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Abstract

This paper uses panel data on life satisfaction of about 40,000 individuals in Germany from 1994 to 2013 to analyze the relationship of subjective well-being and several measures of fuel poverty. We study fuel poverty and its effects on life satisfaction in terms of incidence, intensity and in comparison to income poverty. We find a negative and significant effect of fuel poverty on subjective well-being. The effect is comparable in magnitude to those of other important factors of life satisfaction. The impact we find is beyond the effect of mere income poverty. We classify measures of fuel poverty into several types and find that there is a difference with respect to their well-being effects depending on the type of measure. Our findings confirm the argument of the recent literature that fuel poverty is an important issue and should be on the agenda of policy makers.

Keywords: fuel poverty; consumer welfare; subjective well-being; Germany

JEL classifications: I3; D12; C2; Q4

1. Introduction

The consumption of energy is an important part of overall consumption of households. It contributes to people's well-being as it is used to provide warmth or electricity allowing households to have a well tempered home or to use appliances such as computers, washing machines, refrigerators etc.

Different from many other consumption goods, the consumption of energy can be considered a basic need, required to ensure a minimum quality of life. Consistent with this idea, studies of residential energy demand typically found low price and income elasticities, whereas fixed factors such as socio-economic and housing characteristics are important determinants of residential energy demand.[1] These features of energy demand may imply high "forced" expenditures on energy even at high prices and low income.

The link between fuel poverty and income poverty has gained attention in the economic literature and in policy research over the last decade (Bouzarowvski and Petrova, 2015, provide a review of the literature). The issue of high forced energy expenditure is at the core of the notion of fuel poverty. Fuel poverty is defined as the inability to afford the most basic levels of energy for adequate heating, cooling, cooking, lighting and use of appliances in the home (Hills, 2012).[2] In addition, the expenditures for necessary energetic requirements affect consumers by constraining their income available for goods other than energy (Brunner et al. 2011), a phenomenon that will be referred to as the income-deprivation effect of fuel poverty. The issue of fuel poverty has attracted the interest of researchers since the 1990s (Boardman 1991) and, more recently, in connection with changes in energy policies that may affect energy affordability by increasing residential energy prices (Butler and Neuhoff, 2008).

[1] See Madlener 1996 for an overview of early studies and, more recently, Liao and Chang 2002 for the US, Halvorsen and Larsen 2001 and Vaage 2000 for Norway, Rehdanz 2007 for Germany, and Meier and Rehdanz 2010 for the UK.

[2] In contrast to fuel poverty, energy poverty denotes the lack of access to modern energy services and refers primarily to developing countries (OECD/IEA, 2011).

The literature on fuel poverty to date has been mainly concerned with the notion and measurement of fuel poverty (Heindl 2013) and with policies to deal with it (EPEE, 2009; Walker and Day, 2012; Boardman, 2010), whereas little is known on the direct impact of fuel poverty on individual welfare (utility). This issue is important, however, because attempts at tackling fuel poverty may be misguided unless the welfare significance of fuel poverty is sufficiently well understood. This paper addresses this research gap, using an indicator of subjective well-being (SWB) as a proxy for consumers' welfare.[3]

Similar to the relationship between fuel poverty and individual welfare (SWB) to be studied in this paper, Clark et al. (2013) studied the relationship between income poverty and SWB. Their analysis differentiated between the incidence of poverty (whether a person is poor or not) and its intensity (how far a person is below the poverty line) and found a significant negative effect of the incidence and intensity of income poverty on German citizens' SWB.

There is some debate in the literature about the measurement of income and fuel expenditure. The economics literature has suggested using equivalent income, as it represents the standard of living of one adult (e.g. Ebert, 2004). In their analysis of the poverty-SWB relationship, Clark et al. (2013) use equivalent household income arguing that it captures returns to scale in larger households.[4] With regard to fuel poverty, some studies use non-equivalised energy expenditure and income (Boardman, 1991; Healy and Clinch, 2004; Moore, 2012) while Hills (2012) proposes to use both equivalent income and equivalent expenditure. Given that we want to compare the effects of the different measures on individual welfare of one typical adult, we use

[3] Data on SWB (sometimes referred to as happiness) are increasingly used as a measure of utility, see e.g. Kahneman and Krueger (2006) or Di Tella and MacCulloch (2006). Welsch and Biermann (2017) conducted a first analysis of the relationship between energy affordability and SWB. In contrast to the present study, that paper focused on energy prices as an indicator of low energy affordability. The paper showed that the well-being effect of higher prices is greater the higher is the share of forced energy expenditures in income.

[4] The notion "larger households" refers to the number of household members, not to the size of the flat or dwelling.

equivalised income and energy expenditures throughout.[5] Whenever we mention income or expenditure we refer to the equivalised income and the equivalised expenditure.

Given the findings of Clark et al. (2013), a natural question is whether fuel poverty affects individual welfare independently from income poverty or whether the effect of the former is already implicitly captured by the latter. Whether or not fuel poverty possesses welfare significance over and above income poverty obviously has significant policy implications.

Building on the literature on fuel poverty on the one hand and the poverty-SWB relationship on the other, we study fuel poverty and its effects on SWB in terms of incidence, intensity and in comparison to income poverty. Specifically, we address the following research questions: (1) Does fuel poverty affect individual welfare (proxied by SWB)? (2) Does the intensity of fuel poverty affect individual welfare in addition to the mere incidence of fuel poverty? (3) Does fuel poverty affect individual welfare independently of income poverty? (4) Do different notions (types) of fuel poverty imply different relationships between fuel poverty and individual welfare?

Using panel data on life satisfaction of about 40,000 individuals in Germany from 1994 to 2013, we find a negative and significant effect of several measures of fuel poverty on SWB. The effect is comparable in magnitude to those of other important factors of life satisfaction. The impact we find is beyond the effect of mere income poverty. Classifying measures of fuel poverty into three types, we find that there is a difference with respect to their well-being effects depending on the type of measure. Our findings confirm the argument of the recent literature that fuel poverty is an important issue and should be on the agenda of policy makers.

