Fuel poverty, health and subjective assessment: A latent class approach and application to the case of Spain

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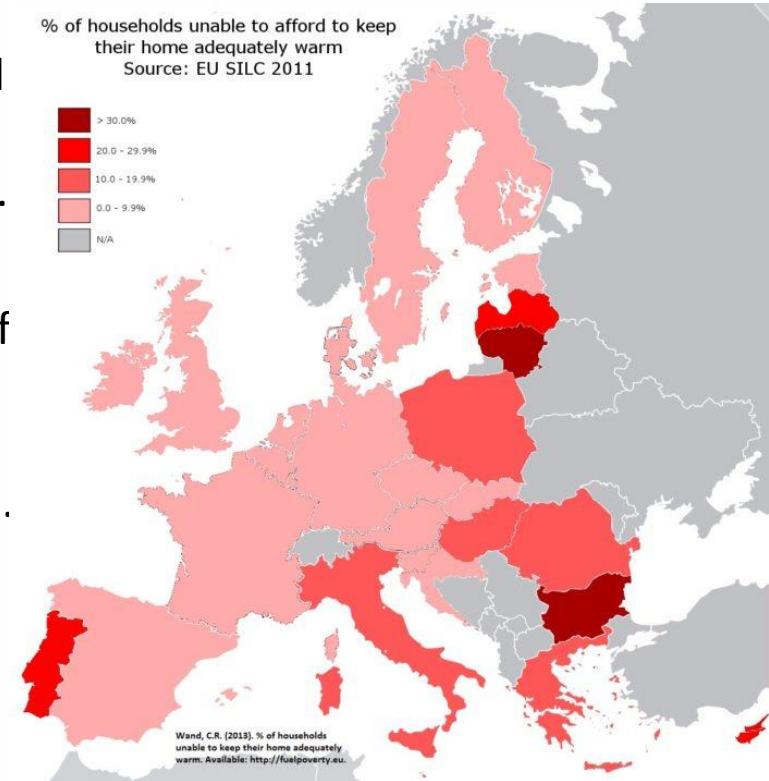Hofburg Congress Center, Vienna, 6 September 2017

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- **Fuel poverty** (or **energy poverty**) occurs when a household cannot afford the most basic levels of energy services such as space heating, space cooling, lighting or cooking.

- Components (Boardman, 2010):

Income

Fuel prices   Efficiency of the home
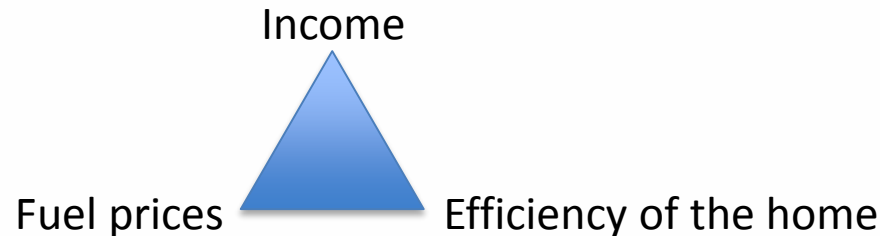
Fuel poverty in Europe

- First studies on fuel poverty were published in the UK. According to NEA, over 4 million UK households are currently in fuel poverty.

- Increasingly serious issue in Europe: 9.8% of households in EU27 and 15.8% in the 12 new Member States could not afford to heat their home adequately (EU SILC, 2011).

- Fuel poverty can pose a social policy problem even in countries with mild climates.

% of households unable to afford to keep their home adequately warm
Source: EU SILC 2011

> 30.0%
20.0 - 29.9%
10.0 - 19.9%
0.0 - 9.9%
N/A

Wand, C.R. (2013). % of households unable to keep their home adequately warm. Available: http://fuelpoverty.eu.

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- Households that spend more than 10% of their income on fuel (Boardman, 1991).

- Low Income - High Costs (LIHC) indicator (Hills, 2011).

- Minimum Income Standard (MIS) (Moore, 2012).

