# Fuel poverty and Health

## An analysis of the relationship between fuel poverty and health in Sweden

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## Abstract

For the past decade, fuel poverty has become a major health concern in developed countries. In this paper, we contribute to the literature by conducting the first study that seeks to determine if there exists a causal relationship between fuel poverty and self-assessed general health in a country with high-income equality and low rates of fuel poverty. The empirical findings in this thesis add to the debate on policy implications where energy efficiency is essential to combat health outcomes from fuel poverty. Economic preferences are validated using methods that have been previously published in studies and theoretical frameworks. Using linear regression, we examine the relationship between fuel poverty and health in Sweden through our own conducted survey. Health is the dependent variable, fuel poverty is the main independent variable, and income and education are our control variables. In the absence of the national median income and heating costs, the analysis could not use the after-housing costs that are mainly used in previous literature. Instead, the study uses the average housing costs. The study found a statistically significant relationship between fuel poverty and health, and our thesis concludes that fuel-poor populations are more likely to have poorer health than non-fuel-poor populations.

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***Keywords****: energy poverty; fuel poverty; self-assessed health; health inequalities; energy efficiency*

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# 1. Introduction

*This section gives an introduction and an overview of the two terms used within the field, energy poverty and fuel poverty. The background, research questions, limitations, and the outline for the thesis will also be presented below.*

## 1.1 Background

In recent years, there has been an increasing interest in energy and fuel poverty within the European Union. Increasing energy prices, low incomes, and poor energy efficiency have contributed to fuel poverty becoming a global health issue. Every year, nearly 3000 Britons die in their homes due to insufficient heating and a total of 34 million people are estimated to live in fuel poverty in Europe (Bergkvist, 2021; Chapman, 2018). Although the situation is still far from the worst in Sweden, the trend suggests that an increasing number of Swedes may be unable to pay for heat, electricity, and fuel according to an investigation done by the Swedish Energy Agency (Åslund, 2014). Recent studies have found that there is a statistically significant relationship between fuel poverty and health, where fuel-poor populations tend to have poorer health than non-fuel-poor populations (Legendre and Ricci, 2015). Consequently, improving energy efficiency and reducing fuel poverty could improve living standards in many countries.

In Awaworyi Churchill and Smyth's (2021) and Kahouli's (2020) studies of fuel poverty and health, they all concluded that there was a significant relationship between fuel poverty and health. (Pan, Biru and Lettu, 2021) found that countries with high living standards had tendencies to reduce the negative effects of energy poverty on public health. Additionally, Ormandy and Ezratty (2012) found that elderly individuals and young children were most vulnerable to thermal discomfort. At the same time, Legendre and Ricci (2015) found a significant relationship between fuel poverty and individuals that were living alone, were paying rent, were retired, and had poor roof insulation. Other studies found that energy-poor populations had a higher incidence of having poor health than non-energy-poor populations (Thomson, Snell & Bouzarovski, 2017).

There have been no previous studies in Sweden examining fuel poverty. Thus, our understanding of how fuel poverty impacts individuals' health remains uncertain. In recent years, the cost of energy within the EU has risen dramatically, impacting both electricity and fuels in Sweden (Bergholtz, 2021). With the effects of the Covid-19 pandemic wearing off and energy production being decreased, energy prices in Sweden have increased rapidly

(Bergholtz, 2021). As a result, coal, natural gas, and emission prices have risen at record levels. Furthermore, the decrease in the production of wind power in 2021 has led to a higher demand for coal and natural gas, further driving up the prices of electricity (Bergholtz, 2021).

With electricity becoming rapidly more expensive, it is becoming increasingly difficult for individuals in Sweden to afford to heat their homes (Bergholtz, 2021). Swedish households with the lowest disposable income spent twice as much on their energy bills last year than they had previously. At the same time, those considered to have the highest household heating costs are individuals who live in larger cities, who own their homes, who have low incomes, and are unemployed or retired. However, fewer people in Sweden suffer from high heating costs, due to the high level of roof insulation in Swedish homes and the heating costs being included in many rental apartments. Many researchers now question whether higher energy prices could potentially lead to fuel poverty in Sweden (Bergholtz, 2021; Morel, 2014).

Existing studies on fuel poverty related to these outcomes are mainly based on Southern Europe and developing countries. There is currently no new statistical microdata available on national disaggregated statistics in Sweden and therefore no previous studies examining the field in Sweden. Our paper fills this gap and provides a perspective on health outcomes due to fuel poverty in a developed country with high-income equality and low rates of fuel poverty.

## 1.2 Defining fuel poverty

Many studies tend to confuse the terms fuel poverty and energy poverty, both of which refer to a household’s access to domestic energy consumption (Li, Lloyd, Liang & Wei 2014). Both focus on residential energy consumption and income as large factors. Furthermore, both tend to exacerbate poverty, poor health, undermine equity, and obstruct society’s development.

Fuel poverty refers to the inability to afford energy and the inability to maintain an adequate indoor temperature. This is more common in developed countries such as the UK and New Zealand (Li *et al.*, 2014). Fuel poverty might occur in those households with poor roof insulation where more energy is needed to reach satisfactory indoor temperatures (Li *et al.*, 2014). Fuel poverty may negatively impact household income and expenditure whereas fuel-poor populations tend to be more vulnerable to high fuel prices. The issue of health can also arise when discussing fuel poverty: living in a comfortable heated home in colder climates is generally thought to be beneficial to health, especially for elderly and children. Living in cold temperatures due to poor roof insulation could potentially lead to higher mortality rates and have a negative effect on health (Li et al., 2014).

Energy poverty, on the other hand, refers to the lack of access to electricity, which is seen as one of the most important factors in enabling employment opportunities, improving health outcomes, elevating education, and facilitating sustainable development (Li et al., 2014). The issue of energy poverty mostly concerns the availability of energy in developing countries. For example, only 31% of Sub-Saharan Africa has access to electricity (Li et al., 2014). An alternate definition of energy poverty have been a "lack of energy for generating an income" Gunningham, 2013; Li et al., 2014). The European Union's Energy Poverty Advisory Hub (International Energy Agency, 2010; Gunningham, 2013; Li *et al.*, 2014). The European Union's Energy Poverty Advisory Hub (Thema & Vondung, 2020) do not seek to define energy poverty, but instead attempt to assist member states in measuring energy poverty by referring to "indicators". Two of these indicators are if the households can heat their home to an adequate level and if the heating costs relative to the income are above twice the national median (Thema & Vondung, 2020). These indicators are very similar to some of the definitions of fuel poverty and illustrate the overlap of both terms. The fact that some studies have used the term energy poverty and used the 10% indicator further illustrates the overlap of these terms (Awaworyi Churchill & Smyth, 2021)

To summarize, fuel poverty focuses on affordability in energy, while energy poverty deals with basic issues of energy access (Li et al., 2014). Most commonly, fuel poverty is used in developed countries and in wealthy, colder, or diverse climates, while energy poverty is used in more developing countries, across diverse climates, but primarily in poor countries. Since energy poverty and fuel poverty can be measured using different methods, it might be essential to understand the difference between the two terms but also acknowledge that both terms have been used with similar indicators before as described ( Li et al., 2014).

In our study, we will be referring to energy poverty and fuel poverty by using a unit term as fuel poverty. We will be using the same approach as the European Energy Poverty Observatory (Thema & Vondung, 2020) and do not define it explicitly but instead use several indicators used within the literature to measure it.

## 1.3 Measurements of fuel poverty

Several indicators for measuring fuel poverty are used as proxies within the literature. These can be divided into objective and subjective indicators, where the former are direct measurements, and the latter is based on the respondent's subjective view. The rest of this section will primarily cover the most common objective indicators used.

The first objective indicator is the “10% approach” which defines a household as fuel poor if the ratio between the required heating costs to reach a comfortable temperature and the household’s disposable income is higher than 0.1.  According to the 10% approach, a comfortable temperature is an objective level, and the researcher decides what that level will be. Using the required heating costs to reach a sustainable temperature seems to be ignored in the literature (Kahouli, 2020; Lacroix & Chaton, 2015). The disposable income is measured before housing costs (BHC) and is not equivalized for household composition.

The threshold was set at 10% because, at the time the indicator was made, the median household’s heating costs to income were 5%, and spending twice as much as income was deemed unreasonable. In addition, the poorest 30% of the individuals had an energy cost to income ratio of 10%.

The 10% approach has been criticized for numerous reasons: First, the 10% threshold might have been reasonable when it was constructed, but it does not account for variability in median heating costs. Second, the indicator understates the issue of fuel poverty because income is measured BHC which leads to the indicator overstating the affordability of the heating costs. Third, neither the income nor the heating costs are equivalized for household composition. Fourth, some wealthy households might be considered fuel poor with this indicator due to larger houses having higher heating costs. Finally, having the fuel poverty threshold at twice the median of heating costs relative to income is deemed highly arbitrary. The first three issues can be easily corrected by using a twice the median for the current year, calculating everything AHC and equivalizing heating costs and income to household composition (Hills, 2011). Using a twice the median approach has on the other hand been shown to not rise in proportion to rising energy prices while a fixed indicator does (Moore, 2012). The 10 % indicator is currently used in Scotland (*Home energy and fuel poverty*, no date).

Hills (2011) recommends the low-income-high-costs (LIHC) indicator as an alternative to the 10% indicator. With this indicator, a household is considered fuel poor if their heating costs are above the national median *and* if their residual disposable income after housing costs (AHC) and heating costs are below the income poverty threshold. This solves the issue with high-income households being considered fuel poor when using the 10% indicator. Also, LIHC uses the income after housing costs which solve the second issue mentioned above. In addition to measuring if a household *is* fuel poor, it is also possible to measure *how* fuel poor they are by measuring the difference in what their heating costs should be if they were not fuel poor and what their heating costs are right now (Hills, 2011). The LIHC-indicator is currently used in Wales together with a low-income low-efficiency (LILEE) indicator (see below) (*Tackling fuel poverty 2021 to 2035 [HTML]*, 2021).

The LIHC-indicator has also been criticized for several reasons. One being that the low heating costs threshold leads to low-income households, which tend to have smaller homes and thus lower heating costs, not being classified as fuel poor (Walker, Liddell, McKenzie, Morris & Lagdon 2014).

The final objective indicator is the low-income low-efficiency (LILEE) indicator which defines an individual as fuel poor if the home falls under a certain energy efficiency *and* the residual income is below the poverty line. While this indicator takes into consideration the energy efficiency aspect of fuel poverty it does not consider the energy prices (Hills, 2011).

A subjective indicator is, for example, if the household members feels that they are able to maintain a comfortable temperature in their homes (Awaworyi Churchill & Smyth, 2021; Kahouli, 2020; Legendre & Ricci, 2015). Hills (2011) points out that a subjective indicator takes into account the preferences of households for using electricity, in contrast to objective indicators. With a subjective indicator, one can account for the fact that some households prefer to spend a high percentage of their income on heating.

Moreover, Thomson, Snell and Bouzarovski (2017) argues that adding subjective indicators allows researchers to capture experiences that cannot be captured by objective indicators. They further argue that using a subjective indicator could help measuring social exclusion and deprivation (Thomson, Snell & Bouzarovski, 2017). The last approach is to use a composite indicator which combines several indicators. One example is considering a household fuel poor if it falls under fuel poverty according to any of the other indicators used (Awaworyi Churchill & Smyth, 2021).

## 1.4 Fuel poverty as a distinct issue

While fuel poverty and income poverty overlaps, they differ from each other in some ways and fuel poverty should be seen as a distinct issue according to Boardman (1991) and Hills (2011). They argue that heat as a good is very price inelastic compared to other goods due to high capital requirements to increase energy efficiency. Buying cheaper heat is thus harder than buying cheaper food, which makes it different from income poverty itself. Hills (2011) further argues that the negative health effects of lower temperatures differ fuel poverty further from income poverty.

## 1.5 Purpose and Research question

This paper examines the relationship between household individuals' health and fuel poverty in Sweden using five different approaches for measuring fuel poverty. To be able to achieve this, it is essential to understand how individuals self-assess their health based on their affordability of electricity. This study uses both objective and subjective indicators where data is mainly collected from our own survey conducted in Sweden. Additionally, the study is conducted by using a multidimensional index when measuring health.

To understand this matter, the following question will be answered:

*(1) How are household individuals' health in Sweden affected by fuel poverty?*

This thesis is limited to focusing primarily on household individuals' health caused by fuel poverty. Additionally, we did not investigate the housing quality of our respondents, which previous studies review as being an important factor in fuel poverty (Legendre & Ricci, 2015). However, it is unlikely that this would be a major factor in our country of interest since Swedish homes are well insulated (Bergholtz, 2021). Moreover, due to a limited timeframe, the study was not able to use a larger sample size and therefore, the study is unable to encompass the entire population in Sweden. In addition, most respondents were wealthy and well-educated, which could have impacted the results and might not have targeted the primary population of interest.