The remainder of the paper is structured as follows: section 2 describes and classifies the different measures of fuel poverty. Section 3 presents our dataset and methodology and section 4 discusses the results. Section 5 concludes.

[5] We checked our empirical results for robustness using non-equivalized income and energy expenditure. The results remain qualitatively unchanged.

2. Measuring fuel poverty

The measurement of fuel poverty is similar to the measurement of income poverty in that both involve a poverty measure and a poverty line. Both the poverty measure and the poverty line are subject to discussion in the literature. Heindl (2013) shows how different fuel poverty measures result in a varying share of the population considered being fuel poor.[6]

Throughout this section we want to classify the different fuel poverty measures existing in the literature. We distinguish three types of fuel poverty measures. They all involve households´ expenditure on energy. There are measures considering the absolute expenditures on energy (type one) and the expenditures on energy relative to household income (type two). The third type of measure accounts for both high energy expenditures and low household income as two necessary criteria to define households being fuel poor.

The first type of fuel poverty measures defines households to be fuel poor when their absolute expenditure on energy exceeds a certain threshold, i.e. they have unusually high expenditure on energy. More precisely the poverty line is defined as two times the mean (EU, 2010) or two times the median (Boardman, 1991) expenditure on energy compared to the mean/median expenditure of the reference population. The type one measures themselves differ in the sense that the two times median expenditure approach is more robust towards outliers since it splits the population into two equal parts with half of them having higher/lower expenditures than the median.

The second type of fuel poverty measures is the expenditure-relative-to-income approach where the *share of income* spent on energy exceeds a certain threshold. The type two measures differ in terms of the fuel poverty line applied. We distinguish the two times median share of

[6] The poverty ratio is used as a term describing the share of the population being energy poor. It is used to distinguish from other poverty definitions/measures. To get an insight on the concept of poverty measurement and definition (in terms of income poverty) see Foster et al. (1984) and Alkine and Foster (2011).

income, the two times mean share of income and the ten percent share of income approach (Moore, 2012; Lidell et al. 2012). The two times median share defines households to be fuel poor if their energy expenditures relative to income are higher than two times the median of this ratio in the reference population.[7] The 10 per cent threshold measure defines households to be fuel poor when they "would need to spend at least 10% of their income in order to heat the house to an acceptable level of warmth" (UK Fuel Poverty Strategy 2001).

A common disadvantage of the type one and type two measures is that households are always considered to be fuel poor when they report high expenditures (or expenditures relative to income). The definitions neglect that there might be households which *choose* to spend a lot on energy corresponding to their preferences. Those households would be assumed to be fuel poor although they do not face the problem of a relevant reduction of the residual income after necessary energy expenditure. They just spend a high amount of income on energy due to their preferences for those goods. Their energy expenditures are not representing high necessarily required energy expenditure. When using these measures the negative effect of being fuel poor might be biased through households with high preference-driven energy expenditures, though they are not affected by the income-deprivation effect. This caveat is expected to be more prominent with regard to the type one measures where no aspects of household income are considered.

The third type of fuel poverty measures was developed to address this issue. It is denoted the high cost-low income approach (HCLI). In a report commissioned by the British Department of Energy and Climate Change, Hills (2012) proposed this new measure of fuel poverty. He defines households to be fuel poor when they fulfill two criteria. Their expenditures on fuel/energy on the one hand have to exceed the median level of the energy expenditure of the reference population. On the other hand the households´ residual income (equivalised income after

[7] The relation for the two times mean share is equivalent but uses the mean instead of the median of the expenditure-income-ratio. It is less robust towards extreme levels of energy expenditure in terms of the fuel poverty line.

equivalised energy expenditure) has to be below the income poverty line of 60 per cent of the median income after housing costs. The main advantage of this method is that it does not assume households to be fuel poor when they are spending a high amount of their income on energy goods rather than non-energy goods according to their preferences while having high residual income left.

In the present study we analyze several measures of all types with respect to their impact on SWB.[8] We are not interested in an abstract discussion about the most appropriate measure of fuel poverty (Hills 2012) but rather want to analyze whether fuel poverty affects people´s SWB, taking this as an indication of the welfare significance of fuel poverty. We also study whether fuel poverty affects SWB over and above the effect of low income. If so, fuel poverty has an effect that is beyond pure income-deprivation.

3. Data and Method

3.1 Data

The data we use in our analysis are taken from the German socio-economic panel (GSOEP). It contains data on the personal and household level from 1984 to 2013 for about 40,000 individuals. The survey is conducted in annual waves and was extended in 1990 to include former East Germany. The main questionnaire contains a wide range of questions on household and personal characteristics. The main advantage of the dataset with respect to the present study is the detailed income and fuel expenditure information. The question about individual life satisfaction which we use as our measure of SWB appears in the questionnaires as "How satisfied are you at present with your life, all things considered? Please respond using the following scale, where '0' indicates *not at all satisfied* and '10' indicates *completely satisfied*". Moreover the GSOEP dataset has a panel structure which allows the analysis of households and individuals over time.

[8] An overview of the different fuel poverty definitions is presented in table A1.

We use data on the standard correlates found to influence SWB, such as marital status, employment status, health status, education level and age (for reviews on the socio economic determinants of SWB see for example Diener et al., 1999; Frey and Stutzer, 2002 or Dolan et al., 2008). Our sample consists of adult respondents with valid information on income and life satisfaction.[9] Due to missings and non-responses concerning some of the variables used in our model, we end up with an overall sample size of 330,088 observations.

The income variable we use for our analysis is monthly household net income in Euros. It reports the monthly household net income. The variable used as a proxy for energy expenditure is the expenditure on heat and warm water per month. Both variables are asked for in the GSOEP household questionnaire.

