UNIVERSITY OF CAMBRIDGE | Energy Policy Research Group

Is Spain's energy voucher lighting the way for the poor? A microeconomic evaluation of the Bono Social Eléctrico

EPRG Working Paper EPRG 2516

Cambridge Working Paper in Economics CWPE 2542

Manuel Llorca and Ana Rodriguez-Alvarez

Abstract: Energy poverty refers to the inability of households to afford adequate energy services, connected to negative impacts on health, well-being, and economic opportunities. It is a social policy issue that exacerbates inequality and limits access to essential services, particularly among vulnerable populations. In Spain, energy poverty has become an increasing concern, with many low-income households struggling to meet their energy needs despite various social protection mechanisms. This paper analyses the effectiveness of the Bono Social Eléctrico (BSE), a Spanish social electricity voucher aimed at alleviating energy poverty among vulnerable households. Departing from a microeconomic theoretical framework and a applying a Stochastic Frontier Analysis (SFA) approach, the study evaluates the gap between observed and potential energy poverty levels. The empirical analysis employs Spanish household panel data from 2021 to 2023, capturing key household characteristics and subsidy information. The findings indicate that, while the BSE contributes to reducing energy poverty, its effectiveness is constrained by insufficient coverage and lack of impact on the poorest households. Moreover, energy poverty has worsened over the years and there has been a decline in the mitigating effect of the BSE, while some regional disparities persist. Education and computer access play an important role in addressing energy poverty. The study suggests policy recommendations to enhance the voucher's targeting mechanisms and explores strategies for more effective interventions to tackle energy poverty.

Keywords: energy poverty; policy evaluation; stochastic frontier analysis; Spain; bono social eléctrico.

JEL Classification: C23; D12; I38; Q48.

Contact	mll.eco@cbs.dk
Publication	<month year>
Financial Support	Grant PID2020-115183RB-C21 funded by MCIN/AEI//10.13039/501100011033 (Spanish Ministry of Science and Innovation)

Is Spain's energy voucher lighting the way for the poor? A microeconomic evaluation of the Bono Social Eléctrico

Manuel Llorca [a,1], Ana Rodriguez-Alvarez [b]

[a] *Copenhagen School of Energy Infrastructure (CSEI), Dept. of Economics, Copenhagen Business School, Denmark*

[b] *Oviedo Efficiency Group, Department of Economics, University of Oviedo, Spain*

Version: 28 June 2025

Abstract

Energy poverty refers to the inability of households to afford adequate energy services, connected to negative impacts on health, well-being, and economic opportunities. It is a social policy issue that exacerbates inequality and limits access to essential services, particularly among vulnerable populations. In Spain, energy poverty has become an increasing concern, with many low-income households struggling to meet their energy needs despite various social protection mechanisms. This paper analyses the effectiveness of the *Bono Social Eléctrico* (BSE), a Spanish social electricity voucher aimed at alleviating energy poverty among vulnerable households. Departing from a microeconomic theoretical framework and a applying a Stochastic Frontier Analysis (SFA) approach, the study evaluates the gap between observed and potential energy poverty levels. The empirical analysis employs Spanish household panel data from 2021 to 2023, capturing key household characteristics and subsidy information. The findings indicate that, while the BSE contributes to reducing energy poverty, its effectiveness is constrained by insufficient coverage and lack of impact on the poorest households. Moreover, energy poverty has worsened over the years and there has been a decline in the mitigating effect of the BSE, while some regional disparities persist. Education and computer access play an important role in addressing energy poverty. The study suggests policy recommendations to enhance the voucher's targeting mechanisms and explores strategies for more effective interventions to tackle energy poverty.

Keywords: energy poverty; policy evaluation; stochastic frontier analysis; Spain; bono social eléctrico.

JEL classification: C23; D12; I38; Q48.

---

[1] Corresponding author: Copenhagen Business School, Department of Economics, Porcelænshaven 16A, 2000 Frederiksberg, Denmark. Tel. +45 3815 2218. E-mail: mll.eco@cbs.dk.

Acknowledgements: The authors acknowledge financial support from the grant PID2020-115183RB-C21 funded by MCIN/AEI//10.13039/501100011033 (Spanish Ministry of Science and Innovation). Financial support from the Copenhagen School of Energy Infrastructure (CSEI) is also acknowledged. The activities of CSEI are funded by the Copenhagen Business School and energy sector partners.

1. Introduction

Energy Poverty generally refers to a situation in which a household cannot meet basic energy needs. In recent years, geopolitical tensions and energy market volatility have increasingly confronted households with significant obstacles to achieving energy security and affordability (Carfora and Scandurra, 2024). To address this issue, various governmental policies have been proposed around Europe to reduce and mitigate the negative effects of energy poverty on vulnerable households and consumers (see examples for Europe in Cadaval et al., 2022). These measures may aim either to increase income (through financial support) or to reduce expenses (through energy-saving measures).

