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# The effect of regional factors on energy poverty

Elisenda Jové-LLopis
*Department of Economics, Chair of Energy Sustainability and Barcelona Institute of Economics (IEB), Universitat de Barcelona, Barcelona, Spain, and*

Elisa Trujillo-Baute
*Department of Economics and Business, University of Lleida, Lleida, Spain*

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## Abstract

**Purpose** – Within the framework of EU policies and measures to develop a just and fair green energy transition model. This paper aims to offer valuable insights into a paramount concern not so well debated in the literature, i.e. the spatial variation of energy poverty.

**Design/methodology/approach** – This empirical analysis investigates the regional variation of energy poverty we draw on a sample of more than 300,000 Spanish households, extracted from the Spanish Household Budget Survey (HBS) for the period 2006–2022. To characterize the probability of a household finding itself in a situation of energy poverty the authors use a discrete choice univariate probit model.

**Findings** – The results confirm that energy poverty is a phenomenon that is asymmetrically distributed across Spain, and mainly occurs in un-densely populated regions. In addition, the findings demonstrate that the incidence of energy poverty drivers is highly heterogeneous across regions.

**Research limitations/implications** – The paper ends with some recommendations for policymakers suggesting that countries need to design an energy poverty policy for the households that jointly pursue both a correct identification of vulnerable groups and a match with the type of measure to the characteristics of each region.

**Originality/value** – This study enhances previous research by considering the case of areas at a lower level of aggregation (i.e. on the NUTS two regions in Spain called autonomous communities) and offers the opportunity to tailor policies to those regions most in need. Furthermore, to provide a more realistic picture of the complex phenomenon of energy poverty, the authors use the information for the period 2006–2022 differentiating by economic micro-cycle. This timespan allows the authors to understand the dynamics of energy poverty in periods of economic crisis, including the effects of the 2008 crisis and the present global energy crisis.

**Keywords** Spain, Drivers, Energy poverty, Regional analysis, Energy economics

**Paper type** Research paper

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## 1. Introduction

The EU is strongly committed to reducing energy poverty and protecting vulnerable consumers through the adoption of specific policies, measures and recommendations designed to achieve a significant curtailment to a problem estimated to affect more than 40 million of its citizens (European Commission, 2023). Although the concept of energy poverty is not entirely new (see, for example, the pioneering contribution made by Brenda Boardman, 1991), the first EU-wide definition was not published until as late as 2023 in its Directive (EU) 2023/1791 on energy efficiency, indicative perhaps of the complexity of the phenomenon and the need to integrate government efforts across the social, energy, health and climate policy areas (Vandyck *et al.*, 2023). According to Art 2 (52) of this Directive, therefore, energy poverty can be understood to be "a household's lack of access to essential energy services, where such services provide basic levels and decent standards of living and health, including adequate heating, hot water, cooling, lighting, and energy to power appliances".

The current EU legal framework establishes that Member States have a duty to identify energy poor households in their National Energy and Climate Plans and to be active in their efforts to palliate and prevent energy poverty, prioritizing structural measures to address root causes of the problem. However, each Member State has tended to prioritize different instruments in their endeavors to protect vulnerable consumers, albeit with a marked top-down approach in which, in general, they have opted to implement one-size-fits-all policies for all regions (Mashhoodi *et al.*, 2019). Although such an approach, while setting the general framework, highlights the dimension of the problem (EPAH, 2022), it fails to impact the most vulnerable groups, making the adoption of a more specific, local perspective necessary so that this policy gap can be addressed (Creutzfeldt *et al.*, 2020).

An overview of the problem shows that energy poverty is an unevenly distributed phenomenon that asymmetrically impacts social groups and which is heavily dependent on the spatial context (Bardazzi *et al.*, 2021; Guevara *et al.*, 2023; Stojilovska *et al.*, 2022). While the literature no longer considers energy poor households a homogeneous group but rather concerns itself with identifying which social groups and household members (male, female, children, pensioners, the disabled, etc.) are most intensely affected by energy poverty (González-Pijuan *et al.*, 2023; Ivanova and Middlemiss, 2021), the links between energy poverty and its geographic dimension remain largely neglected despite their obvious relevance for policy initiatives (EPAH, 2022; Mashhoodi *et al.*, 2019; Okushima, 2019).

Despite acknowledging the importance of the regional dimension for the governance of energy poverty – both in the literature (Bouzarovski and Simcock, 2017; Creutzfeldt *et al.*, 2020; Stojilovska *et al.*, 2022) and in public policy documents (see the latest Commission Recommendation on energy poverty [1]) –, studies to date have tended to consider energy poverty determinants as being common at the country level, thereby ignoring the possibility that certain regional characteristics might not be generalizable and that the problem is better addressed by policies at the local level. This failing is attributable to the fact that energy poverty is a complex issue in what is a nascent debate on the required public policy (Guevara *et al.*, 2023; Stojilovska *et al.*, 2022), but also to a dearth of official statistical data, not only in terms of spatial disaggregation, but also as regards the continuity and updating of this data (EPAH, 2022).

This shortcoming is far from negligible if we recognize – as we have stressed above – that there is a need for energy poverty instruments that are designed and implemented at the regional level. It is against this backdrop that this study seeks to analyze the spatial distribution of energy poverty at this subnational level, an approach which we believe should enable policymakers to improve the impact of their energy poverty strategies. In so doing, we draw on data from the Spanish Household Budget Survey (HBS) for the period 2006–2022 to address the following two research questions: 1) Does the geographical dimension affect the probability of being energy poor? and 2) Do the drivers of energy poverty vary across the Spanish regions?

This study contributes to the literature on the spatial dimension of energy poverty in several ways. First, because the literature to date has been overly reliant on heterogeneous national contexts rather than on other geographical contexts (Costa-Campi *et al.*, 2024; Healy and Clinch, 2004; Legendre and Ricci, 2015; Oliveras *et al.*, 2021), here we are able to enhance extant findings by focusing on areas at a lower level of aggregation (i.e. on Spain's NUTS-2 regions or autonomous communities) and offer the opportunity for policies to be tailored to those regions most in need. Second, in seeking to provide a more realistic picture of the complex phenomenon of energy poverty, we draw on information for the period 2006–2022 differentiating by economic micro-cycles. More specifically, this timespan allows us to understand the dynamics of energy poverty in periods of economic crisis, including the effects of the 2008 crisis and the present global energy crisis. These fresh insights should prove valuable for policymakers when facing future emergencies or crises.

