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Energy poverty and health: does the social energy tariff help?

Elisenda Jové-Llopis [a], Marta Trapero-Bertran [b], Elisa Trujillo-Baute [c,*]

[a] Department of Economics, Chair of Energy Sustainability and Barcelona Institute of Economics (IEB), Universitat de Barcelona, Spain
[b] Department of Economics and Business, Universitat de Lleida, Spain
[c] Department of Economics and Business, Universitat de Lleida and Barcelona Institute of Economics (IEB), Spain

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ABSTRACT

This study examines the impact on health outcomes of the social energy tariff, a policy tool in Spain designed to alleviate energy poverty. Energy poverty—being unable to afford adequate heating, cooling, or other energy needs— is linked to poor physical and mental health. Using a recursive bivariate probit model, we analyze data from the 2022 Spanish Living Conditions Survey, focusing on the health implications of energy poverty, measured through inadequate home temperature and delayed bill payments. The results show that, while the social energy tariff moderately reduces energy poverty —with only a 1 %–2 % decrease, its impact on improving health outcomes remains limited. The average treatment effect on the treated suggests that individuals experiencing energy poverty are significantly more likely to report poor physical and mental health, with a 7 %–23 % decrease in the likelihood of reporting good health. Our findings indicate that, although the social energy tariff provides some financial relief, structural solutions such as energy efficiency improvements and increased access to renewable energy are needed to address the broader health impacts of energy poverty. The study offers policy recommendations to enhance both energy access and public health, emphasizing the importance of integrating health considerations into energy poverty interventions.

1. Introduction

The intersection of energy poverty, the social energy tariff scheme,[1] and health outcomes is a critical area of research with significant implications for public health, social policy, and a fair transition. Energy poverty —defined as the inability to maintain homes at a comfortable temperature—affects more than 40 million Europeans (Eurostat, 2024), leading to adverse health outcomes and exacerbating social inequalities (Champagne et al., 2023; Ballesteros-Arjona et al., 2022).

Research has consistently shown that energy poverty is closely linked to poor health outcomes (Pan et al., 2021; Katoch et al., 2024). For instance, studies have found that individuals living in energy-poor households are more likely to suffer from respiratory diseases, cardiovascular problems, and mental health issues (Xu et al., 2022; Bentley et al., 2023). These health problems are often exacerbated by inadequate living conditions, such as dampness and poor insulation, which are common in energy-poor households (Polimeni et al., 2022). Furthermore, the stress and anxiety associated with the inability to afford adequate energy can significantly impact mental health and overall well-being (Carrere et al., 2022).

To address the issue of energy poverty, various countries have implemented social energy tariff schemes that provide financial assistance to low-income households to help cover their energy costs, thereby improving their living conditions and overall well-being (Kyprianou et al., 2019; Stojilovska et al., 2022). Designed to alleviate energy poverty, these schemes have gained traction as a policy tool for mitigating the associated health impacts. Although evidence suggests these schemes may reduce healthcare costs and improve health outcomes (Bentley et al., 2023; Polimeni et al., 2022), their overall effectiveness remains underexplored (Rodrigo et al., 2024). There is also a need to integrate economic evaluations into policy assessments to better understand their long-term sustainability (Jacques-Aviñó et al., 2019).

This research aims to fill these gaps by investigating the effectiveness[2] of the social energy tariff in Spain, the main policy response to

* Corresponding author.
E-mail address: elisa.trujillo@udl.cat (E. Trujillo-Baute).

[1] Social energy tariffs are a price regulation measure specifically designed to protect vulnerable consumers with limited financial resources, typically through discounts on their bill or energy, special tariffs, or vouchers (European Commission, 2023).

[2] The effectiveness of the social energy tariff is defined as its capacity to achieve its primary objectives: alleviating energy poverty among vulnerable households and improving associated health outcomes.

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energy poverty in the country. Specifically, it seeks to evaluate the impact of this policy on the health and well-being of its recipients, contributing new insights into the relationship between energy poverty, social policy, and health outcomes. The ultimate goal is to inform policymakers and stakeholders about the importance of integrating health considerations into social and energy policies to improve the well-being of vulnerable populations.

This study contributes to the literature on energy poverty in several ways. Firstly, it focuses on the analysis of the case in Spain, a country that has recently been identified as having the highest rate of energy poverty in the European Union, making it one of the most vulnerable countries to this issue (Eurostat, 2024). Secondly, while previous studies have demonstrated an association between energy poverty and adverse health outcomes, few have quantified the extent of this public health issue in Spain or linked a policy aimed at reducing energy poverty to the health outcomes of its beneficiaries. Thirdly, although European countries have implemented several measures to tackle energy poverty (European Commission, 2023), there has been little focus on evaluating the effectiveness of these policies (García-Alvarez and Tol, 2021). By analyzing the Spanish social energy tariff, this study provides evidence on how such interventions can reduce health burdens and lower healthcare costs within the National Health System as it exists in Spain. Additionally, it offers guidance for policymakers on integrating health impacts into energy and social policies, demonstrating how these measures can enhance both health outcomes and system efficiency.

The remainder of this paper proceeds as follows: section 2 presents the background to the study, briefly discussing the emerging links between energy poverty, social energy schemes, and health; section 3 describes the database and outlines our econometric methodology; and section 4 reports and discusses the main findings. In the last section, we draw various conclusions from our findings and discuss their policy implications.

2. Background literature review

2.1. Tackling energy poverty through policy intervention

In recent years, the commitment of the European Union and its member states to reducing energy poverty has reached levels that were scarcely imaginable just over three decades ago (European Commission, 2023), when the first specialized literature was being established with the seminal contribution of British scholar Boardman (1991). The UK researcher laid the groundwork for a progressive understanding and scope of energy poverty. In fact, energy poverty was not incorporated into EU energy policy until 2009, with the introduction of the Electricity Directive (Directive, 2009/72/EC) (European Parliament and the Council of European Union, 2009).

Initially, the European approach to dealing with energy poverty was limited to promoting energy affordability through price regulation, direct income support systems, and disconnection prohibition mechanisms. However, since the publication of the European Green Deal in 2019 (European Commission, 2019), which addresses the current climate crisis and supports a socially just and inclusive energy transition, and more recently, the European "Fit for 55″ plan, a new comprehensive vision has emerged for tackling the causes of energy poverty, complementing social policy.