An example is the introduction of a electricity social voucher aimed at financially alleviating electricity bill costs in Spain (*Bono Social Eléctrico,* BSE), where substantial empirical evidence highlights the prevalence of energy poverty (see, e.g., Aristondo and Onaindia, 2018; Costa-Campi et al., 2021; Linares et al., 2017; Linares-Llamas and Romero-Mora, 2015; Llorca et al., 2020; Phimister et al., 2015; Rodriguez-Alvarez et al., 2019; Romero et al., 2014; Scarpellini et al., 2015; Tirado-Herrero et al., 2016, 2012).[2] In particular, the energy poverty issue has worsened since 2021 due to rising energy prices, which have tripled compared to pre-COVID-19 levels, and the effects of the health crisis derived from the pandemic (Carfora and Scandurra, 2024). These factors have significantly reduced the purchasing power of Spanish households, particularly affecting the most vulnerable ones and exacerbating energy poverty (Palma et al., 2024). According to Eurostat, the statistical office of the European Union (EU), as of 2023, approximately 20.8% of the Spanish population reported being unable to keep their homes adequately warm, which is the highest rate in the EU.

In this scenario, the BSE was introduced by the Spanish Government in 2009 following the 2008 financial crisis. Some studies have tried to analyse and question the effectiveness of the BSE as an effective policy for reducing energy poverty in Spain. For instance, according to data from the National Commission on Markets and Competition, in 2019, almost one-third of Spanish households (30.4%) were still unaware of the BSE's

[2] The BSE offers a direct subsidy to alleviate electricity costs. Other countries have explored mechanisms such as Increasing Block Tariffs (IBTs), which aim to subsidise basic consumption while charging higher rates for excessive use. This structure can simultaneously address affordability and encourage energy efficiency. As shown by He and Reiner (2016), the effectiveness of IBTs critically depends on accurately setting the initial block to reflect basic electricity needs, which is linked with the concept of energy poverty.

existence. Furthermore, Martinez-Jorge et al. (2023), using 2021 data from the Spanish Living Conditions Survey (LCS, *Encuesta de Condiciones de Vida*), observed that only 13% of the poorest households received the BSE. Surprisingly, among households in the first income decile, only 12% received the electric social voucher, compared to 13-14% in the second and third deciles. Notably, in the 10^{th} decile (i.e., the highest income households), the proportion receiving the voucher increased relative to the previous decile (4% versus 2%). This trend persists even when other factors are considered. For example, only 30% of low-income large families received the BSE, while among wealthier large families, 55% receive it. These figures suggest that the BSE may not be reaching the most vulnerable households, leading to suboptimal and inefficient outcomes.

Empirically, four academic studies have evaluated the effectiveness of the BSE in Spain examining eligible households (i.e., those meeting BSE requirements regardless of receipt). Garcia Alvarez and Tol (2021), apply Difference-in-Differences (DiD) and propensity score matching to LCS data from 2008 to 2011. They find no statistically significant impact of the BSE on three self-reported indicators of energy poverty: the ability to keep the home adequately warm; the presence of damp walls, rotting windows, and leaking roofs; and delays in paying electricity bills.

Bagnoli and Bertoméu-Sánchez (2022) analyse the effect of the BSE using repeated cross-sectional data from the Household Budget Survey (HBS) from 2006 to 2017. Taking advantage of expenditure-based indicators of energy poverty and, also, a DiD model, they find that, while the BSE significantly reduces energy poverty among eligible households, the effect is modest, reducing the probability of energy poverty by only 2 percentage points on average. They further find that while the BSE reduces the effective price of electricity and electricity expenditure, it does not alter the amount of energy consumed.

Similarly to the two previous papers, Cadaval et al. (2022) applies a DiD approach, but uses two LCS samples, one for 2008-2011 and another for 2016-2019, with both subjective and objective energy poverty indicators, to analyse the BSE's effect on eligible households. When using subjective indicators, they find no significant positive impact, consistent with Garcia Alvarez and Tol (2021). However, when using objective indicators, their results align with those of Bagnoli and Bertoméu-Sánchez (2022), showing a positive but moderate effect in reducing energy poverty.

Jové-Llopis and Trujillo-Baute (2024a) evaluate the theoretical effectiveness of reducing energy poverty in terms of both costs and benefits, assuming optimal behaviour and universal coverage for energy-poor households. Using microdata from the HBS for 2019 and a Low Income Hight Costs (LIHC) indicator to define energy poverty,[3] they find that income-based policies (electricity and heating vouchers) could reduce the number of households in energy poverty, but the effect would be modest. In contrast, potential policies that target expenditure (energy efficiency measures) could have a much greater potential impact on energy poverty. Moreover, combining multiple energy efficiency measures could yield better results than implementing individual efficiency measures.

The first contribution of our paper is the proposal of a microeconomic theoretical framework and an empirical model to assess the ability of households to minimise their energy poverty level. This approach, which allows analysing the influence of diverse factors on energy poverty, is inspired by the one developed by Rodriguez-Alvarez et al. (2021) for analysing the energy poverty of European countries at a macro level. We apply the proposed method to the case of Spain, aiming to shed light on the discussion surrounding the impact of the BSE. The framework presented relies on a Stochastic Frontier Analysis (SFA) approach and tries to address some of the issues identified in previous literature. For example, as Garcia Alvarez and Tol (2021) note, the DiD methodology previously applied to assess BSE effectiveness has limitations, as assignment to the control or treatment group is not random since eligible and ineligible households are considered in forming these groups, yet eligibility is not random but depends on household characteristics. The second contribution of our paper is related to the data utilised. Previous studies analyse eligibility rather than actual treatment. In contrast, our database (a panel dataset from the LCS for 2021-2023) provides information on which households are actually receiving the BSE. This enables an analysis of the characteristics of eligible households that do or do not receive this support, offering new insights into effective policy access.