- Indicators from the EU SILC: inability to keep the house adequately warm, living in a damp home and being in arrears in utility bills (Devalière *et al*., 2011; Waddams Price *et al*., 2012; Charlier and Legendre, 2016).

- Little visibility, related to other circumstances such as material deprivation, lack of participation in the society, with influence on wellbeing, health, etc.

- Difficult to recognise, which affects the implementation of adequate policies to tackle it.

Effect on health

- Mainly cardiovascular and respiratory problems, less resistance to infections, poor mental health (anxiety and stress) (WHO, 2011).

Fuel poverty in Spain (news)

Fuel poverty in Spain

GDP per capita
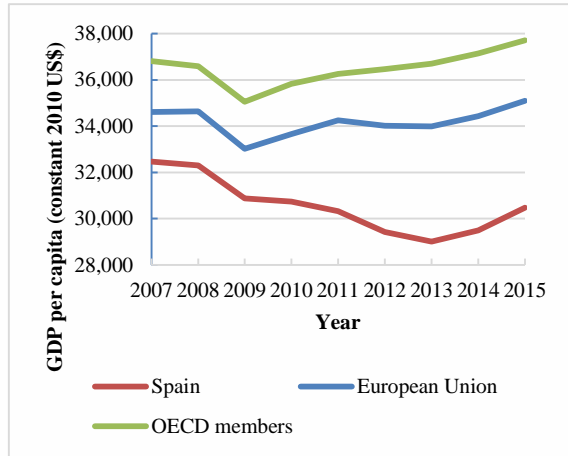
Source: World Bank

Price of electricity
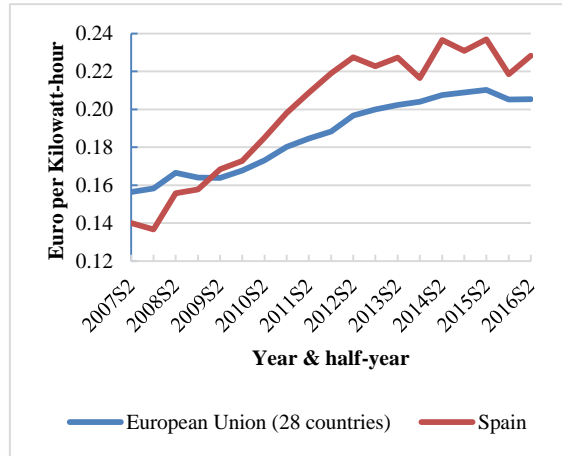
Source: Eurostat

Price of gas
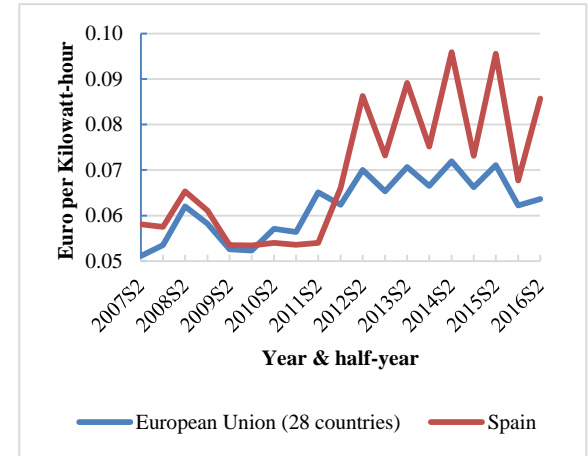
Source: Eurostat

Fuel poverty in Spain

- In 2014, 5.1 million people could not afford to keep their homes at an adequate temperature during the winter (Association of Environmental Sciences, 2014). This implies a 22% growth from 2012.

- Romero *et al*. (2015): The MIS indicator is the one that offers the best approximation to the problem for Spain. Fuel poverty is present in 8-9% of the Spanish households.

Policy issues

- Social electricity tariff called "Bono Social" → Criteria based on contracted power & online application.

- Validation of a decree in recent months to avoid cut offs of electricity and defining the mechanism of funding the social tariff.