As we discussed in section one, we equivalised the household specific variables on income and energy expenditure used to define our poverty lines. To equivalise household income we use the OECD square root scale (OECD 2011, OECD 2008) where net household income is divided by the square root of the number of people living in the household. The scale we use to equivalise energy expenditure is following Hills (2012) and contains household type specific equivalence factors. The equivalence factors range from 0.82 for a single person household to 1.15 for couples with dependent children. The descriptive statistics of our main dataset are shown in table A2.

The fuel poverty rate (share of individuals living in fuel poor households) shows significant variation depending on the measure applied. Table A3 shows the different poverty rates by measure in the sample we used for our analysis, ranging from 5.2 per cent for the HCLI measure to 17.9 per cent for the ten-per-cent-expenditure share of income measure. Less than one per cent of the sample population is defined to be fuel poor by all the measures at the same time.

[9] Adult respondents in this context mean individuals which are at least 16 years old.

3.2 Method

In our empirical analysis we estimate micro-econometric life satisfaction equations with fixed-effects estimation technique in order to make full use of the panel structure of the SOEP dataset.[10] This approach offers the possibility to control for unobserved, time-invariant individual characteristics. It also helps to avoid the problem of a potentially different perception of the life satisfaction scale across individuals. We estimate an equation where life satisfaction (LS) depends on individual socio-economic characteristics and our fuel poverty indicators. Fuel poverty enters the regressions as a dummy variable indicating whether a household is above the expenditure based fuel poverty line, where expenditure refers to heating and warm water.[11] The dummy equals one for any household reporting an equivalised expenditure being above the poverty line threshold – for example two times the median expenditure from the sample in the respective year – and zero otherwise. With regard to the HCLI measure an additional condition has to be fulfilled for a household to be regarded as fuel poor. The household´s equivalised income has to be below the income poverty line of 60 per cent of median equivalised income. We add the fuel poverty dummy to a regression that includes the standard socio economic control variables. Our basic regression equation looks as follows:

$$LS_{it} = \alpha_i + \gamma_t + \beta * fuelpoverty_{it} + \delta \boldsymbol{controls_{it}} + \varepsilon_{it}, \qquad (2)$$

where LS_{it} is the reported life satisfaction of individual i at time t. The vector $\boldsymbol{controls_{it}}$ denotes individual time-varying observed characteristics. Our $fuelpoverty_{it}$ dummy denotes whether the household the individual lives in was affected by fuel poverty at the time of the interview (incidence of fuel poverty). While α_i denotes the individual fixed effects, γ_t captures the time fixed effects and ε_{it} denotes the individual and time specific error term. As an extension to our

[10] See Ferrer-i-Carbonell and Frijters (2004) for a discussion of methodology with respect to subjective well-being analysis.

[11] Since fuel poverty is defined as *high* necessary expenditure we are talking about households being *above* the fuel poverty line while in the income poverty literature people are income poor when their income is *below* the poverty line.

basic model, we include the intensity of fuel poverty as an additional variable. The intensity of fuel poverty is defined as the relative distance from the fuel poverty line. It measures how much household´s equivalised energy expenditure exceeds the fuel poverty threshold. The basic regression equation (2) is extended to:

$$LS_{it} = \alpha_i + \gamma_t + \beta * fuelpoverty_{it} + \delta \boldsymbol{controls_{it}} + \varphi * intensity_{it} + \varepsilon_{it}, \quad (3)$$

where $intensity_{it}$ denotes the relative distance to the fuel poverty line. It is calculated by subtracting the threshold from the equivalised energy expenditure and then dividing by the threshold to get a relative shortfall from the fuel poverty line:

$$intensity_{it} = \frac{expenditure_{it} - threshold_t}{threshold_t} \quad (4)$$

The $intensity_{it}$ variable is defined to be non-negative, i.e. it is set to zero when the household is not considered to be fuel poor.[12]

To see whether the effect of fuel poverty on life satisfaction is beyond the income-deprivation effect, we add net equivalent income and income poverty to the regression. Net equivalent income captures the standard of living a person can attain while income poverty should capture a relative income effect. The regression equation looks as follows:

$$LS_{it} = \alpha_i + \gamma_t + \beta * fuelpoverty_{it} + \delta \boldsymbol{controls_{it\ t}} + \lambda * netinc_{it} + \omega * incpoverty_{it} + \varepsilon_{it}, \quad (5)$$

where the variables $netinc_{it}$ and $incpoverty_{it}$ capture equivalised income and income poverty respectively. If a major effect of fuel poverty is the reduction of the standard of living (through a reduction of the residual income), the coefficient β should reduce in magnitude or become insignificant.

As mentioned above, the share of the sample population defined as fuel poor varies significantly with the respective fuel poverty measure (Table A3). Furthermore the coefficients of the type one measures are different from those of the other measures (see section 4). With an

[12] In the case of the HCLI measure we averaged the distance from the fuel poverty line and the distance from the income poverty line to account for both aspects with regard to intensity.

additional variant of our model we try to find out the reason for the differences of the effects of the respective measures. To shed light on these differences we calculate a dummy variable indicating whether an individual is fuel poor with regard to all kinds of fuel poverty measures at the same time. We call this the sampling effect. We add a dummy variable which represents this effect to our model. It will show whether the effects of the type one measures are driven by a subgroup of individuals which are defined as fuel poor by all measures – i.e. independent of the type of measurement. The subgroup which is defined to be fuel poor by all measures is illustrated in figure 1. The estimated equation looks as follows:

$$LS_{it} = \alpha_i + \gamma_t + \beta * fuelpoverty_{it} + \delta' \boldsymbol{controls_{it}} + \lambda * netinc_{it} + \omega * incpoverty_{it} + \phi * sampling_{it} + \varepsilon_{it}, \quad (6)$$

where $sampling_{it}$ equals one if the individual is defined to be fuel poor by all measures at the same time (see figure 1). This term will absorb some of the variation caused by individuals that are defined to be fuel poor independently of the measurement approach. The weight of those individuals having both high expenditures and high income in the effect of the respective $fuelpoverty_{it}$ variable will increase and measures which have an effect driven by this subgroup are expected to become insignificant.

