Energy Affordability and Subjective Well-Being: Evidence for European Countries

Heinz Welsch and Philipp Biermann***

ABSTRACT

This paper uses data on the life satisfaction of more than 100,000 individuals in 21 European countries from 2002 to 2011, to study the relationship between subjective well-being and the affordability for households of electricity, heating oil and natural gas. We find that energy prices have statistically and economically significant effects on subjective well-being. The effect sizes are smaller than but comparable to the effects of important personal factors of well-being. Effects above average are found in individuals from the lowest income quartile. In addition, effects are strongest at times when required energy expenditures can be expected to be high. The empirical results are consistent with the prediction that greater fuel poverty implies a greater effect of energy prices on well-being.

Keywords: Energy affordability, Energy price, Fuel poverty, Welfare, Subjective well-being

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1. INTRODUCTION

The residential consumption of fuel and power is an important component of household consumption. It contributes to well-being through heating and cooling, lighting, cooking, and the operation of appliances. Different from most other consumer goods, fuel and power consumption are usually considered a basic need whose satisfaction is necessary for an acceptable quality of life. The access to and affordability of energy are therefore important issues in research and public debates, not least because of rising energy prices in the context of recent energy and climate policies (EU 2010, Neuhoff et al. 2013).

The affordability of energy is obviously a significant issue especially for low-income households. This has spurred an interest in studying what has come to be known as fuel poverty. Fuel poverty refers to a situation in which prevailing energy prices prevent a household from satisfying a minimum requirement of energy or if the costs of satisfying the minimum energy requirement exceed a certain threshold, even if those costs stay within the limits of the budget constraint.[1] A rationale for this notion of fuel poverty is that a high level of required energy costs

1. EU Fuel Poverty Network (www.fuelpoverty.eu). In contrast to fuel poverty, the term energy poverty usually refers to energy access challenges in the developing world (Halff et al. 2014).

* Corresponding author. Department of Economics, University of Oldenburg, 26111 Oldenburg, Germany. E-mail: welsch@uni-oldenburg.de. Phone: + +49 441 798 4112.

** Department of Economics, University of Oldenburg, 26111, Oldenburg, Germany.

constrains the consumption of non-energy goods and thus consumer welfare (Brunner et al. 2011).[2]

Though fuel poverty has been discussed for several decades (e.g., Boardman 1991), the issue has recently gained increasing attention in research (e.g., Hills 2012, Moore 2012, Thomson and Snell 2013, Walker et al. 2014, Middlemiss and Gillard 2015, Sovacool 2016) and in public policy (EU 2010). The policy relevance of fuel poverty is evidenced by programs in several countries, such as the UK Winter Fuel Payment, national or municipal energy assistance funding for low-income households in Belgium and Italy, and financial support of measures to improve poor households' residential energy efficiency.[3]

The literature so far has been concerned with definitions of fuel poverty, the empirical measurement of its incidence and intensity, the health consequences and lived experience of fuel poverty, and programs to tackle it. In spite of its importance, measuring and analyzing fuel poverty is hampered by ambiguity as to the appropriate definition and measure.[4] Beyond the ambiguity of measurement, an important issue in the study of fuel poverty is its welfare significance, however fuel poverty is specified. Though it is intuitive to expect a negative effect of fuel poverty on consumer welfare, the nature of the relationship is surrounded by considerable vagueness.

Against the background of those practical and theoretical ambiguities, this paper pursues a different approach to energy prices, fuel poverty and welfare, focusing on the welfare issue directly. Based on the insight (to be derived below) that a higher fuel poverty ratio—the ratio of required energy costs to income—implies a greater effect of energy price increases on consumer welfare (utility), we identify the degree of fuel poverty with the effect of energy prices on utility. According to this conceptualization, fuel poverty is greater if consumers suffer greater welfare losses from a price increase. We view this approach to be in line with the idea that the ultimate rationale for the notion of fuel poverty rests on its implications for welfare and the quality of life.

The purpose of this paper thus is to measure the relationship between energy prices and individual welfare, taking the strength of that relationship as an indicator of fuel poverty. Empirically, we implement this research strategy by using data on subjective well-being (SWB) as a proxy for utility. Based on data for between 100,908 and 117,819 individuals in 21 European countries from 2002 to 2011, we estimate well-being equations that include the prices to households of electricity, gas and light fuel oil (LFO) among the explanatory variables while controlling for the usual covariates of well-being as well as for county and time fixed effects.

We find that energy prices have statistically and economically significant effects on SWB. On average, a one-standard-deviation increase in the prices of electricity and gas reduces well-being—measured on an eleven-point scale—by about 0.10 and 0.12 points, respectively. In the lowest income quartile a one-standard-deviation increase in the prices of electricity, light fuel oil and natural gas reduces well-being by 0.14, 0.16 and 0.15 points, respectively. These magnitudes

2. Households' average expenditure shares for fuel and power are 4.2 percent in France, 5.8 percent in Germany, 5.5 percent in Italy, and 5.1 percent in the U.K. (data taken from Eurostat's Household Budget Surveys, accessible at ec.europa.eu). Even if the cost shares are not very high, the low elasticity of energy requirements implies significant welfare effects of energy price increases, as will be demonstrated below.

3. See European Fuel Poverty and Energy Efficiency Projects: Detailed Report on Different Types of Existing Mechanisms to Tackle Fuel Poverty. Accessible at www.fuel-poverty.org.

4. For instance, Moore (2012) and Heindl (2013) have shown that applying different measures of fuel poverty discussed in the literature implies a large variation in the number of households identified as fuel poor as well as in the population subgroups affected by fuel poverty.

are smaller than but nevertheless comparable to the well-being effects of important personal life circumstances like being unemployed.[5] In addition, effects are seasonally concentrated at times when required energy expenditures can be expected to be high due to, for instance, heating requirements. The empirical results are consistent with the prediction that greater fuel poverty implies a greater effect of energy prices on consumer welfare.