Nowadays, energy poverty is granted significant importance in European legislation and is recognized as a form of deprivation that must be systematically controlled and remedied by the member states. In fact, current regulations require member states to address energy poverty in their National Energy and Climate Plans by quantifying the number of households experiencing energy poverty, defining national reduction targets, specifying timelines for achieving these targets, and determining policies and measures to tackle energy poverty. Despite the European Union's strong commitment to advancing the mitigation of this issue, the fight against energy poverty at the political and social levels is at varying stages of development within the European framework, reflecting the different institutional and territorial contexts of each country (Stojilovska et al., 2022). The final choice of implemented measures, as well as their intensity and scope, rests with national governments, resulting in fragmented policies that exacerbate vulnerability differences within the European Union (Bouzarovski et al., 2012; Costa-Campi et al., 2020). Therefore, the extent of energy poverty varies among member states (Eurostat, 2024). In Spain, the situation is even more concerning, with 20.8 % of the population facing difficulties in maintaining their homes at a comfortable temperature (Eurostat, 2024). This makes Spain, along with its neighbor Portugal (20.8 %), the country with the highest incidence of energy poverty in the European Union.

Energy poverty in Europe and, therefore, Spain is not a new or temporary issue resulting from the impacts of the COVID-19 pandemic and the current energy crisis. On the contrary, it remains a significant concern following the severe impact of the 2008 financial crisis and is closely linked to the economic cycle (Costa-Campi et al., 2024). This situation underscores the need for legislative measures to protect the most vulnerable segments of the population, as well as an evaluation of the implemented policies to determine whether the problem is being mitigated or the measures need adjusting to enhance their effectiveness.

As a response to tackle energy poverty in Spain, Royal Decree-Law 6/2009, dated April 30, 2009 (Spanish Government, 2009), was enacted to establish the social energy tariff. This instrument was initially designed to provide a discount on electricity bills for vulnerable households enrolled in the Voluntary Price for Small Consumers scheme (PVPC). Since its inception, the social energy tariff has undergone several modifications aimed at improving its benefits and reaching a broader vulnerable population.[3] These changes include revised income eligibility criteria, increased annual electricity consumption limits for discounted rates, and the inclusion of additional vulnerable groups, such as single-parent families and individuals with level II or III dependency. In 2018, the tariff was expanded to also provide an annual financial allowance for heating, hot water, and cooking. Today, the social energy tariff covers both electricity and thermal energy needs.

Even though, in recent years, new or improved instruments have been created specifically aimed at mitigating energy poverty, the literature focused on examining the efficacy of government tools and responses to energy poverty is limited (Bienvenido-Huertas, 2021; Pillai et al., 2023). One of the early studies on the impacts of the social energy tariff policy in Spain was conducted by the researchers García-Alvarez and Tol (2021). Using a sample of households from 2008 to 2011 and employing a difference-in-differences approach, their work confirms that the initial version of the social energy tariff has limitations in terms of mitigating energy poverty. Similar conclusions were reached by Cadaval et al. (2022) and Bagnoli and Bertoméu-Sánchez (2022), who analyzed a more recent version of the policy and found that it modestly reduced energy poverty among eligible households. In contrast, although in a different socioeconomic context, Pillai et al. (2023) analyzed the impact of government support (fuel subsidies and modernization grants) on energy poverty for a sample of Irish households. Their results show that these measures have a significant positive impact on reducing energy poverty. However, they conclude that such support does not reach the entire vulnerable population, indicating a need for changes in the eligibility criteria.

More recently, Jové-Llopis and Trujillo-Baute (2024) evaluated the impact of income transfer and energy efficiency policies in Spain for reducing energy poverty, and their complementarity. The results reinforce previous findings and show that policies targeting income (the social energy tariff) have reduced the number of energy-poor households. However, the effect is relatively modest, with just 9 % of Spanish households escaping energy poverty due to income-based policies. In

[3] For more details, see https://www.miteco.gob.es/ca/energia/energia-electrica/bono-social.html.

contrast, they demonstrate that policies focusing on spending through energy efficiency improvement measures show greater potential.

In other countries, similar energy subsidy programs provide additional insights (Heller et al., 2024). In light of this, while various programs such as Spain's social energy tariff, the UK's Warm Home Discount Scheme, and the US's Low Income Home Energy Assistance Program have provided partial relief from energy poverty, their long-term effectiveness remains debated due to implementation challenges, limited reach, and behavioral barriers. Integrated approaches, such as those combining subsidies with energy efficiency measures, appear more promising for sustainable impact. Beyond economic and energy consumption outcomes, recent literature underscores the importance of addressing energy poverty as a social determinant of health. There is growing recognition that inadequate energy access affects both physical and mental health, particularly among vulnerable populations.

For instance, Rodrigo et al. (2024) analyzed the UK's financial support schemes, finding that direct energy subsidies to low-income households significantly reduced health risks associated with thermal discomfort. Similarly, Oliveras et al. (2020) emphasized that integrating health into energy policy design can reduce healthcare utilization and associated costs. These findings are consistent with recent European Union reports (O'Connor et al., 2024), which highlight the dual benefit of energy efficiency upgrades: they improve household energy security and contribute to better overall health outcomes.

However, most existing studies focus on isolated policy effects —either on energy consumption or on health— without fully exploring the complex interrelation between energy poverty, targeted subsidy schemes like the social energy tariff, and their health impacts. Bridging this gap is essential for designing more effective, equity-oriented policies.

2.2. Energy poverty and health

Energy poverty has significant implications for health through various interconnected mechanisms. These impacts manifest across physical, mental, and psychosocial dimensions and arise from inadequate living conditions, financial strain, and the inability to access essential energy services.

Energy poverty is strongly associated with a range of adverse physical health outcomes through which energy poverty affects health and thermal stress due to inadequate heating or cooling in homes (Oliveras et al., 2020; Llorca et al., 2020; Churchill and Smyth, 2021; Ballester-os-Arjona et al., 2022; Bentley et al., 2023; Charlier and Legendre, 2023; Katoch et al., 2024). Many households facing energy deprivation rely on solid fuels such as wood, coal, or biomass for cooking and heating, often in poorly ventilated environments. This reliance contributes to significant indoor air pollution, exposing residents to harmful particulate matter and toxic gases. The resulting health consequences include respiratory diseases such as chronic obstructive pulmonary disease, asthma, and lung cancer, alongside cardiovascular conditions linked to prolonged exposure to air pollutants. Moreover, poor air quality compromises the immune system, increasing vulnerability to respiratory infections. For instance, Katoch et al. (2024) found that energy poverty increases the risk of poor physical condition, malnutrition, respiratory disease, depression, asthma exacerbations and other negative effects on health. Homes affected by energy poverty are often poorly insulated and prone to dampness, condensation, and mold growth. These living conditions create an environment that exacerbates respiratory infections, allergies, and asthma. Chronic exposure to such conditions can lead to long-term impairments in respiratory function and overall health. This association is consistent with findings from Polimeni et al. (2022), who reported that energy poverty in the European Union is linked to higher incidences of both acute and chronic health conditions. Research by Mohan (2021) further underscores the negative impacts of energy poverty on children's health. The study found that children living in energy-poor households are more likely to suffer from developmental issues and chronic illnesses, which can have long-term consequences on their overall well-being. Similarly, Oliveras et al. (2020) highlight that energy poverty homes lead to increased rates of asthma and overweight among children. Kose (2019) found the same type of effects in other vulnerable population subgroups such as the elderly.