In summary, this study presents an innovative model that not only evaluates the effectiveness of policies aimed at reducing energy poverty, but also serves to identify the factors that may facilitate better accessibility to support for consumers. Specifically, we analyse the determinants that help individuals effectively address vulnerability considering the resources and assistance provided by public institutions. This information

[3] For details about this indicator, see Hills (2011).

can be valuable as it allows for an analysis of factors that may explain why public support does not always reach vulnerable families. If public support does not reach all households in energy poverty, these households may experience higher levels of energy poverty than they should, given their available income, energy prices, and available social assistance. Therefore, understanding the factors that can enhance public support efficiency could guide the redesign of policies for a more effective resource distribution.

The paper is organised as follows. Section 2 briefly describes the *Bono Social Eléctrico*, its legal background and the granting requirements. Section 3 presents the proposed theoretical and empirical model. Section 4 presents the data. Section 4 provides the estimates and discusses the results. Finally, Section 5 offers some conclusion and policy implications.

2. Bono Social Eléctrico: Legal Background and Requirements

In 2003, the EU, through Directive 2003/54/CE on common market rules, determined that it was necessary to protect vulnerable consumers and guarantee their access to electricity. Article 3 of this directive provided guidelines for member states, allowing them broad discretion in how they define and protect vulnerable consumers.

Despite the EU's early action in 2003, this directive was only later incorporated into Spanish legislation, prompted by the 2008 financial crisis. The "*Bono Social*" was established through Royal Decree (RD) 6/2009, dated April 30, which introduced specific measures in the energy sector, including the creation of the social voucher. In July 2009, the coexistence of the free market and the "*Tarifa de Último Recurso*" (TUR, Last Resort Tariff) was introduced. This tariff, fully regulated by the government and considered a safety net, was available to users with less than 10 kW contracted and had to be contracted through one of the five designated last-resort energy suppliers approved by the government. Additionally, for all users under the TUR who met certain social criteria, the *Bono Social* was established and regulated in Article 2 of the RD, which describes the voucher as an additional mechanism of protection for the right to electricity supply (Art. 2.2 RD 6/2009). The social voucher covers the difference between the TUR and a reference rate, called the reduced tariff. After this decree, the Secretary of State for Energy set the criteria for this social assistance, which consisted of freezing the tariff at 2009 prices. Essentially, this voucher benefited four groups: pensioners aged 60 or above receiving minimum pensions, households where all members of working age were unemployed, consumers with contracted power less than 3 kW in their primary residence, and large families.

In 2017, with the implementation of Royal Decree 897/2017, the criteria for the *Bono Social* were reformed to establish vulnerability categories based on income levels and other family circumstances (vulnerable, severely vulnerable, and at risk of social exclusion), expanding access and modifying the requirements to receive this grant.[4]

In 2018, the *Bono Social Térmico* (Thermal Social Voucher) was created, as outlined in Article 5 of RD 15/2018, as a "programme of direct grants aimed at alleviating energy poverty for vulnerable consumers concerning energy used for heating, hot water, or cooking." The thermal social voucher is granted to those who already benefit from the *Bono Social Eléctrico*, thus complementing the electric social vouchers to aid families experiencing energy poverty. Households receiving the *Bono Social Eléctrico* are eligible for the thermal voucher, with the amount determined by their degree of vulnerability and the climatic zone where they reside.

With the emergence of the COVID-19 pandemic, RD 8/2021 was passed, which included measures like banning energy disconnections for *Bono Social* beneficiaries to prevent the economic impact of the pandemic from leaving the most vulnerable consumers unprotected. This was followed by other decrees, such as RD 16/2021, which extended these measures until the situation normalised, covering the period until the end of 2023.

The "*Plan Más Seguridad Energética*" (More Energy Security Plan), introduced in 2022, aims at "providing more protection against energy prices to households and the Spanish economy as a whole, and contributing to enhancing the security of supply for the European Union," as defined on the website of the Ministry for Ecological Transition and the Demographic Challenge. This plan comprised short-term measures with quick impact, specifically targeted at the winter of 2022/2023. One of its main actions was to increase protection for vulnerable consumers.

Also, in 2022, the RD 6/2022 introduced urgent measures as part of the National Plan to address the economic and social impacts of the war in Ukraine. As the name suggests, these modifications aim to support consumers who were potentially most affected by the

[4] See Annex I for more details about the definition of vulnerable consumers in Spain.

consequences of the conflict between Russia and Ukraine, extending temporary measures for *Bono Social* beneficiaries.

Through RD 18/2022, in response to the ongoing effects of COVID-19 and the protracted conflict between Russia and Ukraine, a new TUR for natural gas was temporarily applied to residential communities, the discount rates for the *Bono Social Eléctrico* were increased, maximum consumption limits were raised based on household types, electricity disconnections for all types of vulnerable consumers were banned, and a new category of vulnerable consumers was created: low-income working households particularly affected by the energy crisis. These measures were initially in place until 31 December 2023 but were later extended.