Our approach of using SWB regressions for a welfare assessment of energy prices follows a recent trend in economics of using subjective data for evaluating policies, institutions, and non-market goods. The SWB approach has previously been applied to several economic and societal phenomena, such as inflation and unemployment (see Frey and Stutzer 2002 for a survey), and environmental issues (e.g. Welsch 2002, 2006; Rehdanz and Madison 2005; van Praag and Barsma 2005; Luechinger 2009; Ferreira and Moro 2010; Levinson 2012). With respect to energy, the SWB approach was used by Welsch and Biermann (2014a) in an assessment of electricity supply structures in Europe, Welsch and Biermann (2014b) and Rehdanz et al. (2015) in studies of the Fukushima nuclear accident, Welsch and Biermann (2016) in a study of nuclear power plant externalities in Switzerland, and von Möllendorff and Welsch (2017) in an analysis of renewable power externalites in Germany.

The paper is organized as follows. Section 2 presents the conceptual and section 3 the empirical framework. Section 4 reports and discusses the results. Section 5 concludes.

2. CONCEPTUAL FRAMEWORK

2.1 Fuel Poverty Measures

Measures of fuel poverty typically rely on the fuel poverty ratio and apply it in various ways to arrive at an assessment of overall fuel poverty in society as well as its incidence across subgroups.

The fuel poverty ratio (*FPR*) is the ratio between the costs of "required" energy consumption and income:

$$FPR = p * R / Y, \tag{1}$$

where p, R and Y denote the energy price, required energy consumption and income, respectively.

Definitions of fuel poverty usually relate the *FPR* to some threshold level (poverty line) and identify households as fuel poor if their *FPR* exceeds that threshold. Examples of poverty lines include the 10-percent threshold and the 2-times median or 2-times average expenditure share thresholds (Moore 2012). The high-cost/low-income approach (Hills 2012) defines those households as fuel poor whose *FPR* exceeds a fuel poverty threshold while their income falls below a general-poverty threshold. In addition, some fuel poverty measures refer to the difference rather than the ratio between income and energy expenditures and identify households as fuel poor if their income net of energy costs falls short of a specified level.[6]

5. We find that 11-point life satisfaction of persons involuntarily unemployed is about 1 point lower than that of people in paid work (see below).

6. See Moore (2012) and Heindl (2013) for a discussion of fuel poverty measures.

There is thus a diverse set of fuel poverty measures which differ by whether they refer to ratios or differences between required energy costs and income, by the threshold they apply, and by whether or not they incorporate general poverty (income poverty). In practice, they are typically computed by replacing "required energy expenditures" by actual energy expenditures because the former are unobserved. Following this practice, Moore (2012) and Heindl (2013) found that applying different measures of fuel poverty implies a large variation in the number of households identified as fuel poor as well as in the population subgroups affected by fuel poverty.

2.2 Fuel Poverty and Consumer Welfare

Though the notion of fuel poverty seems to be rooted in a concern for welfare, the relationship between fuel poverty and its constituents—energy prices, energy requirements, and income—on the one hand, and consumer welfare on the other is usually not made explicit. This subsection discusses the channels through which fuel poverty—high required energy expenditures relative to income—affect welfare. As it will be seen, the welfare significance of fuel poverty rests on the fact that it makes consumers more vulnerable to energy price increases in the sense that an energy price increase has a greater effect on utility if the level of fuel poverty is higher. This insight will motivate our empirical analysis of the relationship between energy prices and well-being.

Consider an individual who derives utility from energy E and a non-energy good N according to a monotonically increasing and strictly concave utility function:

$$u = U(E,N), \tag{2}$$

Treating the non-energy good as the numeraire and denoting income and the energy price by Y and p, respectively, the consumer's problem is to maximize utility subject to a budget constraint $p{*}E + N = Y$. This yields demand functions E(p,Y) and N(p,Y), and substituting these into (2) gives the indirect utility function:

$$u = U(E(p,Y),N(p,y)) = : V(p,Y).$$ [7]

The utility effect of an energy price increase, written in elasticity form, is given by:

$$\eta_{Vp} = \eta_{UE}\eta_{Ep} + \eta_{UN}\eta_{Np}, \tag{3}$$

where $\eta_{XY}: = (\partial X/\partial Y)/(X/Y)$ denotes the elasticity of a variable X with respect to Y.

According to (3), the effect of an energy price increase is composed of the changes in energy demand and non-energy demand, each weighted by the corresponding elasticity of utility. Basic microeconomics implies that the total effect is negative. It also implies that the effect on non-energy demand is negative ($\eta_{Np} < 0$) if and only if energy demand is inelastic ($-1 < \eta_{Ep} < 0$).[8]

Against this background, we now address the welfare significance of a "required" level of

7. Theoretical treatments of the indirect utility function usually do not explicitly focus on particular aspects of energy prices (e.g. Mas-Colell et al. 1995). In particular, the role of "required" levels of energy consumption in the price-utility relationship that we will address below is not discussed.

8. Intuitively: If energy demand is inelastic, the income effect dominates the substitution effect in the response of non-energy demand to energy price increases.

energy consumption, R, and of fuel poverty. It is convenient to refer in this discussion to the Stone-Geary utility function (which underlies the popular linear expenditure system) because it directly focuses on a minimum required level of energy consumption.[9] Hence we consider:

$$u = U(E,N) = a(E-R)^{\alpha} N^{1-\alpha} \tag{4}$$

where the scaling parameter a is positive if $E-R$ is non-negative, and zero otherwise. The demand functions associated with (4) are $E = R + \alpha(Y/p - R)$ and $N = (1-\alpha)(Y-pR)$, and it is easy to compute that $\eta_{UE}\eta_{Ep} = -\alpha Y/(Y-pR)$ and $\eta_{NE}\eta_{Np} = -(1-\alpha)pR/(Y-pR)$. Hence, under (4) the utility effect of an energy price increase, equation (3), takes the following form:

$$\eta_{Vp} = \eta_{UE}\eta_{Ep} + \eta_{UN}\eta_{Np} = \frac{-\alpha Y}{Y-pR} + \frac{-(1-\alpha)pR}{Y-pR} = -\frac{\alpha + (1-\alpha)FPR}{1-FPR}, \tag{5}$$

where FPR = p*R/Y is the fuel poverty ratio, see equation (1).