The remainder of this paper proceeds as follows. Section 2 presents the background to the study, briefly discussing regional differences in energy poverty; Section 3 describes the database and the main trends in energy poverty in Spain; and, Section 4 outlines our econometric methodology and reports the main findings. In Section 5 we derive various conclusions from our findings and discuss their policy implications.

## 2. Background literature review

Although research in the field of energy poverty initially focused on how to measure the extent of the problem – see Tirado Herrero (2017) and Gouveia *et al.* (2023) for a discussion of such indicators –, more recently the field has paid increasing attention to understanding household profiles exposed to energy poverty in its efforts to design the most suitable actions to address the problem. Indeed, the theoretical literature has identified the main drivers of the probability of being energy poor as a household's socio-economic characteristics, housing conditions and climate factors (Costa-Campi *et al.*, 2024; Stojilovska *et al.*, 2022). Here, however, we seek to look beyond these traditional drivers to provide a more nuanced understanding of those most vulnerable to energy poverty.

Additionally, therefore, we also incorporate an examination of the spatial dimension of the problem. The first major difference in spatial terms is marked by the conceptual contrast between the developed countries of the Global North and the developing countries of the Global South. Thus, while in the latter energy poverty is fundamentally a problem of access to adequate energy services, in the former the problem is that households cannot afford to pay their energy bills. However, this North-South dichotomy is clearly overly broad to reveal the differences between households within regions, making a more granular understanding necessary.

An in-depth analysis of the extant literature shows that the regional dimension of energy issues – particularly those related to energy vulnerabilities – is a relatively young line of research (Bouzarovski and Simcock, 2017; Castán Broto and Baker, 2018). The main focus of the burgeoning literature on energy poverty has been placed on the inequalities between socio-demographic groups and household members (in terms of gender, ethnicity, disability, children, etc.) at the expense of the impact of the spatial inequities operating at levels below that of the national level (i.e. regions and cities). Indeed, most studies to date refer either to single countries (Healy and Clinch, 2004; Legendre and Ricci, 2015) or undertake a comparison of countries (in an aggregate approach (Oliveras *et al.*, 2021; Thomson and Snell, 2013), while studies of regional differences remain very much the exception.

The importance of spatializing energy poverty has been stressed on more than one occasion (Bouzarovski and Simcock, 2017; Mulder *et al.*, 2023), since national statistics often paint a picture that is far removed from the reality on the ground and provide, as a result, a limited, inadequate image for public policymakers (EPAH, 2021). Consequently, it has been argued that greater attention be paid to defining territorial profiles of energy vulnerability, distinguishing between those determinants that might be spatially homogeneous and so affect all households equally across a given city, region or country and those that are clearly dependent on spatial characteristics (Mashhoodi *et al.*, 2019). The outcome of this concern has been an initial effort to quantify the incidence of energy poverty at the regional/local level and to examine location-specific determinants.

The characteristics of the home, specifically whether it has a rural or urban location, can impact on the probability of its being energy poor. It is typically believed that households in rural areas are at a disadvantage owing to the availability of different combustible materials at different prices. Moreover, rural housing stocks, it is argued, are characterized by significant proportions of large or isolated households that face difficulties in maintaining adequate thermal levels. However, empirical studies actually highlight the presence of considerable diversity in the impact of rural/urban location on energy poverty, ranging from negative through non-significant to moderately (or even strongly) positive links between location and energy vulnerability. For instance, in the UK, Robinson *et al.* (2018) and Roberts *et al.* (2015) report that urban energy poverty is more persistent than rural energy poverty; however, the latter recognizes that the rural energy poor are more vulnerable to energy price shocks. In a cross-European study, Pereira and Marques (2023) conclude that energy sources have differing impacts on energy poverty in areas with different levels of urbanization, and find that the consumption of primary energy sources (wood/biomass and natural gas) alleviates energy poverty in sparsely populated areas. In the case of The Netherlands, Mulder *et al.* (2023) find that energy poverty is not solely a problem of big cities but that it occurs in peripheral rural regions too. In Spain, Aristondo and Onaindia (2018) report that levels of energy poverty are higher in rural areas than in densely populated areas, and, more recently, Costa-Campi *et al.* (2024), in a study also of Spanish households, find evidence of a positive relationship between living in a rural area and the probability of being energy poor, although these estimates are only statistically significant prior to 2019. The highly varied nature of these results suggests that the relationship between degree of urbanization and energy vulnerability is especially complex and that it remains poorly understood; hence, there is a need for a greater research effort that can shed light on the links.

Another spatial dimension that has attracted the interest of researchers is the dependence of energy poverty on regional economic inequalities. In Italy, Bardazzi *et al.* (2021) assess whether the geographical variability of energy poverty is connected to income inequality and find that the latter correlates significantly with energy poverty. As such, the study highlights the importance of income redistribution policies as an instrument for reducing energy poverty rates not just at the national level, but also at the local level. In a similar vein, Mashhoodi *et al.* (2019), in an analysis of more than 2,450 neighborhoods in The Netherlands, show that low-income households are in danger of being diagnosed energy poor in all neighborhoods of the country, thus highlighting the need for policies that can provide these vulnerable groups with social protection. All in all, the literature suggests that labor force status, household composition and educational attainment – as reliable indicators of household income and social class – are highly correlated with energy poverty (Legendre and Ricci, 2015; Stojilovska *et al.*, 2022). In the case of Spain, two studies

Romero *et al.* (2018) and Costa-Campi *et al.* (2024) provide results in the same direction to the effect that Spanish households in which the main breadwinner is unemployed or has only primary studies or no education at all are more likely to be energy poor.