3. Methodology

3.1. The theoretical model

The aim of this paper is to estimate the extent to which vulnerable households can minimise their level of energy poverty given a certain level of income and prices, while controlling for other factors. Our framework is based on Rodriguez-Alvarez et al. (2021), who proposed a similar approach to analyse energy poverty at macroeconomic level in European countries. As Welsch and Biermann (2017) point out, defining energy poverty implies the challenge of setting some threshold level or poverty line, and identifying the households that fall below (or above) that threshold. To this end, we define $\overline{V}^{z}$ such as the level of utility that a set of *m* energy goods ($\boldsymbol{x} = x_1, \dots, x_m$) reports to the individuals of a specific household and enables them to live above the energy poverty threshold z; and $V = V(\boldsymbol{p}, y)$ is the indirect utility function that represents the utility or wellbeing achievable by the individuals in a household given their vector of energy prices of goods $\boldsymbol{p} = (p_1, \dots, p_m)$ and the household income y. Following the microeconomic theory of the consumer, the function V satisfies the following properties:

$$\frac{\partial V(\boldsymbol{p},y)}{\partial y} > 0 \qquad (1)$$

$$\frac{\partial V(\boldsymbol{p},y)}{\partial p_i} \leq 0 \quad \text{for all} \quad i = 1, \dots, m \qquad (2)$$

Under these assumptions, we define the Energy Poverty Index (*EPI*) as:

$$EPI(\boldsymbol{p}, y) = \frac{\overline{V}^z}{V(\boldsymbol{p}, y)} \quad \text{for all} \quad V(\boldsymbol{p}, y) < \overline{V}^z \tag{3}$$

When *EPI* is greater than one, i.e., when $V(\boldsymbol{p}, y) < \overline{V}^z$, the household is in a situation of energy poverty. In this case, the higher the value of the *EPI* in Equation (3), the greater the degree of household vulnerability from an energy perspective. Therefore, considering the utility function $U = U(\boldsymbol{x}, \boldsymbol{x_r})$, where $V(\boldsymbol{p}, y) = \max_x \{U(\boldsymbol{x}) \mid \boldsymbol{p} \cdot \boldsymbol{x} + \boldsymbol{p_r} \cdot \boldsymbol{x_r} = y\}$,[5] it is possible to define the minimum level of *EPI* as:

$$EPI(\boldsymbol{p}, y) = \frac{\overline{V}^z}{V(\boldsymbol{p}, y)} = \min_x \left\{ \frac{\overline{V}^z}{U(\boldsymbol{x})} \;\middle|\; \boldsymbol{p} \cdot \boldsymbol{x} + \boldsymbol{p_r} \cdot \boldsymbol{x_r} = y \right\} \tag{4}$$

where *EPI* is non-decreasing in $\boldsymbol{p}$ and decreasing in y:

$$\frac{\partial EPI(\boldsymbol{p}, y)}{\partial y} = -\frac{\overline{V}^z}{V(\boldsymbol{p}, y)^2} \cdot \frac{\partial V(\boldsymbol{p}, y)}{\partial y} < 0 \tag{5}$$

$$\frac{\partial EPI(\boldsymbol{p}, y)}{\partial p_i} = -\frac{\overline{V}^z}{V(\boldsymbol{p}, y)^2} \cdot \frac{\partial V(\boldsymbol{p}, y)}{\partial p_i} \geq 0 \tag{6}$$

Given $\boldsymbol{p}$ and y, it is possible to define u as the difference between the potential $EPI(\boldsymbol{p}, y)$ and the current level EPI^0 in logarithmic terms as:

$$\ln(EPI^0) = \ln\big(EPI(\boldsymbol{p}, y)\big) + u, \quad where\ u \geq 0 \tag{7}$$

$$\text{Then, } u = \ln\left(\frac{EPI^0}{EPI(\boldsymbol{p}, y)}\right) \geq 0, \text{ so } \frac{EPI^0}{EPI(\boldsymbol{p}, y)} \geq 1 \tag{8}$$

Operating:

$$e^{-u} = \frac{EPI(\boldsymbol{p}, y)}{EPI^0} \tag{9}$$

Since $u \geq 0$, the ratio in Equation (9) is bounded between 0 and 1. In other words, the index defined by Equation (9) measures the difference between the observed level of energy poverty and the minimum that could be achieved for each household given the resources available to them. We will refer to this as the Energy Poverty Gap Index (*EPGI*).

As mentioned before, the aim of our study is twofold. First, to estimate the difference between observed energy poverty and the minimum level according to Equation (9) to calculate the maximum feasible reduction in energy poverty for a household given its resources available. Second, to analyse the factors that may be hindering or helping

[5] Where p_r and x_r are the price and quantity vectors of non-energy goods that a household consumes. We consider both vectors as given.

households in reducing their energy poverty, including the *Bono Social Eléctrico*. Both issues are addressed in the following section, which explains the empirical model based on an SFA approach.