From equation (5) several insights can be gained:

Proposition 1. Given the utility function (4) with 0<R<Y/p, the following holds:

(a) A greater fuel poverty ratio implies greater marginal disutility from a rise in the energy price: $\partial|\eta_{Vp}|/\partial FPR > 0$.
(b) A rise in the energy price implies a decrease in the consumption of both energy and non-energy: $\eta_{Ep} < 0$, $\eta_{Np} < 0$.
(c) A greater fuel poverty ratio implies that a greater share of the overall disutility effect of energy price increases accrues to the reduction in non-energy consumption: $\partial(\eta_{UN}\eta_{Np}/\eta_{UE}\eta_{Ep})/\partial FPR > 0$.

Result (a) demonstrates that the welfare effect of fuel poverty consists in raising the effect of energy price increases on consumer utility while results (b) and (c) clarify the channels through which this effect operates.

Considering the constituents of fuel poverty, a corollary of result (a) is that the disutility from an energy price increase is greater if (i) income is lower, (ii) the energy price is higher, and (iii) the energy requirement is higher.

Against the background of Proposition 1, studying the effect of energy prices on utility is not only important per se; it also permits to shed light on the welfare implications of fuel poverty. In addition to its conceptual motivation, a practical advantage of such an approach is that it does not involve a measure of "required energy expenditures" which, in view of their unavailability, are usually replaced with observed energy expenditures in conventional analyses of fuel poverty.

3. EMPIRICAL FRAMEWORK

3.1 Data

We use survey data from the first five waves of the European Social Survey (ESS).[10] The ESS is a repeated cross-sectional, multi-country survey covering over 30 nations. Its first wave was

9. To be concise, we consider a consumption minimum for energy only.
10. See www.europeansocialsurvey.org.

fielded in 2002/2003, the fifth in 2010/2011. ESS data are obtained using random (probability) samples, where the sampling strategies are designed to ensure representativeness and comparability across European countries.

The variable used to capture SWB is life satisfaction. It is based on the answers to the following question: "All things considered, how satisfied are you with your life as a whole nowadays?" Respondents were shown a card, where 0 means extremely dissatisfied and 10 means extremely satisfied, and we use the answers on the eleven-point scale as our dependent variable. In robustness checks we use 11-point happiness instead of life satisfaction as the dependent variable.[11]

The explanatory variables at the individual level include socio-demographic and socio-economic factors that have been found to be related to SWB (sex, age, marital status, household size, employment status and household income), see, e.g., Dolan et al. (2008).[12] In addition, our regressions include macroeconomic control variables (quarterly data for GDP per capita and the rates of inflation and unemployment), taken from the OECD online data base.[13]

Our main variables of interest are the prices of electricity, gas and light fuel oil for households, which we take from the IEA Energy Prices and Taxes database.[14] The data for the gas price refer to natural gas, which—similar to light fuel oil and unlike electricity - mainly serves heating purposes. The prices of electricity and gas are average unit values, which are obtained either from utilities as average revenue per unit delivered to households or from households as average expenditure per unit purchased. Energy price data are reported by country and quarter and we matched each observation from the ESS with the respective energy price variable (real unit energy prices for households at PPP-corrected USD) on a country-quarter level.

The five-wave cumulative dataset of the ESS is a repeated cross-section referring to 2002-2011. It includes about 240,000 observations from 33 countries. Because energy price data are unavailable for some countries, our analysis refers to the following 21 countries in the case of electricity: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Netherlands, Norway, Poland, Portugal, Slovak Republic, Slovenia, Sweden, Switzerland, Turkey and the UK. In the case of light fuel oil the set of countries includes Luxembourg and Spain in addition whereas Hungary and the Slovak Republic are missing. In the case of gas the set of countries corresponds to the one for electricity plus Spain minus Italy and Norway. Due to missing price data and a small number of non-responses in the ESS the final samples for econometric analysis include observations for 100,908 individuals (electricity), 117,819 individuals (light fuel oil) and 101,937 individuals (natural gas).[15]

Tables A1 and A2 in the Appendix contain the variable descriptions and the summary statistics of the main variables. The average electricity price is 0.189 USD per kWh and varies between 0.064 (minimum) and 0.343 (maximum). The average light fuel oil price is 0.856 USD per liter (minimum = 0.260, maximum = 2.767) and the average natural gas price is 0.068 USD per kWh (minimum = 0.018, maximum = 0.162). Energy prices can thus be considered to exhibit sufficient variation to permit identification of their effect on well-being.

11. The happiness question is: "Taking all things together, how happy would you say you are?"

12. With respect to household income, the ESS includes a 12-point scale where 1 corresponds to less than 1,800 Euro annually and 12 corresponds to more than 120,000 Euro. For steps 3 to 8 each step corresponds to 6,000 Euro.

13. See www.oecd.org.

14. See www.iea.org

15. If we were to consider a common sample for all types of energy the number of observations would be reduced to 80,068.

3.2 Empirical Strategy

We estimated a micro-econometric SWB function in which the self-reported life satisfaction (*LS*) of individual *i*, in country *c* and time *t* depends on a set of individual socio-demographic and socio-economic indicators ($\boldsymbol{micro}_{ict}$), macroeconomic indicators ($\boldsymbol{macro}_{ct}$), residential energy prices (pen_{ct}), and country and time dummies ($country_c$, $time_t$, respectively). The general form of the estimating equations reads as follows:

$$LS_{ict} = \boldsymbol{\alpha}' \boldsymbol{micro}_{ict} + \boldsymbol{\beta}' \boldsymbol{macro}_{ct} + \gamma pen_{ct} + country_c + time_t + \varepsilon_{ict}. \tag{6}$$

In this specification, time *t* refers to the quarters 2002.I to 2011.IV; ε_{ict} denotes the error term. The *micro* controls are sex, age, marital status, household size, employment status, and household income. The *macro* controls are quarterly GDP per capita, inflation rates, and unemployment rates. In addition to those controls, we account for unobserved country- and time-invariant factors with country and quarter fixed effects. The *country* fixed effects account for unobserved time-invariant country characteristics (like climate or cultural attitudes) that may affect both the energy prices and well-being whereas the *time* fixed effects (2002.II to 2011.IV) account for unobserved time-specific confounding factors that are common to all countries (e.g. common global shocks). We extend equation (6) to include interactions of the price variables with several factors that may affect the relationship between energy prices and well-being.