4. Results

4.1.Main Results

We start with the question whether fuel poverty affects people´s utility. Table 1 reports the main results from the econometric model described in equation (2), an OLS fixed-effects within regression of life satisfaction on fuel poverty and socio-economic characteristics. The respective regressions include variables controlling for time fixed effects.

The results of the socio economic control variables are in line with the findings from previous studies (Diener et al., 1999; Frey and Stutzer, 2002 or Dolan et al., 2008). Being unemployed and reporting a bad health status have the highest estimated welfare effects.[13]

Columns A and B report the results of the regressions including our type one measures, the absolute expenditure related definitions of fuel poverty. Columns C, D and E refer to the type two measures, the expenditure-relative-to-income measures of fuel poverty. In column F we see the result of the regression including the HCLI measure (type three). All fuel poverty measures in the model indicate a negative effect of fuel poverty on life satisfaction. The results are significant for the type two and three measures. A person living in a household which is fuel poor because of equivalised energy expenditures above two times the median, reports a life satisfaction which is 0.123 points lower than an individual living in a household that is not considered to be fuel poor. The magnitude of the negative effect of the type two and type three fuel poverty measures ranges from 0.115 points, which is comparable to the positive effect of getting married but in opposite direction, to 0.170, comparable to the effect of separation. The effect is about one fourth of becoming unemployed or reporting a worse health status.

These results indicate that people report lower life satisfaction scores when they spend a high *share* of their income on heating and warm water. In contrast, the type one measures are not or only weakly significant. This might reflect the issue that only incorporating *absolute* expenditures in the fuel poverty measure captures a certain group of households as fuel poor which is not affected in terms of welfare because of their high income. This approach defines households as fuel poor which are spending a lot of their income on heating and warm water because of their preferences for those goods rather than fulfilling their basic energetic requirement. We will focus on this issue in subsection 4.4.

[13] Table A5 reports the detailed results being in line with the literature on the determinants of SWB. People getting married are more satisfied with their life than singles while separation is negatively related to life satisfaction. Getting a degree of more than high school is associated with higher life satisfaction. The effect of the age of the individuals is u-shaped up to the age of 80.

4.2.Intensity

One of the findings in the literature on income poverty and SWB is that its welfare effect is also depending on the relative shortfall from the poverty line (Clark et.al, 2015). We analyze this relationship in terms of fuel poverty by adding an intensity term to our regressions. The results are reported in table 2.[14]

Including both incidence and intensity to the regression yields an additional effect of the distance from the fuel poverty line on reported life satisfaction. According to the results from column C, an individual being fuel poor due to expenditure just at the poverty line (intensity is close to zero) reports a life satisfaction score that is 0.073 points lower than an individual who is not regarded as fuel poor. An individual being fuel poor with expenditure share of income being 3.4 per cent higher than two times the median reports a life satisfaction score which is 0.081 points lower than an individual not being fuel poor.[15] This is comparable in magnitude to the life satisfaction boost from getting married. Our results suggest that the intensity of fuel poverty has an additional effect on welfare.

4.3.Income and fuel poverty

Table 3 reports the results of the regressions additionally controlling for net income and for income poverty. We first add net income to the analysis in columns A, B and C. In columns D, E and F we additionally control for income poverty. The estimated coefficients for our income poverty variable are in line with the results by Clark et al. (2013). When controlling for income, the coefficients of the type two and type three measures (columns B and C) remain unchanged with respect to sign and significance. The magnitudes of the coefficients slightly decrease. This reduction is intuitive since we now compare household with the same level of income due to the ceteris paribus assumption of the model. The coefficients also remain negative and significant

[14] To make the tables clearly represented we set aside reporting the coefficients of the two times mean expenditure and the two times mean expenditure share of income fuel poverty measures since the qualitative results do not differ from those of the respective median measures.
[15] 3.4 per cent is the average of the normalized distance to the two times median expenditure share of income fuel poverty line.

when we include income poverty in columns E and F. The magnitudes of the coefficients decrease by half under the control for income poverty. Income poverty absorbs some of the variation caused by the relative-income effect of fuel poverty. The reduction of the magnitude of the coefficients stems from the fuel poverty measures of type two and three being measured as expenditures relative to income. Part of this effect is now captured by the coefficient of the income poverty dummy. The results are inconsistent with the view that fuel poverty influences peoples´ utility only through the income channel.[16] The regressions controlling for income and income poverty imply that the negative impact of fuel poverty on life satisfaction holds beyond the income-deprivation effect. People are negatively affected by fuel poverty apart from having higher or lower residual incomes and also independent from being income poor or not. There seems to be a perception of the individual situation of being fuel poor affecting people beyond the pure income effect through other channels, for example being cold when outside temperature is low as argued in the fuel poverty literature (see for example Boardman, 1991).

The result for the HCLI measure in column F seems surprising since it indicates that on top of being income poor there is, *additionally*, an effect of being income poor and fuel poor at the same time. When we look at the coefficient of the HCLI measure we see that it is almost of the same magnitude as the coefficient of the two-times-median-expenditure share in column E. Since the HCLI measure is a combination of high expenditures and low income, this indicates that the coefficient of the HCLI measure in column F represents the expenditure-share-part of the effect of the HCLI measure. This hypothesis is supported by the fact that including income poverty to the model has a decreasing impact on the difference of the effects of the HCLI measure and the two-times-median-expenditure share measure if we compare columns B and C with E and F. In column C the HCLI measure has a higher effect than the two-times-median-expenditure-share measure in column B. When we control for income poverty in column F, the HCLI is now

[16] The income channel was argued to be the effect of a high share of income spent on basic energetic requirements reduces the residual income available for the purchase of other consumption goods.

representing only the high-expenditure-share effect and not the effect of being income poor anymore.