3.2. The Empirical Model

We propose the use of Stochastic Frontier Analysis (SFA) to estimate a frontier function (for more details on SFA, see, e.g., Kumbhakar and Lovell, 2000). By applying this approach, it is possible to estimate the maximum possible reduction in energy poverty for households, given their accessible means.[6]

For empirical purposes, and taking advantage of the duality between the expenditure function $E(U,\boldsymbol{p})$ and the indirect utility function $V(y,\boldsymbol{p})$,[7] it is possible to redefine *EPI* in terms of expenditure through the following ratio:

$$EP = \frac{\overline{E}^{z}}{E(\,\overline{U},\boldsymbol{p}\,)} = \frac{\overline{E}^{z}}{\boldsymbol{p}\cdot\overline{x}} \tag{10}$$

where we now define Energy Poverty (*EP*) as the ratio between the minimum expenditure required to obtain a set of energy goods that allows household members to live above the energy poverty level ($\overline{E}^{z}$), and $E(\overline{U},\boldsymbol{p})$ is the expenditure necessary to obtain the set of energy goods ($\overline{\boldsymbol{x}}$) available to the household at prices $\boldsymbol{p}$. As before, the higher the value of *EP*, the greater the degree of energy poverty of the household.

Considering the previous model and including household (*H*) variables, as well as a term (v) to capture random noise, Equation (7) becomes:[8]

$$\ln(EP^{o}) = \ln EP(\boldsymbol{p}, y, \boldsymbol{H}) + u + v \tag{11}$$

where v is distributed according to $N(0, \sigma_v^2)$ and u follows a non-negative error distribution, such as a truncated normal distribution $N^{+}(\mu, \sigma_u^2)$. Thus, Equation (11)

[6] SFA is an econometric method that has been commonly used to estimate production efficiency by distinguishing random errors from inefficiencies. It has been applied in industries such as agriculture, manufacturing, and banking to assess firm performance against an estimated production frontier. SFA has also been used for other purposes, such as estimating pandemic cases and deaths (Millimet and Parmeter, 2022), measuring local employment multipliers and informal employment (Bashford-Fernández and Rodríguez-Álvarez, 2024), analysing energy efficiency (Filippini and Hunt, 2011), and assessing rebound effects (Orea et al., 2015).

[7] For $\overline{\boldsymbol{x}}$ which maximizes utility $\overline{U}$ given prices, the income $\overline{y}$ and the quantity of the non-energy goods $\boldsymbol{x}_r$, it holds that: $\overline{U} = U(\overline{\boldsymbol{x}}) = V(\boldsymbol{p}, \overline{y}) = V\big(\boldsymbol{p}, E(\boldsymbol{p}, \overline{U})\big)$.

[8] The model represented in Equation (11) is similar to a cost frontier in a traditional SFA framework.

represents a 'frontier' of relative energy poverty, meaning that the analysis compares households with similar characteristics to assess their levels of *EP*.

4. Data

We use data from the Spanish LCS to estimate the model presented in Equation (11). Specifically, we utilise panel data for the years 2021-2023, which includes information on specific energy-related subsidies (*Bono Social Eléctrico y Bono Social Térmico*) as well as other household features and forms of assistance received–an essential aspect of this study. In total, we have an unbalanced panel of 3,085 households surveyed over a period of three years.

Energy poverty is a complex concept, encompassing both objective and subjective factors, and its interpretation often varies depending on the living conditions and circumstances of individuals. According to the European Commission,[9] there are various indicators to approximate energy poverty, including subjective indicators, such as the inability to maintain an adequate home temperature; and objective indicators, such as delays in bill payments, extremely low energy consumption, or an energy expenditure that is disproportionately high relative to income levels (see, for example, Cadaval et al., 2022; for a review of different definitions of energy poverty in the Spanish context).

Based on the definition of Energy Poverty (*EP*) in Section 3.2, objective indicators are more suitable than subjective indicators for the aim of this study, as they are generally based on continuous variables. In order to approximate this type of indicators, and as noted by Welsch and Biermann (2017), it is necessary to define a threshold level, thereby identifying households that fall above or below this limit (examples include thresholds such as 10% of income and twice the median or twice the average expenditure share). Choosing this threshold is important, as it affects the identification of vulnerable households (Heindl, 2015; Moore, 2012). Romero et al. (2014) analyse these indicators and find that the index based on the Minimum Income Standard (MIS) is best suited to the Spanish context. However, this indicator is defined at the regional level. Our study follows the methodology recently used by Qiu et al. (2024), which employs a more accurate indicator that can be constructed from household data samples. To this end, it is

[9] https://energy.ec.europa.eu/topics/markets-and-consumers/energy-consumers-and-prosumers/energy-poverty_en.

first necessary to calculate the minimum energy consumption required for a household to stay above the poverty level $\left(\overline{V}^{z}\right)$. Following Qiu et al. (2024), this consumption is calculated after estimating the following equation:

$$E_{ht} = \alpha + \beta_y income_{ht} + \sum_{c=1}^{19} \beta_c AACC_{ht} + \beta_u urban_{ht} + \beta_s size_{ht} + \sum_{t=1}^{3} \beta_t D_t + \varepsilon_{ht} \quad (12)$$

where E_{ht} is the annual energy expenses in household *h* for year *t*, including the consumption of gas, electricity, and water, provided by the LCS from the Spanish National Statistics Institute (INE, *Instituto Nacional de Estadística*). *Income* refers to the household's net annual income, AACC represents a set of dummy variables that indicate the autonomous community in which each household is located, *urban* is a dummy variable that indicates whether the household is in a rural or urban environment, *size* proxies the size of the dwelling by the number of rooms, D_t is a yearly dummy, α is the intercept, ε_h is a random error term with zero mean and constant variance, and the βs represent the parameters linked with the regressors. From the estimation of Equation (12), we utilise $\hat{\alpha}$, $\hat{\beta}_c$, $\hat{\beta}_u$, $\hat{\beta}_s$, and $\hat{\beta}_t$ to compute a different $\overline{E}^{z}$ for each autonomous community, degree of urbanisation, dwelling size, and year.

