EXTENDED ABSTRACT

Title: Energy poverty across Spain: before and during the pandemic

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Abstract: *(minimum1500 words)*

Energy poverty is not a new phenomenon in Spain and in many other European countries (Bouzarovski, Petrova, and Sarlamanov 2012; Halkos and Gkampoura 2021). In fact, it is a structurally problem, present in many Spanish households before the Covid-19 emerged. However, the economic disruption thus far caused by the Covid-19 pandemic has excecated pre-existing inequalities related to energy affordability.

The debate in Europe about the problem of energy poverty is more present than ever, not only as an energy issue but also as a broader social concern related to climate change, poverty, and health deprivation (European Commission, 2020; 2021). During last decade an important part of the academic literature has focused its efforts on the dominant discussions on the concept and metrics of the energy poverty (Moore 2012; Romero, Linares, and López 2018; Tirado Herrero 2017), however the identification of the drivers behind the energy poverty is still widely debated with ambiguous and heterogeneous results. Furthermore, as the EU Energy Poverty Advisory Hub (2022) has recently highlighted the identification of households at risk of energy poverty should be more accurate at regional level since different contexts may require tailored policies. Spain is a country characterized by profound regional differences in socioeconomic characteristics and climatological conditions that deservers special attention. Although many studies in this field have already carried out at national level,

they only show a static identification of the energy poverty in a certain period of time, showing an incomplete picture of the whole problem. Understanding the determinants of being energy poor at regional level and the new forms of vulnerability among population, is fundamental for evaluating the potential that public policy can have in attempting to eradicate the persistent problem of energy poverty.

In response, the main purpose of this study is to analyse the critical drivers of households falling into a situation of energy vulnerability at regional level. This aim is pursued through econometric analyses, based on an exhaustive sample of more than 300,000 households extracted from the Spanish Household Budget Survey (HBS) for the period 2006-2020. Apart from providing an update on the current extent of energy poverty in Spain, we contribute to the existent literature and the ongoing debate on energy poverty in several ways. First, exploring the incidence, evolution, and determinants of energy poverty in Spain in the period 2006-2020, offers the possibility to examine four distinct economic periods. Second, to account for the multi-dimensional nature of energy poverty, we use different energy poverty indicators. This allows us to identify differences and similarities in the determinants of the energy poverty. Finally, we analyse energy poverty as a spatially uneven phenomenon quantifying the effects of energy poverty determinants at a national level.

The empirical analysis draws on data taken from the two sources of information. The main one is the Spanish Household Budget Survey (HBS) providing household level data on energy expenditure and a wide variety of socioeconomic variables. This database is complemented with extreme temperatures at the regional level. The HBS is carried out annually by the Spanish National Statistics Institute containing data for 19,000-23,000 Spanish households per year. In this study we use data for the period 2006-2020 comprising a total of 312,400 Spanish households. The survey contains an extensive variety of expenditure data. Of particular interest for this study are the expenditures on energy (electricity, liquid gas, natural gas, combustible liquids, and solid fuels in the main home). Additionally, the database contains a rich set of socioeconomic variables such as income profile, house characteristics, household composition, labour market among others that allow us to characterize the main living conditions of the household. This data is key to understand the determinants of energy poverty.

Furthermore, we consider the climatic conditions as key determinant of energy poverty since extreme temperatures are a driver of energy consumption. To do so, we use heating degree days (HDD) and cooling degree days (CDD) statistics from Eurostat at regional (NUTS2) level**.**

There is no consensus for using one particular indicator but rather the literature has agreed the need to use a variety of indicators for quantifying energy poverty. It is important to realize that although very different in construction, these indicators provide different perspectives for understanding a complex multi-dimensional problem However, the diversity of the indicators, each one with its advantages and disadvantages, leads at the same time to a variety of results that can make it difficult to achieve a clear conclusion on the evolution of energy poverty. Because of data limitation, this analysis uses 4 different energy poverty indicators based on the expenditure approach where domestic energy expenditure is compared to income (10%, high share of energy expenditure in income (2M), hidden energy poverty (HEP), Low Income High Cost (LIHC)).

Then, if:[1,2]

- EE_{it} is the energy expenditure of household *i* in period *t*
- $\widetilde{EE}_t$ is the country median energy expenditure in period *t*
- Inc_{it} is the income of household *i* in period *t*
- $\widetilde{Inc}_t$ is the country median income in period *t*
- EE_{it}/UC_{it} is the energy expenditure by unit of consumption of household *i* in period *t*
- $\widetilde{EE_{it}}_t/UC_{it}$ is the country median expenditure by unit of consumption in period *t*

The four energy poverty indicators are defined as follows:

- **10% energy expenditure in income indicator (10%):** a household is energy poor if its energy expenditure is greater than or equal to 10% of its income.

$$EE_{it} > 0.1 * Inc_{it}$$

- **High share of energy expenditure in income (2M):** a household is energy poor if its energy expenditure share on income is more than twice the national median share.