This study is composed of seven themed chapters. Section one introduces an overview of fuel poverty metrology. Section two reviews the empirical evidence found in previous literature between fuel poverty and health as well as other literature we have found to be relevant to our paper. Section three presents the theoretical framework where the Grossman model is being introduced. Section four presents our data and description of our variables. Section five presents our empirical strategy in this paper based on previous studies. Section six presents the empirical results and the discussion of the empirical findings in this study. Section seven is the last section where we make concluding remarks and discusses future research.

# 2. Review of Literature

*This section reviews and briefly summarizes previous studies that have been conducted within the field of fuel and energy poverty,*

The aim of this study is to investigate how different household individuals' health is being affected due to fuel poverty in Sweden by a survey-based approach. Historically, the majority of studies in Europe have been conducted in Southern Europe; therefore, Central and Eastern Europe continue to receive less attention than Southern Europe due to a small number of studies (Pedro & João Pedro, 2022).

Previous studies mainly focus on a specific country, however, there are a few studies that focus on the whole European Union and all its member states when addressing fuel poverty. The previous studies mainly deal with the main reasons for fuel poverty such as rising energy prices, low incomes, retirement, living alone, poor energy efficiency, cold climates, etc.

The diverse climates on other continents, such as Australia, have also been evaluated and how their climate may affect the health of individuals living in energy poverty (Awaworyi Churchill & Smyth, 2021). In China, energy poverty has become a major health issue due to unintended consequences of the Huai River policy (Almond, Chen, Greenstone & Li, 2009).

The studies conducted in Europe combine both objective and subjective indicators with a multidimensional health index. Other indicators used in previous work are mainly based on three different approaches to target fuel and energy poverty and several authors have developed other approaches to measure fuel poverty. Most of the studies have used disaggregated national statistics from different surveys such as Household Budget Surveys and statistics from EU-SILC when conducting their study.

## 2.1 Fuel poverty and health

Awaworyi Churchill and Smyth (2021) focused on the relationship between energy poverty and self-assessed general health in Australia using panel data. Because of its diverse climate, households found difficulty in maintaining an adequate temperature during different seasons of the year. Their data was based on statistics from a national housing survey (HILDA) where citizens had the opportunity to self-assess their health and house expenditures. They used both objective and subjective indicators with a multidimensional health index to measure energy poverty. Their study found a negative relationship between energy poverty and self-assessed general health where energy poverty was associated with lower general health. They also found a correlation between energy poverty and other sociodemographic factors such as marital status, employment status, income, and educational status. The researchers also determined that measuring energy poverty with a subjective indicator rather than an objective indicator had a greater impact on health variables when measuring energy poverty (Awaworyi Churchill & Smyth, 2021).

Another similar study conducted in France (Kahouli, 2020) also examined the relationship between self-assessed health and energy poverty and found a significant relationship regardless of what indicator was being used. They used representative data with a sample of 37 000 households from the National Housing survey. While both studies (Awaworyi Churchill & Smyth, 2021; Kahouli, 2020) used a panel approach with subjective and objective indicators to measure energy poverty, Kahouli (2020) focused on a single measure of health rather than considering a multidimensional health index (Kahouli, 2020). Nevertheless, Awaworyi Churchill and Smyth's (2021) approach is considered more accurate and better for the use of health economics literature, as Horn et al argues in their study (Awaworyi Churchill & Smyth, 2021).

According to Kahouli (2020), rising energy prices could potentially compromise health, since households could be forced to choose between affording an adequate temperature or having other expenditures be affordable, similar to the Grossman model proposed within the theoretical framework. However, Kahouli (2020) argued that this was not likely to occur. Additionally, Kahouli (2020) argued that investing in energy efficiency and improving infrastructure could potentially lead to better health outcomes and reduce energy poverty (Kahouli, 2020).

Legendre and Ricci (2015) studied which households were most fuel vulnerable in France by using a French housing survey. First, they used three different approaches where the 10% ratio approach, the after-fuel-cost poverty approach, and the LIHC Indicator was conducted to find how many individuals were fuel vulnerable. To identify the most fuel vulnerable individuals, they conducted an income-based analysis, where an individual was considered fuel poor because of their domestic energy expenses. They identified those individuals by looking for those below the poverty line (60% of the median adjusted income) after housing and fuel costs. Additionally, they found that energy costs were the main factor that triggered energy poverty. Furthermore, they found a significant relationship between energy poverty and individuals that were retired, living alone, had poor roof insulation, and paid rent (Legendre & Ricci, 2015).

Thomson, Snell and Bouzarovski (2017) examined the relationship between energy poverty and mental and physical health in Europe. The study used a multidimensional index with both objective and subjective indicators with cross-sectional data from 32 European Countries. Further, the authors explained that subjective indicators had been criticized due to their lack of consistency, bias, and potential exclusion errors across respondents. However, subjective indicators continue to be widely used to describe and analyze energy poverty across Europe.

They argued that adding a subjective measure allows researchers to capture experiences that cannot be measured by objective measures. Subjective indicators can also help measure social exclusion and deprivation; they argue. Additionally, they used a multidimensional index to measure an individual's mental health. They found a lower level of well-being for individuals living in energy-poor countries in all countries except Finland. At the same time, they found that energy-poor populations had a higher incidence of having poor health, poor emotional well-being, and being depressed (Thomson, Snell & Bouzarovski, 2017).

Another study by Pan, Biru and Letty (2021) examined the effect of energy poverty in 175 countries using cross-country panel data similar to the study conducted by Thomson, Snell & Bouzaovski (2017). Likewise, they found a negative relationship between energy poverty and public health. They also found that those countries with high standard of living could potentially weaken the negative effect of energy poverty on health (Pan, Biru & Lettu, 2021).

## 2.2 Thermal discomfort and health

Ormandy and Ezratty (2012) studied the relationship between thermal discomfort and health in eight cities across Europe. They collected data on both housing and household characteristics of a sample of 8519 residents where residents had to respond with their perception of thermal comfort and heating system. They found negative impacts of thermal discomfort on health where some groups in society were more vulnerable to high or low indoor temperatures than others. Additionally, they found that elderly and very young people were most affected by thermal discomfort. They also found a negative relationship between self-reported health and poor thermal comfort, inadequate weather, and mold/dampness problems (Ormandy & Ezratty, 2012).

To summarize, fuel-poor populations are often debated on whether they suffer from poorer mental and physical health than non-fuel-poor populations. Previous studies have found empirical evidence that fuel-poor populations tend to have poorer health than individuals living in non-fuel-poor populations. According to studies, those who are fuel and energy poor are often retired, live alone, have low incomes, pay rent, and have poor roof insulation. Moreover, energy costs are one of the major causes of fuel poverty. In addition, researchers found a higher incidence of poor mental health in fuel poor populations.

# 3. Theoretical Framework

*This section will introduce previous literature on fuel poverty and the Grossman model. We will also discuss the application of the Grossman model on the subject of fuel poverty's effect on health.*

## 3.1 Grossman model

In this section, we will briefly give an overview of certain parts of the Grossman model, which illustrates how health is related to income, utility, and other goods (Grossman, 1972; Bhattacharya, Hyde & Tu, 2014; Muurinen, 1982).

In the Grossman model, a consumer's utility is a function of the level of health (H) and home goods (Z). The level of health is a stock that can either be increased, reduced or maintained, while the home good is a flow of input. The utility function can be expressed in the following way:

$$U_t = U(H_t, Z_t)$$

To increase health, a consumer must use *time*. Similarly, a consumer must use time to use the home goods he/she has bought. This brings us to the time constraint in the model:

$$T^T = T^W + T^H + T^Z + T^S$$

$$T^T = Total\ time\ per\ day$$

$$T^W = Time\ spent\ working$$

$$T^H = Time\ spent\ increasing\ or\ maintaing\ health$$

$$T^Z = Time\ spent\ using\ home\ goods$$

$$T^S = Time\ being\ sick$$

Work time is necessary to receive income to consume health and home goods. Time being sick only reduces the amount of disposable time and is denoted as a cost. Increasing health decreases sick time and increases the productive time used. In addition to the time constraint, there is a normal budget constraint.

Both health and home goods have their own production functions. The health production function is a function of time spent increasing health, buying goods that increase health (*M*), and the stock of health from the preceding period. The home good is a function of goods that increases it (*J*) and time spent using it. Below are the production functions:

$$H_t = (H_{t-1}, M, T^H)$$

$$Z_t = (J, T^Z)$$

A consumer must produce a certain amount of health to produce home goods. A complete reduction in the production of health would therefore lead to no home goods being produced. At a certain point, the consumer must choose between producing health or home goods and how much of either will be produced is determined by the consumer's indifference curve. The Grossman model also postulates that a higher education makes production of health more efficient and in turn increases health.

The Grossman model can also be extended over several periods, and into a whole lifetime. The equation below shows the utility function for persons whole lifetime as a function of the home good and health in each given period:

$$U = U(H_0, Z_0) + \delta U(H_1, Z_1) + \delta^2 U(H_1, Z_1) + \cdots + \delta^\theta U(H_\theta, Z_\theta)$$

Where δ equals the consumer's discount factor and it can take any values between 0 and 1. If the value is 1 the consumer values future periods utility as much as the current one. If it is 0, the consumer only values the current period's utility. is equal to the consumer's expected lifespan.

We also have to revise the health production function when considering several time periods because health depreciates over time. Assume that health depreciates at the rate of $\gamma$. The new health production function then becomes:

$$H_t = (1 - \gamma)(H_{t-1}, M, T^H)$$

This illustrates how health is an investment good into the future. The rational consumers investment in health will be equal to its opportunity cost, which is interest rate *r*, and the depreciation rate of health $\gamma$. The Grossman model also assumes that the health deprecation rate increases over time which means that investing in health becomes more costly, assuming that changes in the interest rate do not offset this effect. Thus, older individuals will have less incentive to invest in health and therefore spends more on the home good Z instead and health therefore decreases (Grossman 1972; Bhattacharya, Hyde & Tu, 2014, , pp. 28-46; Muurinen, 1982).

## 3.2 Grossman model and fuel poverty

When applying the Grossman model on the subject of fuel poverty's effect on health, we must establish whether heating is considered a home good or a health good. It could be argued that it is both and depends on certain factors. For example, if the consumer can choose between different temperatures and both these levels of temperatures have the same effect on health, then heating is a home good. Also, if the energy prices increase, the household either has to increase heating costs to maintain the temperature or let the temperature fall. Suppose that neither of these lead to adverse health effects, then the household also considers heating as a home good.

On the other hand, if the current temperature in the home is health reducing, and the consumer could increase health by increasing the temperature, heating will be considered a health good. If the household is in this state and energy prices increase, the household must increase heating costs to maintain the temperature or let the temperature fall. The former would decrease health because health expenditures would have to fall, while the latter leads to lower health due to lower temperatures. If energy prices decrease, the opposite would occur.
The minimum criteria for considering a household energy poor in this model would be if it was in a state where heating is considered a health good and not a home good.

However, if the income is extremely low then heating costs might be considered a health good even if the heating costs are very low, and in this scenario, the household is considered being income poor but not energy poor. A better viewpoint is to see them as energy poor if their heating costs are at a certain threshold and the heating costs are considered a health good. This is very familiar to the LIHC-indicator, but the income poverty criteria has been replaced with the heating costs being considered a health good. This viewpoint would encompass both the effects low temperatures have on health and the effects high heating costs have on the rest of the household's expenditure.

Energy efficiency also plays a role in if a household falls into fuel poverty or not. A decrease in energy efficiency would increase the required heating costs to sustain the same temperature and it would therefore increase the risk of heating costs being considered a health good. Investing in energy efficiency would in this case also be considered a health good. We would assume that energy efficiency, in general, is very price inelastic due to it being hard to change insulation or an oil pan for example, and we would also assume that energy efficiency is essentially fixed in the short run.

In conclusion, fuel poverty's effect on health is twofold. First, fuel poverty might directly affect health through low temperatures. Two, it might lead to a point where the household must reduce other expenditures that might reduce health.