A number of recent studies have turned their attention to the impact of climate on energy poverty. In this specific line, Costa-Campi *et al.* (2024) report that areas of Spain with more extreme climates (either hot or cold) are associated with higher levels of energy poverty, a finding that is probably attributable to the higher energy demands for keeping a home cool or warm as required. Indeed, Kahouli and Okushima (2021) stress the pivotal role played by climatic and spatial differences in the prevalence of regional energy poverty, while Papada and Kaliampakos (2020) report higher energy poverty rates in regions with colder climates. In this regard, the literature has devoted considerable attention to winter vulnerability, but interest in summertime energy poverty is growing. Against a backdrop in which countries are exposed to increasingly extreme summer heatwaves and households are ill-equipped to counter these weather conditions, Sanchez-Guevara *et al.* (2019) assessed population exposure to high summer temperatures in Madrid and London and found that both cities include areas that are vulnerable to summer energy poverty, although Madrid was found to be at greater risk. Finally, Awaworyi Churchill *et al.* (2022) explore the effect of temperature shocks on the incidence of energy poverty in Australia and conclude that each additional cold day increases the magnitude of energy poverty, while global warming can be expected to result in modest reductions in energy poverty levels.

## 3. Data and statistical analysis

### *3.1 Data*

The data used in this study are drawn mainly from the Household Budget Survey (HBS) for Spain. The HBS is conducted annually by the National Statistics Institute and reports detailed information about consumer spending in approximately 24,000 Spanish households. Specifically, the database used in the empirical analysis covers the period 2006–2022 and comprises a total of 329,653 Spanish households – an average of 20,603 per year.

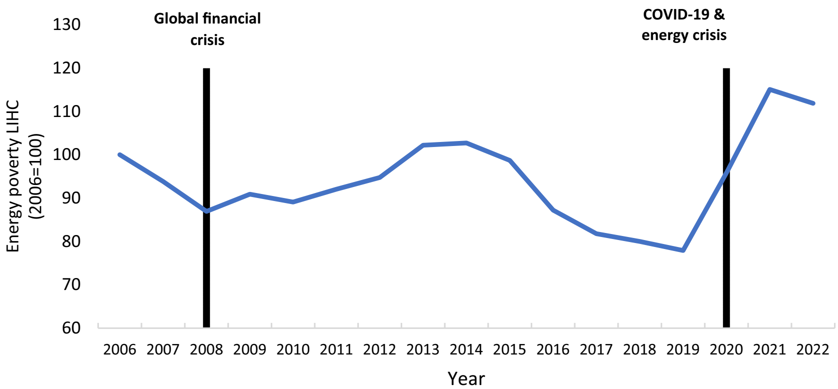
The HBS microdata provides information about household expenditure, including spending on energy by source: i.e. electricity, liquid gas, natural gas, combustible liquids and solid fuels. The survey also provides complete information about a rich set of variables related to the household's dwelling and its living conditions, some of which provide considerable insights into the spatial dimension of energy poverty. One of the main advantages of the Spanish HBS is that the microdata file contains the codes of the regions in which the households are located. These geographical data mean we are able to both calculate and compare the indicators of energy poverty at the NUTS-2 regional level. Indeed, most empirical databases only furnish aggregate information at the country level, so being able to exploit this dimension in the same database gives us a better understanding of energy poverty drivers at the regional level.

Additionally, and with the goal of isolating the effect derived from the climate conditions associated with household location, the database also includes information about the incidence of extreme temperatures at the NUT-2 level. Specifically, temperature variations are calculated as the sum of the differences in temperature between a certain constant indoor temperature and the mean daily outdoor temperature. Thus, we work with two indicators, published by Eurostat, referred to as heating degree days (HDD) and cooling degree days (CDD), where the former measures how much (in degrees) and for how long (in days), outside air temperature was *lower* than a specific base temperature and the latter measures how much (in degrees) and for how long (in days), outside air temperature was *higher* than a specific base temperature. As such, they reflect the influence of climate on energy poverty through the energy consumption required to heat and cool a building, respectively.

We use the low income–high cost (LIHC) indicator to measure the degree of energy poverty in our sample. This indicator considers a household to be energy poor if its fuel costs are high – i.e. above the national median – and its residual income, after energy expenditure, low – i.e. with a threshold set at 60% of the national median or the poverty line. The LIHC energy poverty indicator is characterized by its objectivity, quantifiability and comparability (Brabo-Catala *et al.*, 2024; Siksnelyte-Butkiene *et al.*, 2021). It is, moreover, adaptable to national standards, considering not only energy expenditure but also household income levels and, so, it addresses the issue from both income and cost perspectives (Hills, 2012). However, it should be noted that the indicator has been criticized for its complexity and lack of transparency when it comes to fixing thresholds. To overcome certain limitations, here, our metric employs 60% of both the median income and energy expenditure. More specifically, we adopt the method reported by Romero *et al.* (2018) – developed from Hills (2012) – where median energy expenditure is subtracted from median household income, thereby ensuring the consistency of terms in the equation. By adopting this formulation, we are able to overcome the additional potential problems identified by Robinson *et al.* (2018) associated with considering the median energy cost, this being, according to these authors, its main drawback. Given this debate, and while recognizing the limitations of relying exclusively on the LIHC as a measurement, this study opts to use this modified LIHC indicator to assess energy poverty in Spain.

### *3.2 Statistical analysis: trends in energy poverty*

Drawing on the data described above, we undertook an analysis of the trends and main regional characteristics of energy poverty in Spain. An examination of the evolution of the problem over the past two decades (see Figure 1) shows that the intensity of energy poverty has varied significantly over this period, with both positive and negative fluctuations in the order of up to 20% with respect to the first year (2006) in the sample. These fluctuations appear to be related to the economic cycle, with the two recent crises disrupting the downward trend in energy poverty rates: thus, the global financial crisis of 2008 resulted in a 15% increase in energy poverty intensity, while, more recently, the COVID-19 pandemic and energy price crisis led to an increase of almost 40%, with regard to their respective pre-