$$(EE_{it}/Inc_{it}) > 2 * (\widetilde{EE}_t/\widetilde{Inc}_t)$$

- **Hidden energy poverty (HEP):** a household is energy poor if its energy expenditure per unit of consumption (UC) is less than half of the national median.

$$(EE_{it}/UC_{it}) < 0.5 * (\widetilde{EE/UC_t})$$

- **Low Income High Cost (LIHC):** a household is energy poor if its energy costs are above the national median level and the residual income after energy expenditures below the 60% median residual income or poverty line:

$$EE_{it} > \widetilde{EE}_t$$
$$Inc_{it} - EE_{it} < 60\% * (\widetilde{Inc}_t - \widetilde{EE}_t)$$

Table 1 reports gives an overview of the trends of energy poverty by energy poverty indicator and according to the distinct economic periods (pre-crisis 2008, crisis and austerity 2009-14, recuperation 2015-19 and Covid-19 crisis 2020).[3] The evolution of the different energy poverty indicators since 2006 show that each indicator follows a distinctive path.

Table 1. Evolution of energy poverty in Spain

	10%	2M	HEP	LIHC
Pre-crisis (2006-08)	8.08	18.82	16.12	7.48
Crisis-recession (2009-14)	15.35	18.92	14.72	8.30

[1] The net income is obtained by annualising the total monthly net incomes of the households, while the expenditure on energy of the household takes the annual expenditure on the following categories into account, only considering the principal residence: 1) Electricity: expenditure on electrical energy, contract charges for light, renting and reading of meters. 2) Town and natural gas: expenditure on town gas and natural gas, gas contract charges, renting and reading of meters. 3) Liquefied petroleum gas: expenditure on butane and propane gas, renting and reading of meters, bottles, and containers for these gases. 4)Combustible liquids, expenditure on heating oil, fuel oil. 5) Solid fuels, expenditure on coal, coke, coal agglomerations, wood, vegetable coal, and peat.

[2] All monetary variables were deflated using the Price Index of the National Statistics Institute (INE, Spain).

[3] Appendix 1 shows the evolution of energy poverty in Spain and the unemployment rate.

Recuperation (2015-19)	12.88	16.64	11.95	7.36
Pre-Covid 19 (2019)	11.53	15.16	11.41	6.22
Covid 19 (2020)	10.70	16.22	10.89	6.86

Source: Own elaboration.

Spain is a country characterized by profound regional differences in socioeconomic characteristics and climatological conditions. This is reflected in important regional differences in the energy poverty indicators (Table 2 & Figure 1). For example, considering the 10% and 2M indicators the relatively poor, rural, and cold regions of Castilla y León and specially Castilla la Mancha suffer from very high levels of energy poverty. These two regions are also the most affected by energy poverty using the LIHC indicator although the difference with the rest of the regions is much smaller. This is so because the LIHC indicator leaves out middle-income households that have large energy expenditures and are identified as poor by the 10% and 2M estimators. Finally, the HEP indicator delivers dramatically different conclusions. The HEP energy poverty indicator is the highest in the Canarias region (32.87%), a region with very low energy expenditures and with an extremely benign climatical conditions. The HEP indicator differs dramatically from the other three indicators. For example, the before mentioned region of Castilla la Mancha has a relatively low incidence of energy poverty using the HEP indicator despite being the worst performing region when using the 10%, 2M and LIHC indicators.

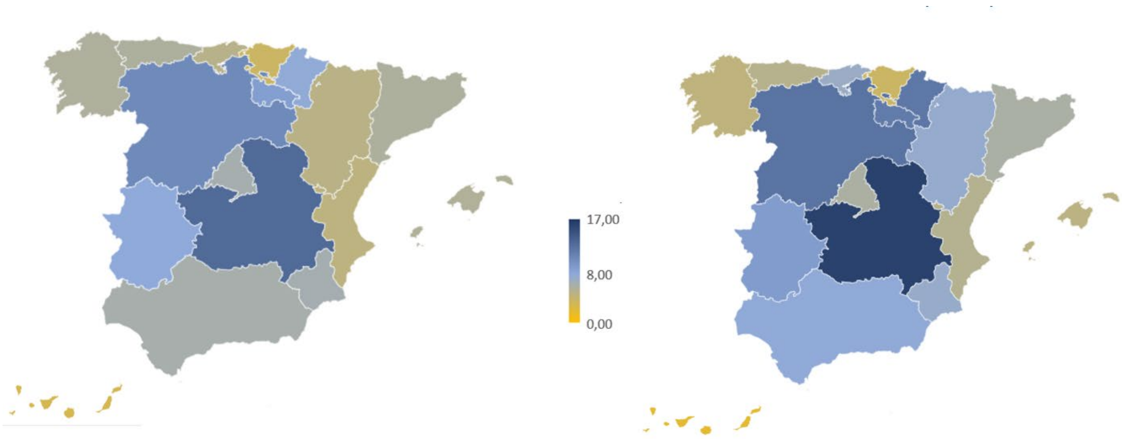
Table 2. Average energy poverty profile by autonomous communities (pooled sample 2006-2020)