In using SWB data for economic analysis it is assumed that there exists a positive monotonic relationship between SWB and the underlying true utility *u* and that utility is ordinally comparable. If, more restrictively, cardinal interpersonal comparability is assumed SWB can be treated as a cardinal variable. Based on the results of Ferrer-i-Carbonell and Frijters (2004) we treat the dependent variable, 11-point life satisfaction, as a cardinal variable in our main analysis. Since our database is a repeated cross-section we are unable to use a fixed effects estimator and estimate equation (6) using pooled OLS. As a robustness check we estimate an ordered probit model.

Another issue with SWB data is that they are bounded from below and from above. This implies that one can neither observe a decline in SWB if it was in the lowest category in the preceding period, nor an increase if it was in the highest category. A way of addressing this problem is by collapsing the information of SWB variables in two categories (high/low), and we will do so in an additional robustness check (see Welsch and Biermann 2014a).

We report robust standard errors adjusted for clustering at the country-quarter level.

We note that our approach of using SWB data as a proxy for utility has its strengths and weaknesses (Frey and Stutzer 2002). On the one hand, the SWB approach allows for a direct welfare assessment, avoiding the assumption of perfectly rational individuals required in traditional approaches that aim at recovering welfare indirectly from observed demand behavior. On the other hand, interpersonal comparability of utility is an assumption of which economists have often been skeptical.

4. RESULTS

4.1 Main Estimation Results

Table 1 presents the main estimation results for equation (6).[16] Panel A refers to energy prices without interactions. The coefficients of the electricity, light fuel oil and gas prices are

16. More detailed results concerning the micro and macro controls are presented in Table A3 in the Appendix. These results do not qualitatively differ with respect to the various energy prices included. As is common in data sets for developed

Table 1: SWB and Energy Prices

Prices in PPP Dollar per Unit	Electricity (USD/MWh)	Light Fuel Oil (USD/1000 liter)	Natural Gas (USD/MWh)
Panel A: Baseline Regressions			
Price	−0.00155*	−0.000354	−0.00459**
	(0.000916)	(0.000229)	(0.00196)
Constant			
	9.494***	7.156***	8.293***
	(0.705)	(0.561)	(0.564)
R-squared	0.208	0.182	0.190
Panel B: Differentiation by Income			
Price*Income<6k	−0.00231**	−0.000397*	−0.00590***
	(0.000962)	(0.000228)	(0.00198)
Price*Income6k-24k	−0.00122	−0.000299	−0.00397**
	(0.000925)	(0.000234)	(0.00201)
Price*Income24k-60k	−0.00114	−0.000382*	−0.00413**
	(0.000913)	(0.000228)	(0.00206)
Price*Income>60k	−0.00118	−0.000492**	−0.00500**
	(0.000933)	(0.000228)	(0.00211)
Constant	9.494***	7.156***	8.293***
	(0.705)	(0.561)	(0.564)
R-squared	0.209	0.182	0.191
Panel C: Differentiation by Season			
Price*QI	−0.00207**	−0.000378	−0.00247
	(0.00104)	(0.000272)	(0.00247)
Price*QII	−0.00190	−0.000427	−0.00173
	(0.00176)	(0.000286)	(0.00672)
Price*QIII	−0.00121	−0.000736**	−0.00717***
	(0.00114)	(0.000286)	(0.00317)
Price*QIV	−0.00158*	−0.000288	−0.00324
	(0.000933)	(0.000224)	(0.00213)
Constant	6.623***	7.266***	6.268***
	(0.343)	(0.617)	(0.273)
R-squared	0.208	0.182	0.190

Dependent variable: life satisfaction (11-point scale). Method: least squares. Cluster-robust standard errors in parentheses. *p<0.1, **p<0.05, ***p<0.01. Regressions include micro controls (sex, age, marital status, household size, employment status and household income), macro controls (GDP per capita and the rates of unemployment and inflation) and country and quarter fixed effects (2002.II to 2011.IV). N = 100,908 (electricity), N = 117,819 (light fuel oil), N = 101,937 (natural gas). Income categories approximately correspond to quartiles.

negative, and they are (at least weakly) significant for electricity and gas. Quantitatively, an increase of the electricity price by 1 USD per MWh (0.1 cent per kWh) is associated with a drop in life satisfaction by 0.00155 points (on the 11-point scale). In the case of gas the drop in life satisfaction for a corresponding price increase is 0.00459 points.

countries (see Dolan et al. 2008), life satisfaction is higher for females than for males, u-shaped in age, highest for married and lowest for separated persons, lowest if being unemployed than in any other employment status, and increasing in household income. At the macro level, life satisfaction is negatively related to the inflation and the unemployment rate and insignificantly related to GDP per capita, the latter being in line with the so-called happiness-income paradox (Easterlin et al. 2010). As indicated by the estimates for the country dummies, Iceland, Switzerland, Norway and Denmark have the highest "generic" (that is, unexplained) levels of reported well-being, which is also consistent with the literature.

We thus find that the well-being effect of a one-USD-per MWh increase of the electricity price is considerably smaller than that of the same increase of the gas price. In the light of the framework from subsection 2.2, an explanation for this difference in effect sizes may rely on different cost shares for (required) electricity and gas. For instance, German data reveal that in 2011 the mean expenditure share of electricity was 3.2 percent, whereas the share of expenditures for space heating (which includes gas) was five percent (Heindl 2013).