Financial stress may also result from energy poverty, particularly when households face high energy costs relative to income, thus representing another pathway linking energy poverty to health. Households facing high energy costs frequently divert resources away from essential needs such as food and healthcare to pay for utilities. This trade-off can lead to nutritional deficiencies and delayed or neglected medical care, exacerbating existing health issues. The psychological strain of managing financial insecurity adds another layer of mental health burden, often contributing to anxiety, depression, and chronic stress. This financial burden disproportionately affects low-income families, who are unable to invest in energy-efficient technologies or home improvements that could lower their energy costs over time. Consequently, they remain trapped in a cycle in which high energy expenses consume a significant share of their income. The mental health implications of energy poverty are equally significant. Xu et al. (2022) demonstrated that households experiencing energy poverty are at a higher risk of depression, anxiety, and other mental health disorders. This is corroborated by Churchill and Smyth (2021), who found a strong correlation between energy poverty and mental distress in Australia, and the systematic review of Katoch et al. (2024), which highlights the relevant effect on mental health and education.

In addition, two papers have explored the effects of energy poverty on physical and mental health. McTague and Trujillo-Baute (2025) analyzed the effect of energy poverty on physical and mental health outcomes among individuals aged over 50 in the United States, showing that energy-poor elders have poorer health, higher body mass index, and higher depressive symptoms. Oliveras et al. (2020) also found effects on mental health in vulnerable subgroup populations, such as children. The impacts of energy poverty are further compounded by inequities that disproportionately affect vulnerable populations. Older adults face heightened mortality risks due to extreme temperatures, while children exposed to cold, damp, or polluted living conditions may experience impaired physical and cognitive development. Individuals with disabilities often struggle to meet their specific energy needs for assistive devices, reducing their quality of life and independence.

Furthermore, Charlier and Legendre (2023) explored the broader psychosocial impacts of energy poverty, revealing that the constant financial strain and social isolation resulting from energy deprivation contribute to deteriorating mental health. The study also highlighted that these mental health effects are not uniformly distributed but rather more pronounced among low-income households and marginalized communities. Social isolation is another critical dimension of energy poverty, both as a cause and a consequence. People living in energy poverty often avoid social interactions out of embarrassment over their inadequate living conditions, such as poorly heated or cooled homes. This avoidance reduces social engagement and increases feelings of loneliness, particularly among vulnerable groups like older adults. Financial constraints also limit participation in social activities, community events, or even essential trips, such as medical appointments, further deepening isolation. This sense of disconnection can exacerbate feelings of exclusion and reduce opportunities for social support, creating a feedback loop between energy poverty and social isolation. This issue is particularly significant for older adults and individuals with limited mobility, who often rely on social connections to maintain emotional health.

2.3. Linking energy poverty alleviation policies with health outcomes

The relationship between energy poverty and health has garnered increasing attention in recent years, prompting researchers and policymakers to explore whether energy-related interventions can yield measurable public health benefits (Liddell and Morris, 2010; Navarro et al., 2010; Llorca et al., 2020; Ballesteros-Arjona et al., 2022; European Public Health Alliance, 2024). While energy poverty is widely recognized as a social determinant of health, most mitigation strategies have focused narrowly on financial relief mechanisms, such as subsidies or price regulations (European Public Health Alliance, 2024; Hernández, 2016). Although these tools are essential in the short term, their potential to improve health outcomes depends not only on the extent to which they alleviate energy deprivation but also on their ability to address the structural vulnerabilities that underpin poor health among energy-poor households.

Among these policy instruments, Spain's social energy tariff offers a valuable case study to examine the intersection between targeted energy subsidies and population health. As a price-based intervention, the social energy tariff aims to reduce the economic burden of electricity consumption for low-income households, thereby enabling them to maintain thermal comfort and access basic energy services. Theoretically, this should mitigate health risks associated with cold or overheated living environments, including respiratory and cardiovascular conditions, as well as mental health disorders triggered by financial stress and energy insecurity. However, empirical research suggests that the actual health benefits of such schemes may be modest and uneven, limited by implementation challenges, eligibility restrictions, low uptake rates, and insufficient integration with other social or health services (García-Alvarez and Tol, 2021).

Evidence from Spain and other European countries indicates that policy design plays a critical role in determining health outcomes (Fan et al., 2024; Lena Heller et al., 2024). For example, while direct subsidies can reduce immediate hardship, they may not significantly improve long-term health unless they are coupled with complementary measures such as energy efficiency improvements, insulation upgrades, and tailored health and social care services. In countries like Germany and the UK, integrated models that combine income support with structural housing interventions have shown greater promise in reducing both energy poverty and its health consequences. These findings underscore the need for holistic approaches that move beyond affordability to address the broader determinants of health vulnerability in energy-poor households.

To enhance policy effectiveness, there is a growing consensus that health indicators should be systematically incorporated into the design, monitoring, and evaluation of energy poverty interventions (European Commission, 2025). This would allow for a better understanding of the causal pathways linking energy deprivation to health outcomes and would help optimize resource allocation across sectors. Furthermore, establishing robust evidence on the health impacts of energy interventions could strengthen the case for intersectoral collaboration between energy, housing, and health authorities, promoting a more equitable and efficient response to energy poverty. In this context, the Spanish social energy tariff represents not only a financial tool but also a potential lever to generate co-benefits in health, provided it is integrated into a broader, multidimensional policy framework.

3. Methods

3.1. Data and empirical strategy

To analyze how the social energy tariff affects energy poverty and health status in Spain, this study uses data from the Living Conditions Survey (LCS), provided by the Spanish Statistical Office (INE). The database includes approximately 50,000 Spanish households in 2022.

The main advantage of the LCS for this study is that it provides detailed, harmonized, and nationally representative data on household income, housing characteristics, energy-related deprivations, and self-perceived health, enabling a comprehensive analysis of the link between energy poverty and health outcomes. In particular, the 2022 wave of the LCS includes, for the first time, a specific module on health and quality of life, along with a new question directly related to energy assistance: "Did the household benefit from any subsidies or discounted tariff to cover expenses for electricity, heating, gas, etc.?" This new information is highly relevant for the purposes of our study, as it allows us to directly identify households receiving energy-related subsidies. As these variables are only available in the 2022 wave, the analysis is necessarily cross-sectional. Despite these advantages that contribute to advancing knowledge, it is important to acknowledge that the LCS is not without limitations. Specifically, as a cross-sectional dataset, it does not allow for tracking households over time. Although a longitudinal design would have been ideal for assessing the effects of a policy such as the social energy tariff on energy poverty and health outcomes, the available cross-sectional data still offer valuable insights when interpreted with appropriate caution.