Once $\overline{E}^{z}$ is calculated and using, from the available data, the observed household energy expenditure needed to obtain the bundle of goods x_0 at prices *p*, it is possible to obtain the household-specific *EP* according to Equation (10). After selecting households with *EP* greater than 1, i.e., households experiencing energy poverty, this indicator will be the dependent variable in Equation (11).

Table B.1 in Annex II shows the average values of $\overline{E}^{z}$ for each region and zone (rural/urban). The average minimum energy expenditure per household $\left(\overline{E}^{z}\right)$, calculated using the coefficient estimates from Equation (12), is €1,054, while the average actual household energy expenditure (E) for the entire sample is €1,670. This aligns with estimates for Spain during our period of analysis.[10] Moreover, as found by Jové-Llopis and Trujillo-Baute (2024b) the results indicate that energy poverty is asymmetrically distributed across Spanish regions and tends to occur in sparsely populated areas.

[10] According to data from the consulting firm AIS Group, the average expenditure of a Spanish household in 2021 was €1,345 (https://www.eleconomista.es/economia/noticias/11373567/08/21/Las-familias-destinan-ya-el-5-de-sus-ingresos-para-pagar-luz-agua-y-gas.html).

EP is the dependent variable in Equation (11). The explanatory variables in this equation include income and prices. To address potential endogeneity between energy poverty and income, lagged income from the previous period is used as an independent variable.[11] For energy prices, the average final price of energy in the electricity market (an average of free and regulated market prices) was €204.79/MWh in 2022, marking the highest value in history for the second consecutive year. This is nearly double the price in 2021 and more than triple the prices of 2018 and 2019. This price is set at the national level and is uniform across the country, so it is captured by the constant in Equation (12). To incorporate the evolution of this price, the set of time dummy variables D_t is included in the model. Additionally, dummy variables for autonomous communities are incorporated to account for regional differences in the prices.

Equation (11) also includes other explanatory variables related to household characteristics that may influence the level of energy poverty. A brief description of these variables is provided in Table 1, while some descriptive statistics are presented in Table 2. Two variables related to education require further explanation in addition to the details given in the table. The early secondary education dummy includes both general and vocational orientations for individuals aged 16-34 (with no access to higher education). Further secondary education encompasses general and vocational orientations, vocational orientation for individuals aged 16-34 (with access to higher education), and post-secondary non-tertiary education.

Table 1. Description of variables

Variable	***Unit***	***Description***
EP	index	Energy Poverty
Characteristics of the household		
income$_{-1}$	euro	household's total disposable income in the previous year
housing	dummy	type of housing (0 = detached or semi-detached house; 1 = flat)
tenure	dummy	tenure status (0 = owned; 1 = rented)
persons per room	persons	number of persons in the household divided by number of rooms in the property
AACC	dummies	Autonomous Communities
sparsely populated	dummy	sparsely populated area (0 = no; 1 = yes)
moderately populated	dummy	moderately populated area (0 = no; 1 = yes)
densely populated	dummy	densely populated area (0 = no; 1 = yes)
computer	dummy	(0 = household without computer; 1 = household with computer)

[11] The receptions of the BSE (*bono*) and child benefit for low-income families (*child benefit*) have also been introduced into our model with a one-period lag and can be considered predetermined. Descriptions of these explanatory variables can be found in Table 1.

bono$_{-1}$	dummy	(0 = household without BSE in the previous year; 1 = household with BSE in the previous year)
child benefit$_{-1}$	dummy	child benefit for low-income families received in the previous year (0 = no; 1 = yes)
Characteristics of the head of the household		
age	years	age
gender	dummy	(0 = male; 1 = female)
single	dummy	marital status (1 = single; 0 = other)
married	dummy	marital status (1 = married; 0 = other)
separated	dummy	marital status (1 = separated; 0 = other)
widowed	dummy	marital status (1 = widowed; 0 = other)
divorced	dummy	marital status (1 = divorced; 0 = other)
less than primary education	dummy	level of completed studies (1 = less than primary education; 0 = other)
primary education	dummy	level of completed studies (1 = primary education; 0 = other)
early secondary education	dummy	level of completed studies (1 = early secondary education; 0 = other)
further secondary education	dummy	level of completed studies (1 = further secondary education; 0 = other)
higher education	dummy	level of completed studies (1 = higher education; 0 = other)
disability	dummy	physical disability (0 = no; 1 = yes)
t	index	time trend