## 3.3 Hypothesis

We propose the following hypothesis based on the previous literature and theoretical framework:

$$H_0: Individuals\ that\ are\ fuel\ poor\ does\ not\ have\ lower\ self-assessed\ general\ health\ compared\ to\ individuals\ that\ are\ not\ fuel\ poor$$

$$H_1: Individuals\ that\ are\ fuel\ poor\ have\ lower\ self-assessed\ general\ health\ compared\ to\ individuals\ that\ are\ not\ fuel\ poor$$

# 4. Method

*This section presents our choice of method. We also show our construction of our health variable and our objective indicator variables. We briefly explain the details behind different approaches and indicators and finally we construct our empirical design for our linear regression model.*

## 4.1 Data collection and survey design

The data was collected by constructing our own survey and distributing them through our own and relatives' social media and also to students at Gothenburg's Business School. The survey was designed to balance the two goals of receiving enough information from each respondent and maximizing sample size. To achieve the latter, some questions that may have been difficult for the respondent to answer were excluded. In particular, we did not ask about household costs other than heating costs (rent, amortization, fees, etc.) since obtaining this information is potentially time-consuming for the respondents, decreasing the likelihood of receiving an answer.

The survey was divided into three parts: The first consisted of questions regarding the respondent's socio-demographic attributes (age, gender, marital status, income after tax, etc.). The second part consisted of four questions about the respondent's general health (see table 1 in section 4.6). These questions were based on the SF-36 survey (Ware, Snow, Kosinski & Gandek 1993), in which respondents were asked to answer 1 to 5 where 1 was the most negative 5 was the most positive. Our questions differ slightly from the SF-36 survey in two ways: First, the last question was removed because it was essentially the same as the first question and therefore redundant; the second difference is that some of the SF-36 questions have 5 as the most negative answer and 1 as the most positive, while ours consistently have 1 as the most negative and 5 as the most positive. The third, and final part of the survey consisted of questions regarding the household's heating costs, if they could heat their home to an adequate temperature and if they had any arrears on utility bills. Some parts of the survey will not be used due to low response rates.

In total, 238 responses were received; however, 144 observations were obtained because some questions did not receive responses. A 90$^{th}$ percentile winsorization was used for the heating costs and the income.

## 4.2 Data limitations

The self-reported data used for this thesis raises some concerns, such as its reliability. Social desirability is described as one of the most frequent biases in self-report surveys (Börger, 2012). A main factor is the desire for social acceptance. Individuals may wish to be viewed as good and therefore report good statements rather than negative ones (Börger, 2012). Additionally, it has been suggested by Dunning, Heath, and Suls (2004) that individuals may overestimate their health in comparison to others. As a result, respondents might answer the questions in an incorrect manner based on their desire to gain social approval or to overestimate their health as compared with others. In addition, the data is based on a small sample, and most of the respondents are well-educated and wealthy. This is not representative of target demographic groups of concern when it comes to fuel poverty. The biased sample is probably due to the choice of distributing the survey (see section 4.1).

## 4.3 Construction of the health variable

In line with the recommendations (Ware, *et al.*, 1993) and previous literature (Awaworyi Churchill and Smyth, 2021), the general health variable was constructed by using the following formula:

$$Transformed\ scale = \left[\frac{Actual\ raw\ score - minimum\ possible\ raw\ score}{Raw\ score\ range}\right] * 100$$

$$Raw\ score = The\ sum\ of\ all\ the\ individual\ scores$$

For example, if a respondent answer 1 on all 4 question we would get the following calculation.

$$Transformed\ score = \left[\frac{(1+1+1+1)-4}{16}\right] * 100 = \left[\frac{4-4}{16}\right] * 100 = \left[\frac{0}{16}\right] * 100 = 0$$

$$0 = 100$$

The transformed health variable can take values between 0-100 with a 6.25 interval. Instead of using an ordered probit regression, which would have been the case if we did not transform the health variable, we can use a normal linear regression. Awaworyi Churchill and Smyth (2021) used the same approach to perform non-ordered probit regression. However, in the robustness (section 6.2), we will perform an ordered probit regression.

## 4.4 Construction of the objective fuel poverty variables

The following indicators will be used to measure fuel poverty, as they were in previous studies (Awaworyi Churchill & Smyth, 2021; Kahouli, 2020; Legendre & Ricci, 2015). The LILEE-indicator could have been added, but we do not have any easy means to measure energy efficiency:

1. The 10% indicator, but with equivalization and after housing costs.
2. The 20% indicator. This is used because the 10% indicator might not be suitable for Sweden.
3. The LIHC indicator.
4. A subjective indicator where a household is considered fuel poor if they cannot heat their home to a comfortable level.
5. A composite indicator where an individual is considered fuel poor if both the subjective indicator *and* one of the objective indicators identifies them as fuel poor. This indicator is chosen as it combines both an objective and a subjective indicator and thus gets the benefits of both.

The objective fuel poverty variables are constructed mostly as described in section 1.3, but with some necessary modifications. First, as the survey did not contain a question about the household costs, we instead used the national median monthly household costs by household type (*Housing expenditures, Median value, per household, SEK 1000s by tenure, type of household and year. PxWeb*, 2021). Secondly, the median national heating costs is not available so the average for houses is used instead (*Expenses owner-occupied dwellings, mean value, SEK by type of expense, background variable and year. PxWeb*, 2021). Thirdly, the national median housing costs from SCB includes the heating costs so this is corrected by subtracting the average heating costs from the median housing costs, and then subtracting this value from each respondent's income. The respondent's actual equivalized heating costs could have been subtracted from the housing costs, but this led to negative values, so we decided to use the national median instead. The national median net income (the disposable was not available so the net income was used instead) was also collected from SCB (*Net income, median income for persons registered in the national population register during the whole year by region, sex, age and year. PxWeb*, 2022).

The final modification is that the household costs, heating costs and median net income were collected from 2020 because no data from 2022 existed, and we therefore had to correct for inflation by converting them to the value of April 2022 (*Prisomräknaren*, no date), which is the period they survey was distributed. The median household costs per month, adjusted for inflation, are for rental apartments 6753 SEK, for condominium its 6475 SEK and 7076 SEK for houses. The national average heating costs and the national median net income adjusted for inflation are 1940 SEK and 21 804 SEK, respectively.

The income poverty threshold is defined as 60% of the national median net income, which is in line with Hills (2011) recommendation and one of SCB:s measurements of income poverty (*Att mäta fattigdom*, 2017). For the AHC income poverty threshold the median household costs for all types of dwellings is used (*Housing expenditures, Median value, per household, SEK 1000s by tenure, type of household and year. PxWeb*, 2021). Note again that household costs taken from SCB includes the heating costs while heating costs are not included in housing costs in the context of fuel poverty, which means that this has to be corrected for. This can be expressed mathematically in the following way:

$$\boldsymbol{Income\ poverty}\ (\boldsymbol{AHC}) =$$

$$(national\ median\ net\ income - national\ median\ monthly\ household\ costs + national\ average\ monthly\ heating\ costs) * 0.6.$$

The income poverty threshold after housing costs therefore is $(21\,804\ - 6762 + 1940) * 0.6 = 10\,330\ \ SEK.$

The income poverty threshold before housing costs is instead:

$$\boldsymbol{Income\ poverty}\ (\boldsymbol{BHC}) =$$

$$national\ median\ net\ income * 0.6 = 21\,804 * 0.6 = 13\,082\ SEK$$

SCB:s guidelines for consumption (*Statistikskolan: Att jämföra inkomster för hushåll*, 2016) was used for equivalizing the income, heating cost and housing costs. Mathematically, this can be expressed in the following way:

$$Equivalized\ income\ after\ tax = \frac{Income\ after\ tax}{Number\ of\ consumption\ units}$$

$$Equivalized\ heating\ costs = \frac{Heating\ costs}{Number\ of\ consumption\ units}$$

$$Equivalized\ housing\ costs = \frac{Housing\ costs}{Number\ of\ consumption\ units}$$

The survey asked if the respondent had “1 child”, “2-3 children” or “3+ children”. According to SCB (*Statistikskolan: Att jämföra inkomster för hushåll*, 2016) the first child has a consumption unit of 0.52 and the subsequent children have 0.42 consumption units. Because “2-3 children” does not specify whether the respondent has 2 or 3 children, the average was taken and counted them as having 2.5 children (1.15 consumption units). If a person answered “3+ children”, it was counted as 4 children (1.78 consumption units).

The 10% indicator was used because it was twice the national median of heating costs to income ratio (see section 1.3). The national median of heating costs to income ratio is seemingly not available from any database. However, it can be approximated by using the national average heating costs and the national median net income (both from 2020 but corrected for inflation). The calculation for the AHC-model is:

$$\frac{Average\ heating\ costs}{median\ national\ disposable\ income\ -\ median\ \ household\ costs} = \frac{1940}{21\ 804\ -6762} = 13\%$$

And the corresponding calculation for the BHC-model is:

$$\frac{Average\ heating\ costs}{median\ national\ disposable\ income} = \frac{1940}{21\ 804} = 9\%$$

## 4.5 Description of variables

Table 1 shows the description of the variables. Most of them are self-explanatory, but this section will provide further details about the reference categories for the demographic composition of the respondents.

Since categorical variables are prone to multicollinearity, the reference categories have been selected in a way that minimizes multicollinearity. The reference category for the education variable is having a university or college education (more than 3 years). The reference category for the household composition is if they have a partner and child. The reference category for the household type is living in a house. For example, we use a dummy variable for sex (1 = Female; 0 = Male) and the reference category is male. The variables chosen are further explained in section 5.1.

**Description of variables**

| Name | Description |
|---|---|
| health | "In general, would you say your health is: 1 means *poor*, 2 means *fair*, 3 means *good*, 4 means *very good* and 5 means *excellent*" |
| healthrelative | "How true or false is the following statement for you? I am as healthy as anybody I know: 1 means *definitely false*, 2 means *mostly false*, 3 means *don't know*, 4 means *mostly true* and 5 means *definitely true*" |
| fraility | "How true or false is the following statement for you? I seem to get sick a little easier than other people: 1 means *definitely false*, 2 means *mostly false*, 3 means *don't know*, 4 means *mostly good* and 5 means *definitely true*" |
| healthexpected | "How true or false is the following statement for you? I expect my health to get worse: 1 means *definitely false*, 2 means *mostly false*, 3 means *don't know*, 4 means *mostly good* and 5 means *definitely true*" |
| healthsum | Sum of all healthscores |
| healthvariable | Transformed sum of all healthscores |
| fuelpov10 | Binary variable equals 1 if respondent is considered fuel poor according to the 10% indicator (BHC) |
| fuelpov10h | Binary variable equals 1 if respondent is considered fuel poor according to the 10% indicator (AHC) |
| fuelpov20 | Binary variable equals 1 if respondent is considered fuel poor according to the 20% indicator (BHC) |
| fuelpov20h | Binary variable equals 1 if respondent is considered fuel poor according to the 20% indicator (AHC) |
| fuelpovlihc | Binary variable equals 1 if respondent is fuel poor based on LIHC indicator (BHC) |
| fuelpovlihch | Binary variable equals 1 if respondent is considered fuel poor according to the LIHC indicator (AHC) |
| fuelpovsubj | Binary variable equals 1 if respondent cannot heat their home to a comfortable level |
| fuelpovcomposite | Binary variable equals 1 if respondent if respondent is considered fuel poor according to any of the other indicators (BHC) |
| fuelcompositeh | Binary variable equals 1 if respondent if respondent is considered fuel poor according to any of the other indicators (AHC) |
| income | Monthly income after tax (SEK) |
| lincome | Log of monthly income after tax (SEK) |
| heatingcost | Monthly heating costs (SEK) |
| householdcosts | Monthly household costs |

| | |
|---|---|
| female | Binary variable equals 1 if respondent is female |
| male | Binary variable equals 1 if respondent is male |
| unimore | Binary variable equals 1 if respondents has studied more than 3 years at university |
| uni | Binary variable equals 1 if respondents highest education is university or college |
| highschool | Binary variable equals 1 if respondents highest education is highschool |
| nohighschool | Binary variable equals 1 if respondent has no highschool education |
| age | Binary variable equals 1 if respondent falls within the age range of 18-24 |
| age2 | Binary variable equals 1 if respondent falls within the age range of 25-34 |
| age3 | Binary variable equals 1 if respondent falls within the age range of 35-49 |
| age4 | Binary variable equals 1 if respondent falls within the age range of 50-64 |
| Highage | Binary variable equals 1 if respondent is 65 years or older and 0 otherwise |
| single | Binary variable equals 1 if respondent is single and has no children |
| singlep | Binary variable equals 1 if respondent is single and has one or more children |
| partnerwithchild | Binary variable equals 1 if respondent has a partner and at least one child |
| partnernochild | Binary variable equals 1 if respondent has a partner and no children |
| other | Binary variable equals 1 if respondent lives in other type of household (e.g living with a friend) |
| condominium | Binary variable equals 1 if respondent lives in a condominium |
| rent | Binary variable equals 1 if respondent lives in a rental apartment |
| house | Binary variable equals 1 if respondent lives in a house |
| highheatingcost | Binary variable equals 1 if respondent's heating costs are above the national mean |
| incomepov | Binary variable equals 1 if respondent is considered income poor (BHC) |
| incomepovh | Binary variable equals 1 if respondent is considered income poor (AHC) |

Table 1 shows the description of the variables.