In this study, we apply a recursive bivariate probit model, which enables us to estimate two binary outcome variables that may be interrelated, allowing for the possibility that one of the outcomes might influence the other. In this context, the "recursive" aspect means that the outcome of one equation affects the outcome of the other, creating a causal relationship between the two. The recursive bivariate probit model is suitable for this analysis as it accounts for the endogeneity of energy poverty in estimating its effect on health. Energy poverty is considered endogenous in this context due to the bidirectional relationship between health and energy poverty: poor health can lead to increased energy needs and financial strain, potentially causing energy poverty, while energy poverty can negatively impact health through inadequate heating or cooling and the inability to maintain a healthy living environment (Thomson and Snell, 2013; Liddell and Morris, 2010; Healy and Clinch, 2004; Hernández, 2016; Grey et al., 2017). This simultaneity necessitates a model that can appropriately handle the endogeneity to avoid biased and inconsistent estimates, using two equations, one for the endogenous variable (energy poverty) and the other for the output variable (health status).

3.1.1. Equation for energy poverty (endogenous variable)

The first equation models the energy poverty as a function of the social energy tariff and other relevant covariates, some of which also appear in the health equation. The energy poverty equation is estimated using a probit model, which accounts for the binary nature of the dependent variable and can be represented as follows:

$$EP_i^* = \alpha_0 + \alpha_1 SET_i + \alpha_2 X_i + u_i \quad \text{(Eq. 1)}$$

where.

- The latent variable EP_i^* represents the propensity for a household to experience energy poverty. The observed variable EP_i takes the value of 1 if $EP_i^* > 0$ and 0 otherwise.
- SET_i is a binary variable indicating whether the household receives a social energy tariff.
- X_i is a vector of other explanatory variables.
- u_i is the error term.

In this context, the LCS offers the advantage of allowing energy poverty (EP_i^*) to be captured from a subjective perspective,[4] based on self-reported experiences of energy-related deprivation. In particular, two indicators are accessed: 1) adequate temperature; and 2) delays in bill payments (see Table 1).

The dataset is a sample that includes both recipients and non-

[4] Although the use of multiple indicators is widely recognized as the most appropriate approach for capturing the multifaceted nature of energy poverty (Siksnelyte-Butkiene et al., 2021), our study—like many others in the literature—is constrained by data availability.

Table 1
Description and summary statistics of variables.

Variable	Descriptions	Mean	Std. Dev.	Equation
Dependent variable				
General health	Binary variable equals 1 if health is excellent, very good or good	0.695	0.460	2
Daily life limitations	Binary variable equals 1 if daily life is severely limited or limited but not severely	0.322	0.467	2
Overall satisfaction	Binary variable equals 1 if satisfaction level is above 5	0.797	0.402	2
Difficulty to remember/ concentrate	Binary variable equals 1 if they have no difficulty remembering or concentrating	0.218	0.413	2
Endogenous variable				
Energy poverty - Home	Binary variable equals 1 if energy-poor, measured as inadequate temperature at home	0.165	0.371	1 & 2
Energy poverty - Bills	Binary variable equals 1 if energy-poor, measured as delays in bill payments	0.077	0.267	1 & 2
Explanatory variables				
Social energy tariff	Binary variable equals 1 if the household benefit from the social energy tariff	0.078	0.268	1
Sociodemographic characteristics				
One-person household	Binary variable equals 1 if the household consists of only one person	0.124	0.330	1 & 2
Single parent family	Binary variable equals 1 if the household consists of family with a single parent	0.073	0.259	1 & 2
Female	Binary variable equals 1 if female	0.520	0.500	1 & 2
External support	Binary variable equals 1 if the household has external support	0.935	0.247	2
Economic characteristics				
Unemployment	Binary variable equals 1 if unemployed	0.090	0.286	1 & 2
Retired	Binary variable equals 1 if retired	0.199	0.399	1 & 2
Higher education	Binary variable equals 1 if highest level of education is a bachelor degree	0.340	0.474	1 & 2
Rent	Binary variable equals 1 if the household rents the home	0.143	0.350	1
Dwelling/Environmental characteristics				
Apartments	Binary variable equals 1 if the household lives in an apartment	0.643	0.479	1
Bedrooms	Number of bedrooms in the dwelling	5.05	1.48	1
Low population	Binary variable equals 1 if the area has a density of under 100 inhabitants per km^2	0.164	0.371	1 & 2
Climate factors				
CDDL	Log of the cooling degree days	5.70	0.78	1
Behavioral factors				
Regular exercise	Binary variable equals 1 if they exercise one or more times a week	0.651	0.477	2
Vegetables	Binary variable equals 1 if they consume vegetables four or more times a week	0.753	0.431	2
Tobacco	Binary variable equals 1 if they consume tobacco one or more times a week	0.167	0.373	2
Medical consultation	Binary variable equals 1 if they attend a medical consultation more than five times a year	0.170	0.376	2

Note: numbers in the last column relate to the equation the variable is used for in the empirical analysis described.

recipients of the social energy tariff and therefore we can estimate the impact of the policy by comparing the energy poverty in these two groups. The variable capturing the policy effect is (SET_i), a binary variable indicating whether the household receives a social energy tariff.

The explanatory variables (X_i) used in the first equation to understand the drivers of energy poverty are grouped into four main categories, in line with the empirical literature (Costa-Campi et al., 2024; Burguillo et al., 2025): sociodemographic characteristics of the household reference person, the household's economic profile, dwelling characteristics, and climate-related factors reflecting extreme temperatures. The "Sociodemographic" dimension includes variables such as ***One-person household***, ***Single-parent family***, and gender, with the variable ***Female*** identifying individuals of the female gender. These factors capture household composition and potential vulnerabilities associated with social structure groups (Costa-Campi et al., 2024; Sardianou, 2024). The "Economic" profile comprises employment status—specifically indicators for *Retired* and ***Unemployed*** individuals—given that income plays a crucial role in explaining energy poverty, as widely documented in the literature (Boardman, 1991; Bouzarovski et al., 2012). Another factor that exacerbates energy poverty is the type of housing tenure (*Rent*). Households that rent their homes are often discouraged from seeking solutions to improve the condition and energy efficiency of the dwelling. Additionally, *higher education* is included as a proxy for human capital and informational access, since educational attainment has been found to be inversely associated with the risk of energy poverty and may also correlate with greater awareness of energy-saving practices (Healy and Clinch, 2004). The "Dwelling characteristics" vector also plays a pivotal role, as it captures the energy needs and potential energy losses associated with different housing structures, which may shape the likelihood of experiencing energy poverty (Grey et al., 2017). For instance, the variable *Apartments* may be negatively associated with energy poverty, since these types of dwellings tend to have lower surface-to-volume ratios and shared walls, which reduce heat loss and improve energy efficiency. In contrast, the number of *Bedrooms* is expected to positively influence energy poverty as larger dwellings generally require more energy for heating and cooling, increasing the risk of energy deprivation. Another variable included is *Low population*, which captures the dwelling location. Although it is commonly assumed that rural households are more likely to experience energy poverty, empirical studies reveal that the opposite is true. These contradictory findings are driven by multiple structural and contextual factors, such as access to different energy sources, characteristics of rural housing stock, vulnerability to price shocks in rural areas, and differences across countries or regions (Burguillo et al., 2025). Finally, to isolate the effect of climate conditions associated with household location on energy demand, which can exacerbate their energy poverty (Costa-Campi et al., 2024), we also include data on 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 the indicator known as cooling degree days (*CDD*), published by Eurostat, which measures how much (in degrees) and for how long (in days), the outside air temperature is higher than a specific base temperature.