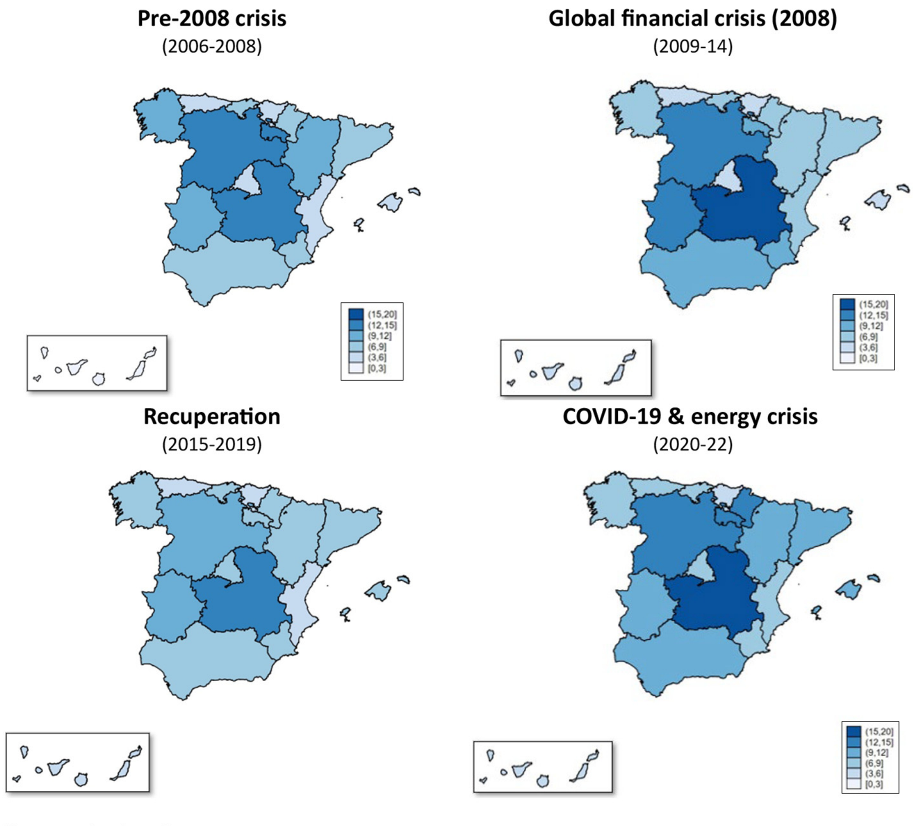



**Source:** Authors' own

**Figure 1.**
Average trend in energy poverty intensity, 2006–2022 (LIHC indicator mean values)

crisis levels. Moreover, the economic recovery after the 2008 crisis ushered in the lowest levels of energy poverty during the observation period, while measures implemented to counter the 2020 pandemic and energy prices crisis seem to be having the planned effect on rates of energy poverty. Typically, policy responses to crisis situations have comprised measures with a short-term impact, requiring the financing of programs on a recurring annual basis. In 2009, for example, a government discount scheme (or *bono*) was applied to electricity bills as a means of tackling energy poverty; yet, according to García Alvarez and Tol (2021), it has not had a significant effect. COVID-19 measures, including a disconnection ban for unpaid bills and the introduction of new categories of beneficiaries for the government's energy discount *bono*, were not only short-term in their impact (recurring nature), but also temporary and, therefore, eliminated some years after their implementation (Mastropietro, 2022).

The regional analysis of energy poverty trends (see Figure 2) shows that while some elements of the spatial distribution similarly depend on the economic situation, there is a group of regions, in the center of Spain (i.e. Castilla-La Mancha, Castile and León and Extremadura) – forming the *energy poverty ring* – that consistently record the highest energy poverty rates. The latter can be attributed to the fact these autonomous communities are characterized by areas with a high number of households living in single-family homes located in rural areas. Additionally, Castile and León is the coldest region in Spain and




**Source:** Authors' own

**Figure 2.**
Geographical trend in energy poverty (% LIHC indicator mean values)

Extremadura has the highest percentage of consumers at risk of social exclusion. In the case of the Mediterranean regions energy poverty levels are typically mid to low, but the intensity increased in the wake of the two crises of the last two decades. The same is true of Spain's richest regions, although the recovery after the global financial crisis resulted in the historically lowest levels of energy poverty. Thus, in line with Bagnoli and Bertoméu-Sánchez (2022) and Romero *et al.* (2018), we also detect a marked regional pattern in the distribution of energy poverty in Spain.

To gain an in-depth understanding of the regional characteristics of the problem – in line, for example with other related studies of a regional nature (e.g. Silvestri *et al.*, 2020), we mapped and classified the Spanish regions according to their static and dynamic performances in relation to energy poverty (see Figure 3). Thus, each Spanish NUT-2 region is plotted on the graph according to a pair of values determined by the static dimension (that is, the level of energy poverty at the beginning of the period) ($x$-axis) and the dynamic dimension (considered in terms of its cumulative growth over the period) ($y$-axis) of their respective energy poverty performance. In this way, we are able to classify the Spanish regions as follows:

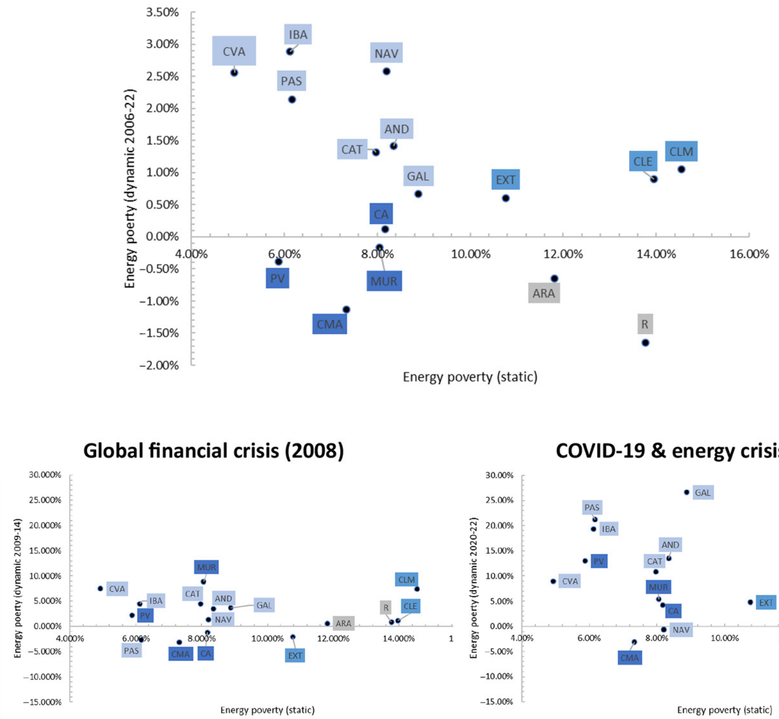



**Figure 3.**
Spanish autonomous communities according to energy poverty performance

**Note:** Group 1 On the right track: CA (Cantabria), CMA (Madrid), MUR (Murcia) and PV (Basque Country); Group 2 In need of attention: AND (Andalusia), CAT (Catalonia), CVA (Valencia), GAL (Galicia), IBA (Balearic Islands), NAV (Navarre), PAS (Asturias); Group 3 Trapped in energy poverty: CLM (Castilla-La Mancha), CLE (Castile and León) and EXT (Extremadura); Group 4 Fighters: ARA (Aragon) and R (La Rioja)
**Source:** Authors' own