- Non-profit organisations, voluntary programmes, etc.

➢ Mismatch between definition of fuel poverty and eligibility for assistance.

Motivation

- Objective of the paper:

  – Contribute to the literature on fuel poverty in Spain.

  – Identify the specific effect of fuel poverty on health.

  – Advocate the use of an econometric method that may help to correct issues of self-assessment (latent class approach).

Methodology

- We estimate a "health production function".

- Dependent variable (self-assessed health). Discrete choice model.

- Unobserved heterogeneity (that may be correlated with subjectivity and/or misreporting).

- Approach: Latent Class Ordered Probit Model (LCOPM).

- Ordered Probit:
  - Latent regression: $$Y^* = X'\beta + \varepsilon$$

  - Y^* is unobserved, what is observed instead of Y^* is the categorical variable Y:

$$
\begin{aligned}
Y &= 0 && if\ Y^* \leq 0, \\
Y &= 1 && if\ 0 \leq Y^* \leq \mu_1, \\
Y &= 2 && if\ \mu_1 \leq Y^* \leq \mu_2, \\
&\vdots \\
Y &= M && if\ \mu_{M-1} \leq Y^*
\end{aligned}
$$

  - The probabilities associated to the alternative values of Y are:

$$
\begin{aligned}
Prob(Y = 0|X) &= \Phi(-X'\beta), \\
Prob(Y = 1|X) &= \Phi(\mu_1 - X'\beta) - \Phi(-X'\beta), \\
Prob(Y = 2|X) &= \Phi(\mu_2 - X'\beta) - \Phi(\mu_1 - X'\beta), \\
&\vdots \\
Prob(Y = M|X) &= 1 - \Phi(\mu_{M-1} - X'\beta)
\end{aligned}
$$

- – Unconditional log-likelihood function:

$$\ln L(\mu, \beta) = \sum_{i=1}^{N} \sum_{m=1}^{M} y_{im} \ln[\Phi(\mu_m - x_i'\beta) - \Phi(\mu_{m-1} - x_i'\beta)]$$

- We propose the use of a latent class model (also called finite mixture models) to control for unobserved heterogeneity. The log-likelihood function for an individual *i* who belongs to class *j* can be represented as:

$$\ln L_{ij}\left(\mu_j, \beta_j\right) = \sum_{m=1}^{M} y_{im} \ln\left[\Phi\left(\mu_{jm} - x_i'\beta_j\right) - \Phi\left(\mu_{jm-1} - x_i'\beta_j\right)\right]$$

- Now the unconditional likelihood function for an individual *i* can be characterised as:

$$L_i(\mu, \beta, \delta) = \sum_{j=1}^{J} L_{ij}\left(\mu_j, \beta_j\right) P_{ij}(\delta_j), \qquad 0 \le P_{ij} \le 1, \qquad \sum_{j=1}^{J} P_{ij}(\delta_j) = 1$$

Methodology

- In latent class models, the class probabilities are usually parameterised as multinomial logit models like the following:

$$P_{ij}(\delta_j) = \frac{\exp\left(\delta_j' q_i\right)}{\sum_{j=1}^{J} \exp\left(\delta_j' q_i\right)}, \qquad j = 1, \dots, J, \qquad \delta_j = 0$$

- The overall likelihood function is a continuous function of the vector of parameters μ, β and δ:

$$\ln L(\mu, \beta, \delta) = \sum_{i=1}^{N} \ln L_i(\mu, \beta, \delta) = \sum_{i=1}^{N} \ln \left\{ \sum_{j=1}^{J} L_{ij}\left(\mu_j, \beta_j\right) P_{ij}(\delta_j) \right\}$$

- The estimated parameters can then be used to compute posterior class membership probabilities which can be defined as:

$$P(j|i) = \frac{L_{ij}\left(\hat{\mu}_j, \widehat{\beta}_j\right) P_{ij}(\hat{\delta}_j)}{\sum_{j=1}^{J} L_{ij}\left(\hat{\mu}_j, \widehat{\beta}_j\right) P_{ij}(\hat{\delta}_j)}$$

Database (variables and sources)

- **Sources**: Spanish Living Conditions Survey and Spanish Household Budget Survey from the National Institute of Statistics (Spanish: *Instituto Nacional de Estadística*, INE).