3.1.2. Equation for health status (dependent variable)

The second equation models the health status as a function of energy poverty (the endogenous variable) and a set of other relevant covariates, some of which also appear in the energy poverty equation. The health equation is specified as follows:

$$H_i^* = \beta_0 + \beta_1 EP_i + \beta_2 Z_i + \varepsilon_i \quad \text{(Eq. 2)}$$

where.

- H_i^* is the latent variable representing the health status of individual i.
- EP_i is the observed binary variable indicating whether the household i is energy-poor (derived from EP_i^*).
- Z_i is a vector of other explanatory variables capturing sociodemographic, behavioral, and environmental characteristics, some of which may overlap with X_i.
- ε_i is the error term.

We assess health status across both physical and mental dimensions, using four binary indicators constructed from self-reported data provided by individuals aged 16 and over. Physical health is captured through: (1) self-rated general health; and (2) limitations in daily activities due to health problems. Mental health is assessed via: (3) overall life satisfaction; and (4) cognitive functioning, specifically difficulty remembering or concentrating (see Table 1).

Explanatory variables are included in the health equation (Z_i) capturing sociodemographic, households economics profile, as in the previous equation (Eq. (1)), along with behavioral, and environmental characteristics. Behavioral related factors are also incorporated, including regular physical activity (*regular exercise*), healthy eating habits (*vegetable consumption*), and the use of tobacco (*tobacco*). In addition, we control for healthcare utilization through a variable indicating whether the individual has attended medical consultations more than five times per year (*medical consultation*), and for external support, which reflects whether the household receives assistance from outside sources. Finally, location-related characteristics such as low population density is, also considered, given their potential influence on living conditions and environmental exposures that affect health.

The methodological approach implies the estimation in two steps. In the first step, we estimate the energy poverty equation using a probit model. This involves determining the probability that a household is energy-poor based on the social energy tariff and other covariates. In the second step, we incorporate the predicted probability of energy poverty from the first step into the health status equation. This step addresses the endogeneity of energy poverty by allowing for the correlation between the error terms u_i and ε_i. The health equation is specified as follows:

$$H_i^* = \beta_0 + \beta_1 \widehat{EP}_i + \beta_2 Z_i + \varepsilon_i \quad \text{(Eq. 3)}$$

where $\widehat{EP}_i$ is the predicted probability of energy poverty from the first equation.

By applying this recursive bivariate probit model, we aim to provide a robust analysis of the causal relationship between energy poverty and health, offering a nuanced understanding of the factors contributing to health disparities within the context of energy affordability, focusing on the role of the social energy tariff. This methodological approach allows for a comprehensive assessment of both direct and indirect effects, thereby informing targeted policy interventions and improving both energy access and health.

The recursive bivariate probit model is particularly well-suited for situations with potential endogeneity where both the treatment and the outcome variables are binary, as in our case. Unlike instrumental variable methods or the Lewbel 2SLS approach—which either require strong external instruments or rely on heteroskedasticity conditions that can be difficult to verify—the recursive bivariate probit model allows for a more direct modeling of the joint determination of the two binary outcomes. This approach accounts for unobserved factors that simultaneously affect both equations by estimating the correlation between their error terms. As a result, it enables us to capture potential endogeneity without the need to rely on external instruments, which are often hard to justify in cross-sectional data and especially challenging in the context of social policy evaluations.

Moreover, while alternative methods such as the special regressor approach are useful under certain conditions, they generally require the presence of a continuous, exogenous regressor with a large support and additional distributional assumptions, which are not easily met in our data. The recursive bivariate probit model provides a more robust and internally consistent framework given the nature of our variables and the structure of the dataset.

3.2. Descriptive statistics

The descriptive statistics presented in Table 1 provide a useful overview of the sample's characteristics and allow us to identify relevant patterns related to health and energy poverty. In terms of health, 69.5 % of the sample reports good, very good or excellent health, while 79.7 % express overall life satisfaction above the midpoint of the scale. However, 32.2 % of individuals experience limitations in daily life, and only 21.8 % report no difficulties remembering or concentrating. These figures suggest that while general well-being and satisfaction are relatively high, a significant share of the population faces physical or cognitive limitations, which may be associated with socioeconomic or environmental stressors.

In relation to energy deprivation, 16.5 % of the sample is classified as energy poor based on inadequate home temperature conditions, and 7.7 % report having experienced delays in energy bill payments. These relatively low but non-negligible rates indicate that energy poverty affects a meaningful portion of the population. Notably, only 7.8 % of households receive the social energy tariff, which suggests that either the eligibility criteria are restrictive or that the coverage of the subsidy is insufficient given the presence of energy deprivation.

4. Results and discussion

In this section, we present the results from the recursive bivariate probit model, structured in three types of effects: social energy tariff on energy poverty, energy poverty on health, and health drivers including the indirect effect of social energy tariff.

Firstly, we aim to detail the marginal effects of the social energy tariff on energy poverty, providing a quantification of the policy's impact on energy poverty (Table 2). Our findings indicate that the social energy tariff has a statistically significant, though moderate, impact on reducing energy poverty, ranging from just 1 %–2 %, depending on the specific energy poverty indicator used (adequate temperature or delays in bill

Table 2
Marginal effect of social energy tariff on energy poverty.