## 4.6 Summary statistics

Table 2 below shows the summary statistics. This section will bring an overview of the data. More details about income distribution and health can be found in section 4.8.

The mean of the dummy variables can be interpreted as the percentage that falls into that category. For example, the table shows that around 69% of the respondents are male. 6% of the respondents are not able to heat their homes to an adequate level of temperature. The table also shows that 10% of the respondents are income poor in the AHC appraoch and this will decrease to 1% in the BHC approach. 17% have high heating costs in comparison to the national average. The table shows the percentage of people considered fuel poor according to the different indicators.

Table 2 also shows that more respondents were considered fuel poor in the AHC indicators compared to the BHC indicators, with the exception of the LIHC-indicators. For example, the 10% indicator (AHC) identified 10% as fuel poor, while the corresponding BHC indicator identified 8% as fuel poor.

**Table 2: Summary statistics**

| | Mean | SD | Min | Max | N |
|---|---|---|---|---|---|
| health | 3.67 | .97 | 1.00 | 5 | 144 |
| healthrelative | 3.94 | 1.01 | 1.00 | 5 | 144 |
| fraility | 1.86 | 1.14 | 1.00 | 5 | 144 |
| healthexpected | 2.44 | 1.13 | 1.00 | 5 | 144 |
| healthsum | 11.91 | 2.21 | 4.00 | 18 | 144 |
| healthvariable | 49.44 | 13.79 | 0.00 | 87.5 | 144 |
| fuelpov10 | .08 | .27 | 0.00 | 1 | 144 |
| fuelpov10h | .1 | .31 | 0.00 | 1 | 144 |
| fuelpov20 | .02 | .14 | 0.00 | 1 | 144 |
| fuelpov20h | .03 | .18 | 0.00 | 1 | 144 |
| fuelpovlihc | .01 | .01 | 0.00 | 1 | 144 |
| fuelpovlihch | .01 | .01 | 0.00 | 1 | 144 |
| fuelpovsubj | .06 | .24 | 0.00 | 1 | 144 |
| fuelpovcomposite | .01 | .12 | 0.00 | 1 | 144 |
| fuelpovcompositeh | .02 | .14 | 0.00 | 1 | 144 |
| income | 56843.37 | 28858.72 | 13000.00 | 125000 | 144 |
| lincome | 10.8 | .58 | 9.47 | 11.74 | 144 |
| heatingcost | 2105.35 | 1899.53 | 150.00 | 7500 | 144 |
| consumptionunit | 1.81 | .56 | 1.00 | 3.29 | 144 |
| householdcosts | 4899.38 | 218.29 | 4443.00 | 5029 | 144 |
| female | .31 | .46 | 0.00 | 1 | 144 |
| male | .69 | .46 | 0.00 | 1 | 144 |
| unimore | .47 | .5 | 0.00 | 1 | 144 |
| uni | .31 | .47 | 0.00 | 1 | 144 |
| highschool | .19 | .4 | 0.00 | 1 | 144 |
| nohighschool | .03 | .16 | 0.00 | 1 | 144 |
| age | .13 | .33 | 0.00 | 1 | 144 |
| age2 | .15 | .35 | 0.00 | 1 | 144 |
| age3 | .39 | .49 | 0.00 | 1 | 144 |
| age4 | .28 | .45 | 0.00 | 1 | 144 |
| highage | .06 | .24 | 0.00 | 1 | 144 |
| single | .16 | .37 | 0.00 | 1 | 144 |
| singlep | .06 | .24 | 0.00 | 1 | 144 |
| partnerwithchild | .53 | .5 | 0.00 | 1 | 144 |
| partnernochild | .23 | .42 | 0.00 | 1 | 144 |
| other | .02 | .14 | 0.00 | 1 | 144 |
| condominium | .15 | .35 | 0.00 | 1 | 144 |
| rent | .14 | .35 | 0.00 | 1 | 144 |
| house | .72 | .45 | 0.00 | 1 | 144 |
| heat | .94 | .24 | 0.00 | 1 | 144 |
| highheatingcost | .17 | .38 | 0.00 | 1 | 144 |
| incomepov | .1 | .31 | 0.00 | 1 | 144 |
| incomepovh | .01 | .08 | 0.00 | 1 | 144 |

**This table (2) shows the summary statistics of the variables**

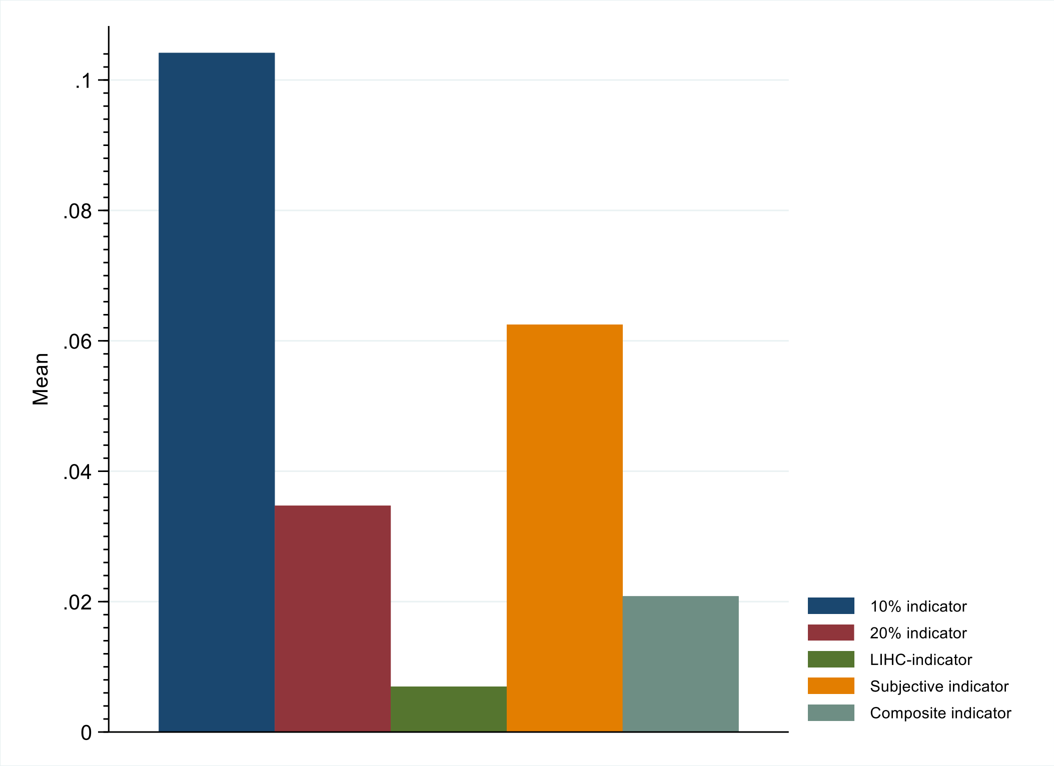


***Figure 1 shows the percentage that are considered fuel poor according to the different indicators***

Figure 1 shows the percentage of the respondents that are considered fuel poor according to the different indicators. The 10% indicator identifies the most as fuel poor (around 10.4%) while the LIHC indicator identifies the least amount as fuel poor (around 0.6%).

Table 3 compares the respondents income distribution for the whole sample and the fuel poor to the national household income distribution from 2020, adjusted for inflation (*Income distribution (fractiles). Upper bound value, SEK thousands by type of income, distribution measurements and year*. *PxWeb*, 2022). The sample's income is higher at all percentiles with the exception of the 99th percentile. The 99th percentile deviation from this trend is probably due to the winsorization[1] of the upper distribution reducing the 99th percentile down to the same value as the 95th percentile. The fuel poor household's income is higher than the national household income between the 1st percentile and the 50th percentile, while it is lower in the percentiles above this.

[1] A 90th percent winsorization was made on both the heating costs and income from the respondents.

| Table 3 | Percentiles | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Income | (1)<br>p1 | (2)<br>p5 | (3)<br>p25 | (4)<br>p50 | (5)<br>p75 | (6)<br>p90 | (7)<br>p95 | (8)<br>p99 |
| Whole sample's household income | 13 000 | 13 000 | 36 723 | 52 000 | 70 000 | 100 000 | 125 000 | 125 000 |
| Household income for the fuel poor | 13 000 | 14 000 | 26 000 | 38 000 | 50 000 | 65 000 | 75 000 | 80 000 |
| National household income | 5020 | 11 782 | 20 762 | 34 673 | 51 942 | 78 371 | 96 942 | 172 537 |

Note: Table 3 compares the household income distribution (after tax) of the respondents to the 2020 national disposable household income (including capital gains)

The "healthsum" and "health" variable have an average of 11.91 respectively 49.44 (see table 2). The former indicates that the self-assessed general health of the average respondent is slightly above the midpoint while the latter shows it is slightly below the midpoint. There exists no national self-reported health with the usage of the SF-36 survey. However, there exists data from 2021 which shows that the 74 percent of the population considers themselves having good or very good health (*Självskattad hälsa efter utbildningsnivå, kön och år. Andel (procent).. PxWeb*, no date). Compared to our study where 90% of the respondents answered that their general health is ”good”, ”very good” or ”excellent”.

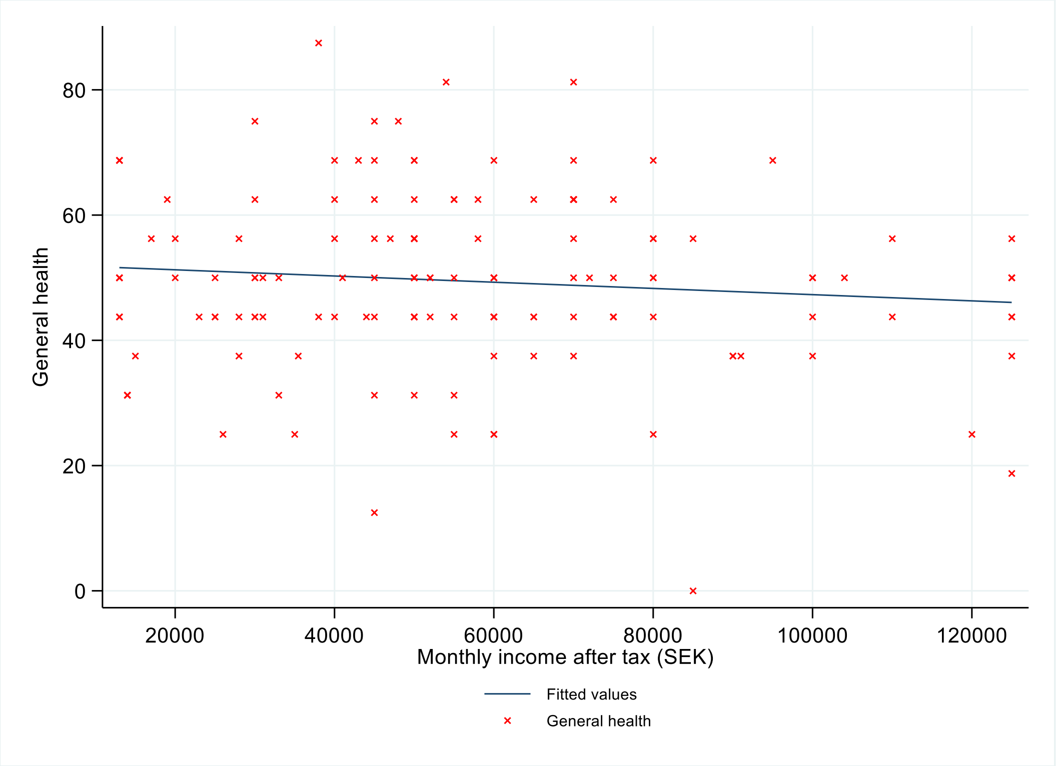


***Figure 2 shows the relationship between general self-assessed health and income***

Figure 2 shows the relationship between self-assessed general health (y-axis) and monthly income after tax (x-axis). The figure shows both the individual observations as red dots and a blue trendline. The trendline shows a negative correlation between income and health outcome.