- **Panel survey**: 4 waves of data (2011-2014).

- **Number of observations**: 54,125 observations (unbalanced panel: 25,038 people from 11,066 households).

- **Variables**: health status (rescaled), chronic condition, age, employment situation, gender, marital status, education, net disposable income, type of dwelling, leaks (dampness or rot), Fuel poverty Index (FPI), material deprivation, affordability, year and autonomous communities dummies.

- **Computation of FPI**: $FPI = \dfrac{MIS - AHEE + ENERGY}{INCOME}$

> *MIS = Minimum Income Standard*
> *AHEE = Average household expenditure in energy*
> *ENERGY = Energy expenditure of the household*
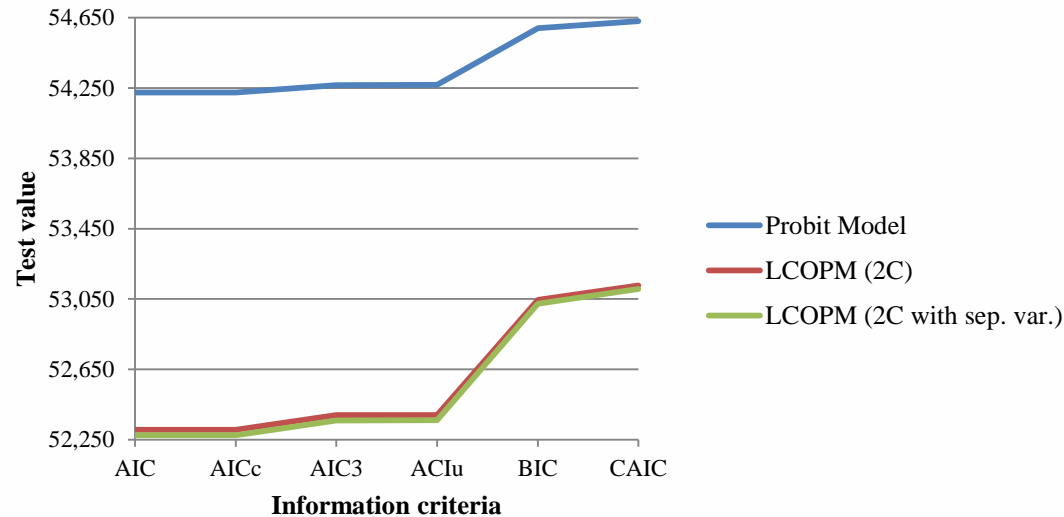> *INCOME = Net disposable income*