Group 1 – labeled "On the right track" (bottom left quadrant) – is characterized by low levels of energy poverty at the beginning of the period (base level) and, moreover, it has succeeded in reducing these levels over time (2006–2022), reflecting, it would seem, the awareness generated in relation to the problem. The group includes some of the richest regions in Spain (Basque Country and Madrid) but also Cantabria and Murcia. Group 2 – labeled "In need of attention" (top left quadrant) – presents moderate levels of energy poverty at the start of the period (base level) but has experienced marked growth in these levels over time, suggesting a declining effectiveness in its efforts to combat energy poverty. The group includes many of the autonomous communities of the Mediterranean (Catalonia, Valencia, Andalusia and the Balearic Islands), and some of the more northerly autonomous communities (Navarre, Asturias and Galicia). Group 3 – labeled "Trapped in energy poverty" (top right quadrant) – is characterized by those autonomous communities with high poverty rates that circle the Community of Madrid. This energy poverty ring comprises Castilla-La Mancha, Castile and León and Extremadura. Finally, Group 4 – labeled the "Fighters" (bottom right quadrant) – and constituted by the autonomous communities of Aragón and La Rioja presented a high incidence of energy poverty at the beginning of the analysis but has since recorded negative growth in terms of energy poverty.

Overall, the graph shows that, while for some groups of regions the problem has remained relatively constant despite their different starting points in terms of energy poverty status (static level), some regions have responded better in their efforts to tackle energy poverty and protect vulnerable consumers. These regional trends and patterns highlight the need for a more exhaustive analysis of the spatial dimension of energy poverty in order to understand better the differences in the drivers of the problem.

## 4. Econometric analysis

### 4.1 Methods

Our econometric analysis seeks, therefore, to characterize the probability that a household finds itself in a situation of energy poverty in accordance with the characteristics of the four groups of regions identified above. To do so, we employ a discrete choice univariate probit model, in which the dichotomous dependent variable ($Y_{it}$) takes a value of 1 when a household is in a situation of energy poverty and 0 when it is not considered to be energy poor.

The general specification can be stated as follows:

$$\begin{aligned}
&\Pr(Y_{it} = \textit{Energy poor} \ \ | X) \\
&= \ \Phi \ (\beta_0 + \beta_1 \textit{dwelling characteristics}_{it} \\
&+ \beta_2 \textit{socio} - \textit{economic characteristics}_{it} \\
&+ \beta w \, 3 \ \textit{climate factors}_{it} \\
&+ \beta_4 \ \textit{regional factors}_i) + \varepsilon_i)
\end{aligned}$$

where Pr is this probability. Additionally, the matrix of explanatory variables ($X$) contains a set of determinants that explain whether a home can be considered energy poor, $\beta$ corresponds to the vector of coefficients to be estimated and reports the effect of a variable on the latent propensity for a positive result, $\Phi$ is the cumulative distribution function of the standard normal distribution and, finally, $\varepsilon_i$ is the idiosyncratic error term.

To capture the diversity of energy poverty drivers, we include a set of independent variables that the empirical literature lists as determinants of energy poverty and which

| Variable | Definition of the variable | Mean |
|---|---|---|
| *Characteristics of the dwelling* | | |
| Rural | Dichotomous variable that takes the value 1 if the home is located in a rural area; 0 if not | 0.187 |
| Old home | Dichotomous variable that takes the value 1 if the home was constructed 25 or more years ago; 0 if not | 0.653 |
| Apartment building | Dichotomous variable that takes the value 1 if the building in which the home is located contains more than one home; 0 if not | 0.656 |
| Number of rooms | Number of rooms the home contains | 5.183 |
| *Socio-economic characteristics of the household* | | |
| Unemployed | Dichotomous variable that takes the value 1 if the main wage-earner in the household has no paid employment or independent employment, is currently seeking employment and is available for work; 0 if not | 0.054 |
| Retired | Dichotomous variable that takes the value 1 if the main wage-earner in the household is retired; 0 if not | 0.295 |
| Higher education | Dichotomous variable that takes the value 1 if the main wage-earner has a higher education (university education and/or higher level professional or technical training); 0 if not | 0.306 |
| One-person household | Dichotomous variable that takes the value 1 if the household comprises one person; 0 if not | 0.029 |
| One-parent household | Dichotomous variable that takes the value 1 if the household comprises one parent and at least one child in her/his care; 0 if not | 0.169 |
| *Climate factors* | | |
| Heating degree days (HDD) | Napierian logarithm of the annual regional values of the HDD indicator | 7.388 |
| Cooling degree days (CDD) | Napierian logarithm of the annual regional values of the CDD indicator | 4.808 |
| *Regional factors* | | |
| Group 1–4 | Dichotomous variable that takes the value 1 if the household is located in a region of the group; 0 if not<br>Group 1: the Basque Country, Madrid, Murcia and Cantabria<br>Group 2: Catalonia, Andalusia, Navarre, Asturias, the Balearic Islands, Valencia and Galicia<br>Group 3 Castile and Leon, Castilla-La Mancha and Extremadura<br>Group 4: Aragon and La Rioja | |

**Source:** Authors' own work

**Table 1.**
Definition of variables

capture factors related to the following four dimensions (see Table 1): characteristics of thee dwelling place, socio-economic characteristics of the household, climate factors showing the extreme temperatures and regional characteristics.

Our approach allows us to identify not only economic, energy efficiency climatic drivers, but also the spatial dimensions of the problem. Using the four dummy variables that correspond to the groups of regions identified above, we can empirically capture all the sources of unobserved heterogeneity between groups, with respect to household energy vulnerability.