. In contrast to the results for the type two and type three measures, the coefficient of the type one measure increases in magnitude and becomes more significant compared to the result in table 1, column B. This result stems from the type one measures being based on absolute expenditures. The measures capture two subgroups of individuals being defined as fuel poor. One subgroup is the same which is defined to be fuel poor by other measures as well, namely households with high expenditures for basic energetic requirements and potentially low household income. The other subgroup captures households which have high expenditure on energy according their preferences and/or households having high basic energetic requirements but at the same time a high residual income. The latter subgroup is not affected by the income-deprivation effect. Controlling for income now puts a higher weight on the first subgroup in the type-one-fuel-poor group since we control for income differences. This yields a significant result for all the households reporting high expenditure. In the following part of this section we want to treat this issue in more detail.

4.4.Absolute vs. relative measures

We learned in the previous sections that the welfare effects of the type two and type three measures are qualitatively similar. The type one measures which only account for the absolute height of the expenditures are significantly different from the other types in terms of their welfare significance. This raises the question whether the type one measures define a group as fuel poor where only some of the households are actually suffering from the negative aspects of high energy expenditures. In table A3 we reported the shares of the sample population being defined as fuel poor when using the different fuel poverty definitions. The amount of individuals in the sample living in fuel poor households at the time of the interview ranges from 5.1 per cent to 17.8 per cent. More interesting is the comparison of these numbers with respect to the share of the population being fuel poor among the income poor. For the type two and type three measures

the fuel poverty rate is higher among the income poor. Regarding the type one measures the fuel poverty rate is significantly lower among the income poor. This might be an indicator that there are individuals in the type one fuel poverty group who face high expenditure on energy while having high residual income. They are not affected by the income-deprivation effect though.

The estimated effects of the type one measures are representing two different subgroups. One subgroup is spending a lot on energy relative to their income. The other is spending a lot on energy corresponding to their preferences. The latter group has high income after energy expenditure and/or a preference for energy beyond their necessary requirements. The negative impact is driven by the first subgroup, while the second one has a decreasing effect on the magnitude of the coefficient. To analyze this hypothesis we use a "sampling" dummy indicating whether a household is defined as fuel poor by all of the different measures at the same time.[17] It equals zero if the household is defined to be fuel poor by only one of the measures or none of them.

The results of the regressions are reported in table 4. The sampling effect appears negatively and significant in all four regressions. It indicates that people living in a household which is defined to be fuel poor with regard to all of the measures report lower life satisfaction. The coefficient of the respective fuel poverty measure now tells us whether controlling for the sampling effect changes the relation between fuel poverty and SWB. The results for the type two and type three measures remain qualitatively the same and even the magnitude of the coefficient does not change appreciably in comparison to the results in table 3. The type one measure in column A, using the absolute expenditure approach, loses its significance and gets closer to zero when controlling for the sampling effect. This result implies that the negative and significant effect of the type one measure in table 3 column A is driven by a subgroup which is already captured by all the other fuel poverty measures. The separation of this effect in table 4 yields an insignificant result for the type one measure.

[17] See Figure 1 for an illustration of the „sampling" subgroup.

5. Conclusion

To our knowledge, this is the first study analyzing the impact of fuel poverty on subjective well-being. We found that living in a household which is regarded as fuel poor has a negative effect on the life satisfaction of individuals. Classifying the fuel poverty measures in three different types we found that the measures using equivalised expenditures on heating and warm water *relative to income* and the HCLI measure yield negative effects. The results for both types are similar with regard to magnitude, direction and significance of the coefficients. The intensity of fuel poverty has an additional effect on SWB. Households with a larger relative distance to the poverty line report lower life satisfaction than household at a lower distance to it. We controlled for the income-deprivation effect of being fuel poor by including net household income and income poverty in our models. The results suggest that fuel poverty negatively affects SWB beyond the effect of the reduction of residual income after energy expenditure, indicating that there are other channels than the income-deprivation effect through which fuel poverty has an impact on SWB.

The type one measures using absolute expenditures to define the fuel poverty line capture a subgroup of households which are not affected by the income-deprivation effect or other negative aspects of fuel poverty. Households that have a high income are also defined to be fuel poor by this type of measures. This is supported by our findings in section 4.3 where we control for income and income poverty which yields significant results for the type one measures by eliminating the income-deprivation effect. Additionally controlling for the sampling effect in section 4.4 we found that excluding this effect of being in a subgroup defined as fuel poor by all the measures yields an insignificant result for the type one measure again. We regard this result as further support of our hypothesis that the type one measures are defining a subgroup of households to be fuel poor which are not affected by the negative aspects of fuel poverty.

The estimated effects of fuel poverty on SWB are about one third of the magnitude of those of income poverty for measures regarding fuel expenditure relative to income and the HCLI approach. Both the incidence and the intensity of fuel poverty negatively affect life satisfaction which indicates that there is some kind of additional severity effect among the households being fuel poor.

Our study shows that fuel poverty is an important issue which has to be accounted for in times where energy expenditures are rising due to high demand or high prices. Especially with regard to major changes in the energy systems like the “Energiewende” it is important to have in mind that individuals are suffering from fuel poverty also beyond the income deprivation effect. Policy makers should have this relationship in mind when restructuring the energy system towards renewables leading to higher energy expenditures. Further research is needed to study additional channels of fuel poverty apart from the income-deprivation effect.