			Energy poverty indicator			
Autonomous Communities	**Household income**	**Energy expenditures**	**10%**	**2M**	**HEP**	**LIHC**
Andalucía	20,441.73 €	864.35 €	12.93%	17.93%	17.62%	8.40%
Aragón	23,416.24 €	1,175.50 €	16.21%	22.80%	9.85%	8.46%
Asturias	24,523.33 €	944.12 €	8.81%	13.22%	13.21%	5.83%
Baleares	25,469.04 €	1,072.61 €	10.82%	15.15%	11.35%	5.85%
Canarias	20,493.68 €	616.38 €	7.59%	10.02%	32.87%	3.67%
Cantabria	23,116.11 €	1,037.63 €	11.89%	17.43%	10.45%	7.18%
Castilla la Mancha	20,603.06 €	1,302.59 €	26.71%	35.04%	9.75%	15.88%
Castilla y León	22,452.76 €	1,194.73 €	20.18%	27.26%	9.82%	12.59%
Cataluña	25,378.50 €	1,105.77 €	12.12%	16.97%	10.54%	6.93%
Comunidad Valenciana	22,009.31 €	881.52 €	9.90%	14.21%	18.24%	6.02%
Extremadura	18,181.43 €	933.32 €	17.07%	23.60%	18.44%	11.30%
Galicia	22,176.03 €	1,016.09 €	13.51%	18.92%	15.32%	7.60%
La Rioja	23,001.11 €	1,191.57 €	17.78%	24.96%	7.58%	11.13%
Madrid	28,094.36 €	1,155.71 €	11.18%	16.00%	8.14%	6.59%
Murcia	21,872.96 €	942.57 €	13.56%	18.40%	15.61%	8.36%
Navarra	25,949.82 €	1,248.99 €	15.58%	21.62%	6.02%	8.84%
País Vasco	28,011.85 €	1,002.61 €	6.86%	10.89%	9.87%	4.80%

Source: Own elaboration.

Figure 1. Energy poverty incidence by Autonomous Community according to LIHC indicator

Pre-covid 19 (2019) **Covid-19 (2020)**



Source: Own elaboration.

In order to characterize the probability that a household is in a situation of energy poverty a discrete choice univariate probit is used. To do this a dichotomous dependent variable was constructed (Y_{it}) that takes the value 1 when a household is in a situation of energy poverty according to each indicator and 0 when a household is not considered to be energy poor.

The specification used was as follows:

$$\begin{aligned} \Pr\,(Y_{it} = Energy\ poor \mid X) \\ = \Phi\,(\beta_0 + \delta_1 rural_{it} + \delta_2 old\ home_{it} + \delta_3 apartment\ building_{it} \\ + \delta_4 num.rooms_{it} + \delta_5 unemployed\ + \delta_6 retired \\ + \delta_7 higher\ education + \delta_8 internet + \delta_9 one\ person_{it} \\ + \delta_{10} one\ parent_{it} + \delta_{11} one\ person\ female_{it} \\ + \delta_{12} one\ parent\ female_{it} Freelancer_{it} + \beta_{13} Business\ owner \\ + \beta_{14} Transport\ and\ comunication + \beta_{15} Hotels\ and\ restaurants \\ + \beta_{16} Construction + \beta_{17} Manuacturing + \beta_{18} Energy\ sector \\ + \delta_{19} HDD_{it} + \delta_{20} CDD_{it} + \varepsilon_i) \end{aligned}$$

where Pr stands for probability, the matrix of explaining variables (X) contains a set of determinants that explain whether a home is considered to be energy poor, β corresponds to the vector of coefficients to be estimated and reports the effect of a variable on the latent propensity for a positive result, Φ is the cumulative distribution function of the standard normal distribution, and finally, ε_i is the idiosyncratic error term.

In particular, in order to capture the multifaceted nature of energy poverty we include a set of independent variables that the empirical literature lists as determinants of energy poverty in capturing factors related to: (1) dwelling characteristics, (2) socio-economic characteristics of the household, (3) market labour characteristics, and finally, (4) climate factors showing the extreme temperatures (Table 4).

Preliminary results of this empirical exercise point out towards relevant policy considerations. Firstly, Energy poverty tend to worsen during the economic crisis and the probability of being energy poor is higher for those who are retired and women living alone. Our empirical results also point the importance of the economic activity performed by the household members in determining the probability of being energy poverty. The results furthermore draw attention to the enormous regional differences on the energy poverty rates.

There is little doubt that energy poverty is a structural problem in Spain and is likely to persist in coming years in consequence of Covid-19 effects and the energy price increases due to Ukraine crisis. For these reasons, the analysis and research interests on energy poverty is now more important than ever, to set up a more comprehensive understanding of the magnitude and the root of this problem, which is an essential step towards an effective just energy transition.

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