Table 2. Descriptive statistics

Variable	*Mean*	*Std. Dev.*	*Min.*	*Max.*
Energy Poverty (*EP*)	1.38	0.44	1.00	8.52
income	23,174	16,234	6.14	118,377
bono	0.14	0.35	0	1
sparsely populated	0.14	0.35	0	1
moderately populated	0.25	0.43	0	1
densely populated	0.61	0.49	0	1
less than primary education	0.10	0.30	0	1
primary education	0.16	0.36	0	1
early secondary education	0.20	0.40	0	1
further secondary education	0.21	0.41	0	1
higher education	0.34	0.47	0	1
computer	0.56	0.50	0	1
gender	0.49	0.50	0	1
single	0.38	0.49	0	1
married	0.22	0.41	0	1
separated	0.04	0.20	0	1
widowed	0.20	0.40	0	1
divorced	0.16	0.36	0	1
child benefit	0.02	0.12	0	1
disability	0.37	0.48	0	1
age	60.13	15.71	21	86
tenure	0.19	0.40	0	1
housing	0.78	0.42	0	1
persons per room	0.36	0.22	0.17	3

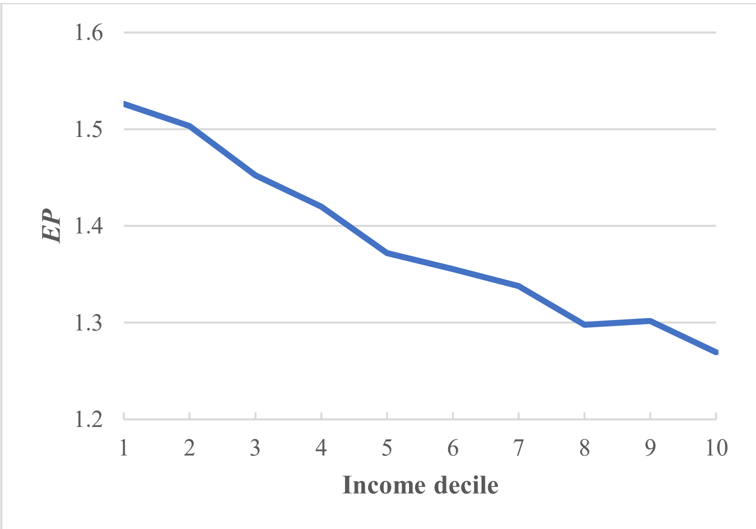
Number of observations: 4,397

5. Results

Before estimating our main model, and to assess the robustness of the proposed energy poverty measure, *EP*, Figures 1-3 show the relationship between *EP* and income levels, alongside its correlation with a standard subjective indicator of energy poverty, such as the household's ability to maintain adequate temperatures during winter. Furthermore, the receipt of the BSE is analysed concerning the *EP* index.

Figure 1 depicts a clear negative relationship between income and our *EP* index. Households in lower income deciles exhibit higher levels of energy poverty, aligning with the hypothesis that energy affordability challenges are most acute for the poorest segments of the population.

Figure 1. *EP* by income deciles



Additionally, Figure 2 exhibits a positive correlation between *EP* and the inability of households to maintain an adequate temperature during winter. This also reinforces the validity of our *EP* index as an appropriate measure for capturing energy poverty. It should be noted that the percentage of households in a subjective situation of energy poverty across the different *EP* deciles is relatively low, reaching only 27% for the highest decile. However, this is consistent with findings from previous literature, which also report low correlations between objective and subjective indicators of energy poverty, due to the complex relationship between the two (Waddams Price et al., 2012; Llorca et al., 2020).

Figure 2. Households unable to maintain an adequate temperature by *EP* deciles

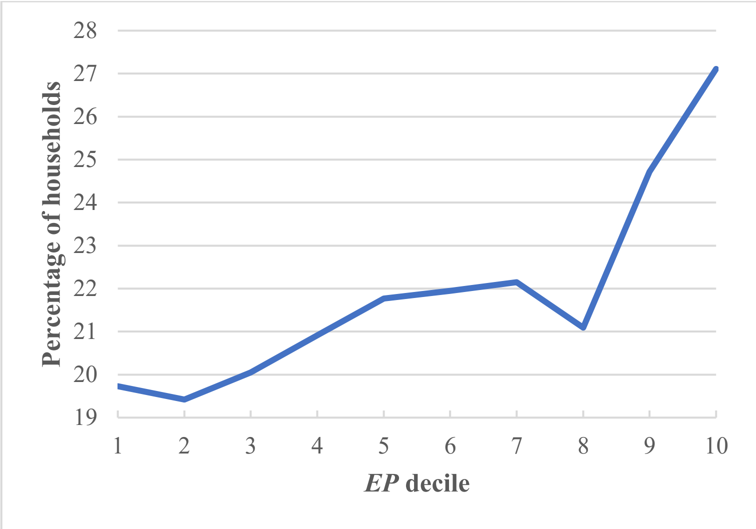


Figure 3 shows that the number of households receiving the BSE increases with higher *EP* values, suggesting that the voucher generally targets households in greater energy poverty categories. However, Figure 4 reveals that fewer than 30% of vulnerable households in the lowest income decile receive the BSE. Surprisingly, the percentage of beneficiaries rises in the highest decile compared to the preceding one, a counterintuitive finding that may be suggesting inefficiencies in targeting or the distribution mechanism. Martinez-Jorge et al. (2023) attribute this issue to better access to information and administrative support among households with higher educational level.