Parameter estimates

Variable	Probit model		LCOPM (without separating variable)				LCOPM (with separating variable)			
			Class 1		Class 2		Class 1		Class 2	
	Est.	Est./s.e.	Est.	Est./s.e.	Est.	Est./s.e.	Est.	Est./s.e.	Est.	Est./s.e.
Health production function										
Intercept	0.872***	21.440	1.797***	21.820	0.465***	5.910	1.801***	21.910	0.468***	5.940
Chronic condition	-1.548***	-109.470	-1.830***	-64.520	-1.611***	-56.490	-1.830***	-64.520	-1.609***	-56.410
Age	0.024***	38.710	0.031***	28.740	0.032***	18.240	0.031***	28.990	0.032***	18.100
$\frac{1}{2}$ (Age)^2	0.000***	-9.830	-0.001***	-6.920	0.000***	-3.550	-0.001***	-7.010	0.000***	-3.430
Employed	-0.224***	-12.200	-0.330***	-10.610	-0.177***	-4.050	-0.330***	-10.640	-0.172***	-3.940
Self employed	-0.186***	-6.460	-0.283***	-6.050	-0.127**	-1.960	-0.283***	-6.050	-0.124*	-1.920
Gender	0.097***	6.990	0.118***	4.870	0.171***	6.240	0.120***	4.960	0.169***	6.170
Married	-0.062***	-2.970	-0.113***	-3.360	-0.044	-0.980	-0.115***	-3.420	-0.047	-1.060
Sep., div. or widow.	-0.008	-0.310	0.051	1.070	-0.027	-0.560	0.046	0.970	-0.034	-0.700
Second. ed. (1st stg.)	-0.165***	-9.260	-0.168***	-5.130	-0.244***	-7.310	-0.164***	-5.030	-0.246***	-7.350
Second. ed. (2nd stg.)	-0.321***	-15.060	-0.337***	-9.080	-0.476***	-10.750	-0.334***	-9.020	-0.470***	-10.670
Post-second. (non-HE)	-0.300**	-2.230	-0.338	-1.370	-0.320	-1.190	-0.332	-1.320	-0.316	-1.180
Higher education	-0.419***	-17.950	-0.425***	-10.970	-0.711***	-12.970	-0.420***	-10.840	-0.707***	-13.030
ln Income	-0.077***	-4.380	-0.122***	-3.810	-0.079**	-2.260	-0.117***	-3.690	-0.074**	-2.100
$\frac{1}{2}$ (ln Income)^2	-0.035***	-4.320	-0.053***	-2.940	-0.032*	-1.890	-0.051***	-2.860	-0.031*	-1.660
Flat	-0.040***	-2.770	-0.008	-0.310	-0.093***	-3.410	-0.007	-0.260	-0.095***	-3.470
Leak	-0.149***	-8.430	-0.174***	-5.370	-0.173***	-5.030	-0.169***	-5.270	-0.167***	-4.820
ln FPI	0.045***	2.710	0.008	0.280	0.099***	2.990	0.007	0.230	0.101***	3.050
Material deprivation	0.301***	13.850	0.341***	8.720	0.295***	6.860	0.280***	7.290	0.259***	5.670
Year 2012	-0.009	-0.390	0.028	0.640	-0.020	-0.410	0.022	0.510	-0.016	-0.340
Year 2013	0.041*	1.820	0.223***	5.480	-0.047	-1.010	0.222***	5.450	-0.050	-1.080
Year 2014	0.092***	4.000	0.244***	5.770	0.051	1.110	0.245***	5.810	0.047	1.010
μ_1	1.319***	115.030	1.576***	61.490	1.835***	51.050	1.576***	61.530	1.840***	50.980
Class membership probabilities										
Prior probabilities			0.367***	27.520	0.633***	47.450	0.367		0.633	
Intercept							-0.588***	-10.200		
Affordability							0.540***	5.730		
Log-likelihood	-27,071.572		-26,070.159				-26,053.912			

Model selection

- Selection criteria

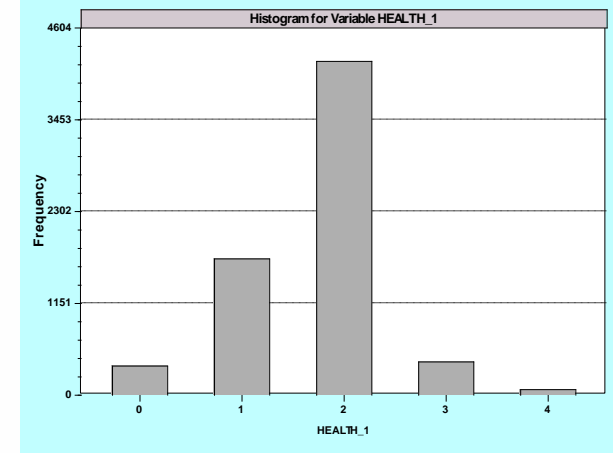| Model	Log LF	k	AIC	AICc	AIC3	ACIu	BIC	CAIC
Probit Model	-27,071.57	41	54,225.14	54,225.21	54,266.14	54,267.22	54,590.00	54,631.00
LCOPM (2C)	-26,070.16	83	52,306.32	52,306.58	52,389.32	52,390.64	53,044.94	53,127.94
LCOPM (2C with sep. var.)	-26,053.91	84	52,275.82	52,276.09	52,359.82	52,361.15	53,023.34	53,107.34