Health equation	Social energy tariff effect on	
	Adequate temperature	Delays in bill payments
General health	−0.018***	−0.012*
	(0.0001)	(0.0001)
Daily life limitations	−0.018***	−0.011***
	(0.0002)	(0.0001)
Overall satisfaction	−0.019***	−0.012***
	(0.0001)	(0.0001)
Difficulty to remember	−0.019***	−0.012***
	(0.0001)	(0.0001)

Notes: Coefficients represent the average marginal effect on energy poverty. All regressions include the usual covariates. Labels on top represent the dependent variable under consideration in the first step (Eq. (1)), while labels in the first column represent the dependent variable in the second equation (Eq. (2)). Robust standard errors in parentheses (***1 %, **5 %, *10 % significance level).

payments). While the reduction in the probability of experiencing energy poverty may appear modest in relative terms, it is important to consider the policy relevance of this effect in context. This estimate refers to a population-level intervention, implying a potentially large number of individuals benefiting from the measure in absolute terms. Moreover, the policy targets a particularly vulnerable segment of the population, for whom even small reductions in energy poverty can translate into meaningful improvements in living conditions.

Our results are broadly consistent with prior studies that have assessed the effects of targeted energy affordability policies. For instance, García-Alvarez and Tol (2021) estimate a modest but statistically significant reduction in energy poverty associated with energy subsidies, although using a different identification strategy. Cadaval et al. (2022) also report limited but positive effects of price interventions on household vulnerability. In addition, Bagnoli and Bertoméu-Sánchez (2022) examine the impact of automatic energy discounts in Spain and find reductions in energy poverty in the range of 2–3 %, depending on household characteristics. The effect estimated in our study—an average reduction in the probability of being energy poor of around 1–2 %—lies within this empirical range, confirming the practical relevance of such policies. While modest in magnitude, these impacts are meaningful given the structural roots of energy poverty and the difficulty of addressing it through short-term measures like the social tariff. The effect remains highly consistent across the different health indicators —both physical and mental—, used as dependent variables in the second equation, reinforcing the robustness of the observed relationship between the social energy tariff and energy poverty.

Secondly, we aim to examine the effect of energy poverty on health outcomes among individuals who are already experiencing it. To achieve this, we use the Average Treatment Effect on the Treated (ATET) derived from the recursive bivariate probit model. This approach specifically quantifies the impact of energy poverty on physical and mental health outcomes among individuals currently facing energy poverty—-whether through difficulties maintaining adequate temperatures or experiencing delays in bill payments.

By focusing on this subgroup, we gain insights into the effectiveness of interventions targeting energy-poor households and can better design policies to alleviate their adverse conditions on health. The results (see Table 3) suggest that, if individuals not currently experiencing energy poverty were to fall into it, the probability of reporting good physical health could decrease by approximately 7 %–15 %, depending on the energy poverty indicator. The magnitude of this decrease is even greater for mental health, ranging from 20 % to 23 %.

Thirdly, to better understand health determinants, we compute the marginal effects. These effects measure the change in the probability of having a certain health status associated with changes in the covariates, considering the endogeneity of energy poverty. Therefore, this answers the question: "How does energy poverty affect the probability of having a certain health status, considering the endogeneity of energy poverty

Table 3
ATET of energy poverty on health.

	General health	Daily life limitations	Overall satisfaction	Difficulty to remember/ concentrate
Energy poverty - Home	−0.159*** (0.0010)	0.106*** (0.0012)	−0.229*** (0.0009)	0.135*** (0.0010)
Energy poverty - Bills	−0.077*** (0.0010)	0.026*** (0.0011)	−0.196*** (00010)	0.068*** (0.0010)

Notes: Coefficients represent the average treatment effect on the treated. All the regressions include the usual covariates. Labels on top represent the dependent variable under consideration in the second step (Eq. (2)), while labels in the first column represent the dependent variable in the first equation (Eq. (1)). Robust standard errors in parentheses (***1 %, **5 %, *10 % significance level).

and other related covariates?" In other words, the estimation aims to quantify the change in the probability of achieving a specific health status (physical or mental) as a result of variations in energy poverty, while also taking into account the interaction and potential reverse causality between energy poverty and health status.

Given that the model is recursive, the marginal effects can be decomposed into two components: (a) the direct effect of each covariate on physical and mental health; and (b) the indirect effect through its influence on energy poverty (see Tables 4 and 5). For instance, if the variable Female affects energy poverty, and energy poverty subsequently influences health status, a change in the variable Female could alter the probability of a specific health outcome not only directly but also indirectly through its effect on energy poverty. This decomposition provides a clearer understanding of the pathways through which a variable influences health.

As the previous section of the analysis has already detailed the indirect effect of particular interest (that of the social energy tariff), this section will focus on the direct effects of the covariates on health outcomes. For comprehensive information, the complete estimation results, including both direct and indirect effects, are presented in Tables 4 and 5

Regarding direct effects, living in a one-person household decreases the likelihood of having improved general physical health and overall mental health satisfaction, while increasing daily life limitations and difficulty to remember/concentrate.

Furthermore, being female is directly associated with a lower likelihood of improving general physical health and overall mental health satisfaction. However, it directly increases daily life limitations and difficulty to remember/concentrate. Although the direct effect of this variable is minimal on general health, it appears that women may be disproportionately vulnerable due to a range of structural and socioeconomic factors. Gender wage disparities and occupational segregation often result in lower incomes for women, directly limiting their ability to afford resources essential for maintaining good health. Additionally, women typically bear a greater share of household and caregiving responsibilities, which can directly affect their physical and mental wellbeing due to increased stress and workload. These conditions can directly exacerbate respiratory or cardiovascular issues, while the psychological stress of managing household constraints may also directly contribute to poorer mental health outcomes. Finally, women may have less direct access to resources that support health, such as nutritious food, medical care, or physical activity, further reducing their likelihood of achieving positive health outcomes.

Higher education is shown to have a significant direct positive impact on increasing the probability of improving general health and overall mental health satisfaction, and a negative direct impact on daily life limitations and difficulty to remember/concentrate. This effect is intuitive, reflecting the direct benefits of education on health literacy, access to better jobs, and healthier lifestyle choices. Conversely, being unemployed directly reduces the probability of improving physical and mental health, and directly increases daily life limitations, likely because of the associated social and psychological stresses. For retirees, their status directly decreases the probability of improving general physical health and overall mental health satisfaction, while directly increasing daily life limitations and difficulty to remember/concentrate. This suggests that being retired directly influences various aspects of health.

Positive health habits, such as regular exercise and a healthy diet, particularly the frequent consumption of vegetables, directly and positively impact both physical and mental health outcomes. They also directly decrease daily life limitations and difficulty to remember/concentrate. Conversely, tobacco use shows a direct negative association with some health outcomes, directly increasing general physical health while directly decreasing daily life limitations, overall mental health satisfaction, and difficulty to remember/concentrate.

Moreover, frequent medical consultations are directly and negatively associated with general physical health and overall mental health

Table 4
Marginal effects of health determinants with ability to keep home adequately warm (direct and indirect).