Panel B of Table 1 reports results differentiated by household income, where income groups approximately correspond to income quartiles. The coefficients for electricity are negative, but significant only for the lowest income quartile. For this group, the coefficient is considerably greater (in absolute terms) than the coefficients for the other groups and for the average household (as reported in panel A). In the case of light fuel oil, coefficients are now significant except for the second lowest group, and the one for the highest group is greater than those for the other groups. In the case of gas, the coefficients are significant for all income groups and the coefficient for the lowest group is the greatest, whereas the coefficient for the highest income group is the second greatest. Overall, the results for electricity and gas are consistent with the expectation that energy price increases have the largest well-being effect at low levels of income. In the cases of light fuel oil and gas we find, in addition, a u-shaped relationship between the price and well-being. A possible explanation for the large coefficient at high income is that high income may be a proxy for larger homes and, hence, greater heating requirements (Lange et al. 2014).[17]

While income represents the denominator of the fuel poverty ratio, the energy price and required energy consumption represent the numerator and hence are expected to raise the disutility from energy price increases according to the framework of subsection 2.2. Both the price and required consumption can be expected to vary across the quarters of the year. On the one hand, heating requirements imply that the demand for light fuel oil is high in autumn when tanks need to be filled for the winter season. On the other hand, high and inelastic seasonal demand may translate into high seasonal prices. In fact, as some complementary regressions show, the price not only of light fuel oil but also of gas is highest in the third quarter (Table A4). Thus, one or both components of required energy expenditures, price and quantity, can be expected to be high in the third quarter. In the case of electricity, prices are highest in the fourth quarter (Table A4) while payment of arrears for the preceding year may drive up electricity expenditures in the first quarter.

To check for seasonal differences in the relationship between well-being and energy prices, we included in the well-being regressions interactions with quarter dummies. Panel C of Table 1 reports the results. In the case of electricity we find a significant negative coefficient in the first and a weakly significant negative coefficient in the fourth quarter, whereas coefficients are insignificant in the second and third quarter. The coefficient in the first quarter is substantially greater than the year-average reported in panel A. The result for the first quarter may arise because of high "involuntary" electricity expenditures due to payments of arrears for the preceding year.

In the cases of light fuel oil and gas we get the interesting results that coefficients are significant only in the third quarter but not at other times of the year. This is consistent with the circumstance that both the "required" demand and the price of light fuel oil are high before the start of the winter season, implying a high expenditure share of light fuel oil.[18] Similarly, high gas prices in the third quarter increase the expenditures for gas and the well-being effect of the price.

17. We do not have information on people's homes.

18. Public agencies sometimes advise consumers to fill up their oil tanks before the heating season begins (e.g. DOER 2014).

Indeed, the coefficient for the gas price is substantially greater in the third quarter than the year-average (panel A).

4.2 Discussion

Our estimation results so far suggest several insights. First, electricity and fuels (light fuel oil and gas) differ in that a significant relationship between well-being and the electricity price exists only at low levels of income, whereas well-being is significantly related to the prices of fuel at all income levels except for the second quartile in the case of light fuel oil. A likely explanation of the difference between electricity and light fuel oil/gas is the lower amount that needs to be spent on required electricity consumption in comparison to expenditures for space heating using light fuel oil and gas.

Second, the strength of the relationship between well-being and energy prices depends on household income. As was just mentioned, in the case of electricity the relationship is significant only in individuals with low income. In the case of gas, the sensitivity of well-being to the price is greatest at low income. Both of this is consistent with the idea that the well-being effect of energy prices is increasing in the degree of fuel poverty through an income effect, holding required expenditures constant.

Third, though electricity and gas prices affect well-being on average over the year, the effects are actually significant only in those seasons (quarters) in which required expenditures are high. In addition, though the light fuel oil price has no significant effect in the average of seasons, a significant negat*iv*e effect exists at the time when expenditures can be expected to be higher than average. The finding that effects are greater when "forced" expenditures are high is consistent with the idea that the well-being effect of energy prices is increasing in the degree of fuel poverty through required expenditures, holding income constant. In general, these findings yield the insight that the well-being effects of fuel poverty are predominantly of a seasonal character.

In quantitative terms, a 1-standard-deviation change in the electricity price is associated with a change in 11-point life satisfaction by 0.096 for the average person and 0.144 for a person from the lowest income group. For a 1-standard-deviation change in the gas price, the effects are 0.119 (average) and 0.153 (low income). For the price of light fuel oil the effect is 0.157 at low income. To put those figures in perspective, note that one of the strongest negative factors for well-being consists in being unemployed. In our data the well-being difference between a person involuntarily unemployed and a person in paid work is between 1.0 and 1.1 points (see Table A3). The well-being effects of a one-standard-deviation difference in energy prices can thus be considered to be of a non-negligible magnitude.

4.3 Robustness

We checked the robustness of our results to a number of factors, including the use of control variables and the treatment of the dependent variable. Results are reported in Table 2.

One factor that may impact on results is inclusion of the inflation rate. When the latter is included, as is the case in the specifications discussed so far, the measured effect of an energy price change is that which goes beyond the effect of a change in the general price level. As panel A of Table 2 shows, the conclusions on the significance of energy prices from panel A of Table 1 stay largely intact when the inflation rate is omitted, except that the significance level of the gas price increases. As for magnitudes, it is seen that, consistent with expectations, the coefficients of the electricity and gas price are greater (in absolute terms) than when the inflation rate is included. The