Class 1:

Questions related to self-assessed health may show an inaccurate reporting (Greene *et al.*, 2015).
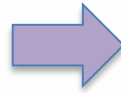
Class 2:
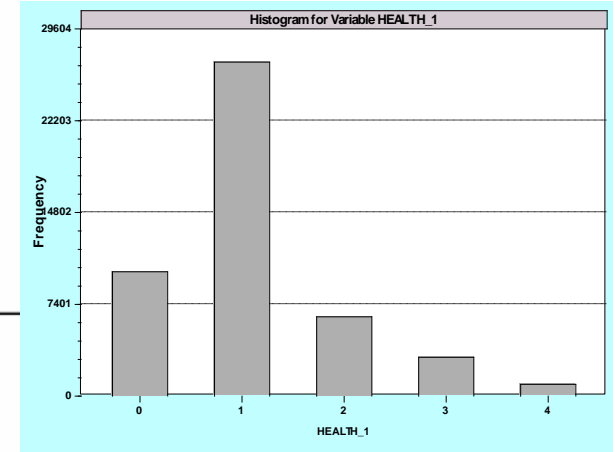
Characteristics of the classes
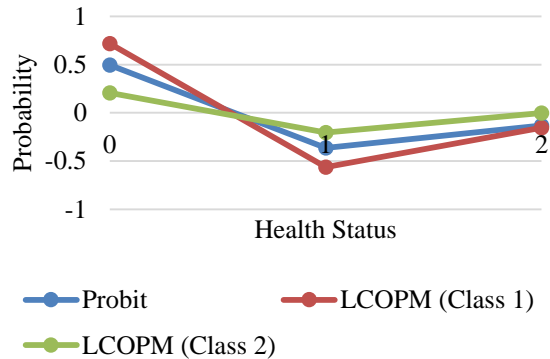
	Number of obs.	Percentage	Chronic Condition	Income	Leak	FPI	Mat. Dep.	Affordability
Total	54,125	100%	70.10%	44,881	84.16%	6.28	9.66%	8.25%
Class 1	6,742	12.5%	64.64%	43,356	82.26%	0.53	11.47%	10.74%
Class 2	47,383	87.5%	70.88%	45,098	84.42%	7.10	9.41%	7.90%
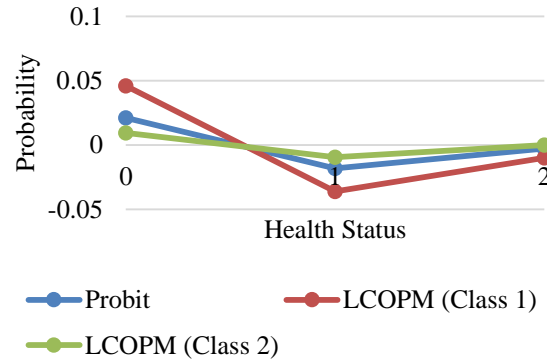
Partial effects on the response probabilities
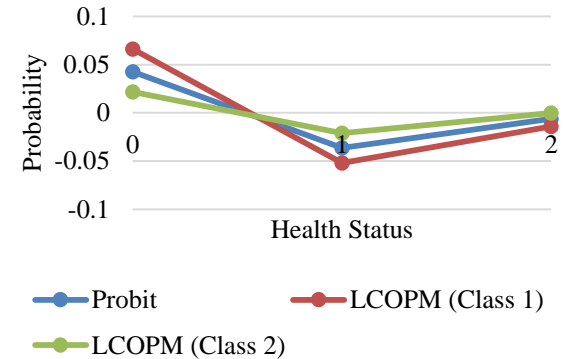
$$\frac{\partial P_m(X)}{\partial X_k}$$ (at means)