	Physical health				Mental health			
	(General health)		(Daily life limitations)		(Overall satisfaction)		(Difficulty to remember/concentrate)	
	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
Social energy tariff		−0.011*** (0.0001)		−0.007*** (0.0001)		−0.012*** (0.0001)		−0.005*** (0.0001)
Sociodemographic characteristics								
One-Person Household	−0.013*** (0.0001)	0.017*** (0.0001)	0.009*** (0.0001)	0.011*** (0.0001)	−0.013*** (0.0001)	0.019*** (0.0001)	0.014*** (0.0001)	0.008*** (0.0001)
Single parent family	0.015*** (0.0001)	−0.001*** (0.0001)	−0.011*** (0.0001)	−0.001*** (0.0001)	0.006*** (0.0001)	−0.002*** (0.0002)	−0.006*** (0.0001)	−0.001*** (0.0001)
Female	−0.007*** (0.0001)	0.009*** (0.0001)	0.008*** (0.0001)	0.005*** (0.0001)	−0.000*** (0.0001)	0.009*** (0.0001)	0.009*** (0.0001)	0.004*** (0.0001)
External support	0.020*** (0.0001)		−0.013*** (0.0001)		0.032*** (0.0001)		−0.014*** (0.0001)	
Economic characteristics								
Unemployment	−0.007*** (0.0001)	0.058*** (0.0001)	0.001*** (0.0001)	0.033*** (0.0001)	−0.029*** (0.0001)	0.055*** (0.0001)	−0.000*** (0.0001)	0.024*** (0.0001)
Retired	−0.038*** (0.0001)	−0.009*** (0.0001)	0.028*** (0.0001)	−0.006*** (0.0001)	−0.007*** (0.0001)	−0.010*** (0.0001)	0.028*** (0.0001)	−0.004*** (0.0001)
Higher Education	0.016*** (0.0001)	−0.058*** (0.0001)	−0.009*** (0.0001)	−0.038*** (0.0001)	0.010*** (0.0001)	−0.063*** (0.0001)	−0.005*** (0.0001)	−0.028*** (0.0001)
Rental property		0.051*** (0.0001)		0.033*** (0.0001)		0.056*** (0.0001)		0.024*** (0.0001)
Dwelling/Environmental characteristics								
Apartment		−0.008*** (0.0001)		−0.005*** (0.0001)		−0.010*** (0.0001)		−0.004*** (0.0001)
Bedrooms		−0.013*** (0.0001)		−0.008*** (0.0001)		−0.014*** (0.0001)		−0.006*** (0.0001)
Low population	−0.003*** (0.0001)	−0.012*** (0.0001)	0.001*** (0.0001)	−0.008*** (0.0001)	0.002*** (0.0001)	−0.014*** (0.0001)	−0.001*** (0.0001)	−0.006*** (0.0001)
Climate factors								
CDDL		0.010*** (0.0001)		0.006*** (0.0001)		0.011*** (0.0001)		0.005*** (0.0001)
Behavioral factors								
Regular Exercise	0.025*** (0.0001)		−0.020*** (0.0001)		0.023*** (0.0001)		−0.012*** (0.0001)	
Vegetable	0.002*** (0.0001)		−0.001*** (0.0001)		0.006*** (0.0001)		−0.003*** (0.0001)	
Tobacco	0.001*** (0.0001)		−0.003*** (0.0001)		−0.007*** (0.0001)		−0.004*** (0.0001)	
Medical Consultation	−0.061*** (0.0001)		0.061*** (0.0001)		−0.026*** (0.0001)		0.028*** (0.0001)	
Observations	47,763							

satisfaction. Conversely, they are directly and positively associated with daily life limitations and difficulty to remember/concentrate, possibly reflecting the direct presence of underlying chronic conditions that necessitate these consultations. In contrast, having a network of external support provides a direct protective effect, enhancing both general physical health and overall mental health satisfaction, and directly decreasing daily life limitations and difficulty to remember/concentrate by offering direct emotional, social, and possibly financial support. Regarding dwelling/environmental characteristics, living in a low population area directly decreases the probability of improving general physical health and difficulty to remember/concentrate, and directly increases daily life limitations and overall mental health satisfaction.

Table 5
Marginal effects of health determinants - with arrears on utility bills (direct and indirect).

	Physical health				Mental health			
	(General health)		(Daily life limitations)		(Overall satisfaction)		(Difficulty to remember/concentrate)	
	Direct	Indirect	Direct	Indirect	Direct	Indirect	Direct	Indirect
Social energy tariff		−0.008***		−0.004***		−0.008***		−0.012***
		(0.0001)		(0.0001)		(0.0001)		(0.0001)
Sociodemographic characteristics								
One-person household	−0.007***	−0.018***	0.005***	−0.009***	−0.007***	−0.018***	0.007***	−0.006***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Single parent family	0.007***	0.009***	−0.005***	0.005***	0.003***	0.009***	−0.002***	0.003***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Female	−0.004***	−0.003***	0.004***	−0.002***	−0.001***	−0.003***	0.004***	−0.001***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
External support Support	0.011***		−0.007***		0.017***		−0.007***	
	(0.0001)		(0.0001)		(0.0001)		(0.0001)	
Economic characteristics								
Unemployment	−0.004***	0.046***	0.001***	0.024***	−0.014***	0.047***	0.000***	0.016***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Retired	−0.018	−0.036***	0.013***	−0.018***	−0.003***	−0.036***	0.012***	−0.012***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Higher education	0.009***	−0.034***	−0.005***	−0.018***	0.006***	−0.034***	−0.003***	−0.012***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Rental property		0.052***		0.027***		0.053***		0.018***
		(0.0001)		(0.0001)		(0.0001)		(0.0001)
Dwelling/Environmental characteristics								
Apartment		−0.003***		−0.001***		−0.003***		−0.001***
		(0.0001)		(0.0001)		(0.0001)		(0.0001)
Bedrooms		−0.009***		−0.004***		−0.009***		−0.003***
		(0.0001)		(0.0001)		(0.0001)		(0.0001)
Low population	−0.001***	−0.010***	0.000***	−0.005***	0.001**	−0.011***	−0.001**	−0.003***
	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)	(0.0001)
Climate factors								
CDDL		0.009***		0.005***		0.009***		0.003***
		(0.0001)		(0.0001)		(0.0001)		(0.0001)
Behavioral factors								
Regular exercise	0.012***		−0.010***		0.011***		−0.005***	
	(0.0001)		(0.0001)		(0.0001)		(0.0001)	
Vegetable	0.001***		−0.001***		0.003***		−0.002***	
	(0.0001)		(0.0001)		(0.0001)		(0.0001)	
Tobacco	0.001***		−0.001***		−0.003***		−0.002***	
	(0.0001)		(0.0001)		(0.0001)		(0.0001)	
Medical consultation	−0.030***		0.030***		−0.013***		0.012***	
	(0.0001)		(0.0001)		(0.0001)		(0.0001)	
Observations	47,539							

The specifics of these direct effects vary by health outcome.