We performed three sets of regressions based on the above model. First, to test whether there are significant differences between groups in terms of their energy poverty intensity, with each regression taking the dummy corresponding to one region. Second, we split the sample into different subperiods to evaluate the differences in behavior of the groups in times of crisis, that is, if these effects are persistent or not. And, third, we estimate separate regressions for each group to test whether the drivers' effects differ from one group to another.

### *4.2 Results and discussion*

Overall, the results of our estimates point to significant differences in the intensity of energy poverty experienced by Spain's regions across the period considered (Table 2) and, in so doing, corroborate a nascent body of literature that highlights regional differences in energy vulnerability (Bouzarovski and Simcock, 2017; Mashhoodi *et al.*, 2019). As such, these findings stress the need to undertake studies that examine both the effect of social factors in tandem with regional variables if we are to achieve a better understanding of the determinants of energy poverty. More specifically, our estimates show that when a household is located in one of the Group 3 regions – i.e. "Trapped in energy poverty" – it is more likely to be energy poor than one of its counterparts located in another group. This result is consistent with the *energy poverty ring* described in the maps and, hence, is indicative of the need for policies that prioritize the energy needs of these regions. Interestingly, the households at least risk of suffering energy poverty are those located in the Group 1 (i.e. "On the right track") and 2 (i.e. "In need of attention") regions, which present similar probabilities of energy poverty. In this respect, our results are in line with the findings reported by Aristondo and Onaindia (2023), who report that the regions of the Basque Country and Madrid present the lowest percentages of energy poor individuals.

To evaluate how the differences between groups vary in times of crisis – that is, whether the differences are persistent or not, we performed two additional regressions using subsamples for the respective periods of crisis. The relevant marginal effects of three sets of estimations are summarized in Figure 4 as follows:

- for the whole period (2006–2022);
- for the global financial crisis (2009–2014); and
- for the COVID-19/energy crisis (2020–2022).

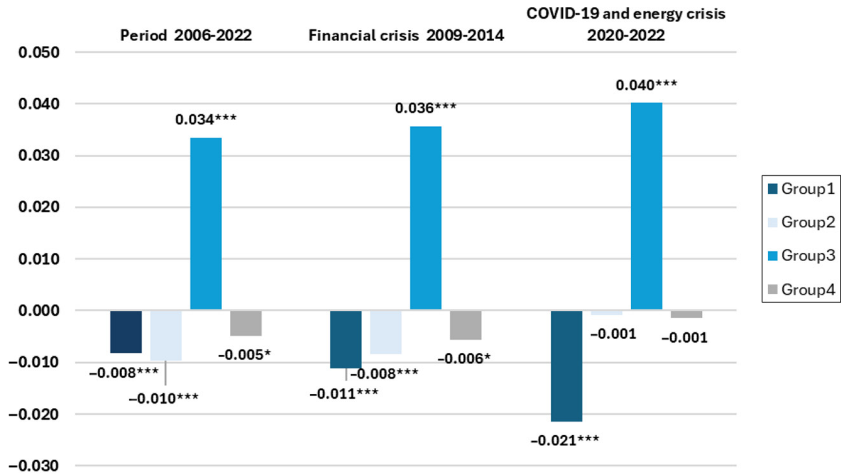
Although, Spain was one of the first countries to implement emergency measures in support of energy consumers (Mastropietro, 2022), our results show that the differences between groups intensified in time of crises, exacerbating the pre-existing imbalances. These findings are in line with those reported by Rodriguez-Alvarez *et al.* (2021) at the country level, who found that negative income shocks quickly increased energy poverty levels. Carfora *et al.* (2021), moreover, showed that the strict lockdown imposed as a result of the pandemic meant a significant shift in energy consumption away from places of work, study and leisure to family dwellings with high occupancy ratios. And, although Cansino *et al.* (2023) reported that the confinement period did not result in higher electricity consumption, Bienvenido-Huertas (2021) found that it was the vulnerable households that were hit hardest in terms of energy poverty because of their increased use of electrical appliances and low incomes.

The households located in one of the Group 3 regions – i.e. "Trapped in energy poverty" – are the ones that suffer the most from the negative effects of the crises, especially those associated with the recent COVID-19/energy crisis. Similar evidence is reported by Barrella *et al.* (2021), who show that the regions in this group lag behind in terms of underconsumption and suffer most from the negative shocks associated with the adverse conditions. In marked contrast are the households located in one of the Group 1 regions – i.e. "On the right track", which find themselves relatively less vulnerable to energy poverty during the crisis than the average household. The intensification of differences observed during the crises may be attributed to a confluence of factors, including the regional/local policies implemented in the wealthier regions and the lack of additional resources in the area formed by the *energy poverty ring*.

**Table 2.** Determinants of LIHC energy poverty indicator (marginal effects) 2006–2022

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| *Characteristics of the dwelling place* | | | | | |
| Rural | 0.0205*** (0.00162) | 0.0191*** (0.00162) | 0.0195*** (0.00162) | 0.0137*** (0.00158) | 0.0207*** (0.00163) |
| Old home | 0.0145*** (0.00111) | 0.0148*** (0.00111) | 0.0147*** (0.00111) | 0.0158*** (0.00111) | 0.0145*** (0.00111) |
| Apartment building | −0.0286*** (0.00144) | −0.0278*** (0.00143) | −0.0289*** (0.00144) | −0.0258*** (0.00143) | −0.0286*** (0.00144) |
| Number of rooms | 0.000391 (0.000462) | 0.000292 (0.000462) | 0.000313 (0.000463) | −0.000197 (0.000463) | 0.000394 (0.000462) |
| *Socio-economic characteristics of each household* | | | | | |
| Unemployment | 0.135*** (0.00393) | 0.134*** (0.00393) | 0.135*** (0.00394) | 0.133*** (0.00393) | 0.135*** (0.00393) |
| Retired | 0.0292*** (0.00129) | 0.0291*** (0.00129) | 0.0294*** (0.00129) | 0.0295*** (0.00130) | 0.0292*** (0.00129) |
| Higher education | −0.0624*** (0.00105) | −0.0620*** (0.00106) | −0.0625*** (0.00106) | −0.0612*** (0.00106) | −0.0625*** (0.00105) |
| One parent | 0.120*** (0.00551) | 0.120*** (0.00549) | 0.121*** (0.00553) | 0.120*** (0.00552) | 0.120*** (0.00550) |
| One person | 0.0692*** (0.00177) | 0.0690*** (0.00177) | 0.0692*** (0.00177) | 0.0684*** (0.00176) | 0.0693*** (0.00177) |
| *Climate factors* | | | | | |
| HDD | 0.0464*** (0.00233) | 0.0490*** (0.00228) | 0.0348*** (0.00264) | 0.0261*** (0.00257) | 0.0474*** (0.00244) |
| CDD | 0.00812*** (0.000471) | 0.00845*** (0.000467) | 0.00679*** (0.000484) | 0.00573*** (0.000501) | 0.00823*** (0.000479) |
| *Regional factors* | | | | | |
| Group 1 | | −0.00827*** (0.00124) | | | |
| Group 2 | | | −0.00970*** (0.00117) | | |
| Group 3 | | | | 0.0335*** (0.00171) | |
| Group 4 | | | | | −0.00484*** (0.00175) |
| Observations | | | 328,862 | | |