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Table 1: Fuel Poverty and Life Satisfaction

	A	B	C	D	E	F
Unemployed	-0.601***	-0.601***	-0.592***	-0.596***	-0.593***	-0.592***
	(0.0111)	(0.0111)	(0.0111)	(0.0111)	(0.0111)	(0.0111)
Poor Health	-0.509***	-0.509***	-0.509***	-0.509***	-0.508***	-0.509***
	(0.00368)	(0.00368)	(0.00367)	(0.00367)	(0.00367)	(0.00367)
2*Mean Exp	-0.0157					
	(0.00988)					
2*Median Exp		-0.0219*				
		(0.0118)				
10% Income Share			-0.115***			
			(0.00734)			
2*Median Exp Share				-0.123***		
				(0.0108)		
2*Mean Exp Share					-0.124***	
					(0.00857)	
HCLI Fuel Poverty						-0.170***
						(0.0122)
Socio-econ. controls	included	Included	included	included	included	included
Time fixed effects	included	Included	included	included	included	included
Individual fixed effects	included	Included	included	included	included	included
N	330888	330888	330888	330888	330888	330888
R-sq	0.092	0.092	0.093	0.093	0.093	0.093

Note: Dependent variable: life satisfaction (11-point scale). Within fixed effects regression. Standard errors in parentheses. *p<0.1, **p<0.05, ***p<0.01.

Table 2: Incidence and Intensity

	A	B	C	D
Unemployed	-0.601***	-0.592***	-0.592***	-0.592***
	(0.0111)	(0.0111)	(0.0111)	(0.0111)
Poor Health	-0.509***	-0.508***	-0.508***	-0.509***
	(0.00368)	(0.00367)	(0.00367)	(0.00367)
2*Median Exp	-0.00708			
	(0.0143)			
2*Median Exp (i)	-0.0509			
	(0.0607)			
10% Income Share		-0.109***		
		(0.00742)		
10% Income Share (i)		-0.0127***		
		(0.00261)		
2*Median Exp Share			-0.0731***	
			(0.0124)	
2*Median Exp Share (i)			-0.229***	
			(0.0403)	
HCLI Fuel Poverty				-0.141***
				(0.0163)
HCLI Fuel Poverty (i)				-0.195***
				(0.0718)
Socio-econ. controls	included	included	included	included
Time fixed effects	included	included	included	included
Individual fixed effects	included	included	included	included
N	330888	330888	330888	330888
R-sq	0.092	0.093	0.093	0.093

Note: Dependent variable: life satisfaction (11-point scale). Within fixed effects regression. Standard errors in parentheses. *p<0.1, **p<0.05, ***p<0.01.

Table 3: Income and Fuel Poverty

	A	B	C	D	E	F
Unemployed	-0.591***	-0.586***	-0.584***	-0.562***	-0.560***	-0.561***
	(0.0111)	(0.0111)	(0.0111)	(0.0112)	(0.0112)	(0.0112)
Poor Health	-0.508***	-0.508***	-0.508***	-0.508***	-0.507***	-0.508***
	(0.00367)	(0.00367)	(0.00367)	(0.00367)	(0.00367)	(0.00367)
Net Income	0.0388***	0.0348***	0.0354***	0.0304***	0.0282***	0.0295***
	(0.00230)	(0.00232)	(0.00231)	(0.00233)	(0.00234)	(0.00234)
Income Poverty				-0.207***	-0.189***	-0.185***
				(0.0104)	(0.0106)	(0.0110)
2*Median Exp	-0.0207**			-0.0211**		
	(0.00988)			(0.00988)		
2*Median Exp Share		-0.107***			-0.0769***	
		(0.00864)			(0.00880)	
HCLI Poverty			-0.148***			-0.0760***
			(0.0123)			(0.0130)
Socio-econ. controls	Included	included	included	included	included	included
Time fixed effects	Included	included	included	included	included	included
Individual fixed effects	Included	included	included	included	included	included
N	330888	330888	330888	330888	330888	330888
R-sq	0.093	0.094	0.094	0.094	0.095	0.094

Note: Dependent variable: life satisfaction (11-point scale). Within fixed effects regression. Standard errors in parentheses. *p<0.1, **p<0.05, ***p<0.01.

Table 4: Absolute and Relative Measures

	A	B	C	D
Unemployed	-0.562***	-0.559***	-0.561***	-0.561***
	(0.0112)	(0.0112)	(0.0112)	(0.0112)
Poor Health	-0.507***	-0.507***	-0.507***	-0.507***
	(0.00367)	(0.00367)	(0.00367)	(0.00367)
Net Income	0.0299***	0.0272***	0.0290***	0.0293***
	(0.00234)	(0.00235)	(0.00234)	(0.00234)
Income Poverty	-0.204***	-0.186***	-0.194***	-0.188***
	(0.0104)	(0.0106)	(0.0106)	(0.0111)
Sampling dummy	-0.158***	-0.137***	-0.130***	-0.121***
	(0.0312)	(0.0293)	(0.0300)	(0.0307)
2*Median Exp	-0.00464			
	(0.0126)			
10% Income Share		-0.0718***		
		(0.00756)		
2*Median Exp Share			-0.0533***	
			(0.0113)	
HCLI Fuel Poverty				-0.0591***
				(0.0137)
Socio-econ. controls	included	included	included	included
Time fixed effects	included	included	included	included
Individual fixed effects	included	included	included	included
N	330888	330888	330888	330888
R-sq	0.094	0.095	0.095	0.095

Note: Dependent variable: life satisfaction (11-point scale). Within fixed effects regression. Standard errors in parentheses. *p<0.1, **p<0.05, ***p<0.01.

Appendix

Table A1: Description of Fuel Poverty Measures

Measure	Description
Two times mean expenditure	Expenditure on heating and warm water greater or equal to two times mean expenditure with a unique poverty line within the sample which is indipendent from household income.
Two times median expenditure	Expenditure on heating and warm water greater or equal to two times median expenditure with a unique poverty line within the sample which is indipendent from household income.
Ten per cent expenditure share of income	Expenditure on heating and warm water greater or equal to ten per cent of income with a household specific poverty line dependent expenditure and household income.
Two times mean expenditure share of income	Share of expenditures on heating and warm water greater or equal to two times the mean share of expenditures relative to income in the sample with a unique poverty line within the sample as ratio of mean expenditures and income
Two times median expenditure share of income	Share of expenditures on heating and warm water greater or equal to two times the median share of expenditures relative to income in the sample with a unique poverty line within the sample as ratio of median expenditures and income
High cost low income	Households that spend more than the median on heating and warm water and fall below the income poverty line (60 per cent of median income after expenditures on heating and warm water) with a household specific poverty line dependent on expenditure and income.