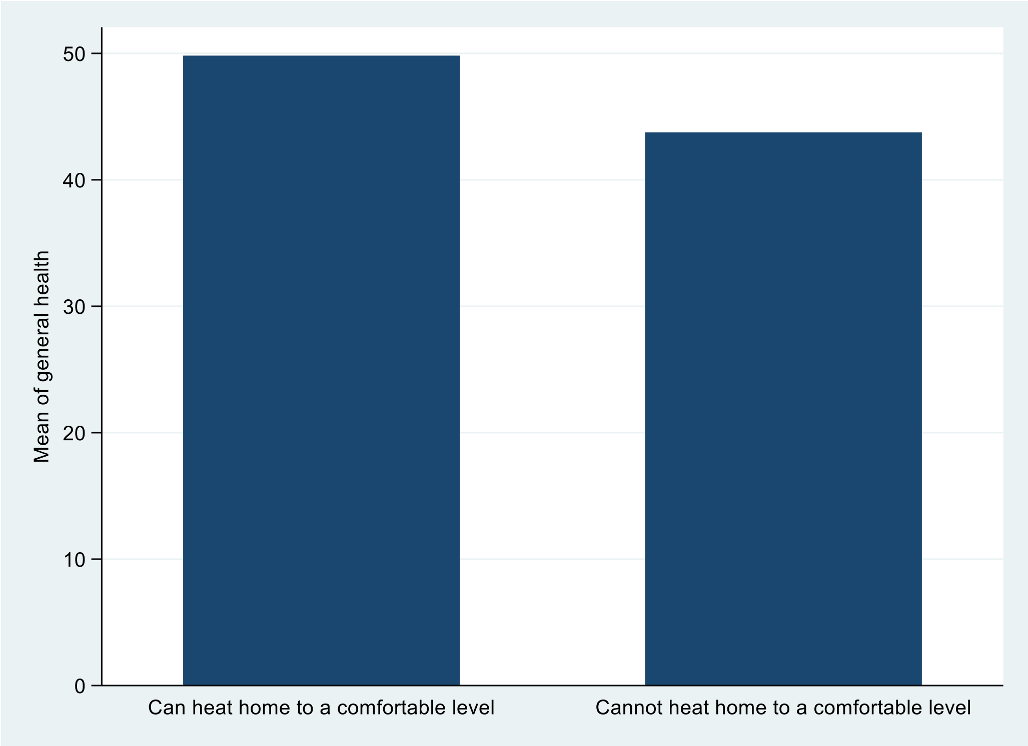


***Figure 3 shows the mean of the health variable and is grouped by the subjective fuel poverty indicator (if the household can heat their home to an adequate level).***

Figure 3 shows the means of self-assessed general health grouped by the subjective fuel poverty indicator (if they can heat their home to an adequate level) and it shows that the average respondent that cannot heat their home to a comfortable level has around 5 less health score points, which translates to approximately 10% less healthy.

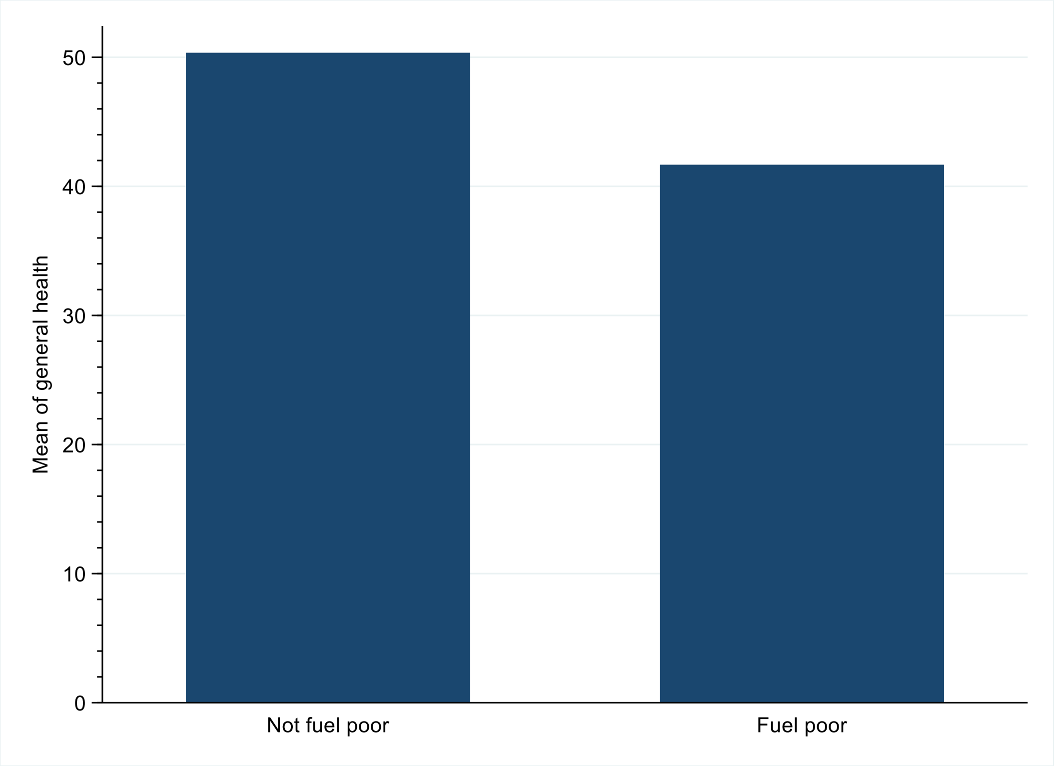


*Figure 4 shows the mean general health for fuel poor (if any of the fuel poverty indicators=1) and not fuel poor individuals.*

Figure 4 shows the average general health for individuals that are fuel poor and not fuel poor. In this figure an individual is considered fuel poor if any of the indicators indicates them as such. The figure shows that the mean health for the non-fuel poor is approximately 50 health scores, and the corresponding value for the fuel poor is around 42.

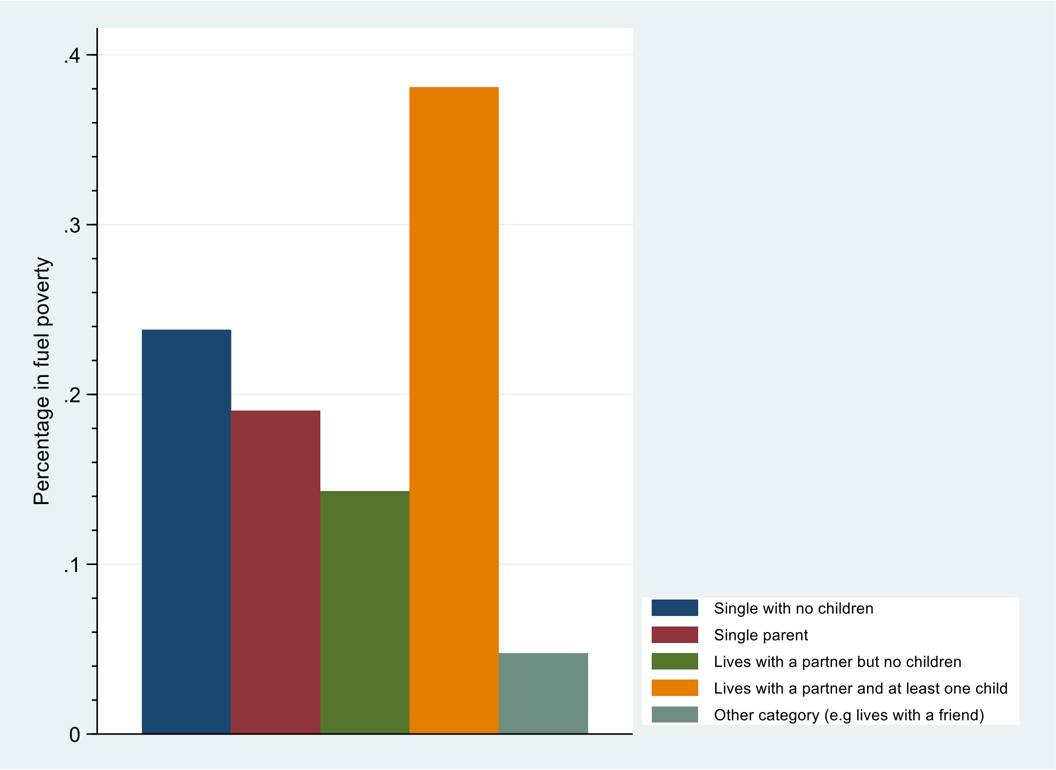


***Figure 5 shows the composition of the different household categories for the fuel poor according to any of the indicators (if any of the fuel poverty indicators=1).***

Figure 5 shows the composition of households that are fuel poor according to any of the indicators (AHC). It shows that around 38% of the respondents live with a partner together with at least one child and around 5% of the households did live in other kinds of households (e.g., living with a friend). Around 24% of the respondents are single with no children, around 19% are single with children and around 15% have a partner but no children.

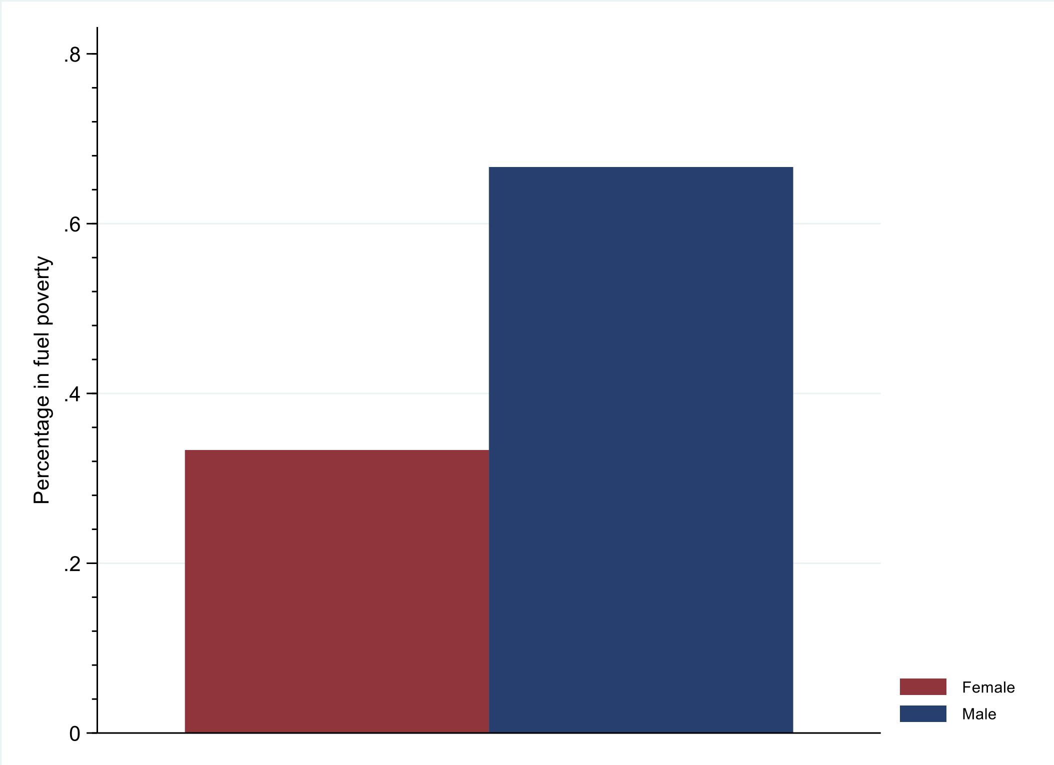


***Figure 6 shows the composition of females and males of the fuel poor according to any of the indicators (if any of the fuel poverty indicators=1).***

Figure 6 shows the composition of females and males that are fuel poor according to any of the indicators (AHC). It shows that around 62% are males and around 38% are females.