Table 2: Robustness Checks

Prices in PPP Dollar per Unit	Electricity (USD/MWh)	Light fuel oil (USD/1000 liter)	Natural Gas (USD/MWh)
Panel A: Inflation rate omitted			
Price	−0.00172*	−0.000354	−0.00503***
	(0.000996)	(0.000229)	(0.00189)
Constant	9.406***	6.928***	8.156***
	(0.743)	(0.566)	(0.572)
R-squared	0.208	0.181	0.190
Panel B: Ordered probit estimation			
Price	−0.000951**	−0.000165	−0.00239***
	(0.000444)	(0.000111)	(0.000874)
R-squared (pseudo)	0.053	0.045	0.047
Panel C: Probit estimation (dependent variable: dummy for high LS)			
Price	−0.00154***	−0.000234*	−0.00353***
	(0.000534)	(0.000123)	(0.000954)
R-squared (pseudo)	0.125	0.104	0.111
Panel D:Dependent variable: 11-point happiness			
Price	−0.00152**	−0.000106	−0.00285*
	(0.000720)	(0.000155)	(0.00152)
Constant	8.874***	9.170***	5.741***
	(0.548)	(0.856)	(0.200)
R-squared	0.176	0.158	0.162

Cluster-robust standard errors in parentheses. *$p<0.1$, **$p<0.05$, ***$p<0.01$. Regressions include micro controls (sex, age, marital status, household size, employment status and household income), macro controls (GDP per capita and the rates of unemployment and inflation) and country and quarter fixed effects (2002.II to 2011.IV). N = 100,908 (electricity), N = 117,819 (light fuel oil), N = 101,937 (natural gas).

increase in coefficient size amounts to 11.0 percent in the case of electricity and 9.6 percent in the case of gas.

To account for the possible non-cardinality of life satisfaction data, panel B in Table 2 reports the results from estimating the models from panel A of Table 1 using an ordered probit instead of least squares. In this case, the prices of electricity and gas become more significant, whereas the light fuel oil price remains insignificant. The coefficient sizes are of course not comparable to those from least squares, but the *ratios* of the significant coefficients are very similar: While under least squares the coefficient of the electricity price is 33.8 percent that of the coefficient of the gas price, it is 39.8 percent in the ordered probit model.

To account for the fact that life satisfaction data are bounded from below and from above (see subsection 3.2) we collapsed them into a “low” and a “high” category (each accounting for about one half of the observations) and estimated a probit model on these data. As panel C in Table 2 shows, the prices of electricity and gas are now more significant than in Table 1 and the light fuel oil price is weakly significant. This suggests that the boundedness of the life satisfaction scale tends to mask some of the well-being effects of energy prices.

Finally, we replace the dependent variable, 11-point life satisfaction, with 11-point happiness and revert to least squares as the estimation method (panel D in Table 2). The electricity price is now more significant whereas the gas price is less significant than with life satisfaction. The light fuel oil price is insignificant as it is in the case of life satisfaction. The magnitude of the electricity price coefficient is practically the same as with life satisfaction whereas the gas price coefficient is now 38 percent smaller.

5. CONCLUSIONS

This paper has used data on the life satisfaction of more than 100,000 individuals in 21 European countries from 2002 to 2011, to study the relationship between subjective well-being and the prices for households of electricity, light fuel oil and natural gas. We found that energy prices have statistically and economically significant effects on subjective well-being. The effect sizes are smaller than but comparable to the effects of important personal factors of well-being. Effect sizes above average were found in individuals from the lowest income quartile. For those, the effect of a 1-SD increase in energy prices is about one sixth of the effect of being unemployed. In addition, effects are strongest at times when required energy expenditures can be expected to be high. The empirical results are consistent with the prediction that greater fuel poverty implies a greater effect of energy prices on well-being.

Our study is the first to use SWB data to investigate the welfare implications of energy affordability. While the preceding literature was mainly concerned with definitions of fuel poverty and the measurement of its incidence, intensity and consequences, the overall welfare significance of fuel poverty has largely been unaddressed. Our study contributed to this issue by elaborating the conceptual relationships between energy prices, fuel poverty and utility and by estimating the effect of energy prices on utility, proxied by life satisfaction.

With respect to policy implications, an important conclusion is that rising energy prices affect SWB in particular when affordability is low as presumably is the case in low-income households. In addition, adverse effects follow a seasonal pattern, being particularly strong when energy demand is inelastic. Together, these findings may provide a strong justification for fuel poverty programs such as the Winter Fuel Payments targeted to low-income households. Moreover, we found that over the period studied the adverse effect of rising electricity prices tended to be smaller than that of gas and in particular heating oil (which is explicable in terms of the typically lower expenditure share of electricity compared to heating fuels). This might change if future electricity prices rise due to, e.g., the costs of nuclear waste disposal, electricity restructuring programs, or rising carbon prices. In such a case, it may be warranted to extend fuel poverty programs and, in particular, energy efficiency programs, to electricity.

Limitations of our study are both of a specific and a general nature. A specific limitation is that housing details are missing which determine heating expenditures. Since bigger houses require more heating and the size of the house tends to be correlated with income, the strong effect of heating oil prices at high income may be a result of missing housing details.

At a more general level, one limitation of the study is that we were unable to measure households' fuel poverty directly. Instead, we focused on energy prices, acknowledging that, as demonstrated conceptually, the welfare effect of energy prices may act as a proxy for the welfare effect of fuel poverty. To overcome this limitation, future work may strive to combine SWB data with household level measures of fuel poverty. This may enable an in-depth analysis of how the incidence and intensity of fuel poverty affect SWB. In addition, by including measures of income poverty in this kind of analysis, the welfare effects of fuel poverty and income poverty can be studied jointly. This may shed some light on the question whether fuel poverty has an effect on SWB that is not already captured by income poverty.