Table A2: Summary Statistics

Variable	Obs	Mean	Std. Dev.
LS11	330888	6.981456	1.773635
1994	330888	0.035991	0.186268
1995	330888	0.0361119	0.1865689
1996	330888	0.0351599	0.1841842
1997	330888	0.0356405	0.1853923
1998	330888	0.0375082	0.1900037
1999	330888	0.0372936	0.1894806
2000	330888	0.0645657	0.2457582
2001	330888	0.0587812	0.2352151
2002	330888	0.0626496	0.242332
2003	330888	0.0588689	0.2353795
2004	330888	0.057246	0.2323123
2005	330888	0.0545713	0.2271419
2006	330888	0.0576781	0.2331341
2007	330888	0.0547889	0.2275681
2008	330888	0.0511895	0.2203844
2009	330888	0.0536012	0.2252294
2010	330888	0.0487083	0.2152579
2011	330888	0.0486872	0.2152135
2012	330888	0.0491798	0.2162436
2013	330888	0.0617792	0.2407545
Education	330888	11.96189	2.650441
Married	330888	0.6358466	0.4811927
Separated	330888	0.0183446	0.1341943
Single	330888	0.2142266	0.4102853
Divorced	330888	0.0692833	0.2539356
Widowed	330888	0.062299	0.2416982
Age	330888	48.10933	16.9151
Age²	330888	2600.627	1712.488
Educ: less than high school	330888	0.2126180	0.286132
Educ: high school	330888	0.5908736	0.4916734
Educ: more than high school	330888	0.1965046	0.397355
No. of children	330888	0.5409776	0.9084758
Single without children	330888	0.1389171	0.3458605
Single with children	330888	0.0497087	0.2173427
Couple without children	330888	0.3442313	0.4751177
Couple with children	330888	0.433757	0.4955932
Ohter hh type	330888	0.0144248	0.1192342
Net income	330888	2632.737	1847.567
Unemployed	330888	0.0704952	0.25598
Poor health	330888	2.628213	0.9530764
2*Mean Exp Share	330888	0.0659135	0.2481313

2*Median Exp Share	330888	0.1157491	0.3199243
10% Income Share	330888	0.1792661	0.3835756
2*Median Exp	330888	0.0828468	0.2756509
2*Mean Exp	330888	0.0548856	0.2277572
HCLI Fuel Poverty	330888	0.0519239	0.2218738

Table A3: Fuel Poverty Rates

	Overall sample		Income poor only	
Measure	Obs.	Mean	Obs.	Mean
Income poverty	330888	0.1092484		
2*Mean Exp Share	330888	0.0659135	33641	0.2728219
2*Median Exp Share	330888	0.1157491	33641	0.390357
10% Income Share	330888	0.1792661	33641	0.5008769
2*Median Exp	330888	0.0828468	33641	0.0472638
2*Mean Exp	330888	0.0548856	33641	0.0309741
HCLI Fuel Poverty	330888	0.0519239	33641	0.3259416

Table A4: Description of Data

Variable	Description
LS11	Life Satisfaction: The question from SOEP: "All things considered, how satisfied are you with your life as a whole nowadays?"
Marital Status	Dummy variables indicating the marital status of individuals. (Single, Married, Separated, Divorced, Widowed)
Age	Age of individual in years
Education	Number of years of education
Education level	Dummy variables indicating whether an individual has gained an educational level lower, equal or higher than high school
No. Of children	Number of children living in the household
Household type	Dummy variables indicating the household composition (Singles or couples with or without children, multi generation households and other combinations)
Net Income	Net monthly household income
Heating exp.	Total amount of monthly expenditure for heating and warm water
Poor Health	Self rated health status on a five-point-scale ranging from 1 (very good) to 5 (very bad).
Fuel Poverty	Dummy Variable indicating whether an individual lives in a household which is defined to be fuel poor by the respective measure

Table A5: Detailed Estimation Results

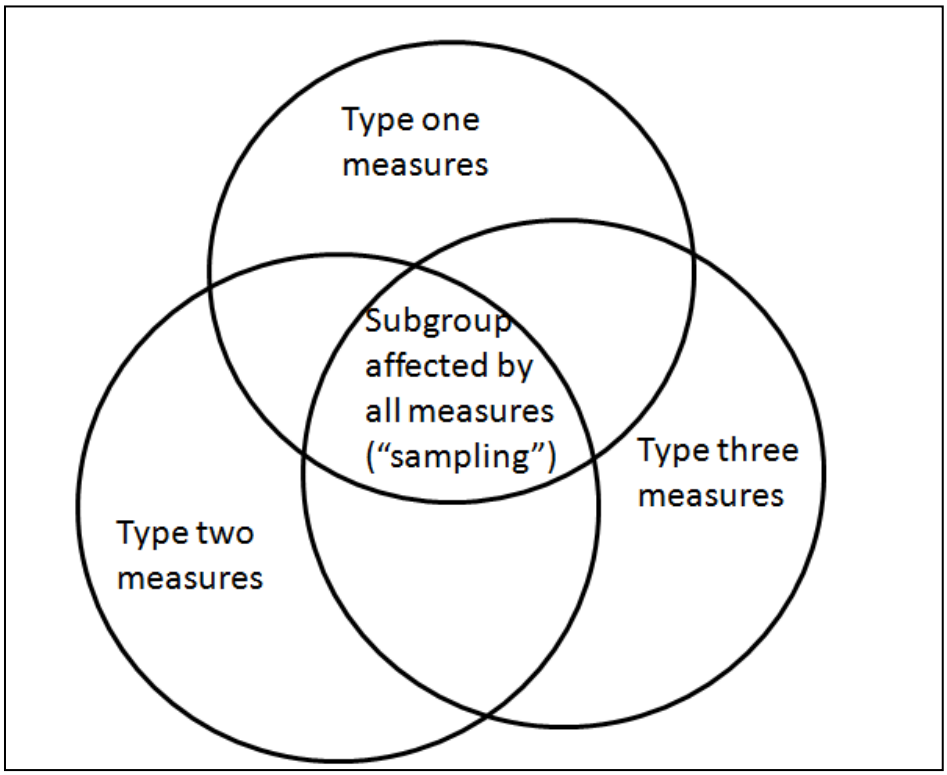
	A	B	C
1994	0.163***	0.158***	0.161***
	(0.0231)	(0.0231)	(0.0231)
1995	0.178***	0.174***	0.176***
	(0.0224)	(0.0224)	(0.0224)
1996	0.169***	0.165***	0.166***
	(0.0219)	(0.0219)	(0.0219)
1997	0.0346	0.0301	0.0315
	(0.0212)	(0.0212)	(0.0212)
1998	0.133***	0.129***	0.130***
	(0.0205)	(0.0205)	(0.0205)
1999	0.173***	0.170***	0.171***