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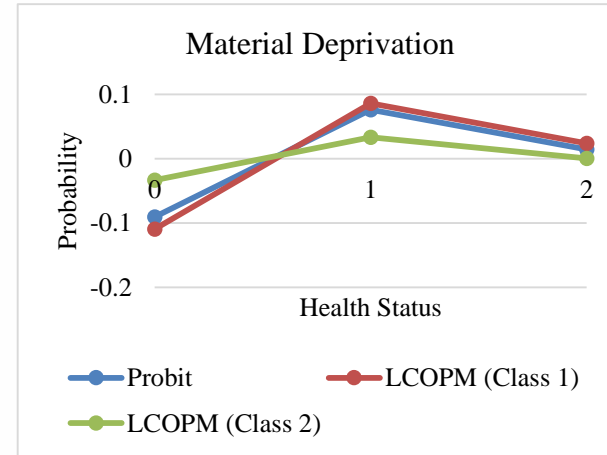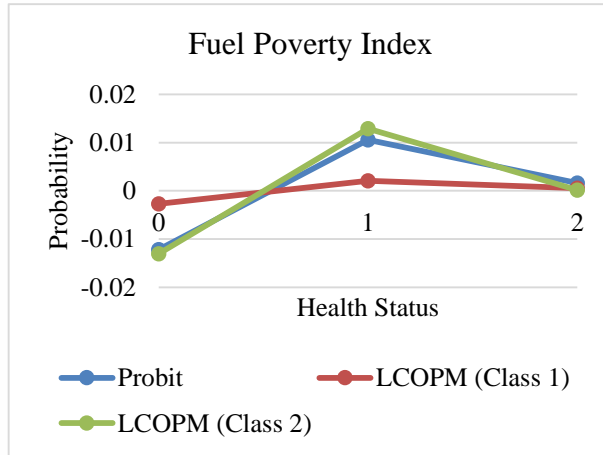
Conclusions

- Fuel poverty is a growing concern in many European countries and particularly in Spain.

- Classifying households using a subjective measure of fuel poverty yields different results from the use of objective measures.

- This issue may also bias the results when analysing the effect of fuel poverty on health.

- If objective measures of fuel poverty are used, subjectivity needs to be controlled.

APPENDIX

Fuel poverty in Spain

Electricity and gas prices in EU countries (2nd half of 2016)
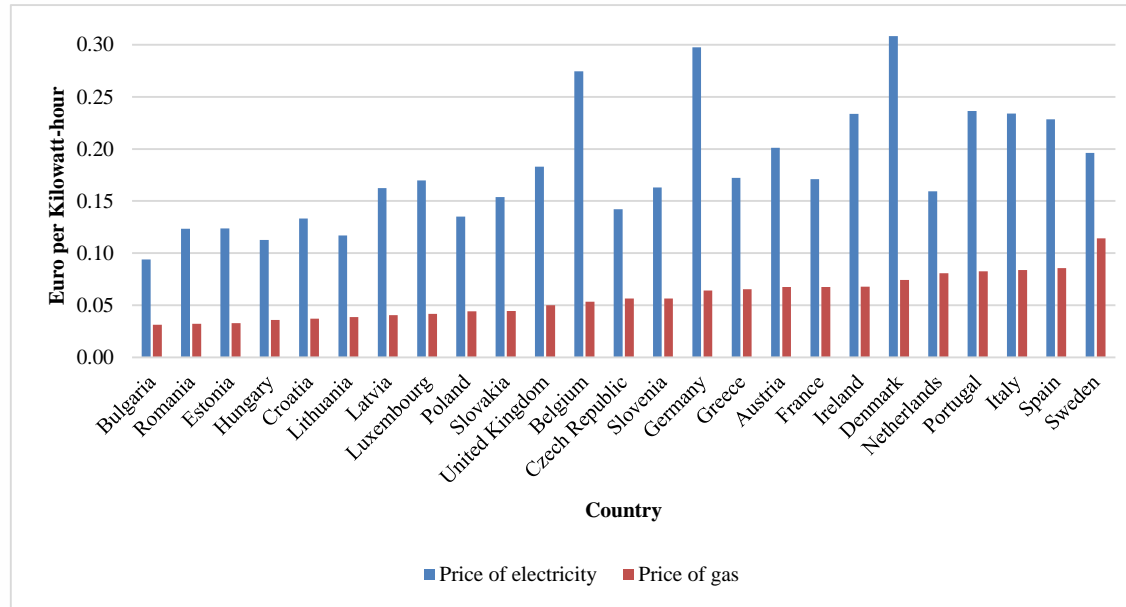
Source: Eurostat (data of gas prices not available for Cyprus, Malta and Finland)