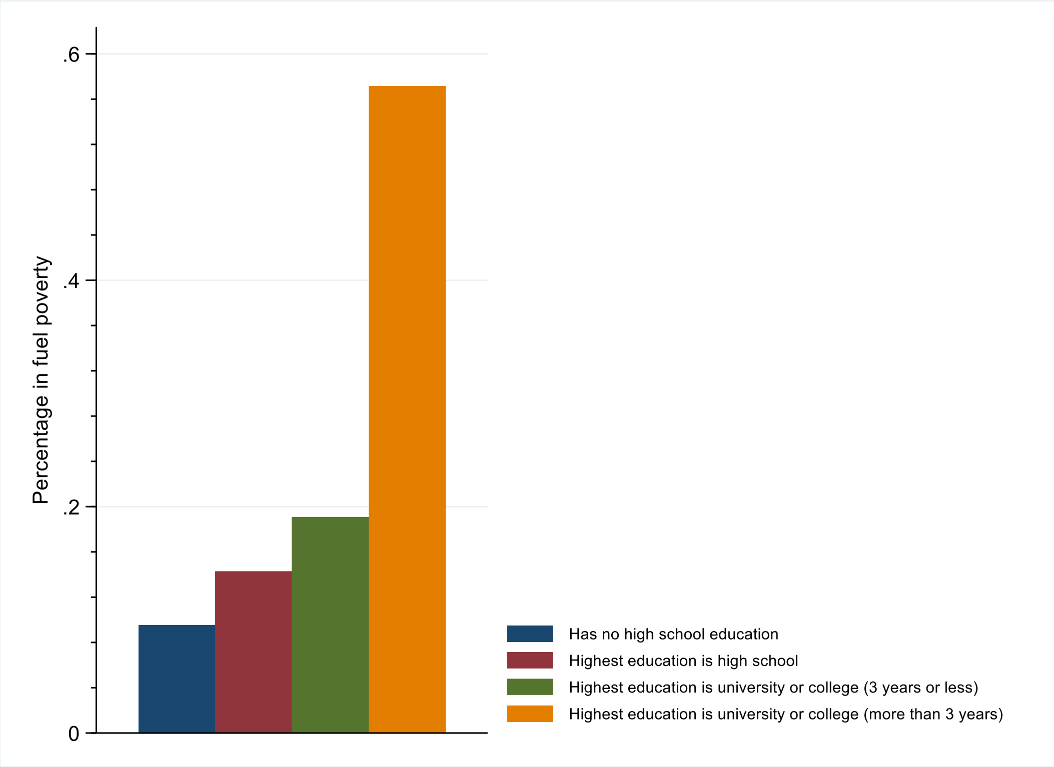


***Figure 7 shows the composition education for the fuel poor according to any of the indicators (if any of the fuel poverty indicators=1).***

Figure 7 shows the composition of education level of those that are fuel poor according to any of the indicators (AHC). The figure shows that close to 56% of the fuel poor have a university or college education of more than 3 years. Respondents that had a university or college education of 3 years or less constituted close to 20%, so the vast majority of the fuel poor have a university or college education of some sort.

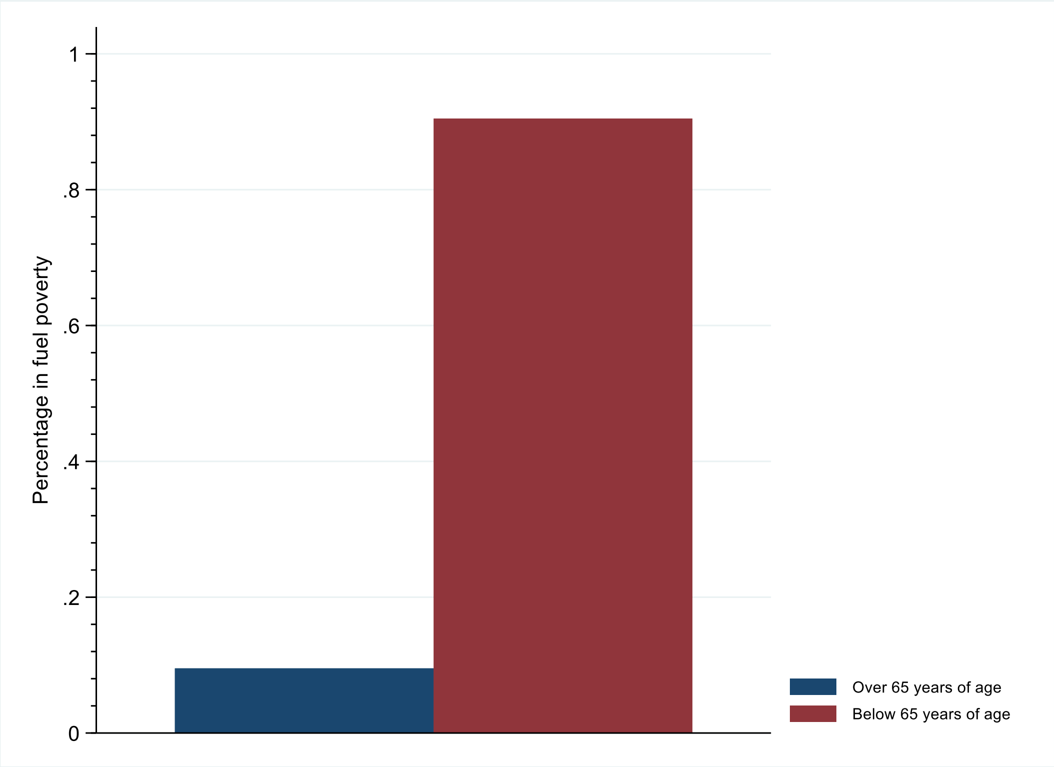


***Figure 8 shows the composition of respondents that are above 65 years of age or not, for the fuel poor (if any of the fuel poverty indicators=1).***

Figure 8 illustrates the age composition of the respondents in fuel poverty according to any of the indicators (AHC). Around 90% of the fuel poor were below 65 years of age and around 10% were above 65 years of age.

# 5. Empirical strategy

## 5.1 Econometric design

A linear regression was performed, and the equation can be seen below:

$$H = \beta_0 + \beta_1 FP_T + X + \varepsilon$$

Where $H$ is a measurement for self-assessed health and can take values between 0 and 100 at 6.25 intervals. The scoring is based on a questionnaire with an ordinal ranking, but in line with previous literature (Awaworyi Churchill & Smyth, 2021) we consider it to be linear after transforming the answers to the 0 - 100 score range. An ordered probit model is used in the robustness section 6.2. $FP$ is a dummy variable that can either take the value of 1 if the respondent is considered fuel poor or it can take the value of 0 if the respondent is not fuel poor. $X$ is a vector of controls and $\varepsilon$ is the error term that represents the unobserved effects that can affect the self-assessed general health.

The underlying specification assumptions for the linear regression model have been controlled and are fulfilled. The normality assumption was controlled by performing a skewness and kurtosis test, and the residuals in all regressions were considered normal at the 5% significance level. The assumption of homoskedasticity has also been checked by performing the Breusch-Pagan/Cook-Weisberg test and the residuals for all regression were considered homoscedastic in all regressions. Multicollinearity has been controlled by producing a VIF chart for all regressions and the mean VIF are around 1.35, none of the variables VIFs are close to 5 nor are any of the tolerance level close to 0.2. Multicollinearity does therefore seem to be a non-issue.

Endogeneity cannot be statistically tested unlike the other specification assumptions, and we must rely on our intuition instead. One way of reducing endogeneity is to reduce the omitted variable bias by including control variables. For example, changes in income itself will intuitively affect both health and fuel poverty. If income is excluded from the regression, then the fuel poverty dummy might capture both the effect of the income change and the fuel poverty change. In other words, an upward bias of the fuel poverty coefficient will occur, and endogeneity will therefore be reduced by including income as a control variable. In addition to income, we include several other variables that are correlated with health and fuel poverty.

As noted in the literature review, Legendre and Ricci (2015) found that living alone and being retired increases the probability of falling into fuel poverty, while owning their own home and having higher education decreases the probability of being fuel poor. Other previous literature on the subject has found that having a higher education is associated with higher health (Awaworyi Churchill & Smyth, 2021). Additionally, OECD (2006) found that individuals with higher levels of education had more of a tendency to seek and afford medical treatment than less educated individuals. Moreover, Goldman and Smith (2011) found that well-educated individuals managed diseases better than uneducated individuals.

Previous findings regarding being female and health have been ambiguous. Being female was associated with lower health in a study from 2015 (Lacroix and Chaton, 2015) while a study from 2020 (Kahouli, 2020) found a positive association between health and being a female. Lacroix and Chaton (2015) also found that being over 60 years old was associated with lower health, and Awaworyi Churchill and Smyth (2021) found that the number of dependents or being single was associated with lower health. Due to education, sex, high age, and different household composition being associated with both fuel poverty and health, we will include similar variables as controls to find any significant correlation between these variables.

The same dependent variable is used for the ordered probit model and the composite (AHC) indicator as the main independent variable because it is one of the stricter indicators out of all the ones used and it was statistically significant in the AHC model. The dependent variable does not have any labels attached to every single value (for example a score of 12.5 does not have a label attached to it), unlike the individual health scores where for example “5” means having “excellent health”. Using the individual health scores would make interpretations of the marginal effects easier, but it would not be congruent with the main regressions made. We, therefore, settled on using the same transformed health variable that ranges from 0-100, and we focus on if the coefficients are statistically significant and have the same sign as the main results.

# 6. Results and Discussions

*This section presents the results of the main linear regression as well as a robustness check. This section also discusses the empirical findings from our regression model and robustness check with the ordered probit model.*

## 6.1 Empirical results

**Table 4: Main regression results**

| | (1)<br>10% | (2)<br>20% | (3)<br>LIHC | (4)<br>Subjective | (5)<br>Composite |
|---|---|---|---|---|---|
| fuelpov10h | -8.377* | | | | |
| | (4.272) | | | | |
| lincome | -1.564 | -1.583 | -1.144 | .006 | -1.388 |
| | (2.721) | (2.763) | (2.71) | (.058) | (2.693) |
| female | -.622 | -.738 | -.366 | .01 | -.749 |
| | (2.815) | (2.824) | (2.847) | (.062) | (2.807) |
| highage | 9.389* | 9.541* | 11.138** | .174* | 10.064** |
| | (4.852) | (4.893) | (5.146) | (.104) | (4.884) |
| rent | 3.748 | 4.219 | 4.212 | .091 | 4.238 |
| | (4.179) | (4.171) | (4.183) | (.089) | (4.122) |
| condominium | 5.734 | 6.002 | 6.357 | .154* | 6.388 |
| | (3.961) | (3.978) | (3.944) | (.083) | (3.886) |
| single | -5.448 | -5.003 | -4.475 | -.083 | -5.245 |
| | (3.892) | (3.912) | (3.947) | (.085) | (3.885) |
| singlep | 3.081 | 4.409 | .643 | .032 | .08 |
| | (5.407) | (5.71) | (5.33) | (.115) | (5.308) |
| partnernochild | .333 | 1.098 | .766 | .012 | .444 |
| | (3.175) | (3.179) | (3.18) | (.069) | (3.165) |
| other | 1.557 | 3.535 | -.701 | .004 | -1.181 |
| | (8.393) | (8.758) | (8.337) | (.179) | (8.28) |
| nohighschool | -8.945 | -9.332 | -11.854 | -.327** | -12.062* |
| | (7.279) | (7.302) | (7.261) | (.156) | (7.21) |
| highschool | .059 | -.136 | -.237 | -.032 | .067 |
| | (3.154) | (3.167) | (3.172) | (.068) | (3.148) |
| uni | 1.052 | 1.444 | 1.475 | .017 | 1.295 |
| | (2.694) | (2.687) | (2.689) | (.058) | (2.674) |
| fuel20h | | -12.897* | | | |
| | | (7.772) | | | |
| fuelpovlihch | | | -24.417 | | |
| | | | (15.44) | | |
| fuelpovsubj | | | | -.166 | |
| | | | | (.105) | |
| fuelpovcompos~h | | | | | -17.237** |
| | | | | | (8.318) |
| _cons | 65.924** | 65.181** | 60.292** | 3.781*** | 63.536** |
| | (30.414) | (30.759) | (30.176) | (.645) | (30.027) |
| Observations | 144 | 144 | 144 | 143 | 144 |
| R-squared | .119 | .112 | .11 | .113 | .122 |

*Standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

Table 2 presents the main regression results. The results show that the 10% fuel poverty indicator and 20% fuel poverty indicator are statistically significant at the 10% level. The results presented above also show that the fuel poverty composite indicator is statistically significant at the 5% level while the subjective fuel poverty indicator is not statistically significant. The results from Model (1), (2) and (5) show a negative relationship between fuel poverty and health. The results indicate that fuel-poor individuals have 8.377 lower health scores than their non-fuel poor counterparts in the 10% fuel poverty model. The 20% fuel poverty indicator shows that being fuel-poor leads to a decrease of 12.897 health scores than being a non-fuel poor individual. Lastly, the composite indicator shows that being fuel-poor leads to a decrease of health scores of 17.237 compared to being a non-fuel poor individual.

Similarly, Awaworyi Churchill and Smyth (2021) and Kahouli (2020) found that there was a significant relationship between self-assessed health and fuel poverty, where fuel poverty was associated with a lower level of self-assessed general health (Awaworyi Churchill & Smyth, 2021; Kahouli, 2020). Additionally, Awaworyi Churchill and Smyth (2021) found that the subjective indicator showed a greater impact on health variables in measuring energy poverty than an objective indicator.