**Notes:** Estimates control for time dummies. Level of statistical significance: ***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors in parentheses
**Source:** Authors' own work




**Source:** Authors' own

**Figure 4.**
Regional differences in time of crises (marginal effects)

Having confirmed the presence of regional differences in the incidence of energy poverty, we then sought to evaluate any potential differences in the effects of the drivers. To do so, we performed a set of four estimates with subsamples, corresponding to each of the regional groups (see Table 3). Our results confirm that there are marked regional differences in the intensity of the effect exerted by the drivers of energy poverty and that these are relevant for all three types of driver considered: characteristics of the dwelling place, socio-economic characteristics of the household and climate factors.

In the case of the characteristics of the dwelling place, it is interesting to highlight the differentiated effects associated with a household being located in a rural area and with a dwelling place being 25 years old or more. These two factors are always positively associated with the probability of being energy poor, but the effect is considerably more marked in the case of rural areas for Group 4 households and old homes for Group 3 households. These results are consistent with the findings of Mulder *et al.* (2023) and Roberts *et al.* (2015), given that these two groups of regions are characterized by their large rural areas. In this specific context, policies should seek to improve the energy efficiency of such dwellings in an effort to alleviate the problem permanently.

In the case of the socio-economic characteristics of a household, our results indicate that those with low levels of income (i.e. associated with an unemployed head of the household) are at risk of energy poverty in all of Spain's autonomous communities, suggesting that this driver is more than likely spatially homogeneous and acts as a national driver. This outcome is consistent with the findings of Legendre and Ricci (2015) and Stojilovska *et al.* (2022) who report a strong correlation between the incidence of energy poverty and household income in different contexts. As such, national policies are required that continue to target general poverty and inequality as this forms very much part of the struggle to end energy poverty. In contrast, all the other factors present marked differences, with the most relevant impacts effecting households in Groups 3 and 4. In fact, in the case of the households in the Group 3 regions, the most notable effects are those associated with the higher education of the main wage-earner and being a one-person household; while in the case of those in the Group 4 regions, the most notable impact is associated with being a one-parent household. Results in

**Table 3.** Determinants LIHC energy poverty indicator (marginal effects) by group 2006–2022

| Variables | Total | Group 1 | Group 2 | Group 3 | Group 4 |
|---|---|---|---|---|---|
| *Characteristics of the dwelling place* | | | | | |
| Rural | 0.0205*** (0.00162) | 0.0126*** (0.00367) | 0.0161*** (0.00231) | 0.00908** (0.00373) | 0.0216*** (0.00545) |
| Old home | 0.0145*** (0.00111) | 0.0151*** (0.00203) | 0.0132*** (0.00151) | 0.0289*** (0.00333) | 0.0258*** (0.00366) |
| Apartment building | −0.0286*** (0.00144) | −0.0145*** (0.00310) | −0.0251*** (0.00182) | −0.0401*** (0.00386) | −0.0339*** (0.00626) |
| Number of rooms | 0.000391 (0.000462) | −0.000925 (0.001000) | −0.000285 (0.000599) | −0.000287 (0.00132) | 0.000468 (0.00175) |
| *Socio-economic characteristics of each household* | | | | | |
| Unemployment | 0.135*** (0.00393) | 0.134*** (0.00842) | 0.130*** (0.00512) | 0.144*** (0.00948) | 0.141*** (0.0162) |
| Retired | 0.0292*** (0.00129) | 0.0243*** (0.00247) | 0.0271*** (0.00176) | 0.0486*** (0.00362) | 0.0522*** (0.00456) |
| Higher education | −0.0624*** (0.00105) | −0.0588*** (0.00198) | −0.0536*** (0.00142) | −0.0996*** (0.00333) | −0.0622*** (0.00357) |
| One parent | 0.120*** (0.00551) | 0.0878*** (0.00879) | 0.125*** (0.00752) | 0.140*** (0.0157) | 0.171*** (0.0231) |
| One person | 0.0692*** (0.00177) | 0.0626*** (0.00346) | 0.0567*** (0.00233) | 0.124*** (0.00511) | 0.106*** (0.00631) |
| *Climate factors* | | | | | |
| HDD | 0.0464*** (0.00233) | 0.00444 (0.00509) | 0.0189*** (0.00352) | 0.148*** (0.0134) | 0.0227 (0.0951) |
| CDD | 0.00812*** (0.000471) | 0.00583*** (0.000754) | 0.00406*** (0.000626) | 0.0353*** (0.00369) | −0.0202** (0.00940) |
| Observations | 328,862 | 87,729 | 157,249 | 57,537 | 26,347 |

**Notes:** Estimates control for time dummies. Level of statistical significance: ***$p < 0.01$, ** $p < 0.05$, * $p < 0.1$. Robust standard errors in parentheses.
**Source:** Authors' own work

this same direction are reported by Romero *et al.* (2018) and Costa-Campi *et al.* (2024). These findings highlight the need for regional differences to be taken into consideration when implementing policies, as in fact occurred in the 2022 regulation of energy discounts, with the regional governments taking charge of the management of the *bonos*, with the option to increase the subsidy and to extend its coverage.