- Descriptive statistics

Variable	Mean	S.D.	Min.	Max.
Health status	1.19	0.88	0	4
Chronic condition	0.70	0.46	0	1
Age	49.87	18.59	16	88
Employment status	4.91	3.21	1	11
Gender	0.52	0.50	0	1
Marital status	1.98	0.97	1	5
Education	2.53	1.43	1	5
Income	44,881.04	33,070.78	0.14	569,967.20
Flat	0.62	0.49	0	1
Leak	0.84	0.37	0	1
FPI	6.28	574.85	0.01	84,929.55
Material Deprivation	0.10	0.30	0	1
Affordability	0.08	0.28	0	1

Matrix of correlations

	Health st.	Chr. cond.	Age	Emp. Sit.	Gender	Marital st.	Education	Income	Dwelling	Leaks	FPI	Mat. depriv.	Afford.
Health st.	1	-0.59133	0.48989	0.31496	0.07647	0.27772	-0.30113	-0.13952	-0.06508	-0.07845	-0.00221	0.07566	0.07244
Chr. cond.	-0.59133	1	-0.37973	-0.27194	-0.05058	-0.2135	0.21336	0.07964	0.03848	0.06618	0.00451	-0.03992	-0.04616
Age	0.48989	-0.37973	1	0.39617	0.05469	0.52096	-0.32713	-0.0824	-0.05323	0.0302	-0.00267	-0.06986	-0.03513
Emp. Sit.	0.31496	-0.27194	0.39617	1	0.24414	0.18543	-0.39659	-0.18709	-0.07937	-0.02129	0.00431	0.04877	0.04065
Gender	0.07647	-0.05058	0.05469	0.24414	1	0.16824	-0.01658	-0.03153	0.023	-0.00118	0.00227	0.00589	-0.00233
Marital st.	0.27772	-0.2135	0.52096	0.18543	0.16824	1	-0.17225	-0.11812	0.00186	-0.00303	-0.00268	0.01856	0.02048
Education	-0.30113	0.21336	-0.32713	-0.39659	-0.01658	-0.17225	1	0.31618	0.1418	0.07209	0.00601	-0.11992	-0.09401
Income	-0.13952	0.07964	-0.0824	-0.18709	-0.03153	-0.11812	0.31618	1	0.07287	0.1025	-0.0141	-0.1915	-0.14211
Dwelling	-0.06508	0.03848	-0.05323	-0.07937	0.023	0.00186	0.1418	0.07287	1	0.14953	-0.01259	0.00033	-0.02975
Leaks	-0.07845	0.06618	0.0302	-0.02129	-0.00118	-0.00303	0.07209	0.1025	0.14953	1	-0.01075	-0.15264	-0.13651
FPI	-0.00221	0.00451	-0.00267	0.00431	0.00227	-0.00268	0.00601	-0.0141	-0.01259	-0.01075	1	-0.00292	-0.00274
Mat. depriv.	0.07566	-0.03992	-0.06986	0.04877	0.00589	0.01856	-0.11992	-0.1915	0.00033	-0.15264	-0.00292	1	0.67694
Afford.	0.07244	-0.04616	-0.03513	0.04065	-0.00233	0.02048	-0.09401	-0.14211	-0.02975	-0.13651	-0.00274	0.67694	1