However, in our case, we found most of the objective indicators to be statistically significant but not the subjective indicator. Our findings are also supported by research in the health field where Dunning, Heath and Suls (2004) argued that people might overestimate their own health compared to others. At the same time, Börger (2012) argued that individuals may report good statements rather than bad ones. This may explain why there was no significant relationship found between fuel poverty and health in the subjective indicator.

According to our finding, an individual that is fuel poor is more likely to have poorer health than an individual that is not fuel poor which is in line with our hypothesis as well as previous studies'.

**HIGH AGE**

The estimations of the socio-demographic characteristics indicate that being over 65 years of age has a positive correlation with self-assessed health and is significant in all models which is unexpected regarding previous studies. Most of the previous literature found a negative relationship between fuel poverty and being retired where fuel poor individuals had poorer health (Legendre and Ricci, 2015). The “highage” variable is statistically significant at the 10% level in the 10% fuel poverty indicator, 20% fuel poverty indicator, and the subjective indicator. At the same time, the “highage” variable is statistically significant at the 5% level in the LIHC-indicator and the composite indicator. Our finding shows that being over 65 years of age increases the self-assessed general health in all five models.

This finding is interesting for two reasons. First, Legendre and Ricci (2015) determined that retired individuals were the most fuel vulnerable in France and that those individuals had higher incidence of poorer health (Legendre & Ricci, 2015). Second, given the theoretical framework, this finding is somewhat surprising. Health is assumed to decrease with age according to the Grossman model (Muurinen, 1982) (Muurinen, 1982), which illustrates how income, utility and other goods are related to health. Consequently, aging will lead to an individual’s health stock depreciating faster, resulting in individuals having to invest in more medical services and goods. As predicted by the model, the desired health stock is likely to decline over a lifetime, and the higher the healthcare costs, the more rapidly it declines (Muurinen, 1982). Our results showed a positive relationship between health and high age, which is contrary to the previous research and theoretical framework.

**INCOME**

Unlike previous studies, we found no statistically significant relationship between self-assessed general health and income.

As the Grossman model explains, individuals with high income are more likely to invest in their health, and therefore in more medical goods and services compared to their own time investment, where cost of time is higher (Muurinen, 1982). Even though our results did not show any significant association between income and health, this may be due to our small sample size of respondents in our survey. Moreover, our sample was predominantly made up of a high-income bias and highly educated individuals which could have impacted the income variable just as the high age variable.

**EDUCATION**

In our results, there is not a significant relationship between health and income. On the other hand, we found that the no high school variable was statistically significant at the 5% level in the subjective indicator. Individuals with no high school education had a decrease in 0.327 health scores in self-assessed general health. The composite indicator showed that having no high school education leads to a decrease of 12.062 health scores in self-assessed general health for individuals.

Organisation for Economic Co-operation and Development found that higher educated individuals were more likely to seek medical treatment and afford healthcare than less educated individuals (OECD, 2006).

At the same time, Goldman and Smith (2011) found evidence of better disease management by well-educated individuals than by uneducated individuals. It is predicted in the Grossman model that an increase in education leads to an increase in demand for health stock, which may explain our finding that no high school education has a negative relationship with health. Those with high educational income according to Grossman's model are intentionally more efficient, where the model suggests that those with higher education have a greater capacity to combine their time and their inputs to produce health (Muurinen, 1982).

Thus, those who are well educated will demand a greater amount of health care than those with no education. Consequently, those with low education may therefore have to choose between reducing their heating costs or other expenditures that will negatively affect their health.

**RENT AND HOMEOWNERS**

Due to previous literature, the rent variable was expected to be statistically significant and have a negative relationship with health (Legendre & Ricci, 2015). Our results showed no significant relationship between people who pay rent and health. It has been explained before that tenants often pay their rent with heat costs already included, which further can explain the non-effect on their rent and therefore no effect on the variable.

On the other hand, homeowners can also be seen as targets of fuel poverty and health since larger homes require more energy, which is further coupled with higher heating costs for the household. At the same time, individuals who own their homes might also have a high income. We found that the condominium variable, at a 5% significance level in the subjective indicator, was associated with an increase of 0.154 health scores.

To summarize, one of the most surprising findings is that, according to previous studies, most of the target groups in relation to fuel poverty and health were individuals older than 65 years. In our finding, we found empirical evidence where health and high age had a positive correlation. However, the Grossman model strongly contradicts this finding. There may exist certain socio-demographic characteristics that make these respondents different from the general population, where most respondents were of higher education with high income. To draw any conclusions from the findings, a larger and more diverse sample would be appropriate.

## 6.2 Robustness check

Table 5: Robustness

| | (1)<br>10% | (2)<br>20% | (3)<br>LIHC | (4)<br>Subjective | (5)<br>Composite |
|---|---|---|---|---|---|
| fuelpov10 | -10.106** | | | | |
| | (5) | | | | |
| lincome | -1.933 | -.762 | -1.084 | .006 | -1.077 |
| | (2.761) | (2.689) | (2.705) | (.058) | (2.731) |
| female | -1.168 | -.515 | -.432 | .01 | -.718 |
| | (2.81) | (2.85) | (2.843) | (.062) | (2.838) |
| highage | 9.806** | 9.839* | 9.942** | .174* | 9.803* |
| | (4.871) | (4.98) | (4.949) | (.104) | (4.982) |
| rent | 3.885 | 5.05 | 5.015 | .091 | 4.546 |
| | (4.157) | (4.13) | (4.118) | (.089) | (4.181) |
| condominium | 5.732 | 6.646* | 6.504 | .154* | 6.723* |
| | (3.952) | (3.941) | (3.929) | (.083) | (3.936) |
| single | -5.178 | -4.973 | -5.348 | -.083 | -5.171 |
| | (3.888) | (3.931) | (3.912) | (.085) | (3.925) |
| singlep | 2.639 | 2.12 | .27 | .032 | .379 |
| | (5.358) | (5.41) | (5.346) | (.115) | (5.362) |
| partnernochild | .642 | .807 | .556 | .012 | .655 |
| | (3.163) | (3.189) | (3.187) | (.069) | (3.194) |
| other | 2.213 | 3.172 | 3.421 | .004 | -1.067 |
| | (8.434) | (8.921) | (8.798) | (.179) | (8.362) |
| nohighschool | -7.971 | -11.769 | -11.648 | -.327** | -11.776 |
| | (7.351) | (7.284) | (7.254) | (.156) | (7.288) |
| highschool | .051 | -.117 | -.301 | -.032 | -.412 |
| | (3.151) | (3.179) | (3.175) | (.068) | (3.194) |
| uni | 1.086 | 1.599 | 1.556 | .017 | 1.406 |
| | (2.688) | (2.693) | (2.687) | (.058) | (2.706) |
| fuelpov20 | | -12.025 | | | |
| | | (9.059) | | | |
| fuelpovlihc | | | -13.904 | | |
| | | | (8.908) | | |
| fuelpovsubj | | | | -.166 | |
| | | | | (.105) | |
| fuelpovcomposite | | | | | -13.529 |
| | | | | | (10.474) |
| _cons | 69.793** | 56.049* | 59.831** | 3.781*** | 59.893* |
| | (30.843) | (29.938) | (30.143) | (.645) | (30.457) |
| Observations | 144 | 144 | 144 | 143 | 144 |
| R-squared | .121 | .105 | .11 | .113 | .104 |

*Standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

Table 5 shows the robustness regressions that are made by using BHC instead of AHC. The 10% indicator is still statistically significant but at the 5% level instead of the 1% level. The LIHC indicator is also non-statistically significant just as in the AHC model. The only difference in the LIHC model is that being over 65 years of age has slightly less effect on self-assessed general health. The subjective indicator is the same regardless if we use AHC or BHC so it being statistically insignificant is expected. The composite and 20% indicators are both statistically insignificant at all conventional levels and this differs the BHC model from the AHC model.

The interpretation of the statistically significant indicators is that being in fuel poverty decreases self-assessed general health with a 10.106 points indicator compared to not being fuel poor according to the 10% indicator.

The difference in the size of the 10% indicator coefficient suggests that while fewer are in fuel poverty according to the BHC model, those that are fuel poor have a stronger association with poor self-assessed general health on average. In other words, the AHC 10% indicator identified a couple more households that were fuel poor, but those households probably had a weaker correlation with self-assessed general health compared to the rest of the fuel poor.

While the 10% indicator for the BHC model is larger than its corresponding AHC model, the opposite is true for the 20% indicator. In fact, the 20% indicator for the BHC model was not even statistically significant, and R-squared is lower in the BHC model compared to the AHC model. We assume that the AHC model for the 20% indicator identified more households as fuel poor and those households had on average a stronger correlation with self-assessed general health compared to the rest of the fuel poor.

The composite indicator was not statistically significant in the BHC model while it was in the AHC model, and R-squared is lower in the BHC model compared to the AHC model. Initially, you could think that this is driven by the statistical insignificance in the 20% indicator. However, intuitively all of the households that are identified as fuel poor according to the 20% indicator and the LIHC indicators are also fuel poor according to the 10% indicators, so this cannot be true and the change in the composite indicator must be driven by the fewer households identified by the 10% indicator.

Living in a condominium is statistically significant at the 10% level in the 20% and composite regressions (BHC) which is different from the corresponding AHC models where it was not statistically significant at any of the convenient levels. Living in a condominium increases health with 6.646 health scores in the 20% regression and 6.723 in the composite regression. We are unsure what causes this difference.

The coefficient for the “nohighschool” coefficient is not statistically significant at any of the convenient levels in the BHC models, while it was statistically significant in the composite regression (AHC).

The coefficient for the “highage” variable is still statistically significant in all regressions, but it is significant only at the 10% level in the composite indicator compared to the 5% level in the AHC model. The opposite is true for the “highage” coefficient in the 10% indicator, it is statistically significant at the 5% level instead of 10% as in the AHC model. One difference is that the coefficient is slightly smaller in the 10% and 20% indicators, while it is slightly larger in the composite model.

Table 6: Ordered probit regression

| Healthvariable | Coefficient | Std. err. | z | P>z | [95% conf. | interval] |
|---|---|---|---|---|---|---|
| energypovcompositeh | -1.3893 | .6306566 | -2.20 | 0.028 | -2.625364 | -.1532356 |
| lincome | -.10347 | .2019523 | -0.51 | 0.608 | -.4992892 | .2923493 |
| female | -.0252075 | .211271 | -0.12 | 0.905 | -.439291 | .3888759 |
| highage | .7770904 | .3681817 | 2.11 | 0.035 | .0554674 | 1.498713 |
| rent | .3279639 | .3094606 | 1.06 | 0.289 | -.2785677 | .9344956 |
| condominium | .4944362 | .2923409 | 1.69 | 0.091 | -.0785415 | 1.067414 |
| single | -.431939 | .2930288 | -1.47 | 0.140 | -1.006265 | .1423869 |
| singlep | -.0360293 | .3973006 | -0.09 | 0.928 | -.8147242 | .7426656 |
| partnernochild | .023499 | .2374276 | 0.10 | 0.921 | -.4418506 | .4888486 |
| other | -.0778924 | .6193672 | -0.13 | 0.900 | -1.29183 | 1.136045 |
| nohighschool | -.9536482 | .5425108 | -1.76 | 0.079 | -2.01695 | .1096535 |
| highschool | -.0227182 | .2360501 | -0.10 | 0.923 | -.4853678 | .4399314 |
| uni | .0932478 | .2007691 | 0.46 | 0.642 | -.3002524 | .4867481 |
| | | | | | | |
| /cut1 | -3.695826 | 2.28952 | | | -8.183203 | .791551 |
| /cut2 | -3.441233 | 2.277563 | | | -7.905175 | 1.022709 |
| /cut3 | -3.269703 | 2.272023 | | | -7.722785 | 1.18338 |
| /cut4 | -2.653871 | 2.254639 | | | -7.072882 | 1.765141 |
| /cut5 | -2.32805 | 2.253743 | | | -6.745304 | 2.089205 |
| /cut6 | -1.972209 | 2.254387 | | | -6.390726 | 2.446308 |
| /cut7 | -1.237212 | 2.254027 | | | -5.655024 | 3.180599 |
| /cut8 | -.6350727 | 2.254769 | | | -5.054339 | 3.784193 |
| /cut9 | -.2659333 | 2.254269 | | | -4.68422 | 4.152353 |
| /cut10 | .1642035 | 2.251289 | | | -4.248243 | 4.576649 |
| /cut11 | .7856697 | 2.2495 | | | -3.62327 | 5.194609 |
| /cut12 | 1.121116 | 2.257295 | | | -3.303101 | 5.545334 |
| /cut13 | 1.585262 | 2.282478 | | | -2.888312 | 6.058836 |

Note: Table 6 shows the results of the ordered probit regression

Table 6 shows the ordered probit regression with the healthvariable as a dependent variable and the composite indicator (AHC). The results show that the composite indicator is statistically significant at the 5% level and the sign of the coefficient is negative which means that fuel poverty has a negative effect on self-assessed general health. Condominium and the “nohighschool” coefficients are statistically significant at the 10% level, and the “highage” coefficient is statistically significant at the 5% level. The signs of the coefficients are also the same for these. We can only interpret the direction of the coefficients but not the size of them. The fact that the coefficients are statistically significant in the ordered probit regression suggests that the results are robust.