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APPENDIX

Table A1: Description of Data

Variable	Source	Description
Socio-demographic Indicators	ESS	
Subjective Well-Being ("How satisfied with life as a whole?")		0 (extremely dissatisfied)—10 (extremely satisfied)
Sex		Dummy: 1 = male
Age		Age of respondent in years
Marital Status		4 categories: married or in civil partnership; separated, divorced; widowed; never married nor in civil partnership (reference)
Household Income		Household's total net income (all sources). Discrete: 1 (low income)—12 (high income)
Employment Status		8 categories: paid work; in education; unemployed and actively looking for job; unemployed and not actively looking for job; permanently sick or disabled; retired; housework; other (reference).
Household size		Number of people living regularly as member of household
Macroeconomic Indicators (quarterly)	OECD (http://www.oecd.org)	
GDP per capita		Measured in 2005 PPP$ per capita
Inflation rate		Measured as the percentage increase of price index compared with the previous year.
Unemployment rate		Measured as the percentage of total civilian labor force
Household Energy Prices (quarterly)		
Electricity Price		End Use Prices for Households (PPP-adjusted USD/MWh))
Light Fuel Oil Price		End Use Prices for Households (PPP-adjusted USD/1000 liter))
Gas Price		End Use Prices for Households (PPP-adjusted USD/MWh))

Table A2: Summary Statistics of Main Variables

Sample Electricity					
Variable	Obs	Mean	Std. Dev.	Minimum	Maximum
Life Satisfaction	100908	7.01979	2.244549	0	10
GDPPC_Q_ppp	100908	7.607159	3.006035	0.3460003	14.61596
Inflat_Q	100908	.4327715	.6313537	−1.43013	3.879408
Unemp_Q	100908	7.447661	3.512062	2.533333	20.26667
Unemp invol	100908	0.0340607	0.1813861	0	1
Net Household Income	100908	5.748831	2.720912	1	12
Electricity Price	100908	189.0693	62.1076	64.36095	342.8068
Sample Light Fuel (LFO)					
Variable	Obs	Mean	Std. Dev.	Minimum	Maximum
Life Satisfaction	117819	7.151368	2.164312	0	10
GDPPC_Q_ppp	117819	8.000223	2.924847	.3460003	17.27039
Inflat_Q	117819	0.4084959	.5947207	−1.650163	3.879408
Unemp_Q	117819	7.634302	3.539856	2.533333	22.03333
Unemp_invol	117819	0.0350283	.1838521	0	1
Net_Household Income	117819	5.976956	2.643891	1	12
LFO_Price	117819	856.5338	394.7213	259.7072	2767.4
Sample Natural Gas					
Variable	Obs	Mean	Std. Dev.	Minimum	Maximum
Life Satisfaction	101937	6.91378	2.25876	0	10
GDPPC_Q_ppp	101937	7.113523	2.381947	.3460003	11.00873
Inflat_Q	101937	0.4378295	0.645011	−1.650163	3.879408
Unemp_Q	101937	8.391749	3.692231	3.033333	22.03333
Unemp invol	101937	0.038308	0.1919397	0	1
Net_HouseholdIncome	101937	5.615949	2.626459	1	12
Gas Price	101937	68.9154	25.98495	18.41632	162.3365

Table A3: Detailed Estimation Results

	(2) Electricity	(1) Light Fuel Oil	(3) Natural Gas
Electr_Price	−0.00155*		
	(0.000916)		
LFO_Price		−0.000354	
		(0.000229)	
Gas_Price			−0.00459**
			(0.00196)
Constant	9.431***	7.207***	8.265***
	(0.712)	(0.557)	(0.553)
Male	Omitted	omitted	omitted
Female	0.120***	0.122***	0.120***
	(0.0145)	(0.0128)	(0.0153)
Age	−0.0668***	−0.0613***	−0.0659***
	(0.00482)	(0.00439)	(0.00474)
Age^2	0.000659***	0.000606***	0.000646***
	(0.0000468)	(0.0000430)	(0.0000464)
Household Size	−0.0236***	−0.0140*	−0.0229***
	(0.00825)	(0.00732)	(0.00800)
Single	omitted	omitted	omitted
Married	0.339***	0.360***	0.346***
	(0.0291)	(0.0262)	(0.0297)

(continued)

Table A3: Detailed Estimation Results *(continued)*

	(2) Electricity	(1) Light Fuel Oil	(3) Natural Gas
Divorced	−0.190***	−0.160***	−0.211***
	(0.0385)	(0.0347)	(0.0390)
Separated	−0.519***	−0.492***	−0.512***
	(0.0662)	(0.0620)	(0.0666)
Widowed	−0.163***	−0.179***	−0.182***
	(0.0360)	(0.0324)	(0.0358)
Paid Work	omitted	omitted	omitted
In School	0.190***	0.185***	0.243***
	(0.0411)	(0.0349)	(0.0407)
Voluntary Unempl	−0.824***	−0.794***	−0.837***
	(0.0866)	(0.0765)	(0.0828)
Sick	−1.151***	−1.189***	−1.156***
	(0.0527)	(0.0562)	(0.0578)
Retired	−0.0394	0.00438	−0.0120
	(0.0361)	(0.0342)	(0.0359)
Civil/Military Service	0.131	0.0997	0.0212
	(0.170)	(0.162)	(0.196)
Housework	−0.0530*	−0.0740***	−0.0716**
	(0.0294)	(0.0280)	(0.0289)
Other_empl	−0.172**	−0.242***	−0.153**
	(0.0679)	(0.0645)	(0.0696)
Invol_Unempl	−1.034***	−1.066***	−1.080***
	(0.0551)	(0.0616)	(0.0653)
Household_Income	0.133***	0.132***	0.145***
	(0.00712)	(0.00655)	(0.00691)
Austria	−0.870***	1.113**	−0.534***
	(0.254)	(0.545)	(0.106)
Belgium	−0.769***	1.186**	−0.582***
	(0.225)	(0.567)	(0.107)
Switzerland	−0.188	1.635**	
	(0.172)	(0.636)	
Czech_Republic	−1.930***	0.337	−1.321***
	(0.422)	(0.354)	(0.287)
Germany	−0.957***	0.719	−0.834***
	(0.232)	(0.545)	(0.0978)
Estionia	omitted	omitted	omitted
Denmark	0.251	2.125***	0.488***
	(0.229)	(0.511)	(0.0969)
Spain		1.340**	−0.231*
		(0.516)	(0.118)
Finland	−0.310	1.692***	−0.0441
	(0.278)	(0.519)	(0.139)
France	−1.975***	0.0682	−1.579***
	(0.288)	(0.511)	(0.131)
United_Kingdom	−1.007***	0.872	−0.800***
	(0.218)	(0.559)	(0.0811)
Greece	−2.126***	0.112	−1.450***
	(0.383)	(0.455)	(0.218)
Hungary	−2.699***	0	−2.135***
	(0.422)	(.)	(0.297)
Ireland	−0.542***	1.310**	−0.404***
	(0.208)	(0.591)	(0.0854)
Italy	−1.338***	0.877**	
	(0.322)	(0.419)	