To sum up, the results show that the direct effect of receiving a social energy tariff reduces the likelihood of experiencing energy poverty, as measured by maintaining an adequately comfortable temperature. However, it does not improve health status or overall life satisfaction. The same appears to happen when using arrears on utility bills to define energy poverty. In contrast, the social energy tariff has a positive impact on daily life limitations caused by health problems and difficulties with memory or concentration. Although the results show that the social energy tariff can alleviate energy poverty, the magnitude of the effect is quite limited. This result is in line with Kose (2019) and Brown and Vera-Toscano (2021), and could be further investigated by incorporating more specific health status indicators, such as quality of life measures or disease-specific variables related to energy poverty, including cardiovascular or respiratory conditions, as well as migraines and/or domestic injuries.

5. Conclusions and policy implications

The aim of this paper is to elucidate how Spain's response to energy poverty, through the well-established affordability measure known as the social energy tariff, impacts the mitigation of energy poverty and contributes to the well-being and health of households, in terms of both the physical and mental dimensions. Despite the recognition of energy poverty in Spanish and European legislation, there is a dearth of literature on the effectiveness of political measures to address it. Concurrently, previous empirical studies have highlighted the negative impact of energy poverty on health. However, this literature often overlooks the intersections between energy poverty and other policy areas, adopting a siloed approach to the design of energy poverty policies. Against this backdrop, this study seeks to analyze the link between the social energy tariff, energy poverty, and health status.

Through the application of a recursive bivariate probit model on a dataset covering a large sample of Spanish households, our empirical results suggest that the social energy tariff is a beneficial measure for alleviating financial burdens; however, its effectiveness falls short of expectations, as its impact on reducing energy poverty ranges from just 1 %–2 %. Reducing the cost of energy bills through income subsidies or social tariffs is an important measure for mitigating energy poverty, especially within a context of high or volatile prices. However, addressing affordability alone is not sufficient to improve the overall well-being of households, especially when health is measured as general health status and overall satisfaction.

In addition, it is important to consider that income measures alone do not effectively encourage behavioral change. Therefore, government responses should prioritize reducing energy bills through structural solutions. These solutions include increasing access to renewable energy sources, incentivizing energy efficiency improvements in homes, and promoting effective communication to target energy-poor households. This approach aims to raise awareness of energy poverty and enhance understanding of potential energy-saving practices.

Furthermore, our results demonstrate a decrease in the probability of reporting good physical and mental health when a household is energy-poor. These findings may aid policymakers in estimating the potential cost savings associated with implementing interventions such as the social energy tariff on National Health System expenditure. By providing a clearer understanding of the financial impact of health improvements resulting from such social interventions, this quantification underscores the importance of integrating health considerations across all policy areas. From a policy perspective, this analysis is crucial as it offers policymakers a tool to quantify the economic benefits of improving public health through social interventions. Understanding how physical and mental health improvements can reduce national healthcare costs enables more efficient resource allocation. The "health in all policies" approach strives to integrate health as a central consideration across various policy domains and this kind of quantitative analysis allows for a more accurate assessment of the positive impact of social policies on public health, ultimately facilitating more informed and effective decision-making.

Social and healthcare workers can play a crucial role in identifying and diagnosing energy poverty, as they are often on the front line of interacting with vulnerable populations. Their close contact with individuals and families allows them to observe the living conditions and health symptoms that may be indicative of inadequate access to energy, such as poor heating or inability to pay utility bills. By integrating assessments of household energy needs into their regular care routines, these professionals may identify cases of energy poverty that might otherwise go unnoticed. Moreover, they are in a unique position to provide referrals to relevant support services or interventions, contributing not only to the well-being of those affected but also to the broader understanding of how energy poverty impacts public health. Their involvement could be essential in bridging the gap between social care, health outcomes, and the structural factors that contribute to energy poverty.

Although the direct marginal effect of the *Female* variable is relatively modest, it appears that women may be disproportionately vulnerable to energy poverty due to a range of structural and socioeconomic factors. Gender wage disparities and occupational segregation often result in lower incomes for women, limiting their ability to afford energy-efficient housing and essential utilities. Additionally, women typically bear a greater share of household and caregiving responsibilities, which can increase their exposure to poor living conditions linked to energy poverty, such as inadequate heating or ventilation. These conditions negatively affect physical health by exacerbating respiratory or cardiovascular issues, while the psychological stress of managing household energy constraints may also contribute to poorer mental health outcomes. Finally, women facing energy poverty may have less access to resources that promote health, such as nutritious food, medical care, or physical activity, further reducing their likelihood of achieving positive health outcomes. The analysis presented provides useful additional results on the intersection between the social energy tariff, energy poverty, and health outcomes. Nevertheless, it is important to highlight some limitations of the paper that could be the subject of fruitful research in the future.

In this analysis, we focus solely on determining whether or not to provide the subsidy, without considering the specific monetary amount that the subsidy should entail. While determining whether to offer a subsidy is a crucial step, it is equally important to explore the optimal size of the subsidy to ensure it effectively tackles energy poverty and maximizes its impact on health. A detailed analysis of the appropriate financial scale could better inform policy decisions and ensure that the intervention is both economically efficient and sufficient to meet the needs of vulnerable households.

On the methodological front, our cross-sectional analysis could be further extended by incorporating temporal dynamics in the analysis as data becomes available. The use of panel data would help correct any remaining unobserved heterogeneity or omitted variables issues. Limitations in the broader health outcome variables, such as diseases related to energy poverty, including cardiovascular and respiratory conditions, may be influencing the magnitude of the observed effect. Therefore, more comprehensive health outcome data should be collected concurrently with the evaluation of energy poverty status. Finally, one of the main shortcomings frequently mentioned in the literature is that, despite containing questions directly related to energy poverty, this database is not specifically designed to fully address the analysis of energy poverty. Unfortunately, it does not contain specific data on energy expenses and housing conditions, which are desirable elements for a detailed analysis of some of the predictors of energy poverty. Nevertheless, it remains one of the reference surveys for examining energy poverty. Another limitation is that the health module is not available for all years so, in this study, we focus on the year 2022. Therefore, we work with a cross-sectional dataset, making the problem of simultaneity somewhat avoidable.

CRediT authorship contribution statement

Elisenda Jové-Llopis: Writing – original draft, Visualization, Validation, Resources, Investigation, Formal analysis, Conceptualization. **Marta Trapero-Bertran:** Writing – original draft, Formal analysis, Conceptualization. **Elisa Trujillo-Baute:** Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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Data availability

Data will be made available on request.

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