Table 7: Marginal effects

| | Delta-method dy/dx (marginal effects) | z | P>z | [95% conf. | interval] |
|---|---|---|---|---|---|
| 0.fuelpovcompositeh | (base outcome) | | | | |
| 1.fuelpovcompositeh _predict | | | | | |
| 0 | .1059996 | 0.85 | 0.395 | -.1382121 | .3502113 |
| 12.5 | .0478597 | 0.86 | 0.387 | -.0606411 | .1563606 |
| 18.75 | .038197 | 0.90 | 0.368 | -.0450345 | .1214284 |
| 25 | .158703 | 1.93 | 0.053 | -.0023884 | .3197944 |
| 31.25 | .0761692 | 2.47 | 0.014 | .0157278 | .1366105 |
| 37.5 | .0537357 | 1.92 | 0.055 | -.001154 | .1086255 |
| 43.75 | -.0330161 | -0.36 | 0.720 | -.2136957 | .1476635 |
| 50 | -.1398277 | -1.90 | 0.057 | -.2840853 | .00443 |
| 56.25 | -.0952024 | -2.74 | 0.006 | -.1633936 | -.0270113 |
| 62.5 | -.0918246 | -3.22 | 0.001 | -.1476406 | -.0360086 |
| 68.75 | -.0793809 | -3.39 | 0.001 | -.1252544 | -.0335075 |
| 75 | -.0208706 | -1.76 | 0.078 | -.0440746 | .0023335 |
| 81.25 | -.0137764 | -1.44 | 0.151 | -.0325754 | .0050226 |
| 87.5 | -.0067654 | -1.01 | 0.312 | -.0198731 | .0063423 |
| 0.highage | (base outcome) | | | | |
| 1.highage _predict | | | | | |
| 0 | -.0077386 | -1.16 | 0.248 | -.02087 | .0053928 |
| 12.5 | -.0056291 | -1.00 | 0.320 | -.0167143 | .005456 |
| 18.75 | -.0055665 | -0.99 | 0.322 | -.0165898 | .0054569 |
| 25 | -.0381055 | -2.28 | 0.023 | -.0708949 | -.005316 |
| 31.25 | -.0351587 | -2.14 | 0.032 | -.0673588 | -.0029585 |
| 37.5 | -.0501089 | -2.24 | 0.025 | -.0939485 | -.0062694 |
| 43.75 | -.110445 | -1.99 | 0.046 | -.2189784 | -.0019116 |
| 50 | -.0348409 | -0.89 | 0.374 | -.111723 | .0420413 |
| 56.25 | .0214556 | 1.81 | 0.071 | -.0017954 | .0447066 |
| 62.5 | .0573063 | 2.60 | 0.009 | .0141019 | .1005107 |
| 68.75 | .0988733 | 1.90 | 0.057 | -.0029021 | .2006486 |

| | | | | | |
|---|---|---|---|---|---|
| 75 | .0425739 | 1.25 | 0.211 | -.0241667 | .1093146 |
| 81.25 | .0384037 | 1.08 | 0.280 | -.0312657 | .1080731 |
| 87.5 | .0289804 | 0.88 | 0.379 | -.0355468 | .0935075 |
| 0.nohighschool | (base outcome) | | | | |
| 1.nohighschool _predict | | | | | |
| 0 | .0466962 | 0.79 | 0.432 | -.0697578 | .1631503 |
| 12.5 | .0254171 | 0.79 | 0.431 | -.0378763 | .0887106 |
| 18.75 | .0218237 | 0.80 | 0.426 | -.0319436 | .0755911 |
| 25 | .1056838 | 1.33 | 0.182 | -.0495341 | .2609017 |
| 31.25 | .0623682 | 1.72 | 0.086 | -.0088304 | .1335669 |
| 37.5 | .0563202 | 2.52 | 0.012 | .0125232 | .1001172 |
| 43.75 | .0203003 | 0.42 | 0.671 | -.0735045 | .1141052 |
| 50 | -.0854601 | -1.22 | 0.224 | -.223081 | .0521608 |
| 56.25 | -.0709978 | -1.81 | 0.070 | -.147749 | .0057535 |
| 62.5 | -.0745512 | -2.21 | 0.027 | -.1406798 | -.0084226 |
| 68.75 | -.0690955 | -2.57 | 0.010 | -.1218573 | -.0163336 |
| 75 | -.0190613 | -1.67 | 0.094 | -.0413905 | .003268 |
| 81.25 | -.012911 | -1.41 | 0.158 | -.0308556 | .0050335 |
| 87.5 | -.0065328 | -1.02 | 0.309 | -.0191216 | .006056 |

Note: Table 7 shows the marginal effects for the statistically significant variables(fuelpovcompositeh, highage, condominium, nohighschool)

Table 7 above shows the marginal effects for the statistically significant variables from the ordered probit model. As noted in section 4.3, the health variable can take on values between 0-100 with a 6.25 interval which adds up to 20 values. However, only 14 of the 20 possible values were generated when transforming the health scores from the individual questions to the 0-100 scale, hence the reason only 14 values are visible in table 7.

The fuel poverty variable is statistically significant at all conventional levels except when health scores are: 0, 12.5, 18.75, 43.75, and 87.5. In other words, being fuel poor did on average not change the probability of having these health scores. On average, being fuel poor increased the probability of having the following health scores: 25, 31.25 and 37.5. For example, being fuel poor increased the average probability of having health scores at a value of 25 with approximately 16%. On the other hand, being fuel poor decreased the average probability of having the following health scores: 56.25, 62.5 and 68.75. In other words, being fuel poor increased the average probability of having poor health, while it decreased the average probability of having good health. The same pattern can be observed for not having a high school education compared to having one, while the opposite pattern is observed for being over 65 years old compared to being younger than 65 years.

| Healthvariable | (1)<br>Income | (2)<br>Heating costs | (3)<br>Income and heatingcosts |
|---|---|---|---|
| lincome | -.347 | | .571 |
| | (2.678) | | (2.692) |
| female | -.93 | -.251 | -.155 |
| | (2.841) | (2.792) | (2.839) |
| highage | 8.428* | 9.259* | 9.313* |
| | (4.88) | (4.826) | (4.85) |
| rent | 5.462 | 3.495 | 3.763 |
| | (4.131) | (3.97) | (4.18) |
| condominium | 7.554* | 5.067 | 5.269 |
| | (3.893) | (3.898) | (4.027) |
| single | -5.32 | -5.179 | -4.901 |
| | (3.933) | (3.658) | (3.898) |
| singlep | .972 | 1.133 | 1.544 |
| | (5.356) | (4.926) | (5.309) |
| partnernochild | .877 | .707 | .686 |
| | (3.197) | (3.153) | (3.166) |
| other | -.964 | 1.623 | 1.879 |
| | (8.383) | (8.306) | (8.424) |
| nohighschool | -10.992 | -9.429 | -9.321 |
| | (7.282) | (7.212) | (7.257) |
| highschool | -.017 | .373 | .393 |
| | (3.187) | (3.148) | (3.161) |
| uni | 1.777 | 1.32 | 1.282 |
| | (2.698) | (2.666) | (2.681) |
| heatingcost | | -.001* | -.001* |
| | | (.001) | (.001) |
| _cons | 51.446* | 50.803*** | 44.523 |
| | (29.822) | (2.717) | (29.725) |
| Observations | 144 | 144 | 144 |
| R-squared | .093 | .118 | .119 |

*Note: Table 8 shows the regressions results with the health variable as dependent variable and "lincome" as the variable of interest in model 1, heatingcost as the variable of interest in model 2 and both lincome and heatingcost as the variables of interest in model 3.*
*Standard errors are in parentheses*
**** p<.01, ** p<.05, * p<.1*

Table 8 shows the robustness results where the variables of interest are the log of income in model 1, heating costs in model 2, and both variables in model 3. Log of income is not statistically significant at any of the convenient levels. However, heating costs are statistically significant at the 10% level in both models 2 and 3. The interpretation is that if heating costs increase by 1 SEK, then health scores will decrease on average by 0.001 units. Alternatively, one could interpret it as an increase of heating costs by 1000 SEK will decrease the health scores by 1 unit on average. Being fuel poor, according to the composite indicator (AHC), decreased health with approximately 17 health scores compared to not being fuel poor. The corresponding value was approximately between 8 and 12 for the other indicators. This means that the heating costs must increase between 8000 to 17 000 SEK to reach the same decrease in health scores as the fuel poverty indicators show. The results in this table suggest that our results are neither driven purely by income or heating costs in isolation nor in combination, but rather it is the fuel poverty itself that causes the negative effect on self-assessed general health.

In summary, the removal of household costs gives ambiguous indications for the relationship between fuel poverty and self-assessed general health. On one hand, the 10% indicator showed a stronger relationship, but the 20% indicator and composite indicator were not significant when removing the household costs. However, the 10% indicator is the least stringent one of all the indicators we have in our opinion. While, one might criticize how accurately the 10% indicator defines fuel poverty, it does show some relationship between the ratio of heating costs and income to health. This argument is further strengthened by the fact that neither income nor heating costs has a large causal effect on self-assessed general health. The ordered probit regression was statistically significant which indicates that the usage of a linear regression did not bias the results in any significant way.

# 7. Concluding remarks and future research

*This section presents the conclusions of this thesis based on the major findings of the research question. Finally, this section is providing suggestions for future research.*

The starting point of this paper was to add to the highly limited knowledge that exists on fuel poverty in a developed country by providing evidence about the relationship between fuel poverty and health. Considering Sweden's record high electricity prices, fuel poverty may become a major health issue much sooner than expected. This study contributes to the growing literature on the impacts of fuel poverty and health. As for policy implications, the evidence presented in this thesis might contribute to the debate on investing in housing energy efficiency, ensuring that electricity is more accessible to households, and protecting those most fuels vulnerable in our society to alleviate fuel poverty. Potentially, this could lead to improved health outcomes and reduced healthcare spending.

As in previous literature, our main findings were that fuel-poor individuals were more likely to have poorer health compared to non-fuel poor individuals. However, only the 10% indicator (the least stringent one in our opinion) found this relationship after adding back the housing costs. The housing costs used in this study was the national average, and it would be interesting if the results are different when using the actual housing costs.

In addition, we found that individuals of high age were likely to have better health than others. Moreover, individuals with no high school education had tendencies to have a decreased health score, which is consistent with the Grossman model. In our thesis, we also found empirical evidence that homeowners had tendencies in having better health than others, which might be related to income or education. Additionally, we did not find any significant relationship between income and health in our regressions. Even though previous studies and theoretical frameworks have shown that income plays a big role when studying health and fuel poverty. However, the descriptive statistics showed a negative correlation between income and self-assessed general health which contradicts previous literature and the theoretical framework and indicates a biased sample. Further, this might be due to our small sample of respondents in our survey where many of our respondents were high income earners, homeowners and had high education, while other respondents in our survey were students who rented and had their heating costs included in their rent.

There are also some improvements we could have done in this study. One approach that is often used in the field of fuel poverty is to use an IV-instrument to estimate fuel poverty. We could not use energy prices because we did not know the energy prices for each respondents. House subsidies have also been used as an IV-instrument, but we faced the same issues here as we did with the energy prices (Kahouli, 2020). Other statistical methods have been used to create an IV-instrument. For example, the Lewbels approach and propensity score matching (PSM) have been used in previous literature (Awaworyi Churchill & Smyth, 2021; Awaworyi Churchill, Smyth & Farrell, 2020). Lewbel's approach assumes heteroskedasticity which the regressions do not have. Unfortunately, we could not apply PSM due to a lack of time.

Considering this, future research should further investigate the relationship between fuel poverty and health in developed countries due to recent rising energy prices to add to the debate on energy efficiency for households. An ideal study would be to involve a larger sample, include more diverse groups and include questions regarding the household costs to find a clearer relationship between fuel poverty and general health. Another interesting follow-up study would be to examine the health of low-income homeowners, thus a study of different populations could reveal more accurate results. Finally, identifying the most fuel vulnerable and protecting them could lead to improving health outcomes in our society.

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