	(0.0200)	(0.0199)	(0.0199)
2000	0.148***	0.145***	0.145***
	(0.0180)	(0.0180)	(0.0180)
2001	0.168***	0.165***	0.166***
	(0.0175)	(0.0175)	(0.0175)
2002	0.0118	0.0132	0.0125
	(0.0169)	(0.0169)	(0.0169)
2003	-0.0519***	-0.0514***	-0.0518***
	(0.0165)	(0.0165)	(0.0165)
2004	-0.215***	-0.214***	-0.215***
	(0.0161)	(0.0161)	(0.0161)
2005	-0.0691***	-0.0689***	-0.0679***
	(0.0158)	(0.0158)	(0.0158)
2006	-0.142***	-0.141***	-0.140***
	(0.0154)	(0.0154)	(0.0154)
2007	-0.106***	-0.105***	-0.105***
	(0.0151)	(0.0151)	(0.0151)
2008	-0.0741***	-0.0723***	-0.0724***
	(0.0150)	(0.0150)	(0.0150)
2009	-0.146***	-0.144***	-0.144***
	(0.0148)	(0.0148)	(0.0148)
2010	-0.0121	-0.0108	-0.0105
	(0.0149)	(0.0148)	(0.0148)
2011	-0.106***	-0.104***	-0.103***
	(0.0145)	(0.0145)	(0.0145)
2012(o)	Omitted	Omitted	Omitted
2013(o)	Omitted	Omitted	Omitted
Single(o)	Omitted	Omitted	Omitted
Married	0.116***	0.114***	0.113***
	(0.0179)	(0.0179)	(0.0179)
Separated	-0.146***	-0.144***	-0.142***
	(0.0293)	(0.0293)	(0.0293)
Divorced	0.175***	0.175***	0.176***
	(0.0264)	(0.0264)	(0.0264)
Widowed	-0.0292	-0.0336	-0.0322
	(0.0315)	(0.0315)	(0.0315)
Age 16-20	0.0348	0.0399	0.0373
	(0.0298)	(0.0298)	(0.0298)
Age 21-30	-0.0334*	-0.0301	-0.0313
	(0.0200)	(0.0200)	(0.0200)
Age 31-40	-0.0151	-0.0139	-0.0141
	(0.0121)	(0.0120)	(0.0120)
Age 41-50	Omitted	Omitted	Omitted

Age 51-60	0.0233*	0.0243*	0.0244*
	(0.0126)	(0.0126)	(0.0126)
Age 61-70	0.0943***	0.0978***	0.0969***
	(0.0202)	(0.0201)	(0.0201)
Age 71-80	-0.00227	0.00247	0.00133
	(0.0279)	(0.0278)	(0.0278)
Age >80	-0.236***	-0.230***	-0.233***
	(0.0395)	(0.0395)	(0.0395)
Education (years)	-0.00142	-0.00173	-0.00176
	(0.00446)	(0.00446)	(0.00446)
Educ: less than high school (o)	Omitted	Omitted	Omitted
Educ: high school	0.0207	0.0186	0.0200
	(0.0147)	(0.0147)	(0.0147)
Educ: more than high school	0.120***	0.117***	0.119***
	(0.0230)	(0.0230)	(0.0230)
No. of children	0.0140**	0.0179***	0.0172***
	(0.00548)	(0.00548)	(0.00548)
Single without children	-0.126***	-0.134***	-0.128***
	(0.0307)	(0.0307)	(0.0307)
Single with children	-0.231***	-0.231***	-0.226***
	(0.0323)	(0.0323)	(0.0323)
Couple without children (o)	0.0910***	0.0879***	0.0923***
	(0.0287)	(0.0287)	(0.0287)
Couple with children	0.0169	0.0190	0.0200
	(0.0276)	(0.0276)	(0.0276)
Ohter HH-type	-0.0186	-0.0181	-0.0179
	(0.0391)	(0.0391)	(0.0391)
Multi-Gen. HH	Omitted	Omitted	Omitted
Unemployed	-0.590***	-0.582***	-0.581***
	(0.0112)	(0.0112)	(0.0112)
Poor health	-0.508***	-0.507***	-0.507***
	(0.00368)	(0.00368)	(0.00368)
2*Median Exp	-0.0160		
	(0.00988)		
2*Median Exp Share		-0.126***	
		(0.00857)	
HCLI Fuel Poverty			-0.172***
			(0.0122)
N	330888	330888	330888
R-sq	0.093	0.093	0.093

Note: Dependent variable: life satisfaction (11-point scale). Within fixed effects regression. Standard errors in parentheses. *p<0.1, **p<0.05, ***p<0.01.

Figure 1: Subgroups of Fuel Poverty Measures



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