Finally, in the case of climate factors, the households located in the Group 3 regions are those that suffer most from energy poverty. The climate in this area – which coincides in part with the central plateau and is exposed to a more continental climate than the rest of the country – is characterized by both extreme winter and summer temperatures. This result – in line with the findings of Sanchez-Guevara *et al.* (2019) – highlights the need to implement actions that can adequately tackle the problems of climate change and the incidence of energy poverty. Indeed, energy efficiency policies can be expected to gain in relevance in the future, not only because of their potential long-term effects, but also because they mediate in the relationship between extreme weather conditions and energy poverty.

## 5. Conclusions

Analyzes of the determinants of energy poverty have evolved from the blanket consideration of the drivers of a country's energy poor households as a homogeneous whole to an approach that incorporates the phenomenon's geographical dimension and recognizes the significance of location-specific drivers. Here, in seeking to understand the mixed outcomes of the burgeoning empirical research into the relationship between energy poverty and regional disparities, we have analyzed the spatial distribution of energy poverty across the NUTS-2 regions of Spain. And, although our findings are specific to the Spanish context, they contribute, we believe, to the extant literature on energy poverty in its concern with identifying the drivers of being energy poor.

Our study has allowed us to identify the regions that are at greatest risk of energy poverty and their evolution in this regard by undertaking a static and dynamic evaluation of the incidence of energy poverty. This exercise allows us to classify the Spanish regions in four groups which we label as follows:

(1) "On the right track" – regions with low levels of incidence and a good awareness of the problem;

(2) "In need of attention" – regions with moderate levels of energy poverty but with declining forces to combat energy poverty;

(3) "Trapped in energy poverty" – regions with high rates of energy poverty; and

(4) "Fighters" – regions with a high incidence of energy poverty at the beginning of the period of analysis but which have since reported a negative growth rate.

Our study has also revealed substantial regional disparities in the exposure of Spain's autonomous communities to the drivers of energy poverty. The literature highlights that energy poverty is influenced by a series of internal factors, including a household's socio-economic and dwelling characteristic; however, our results point to the importance of regional factors in the probability of being energy poor. Indeed, only one driver related to the socio-economic characteristics of the household (i.e. being unemployed) is identified here as being spatially homogenous, positioning it as a national-level driver of energy poverty. In contrast, all the other elements present considerable differences that have marked effects on the phenomenon, highlighting the fact that they can operate as local-level drivers.

These regional results have clear implications for politicians – especially at the present time when the Spanish government is actively engaged in formulating a new National Energy

Poverty Strategy – in their efforts to design policy actions that can address the specific situation of different groups of consumer. In a country where energy poverty remains a chronic problem and energy policy measures are largely ineffective, our findings suggest that policies need to accommodate those social groups most at risk of being energy poor as well as their obvious spatial dimension. Today, the Spanish policy framework to address this problem has a marked top-down component and the measures employed act mainly through the income mechanism, that is, the provision of short-term, palliative, financial relief to the most vulnerable. Specifically, the main instruments are the energy discount *bonos* and the disconnection ban; yet, these measures are applicable to all locations across Spain while we have shown that the drivers of energy poverty are spatially homogenous. While national policies can serve as a social shield, particularly for those on lower incomes and, therefore, at greater risk of energy poverty, what is required are local initiatives to combat energy poverty more effectively, especially for those households that find themselves in regions that are "trapped in energy poverty". Against this backdrop, it is essential to work with an ecosystem of agents that involves all levels of government, and which promotes cooperation between regional and local authorities, civil society and private sector entities.

At the government level, it is critical to continue in the deployment of specific energy support offices that can provide information on energy rights, awareness and education to all the households of an area. In this line, special mention should be made of the proliferation of Energy Advice Points throughout the city of Barcelona (Catalonia) since 2017 and, more recently, in the Valencian Community. These initiatives are deemed highly successful insofar as these offices serve as reference points in a neighborhood or region for energy transition while fostering relationships of trust. Another critical area in which all tiers of government must continue to strive for improvement is in that of simplifying administrative procedures and ensuring adequate levels of digitalization. Agile procedures have significant repercussions on the development of energy initiatives, facilitating operational capacity and execution times, above all in relation to such programs as the rehabilitation of buildings and local self-consumption initiatives. Local governments play a key role in gathering insightful information about households vulnerable to energy poverty via a range of different agencies including social services, energy advice points and housing and urban planning departments that offer subsidies, financial support, loans and credits. This information represents a valuable resource that should be leveraged to address energy poverty issues; however, to date, these data are exploited very little by professionals –including healthcare workers and firefighters – who are especially adept at identifying potentially vulnerable groups. The increased involvement of these professions could contribute significantly to identifying instances of energy poverty, leading to timely intervention by the social services.

Third-sector services can also play a crucial role in identifying individuals at risk of energy poverty, given their close relationship with these vulnerable communities and their management of aid programs with close ties to the problems of the energy poor. Indeed, their collaboration is vital for effectively targeting local interventions to combat energy poverty. Improving the systematization of data collection and sharing it with other social agents would greatly boost these efforts.

Finally, energy utility companies are well-positioned in relation to this issue given their extensive knowledge of the sector's technology and regulations. This expertise is especially valuable for those that work directly with vulnerable families. Understanding the electricity market, the different elements of an electricity bill and concepts such as energy communities requires qualified personnel. Utility companies also possess a wealth of data obtained using digital meters that can monitor household electricity consumption in real-time. The systematic use of these data could facilitate proactive measures to address energy poverty with a focus on prevention as opposed to reactive responses. However, here again, such data are significantly under-exploited by energy companies, but nevertheless they represent an opportunity to enhance the effectiveness of the fight against energy poverty.

Further research might usefully seek to address some of the limitations encountered in this study. First and foremost, the analysis reported here is carried out at the NUTS-2 level, but clearly more fine-grained information is needed to better identify territories with high levels of energy poverty. To be able to achieve this goal, the authorities would need to enhance data availability and, as a result, they would be better placed to make territorial-specific policy recommendations. Despite this limitation, the results obtained herein go some way to advancing understanding of the drivers of energy poverty and opening the door to an examination of this critical problem faced by many households at the regional level.

### Note

1. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:L_202302407

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**Corresponding author**
Elisenda Jové-LLopis can be contacted at: elisenda.jove@ub.edu

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