(continued)

Table A3: Detailed Estimation Results *(continued)*

	(2) Electricity	(1) Light Fuel Oil	(3) Natural Gas
Luxembourg		1.808*	
		(0.923)	
Netherlands	−0.546***	1.327**	−0.361***
	(0.202)	(0.529)	(0.0667)
Norway		1.707**	
		(0.729)	
Poland	−1.626***	0.672**	−0.927***
	(0.413)	(0.317)	(0.291)
Portugal	−2.664***	−0.617	−2.020***
	(0.361)	(0.399)	(0.239)
Sweden	−0.250	1.779***	0.133
	(0.186)	(0.531)	(0.115)
Slovenia	−1.875***	0.540	−1.086***
	(0.433)	(0.380)	(0.300)
Slowak_Republic	−1.874***	omitted	−1.332***
	(0.374)		(0.253)
Turkey	−2.914***	omitted	−1.889***
	(0.594)		(0.487)
Q1_02	omitted	omitted	omitted
Q2_02	−0.272***	−0.683***	−0.298***
	(0.0333)	(0.258)	(0.0331)
Q3_02	0.812***	0.387	0.899***
	(0.0665)	(0.257)	(0.0724)
Q4_02	0.884***	0.410	0.960***
	(0.0590)	(0.257)	(0.0587)
Q1_03	1.071***	0.533**	1.069***
	(0.108)	(0.260)	(0.0735)
Q2_03	0.672***	0.211	0.673***
	(0.121)	(0.264)	(0.0722)
Q3_03	1.371***	0.692**	1.375***
	(0.108)	(0.282)	(0.0860)
Q4_03	1.205***	0.480	1.233***
	(0.0405)	(0.330)	(0.0411)
Q3_04	0.919***	0.503*	1.070***
	(0.0863)	(0.263)	(0.0861)
Q4_04	0.975***	0.543**	1.026***
	(0.0679)	(0.256)	(0.0708)
Q1_05	1.049***	0.541**	1.044***
	(0.109)	(0.264)	(0.0906)
Q2_05	1.204***	0.684**	1.195***
	(0.0915)	(0.267)	(0.0829)
Q4_05	1.742***	1.392***	1.798***
	(0.144)	(0.283)	(0.139)
Q1_06	1.799***	1.418***	1.836***
	(0.114)	(0.274)	(0.109)
Q2_06	1.707***	1.422***	1.763***
	(0.126)	(0.287)	(0.121)
Q3_06	1.036***	0.514*	1.066***
	(0.118)	(0.278)	(0.125)
Q4_06	1.065***	0.609**	1.108***
	(0.102)	(0.266)	(0.110)
Q1_07	1.111***	0.587**	1.165***
	(0.109)	(0.268)	(0.124)
Q2_07	1.276***	0.732**	1.356***
	(0.144)	(0.287)	(0.174)

(continued)

Table A3: Detailed Estimation Results *(continued)*

	(2) Electricity	(1) Light Fuel Oil	(3) Natural Gas
Q3_07	1.336***	0.775***	1.288***
	(0.127)	(0.279)	(0.125)
Q4_07	1.243***	0.714**	1.194***
	(0.123)	(0.283)	(0.112)
Q3_08	1.333***	0.940***	1.338***
	(0.105)	(0.302)	(0.124)
Q4_08	1.127***	0.653**	1.176***
	(0.0985)	(0.280)	(0.124)
Q1_09	1.051***	0.561**	1.125***
	(0.108)	(0.279)	(0.134)
Q2_09	1.383***	0.796***	1.481***
	(0.144)	(0.266)	(0.158)
Q3_09	1.017***	0.569	1.276***
	(0.243)	(0.346)	(0.266)
Q4_09	1.366***	0.828**	1.366***
	(0.202)	(0.323)	(0.208)
Q1_10	1.603***	1.054***	1.541***
	(0.196)	(0.326)	(0.204)
Q3_10	1.350***	0.934***	1.435***
	(0.0930)	(0.279)	(0.116)
Q4_10	1.494***	1.006***	1.521***
	(0.108)	(0.285)	(0.120)
Q1_11	1.408***	0.921***	1.453***
	(0.124)	(0.296)	(0.132)
Q2_11	1.435***	1.576***	2.042***
	(0.139)	(0.328)	(0.198)
Q3_11		1.179***	1.633***
		(0.328)	(0.206)
GDPPC_Q_ppp	−0.139***	−0.0717	−0.0499
	(0.0496)	(0.0533)	(0.0518)
Inflat_Q	−0.102***	−0.109***	−0.121***
	(0.0371)	(0.0344)	(0.0348)
Unemp_Q	−0.0521***	−0.0484***	−0.0502***
	(0.0105)	(0.00998)	(0.00979)
Observations	100908	117819	101937
R-squared	0.208	0.182	0.190

Dependent variable: life satisfaction (11-point scale). Method: least squares. Cluster-robust standard errors in parentheses. *p<0.1, **p<0.05, ***p<0.01.

Table A4: Seasonality of Energy Prices

	Electricity (USD/MWh)	Light fuel oil (USD/1000 liter)	Natural Gas (USD/MWh)
Quarter 1	Omittted	Omitted	Omitted
Quarter 2	1.15***	−9.55***	3.35***
	(5.89)	(10.03)	(31.33)
Quarter 3	0.10	145.66***	12.62***
	(0.44)	(125.97)	(94.74)
Quarter 4	2.19***	70.40***	8.85***
	(9.59)	(60.25)	(66.27)
Constant	78.42***	1250.45***	29.25***
	(121.32)	(333.22)	(77.31)
Country FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes

Method: least squares. t-statistics in parentheses. ***p<0.01.