** **	0.950 (0.076)***
"Warm home"	1.642 (0.119)***	**1.599 (0.246)*** **	1.574 (0.115)***	**1.848 (0.290)*** **	1.621 (0.130)***	**1.267 (0.296)*** **	1.662 (0.107)***
"Telephone"	2.039 (0.202)***	**1.309 (0.609)* **	1.883 (0.083)***	**2.007 (0.757)** **	1.869 (0.235)***	**1.861 (0.481)*** **	1.917 (0.211)***
"Access to car/taxi"	1.592 (0.088)***	**1.279 (0.190)*** **	1.610 (0.089)***	**1.136 (0.187)*** **	1.654 (0.099)***	**1.080 (0.149)*** **	1.561 (0.080)***
"Hair cut"	2.000 (0.113)***	**1.932 (0.274)*** **	1.920 (0.110)***	**2.184 (0.311)*** **	1.948 (0.117)***	**1.944 (0.223)*** **	2.009 (0.105)***
"Warm coat"	2.349 (0.264)***	**1.176 (0.439)** **	2.295 (0.246)***	**1.506 (0.639)* **	2.323 (0.274)***	**1.586 (0.429)*** **	2.172 (0.226)***
"Unexpected expense"	3.164 (0.221)***	**4.400 (0.874)*** **	2.929 (0.207)***	**6.332 (1.761)*** **	2.888 (0.220)***	**4.723 (0.824)*** **	3.270 (0.211)***
Sample size	**11,885**	**1,310**	**12,188**	**1,007**	**11,565**	**1,630**	**13,195**

Note: The standard errors were clustered to account for changes in the HRP across the waves.
*p<0.05 **p<0.01 ***p<0.001

Table E.14 shows that, amongst pensioner households, *Replace cooker* is the most discriminatory item overall, with a discrimination parameter value of 3.781. The least discriminatory item overall is *Damp-free home*, with a discrimination parameter value of 0.950. For both fuel poor groups and the income poor, the most discriminatory item is *Unexpected expense*, with the highest parameter value for the fuel poor under the AFP indicator (6.332), followed by the fuel poor under the 10 per cent indicator (4.400) and the income poor (4.723). For both fuel poor groups, the least discriminatory item is *Damp-free home*, with a discrimination parameter value of 0.896 for the fuel poor under the 10 per cent indicator and 0.716 for the fuel poor under the AFP indicator. For the income poor, the least discriminatory item is *Friends & family*, with a discrimination parameter value of 0.772.