Figure 3. Households receiving the BSE by *EP* deciles

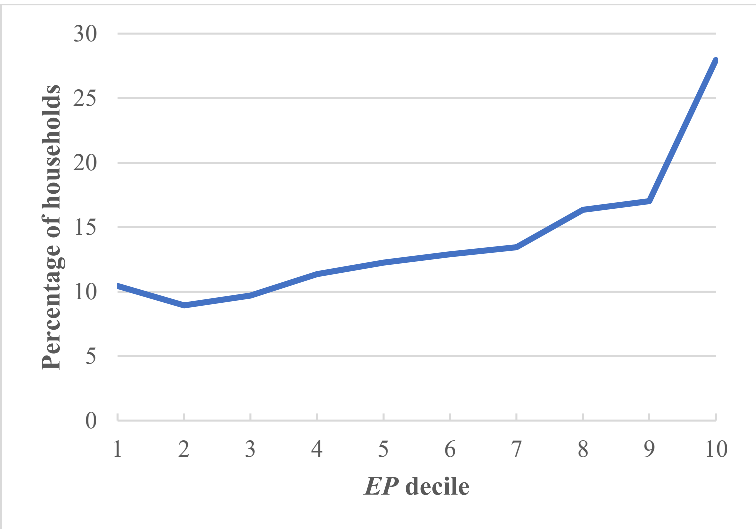


Figure 4. Households receiving the BSE by income deciles

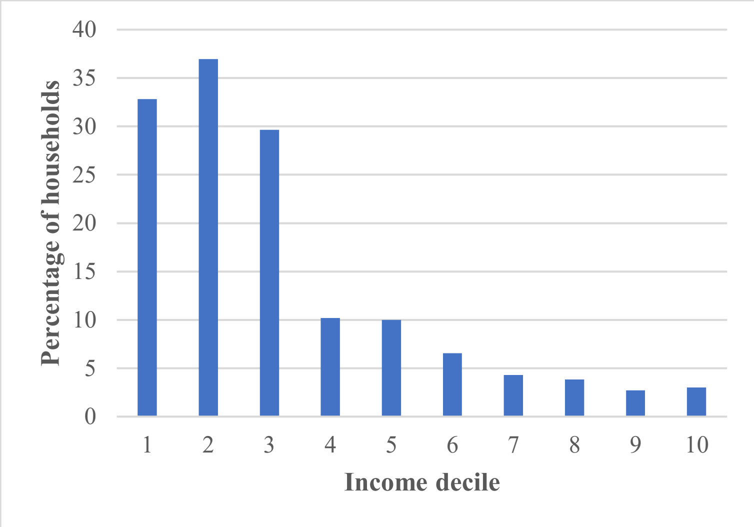


Table 3 presents the estimates of the model specified in Equation (11), using the Random Effects Generalised Least Squares (REGLS) method. This approach implements the random effects model proposed by Pitt and Lee (1981) for stochastic frontiers in panel data.[12] The model employs a Generalised Least Squares (GLS) estimation technique, assuming persistent inefficiency over time. This assumption is reasonable given the short panel structure of the dataset, which constrains the evaluation of time-varying inefficiency.

Table 3 provides valuable insights into the determinants of energy poverty and the role of the BSE. The negative and statistically significant coefficient for the income variable (-0.014, $p<0.05$) confirms the inverse relationship between income and *EP*. This finding aligns with previous studies, such as Aristondo and Onaindia (2018) and Rodriguez-Alvarez et al. (2019), which also report income as a primary determinant of energy poverty.

The coefficients for 2022 and 2023 (0.041 each, $p<0.01$) suggest a worsening of energy poverty over time, likely reflecting the impact of rising energy prices during this period. These results are consistent with observations by Jove-Llopis and Trujillo-Baute (2024b), who identify temporal trends as critical factors in the analysis of energy poverty.

[12] A fixed effects model was also estimated to conduct a Hausman test (Hausman, 1978), but it failed to converge. As an alternative, the Mundlak approach (Mundlak, 1978) was applied to check whether the observed variables were uncorrelated with the unobserved variables. The results indicated that a random effects specification was appropriate.

Regional differences, captured through the Autonomous Community (AACC) dummies, highlight significant heterogeneity across Spain. For instance, AACC 8 (Castile and León) and AACC 9 (Castilla La-Mancha) indicate higher energy poverty levels, whereas AACC 10 (Extremadura) shows reduced levels. These disparities also align with findings by Jove-Llopis and Trujillo-Baute (2024b), who highlight regional variations in energy poverty across Spain. The discrepancies may be reflecting variations in energy prices, housing characteristics, and climatic conditions.

The BSE's impact is captured through several interaction terms. The negative and significant coefficient for "bono" (-0.233, $p<0.01$) confirms the programme's mitigating effect on energy poverty. However, the positive interaction with time (t·bono: 0.066, $p<0.01$) suggests diminishing returns over time, possibly due to rising energy costs during the period or administrative barriers. Interaction terms with income deciles reveal that the BSE's effectiveness does not consistently improve for lower-income households. For instance, the large positive interaction coefficient for the lowest income decile (0.230, $p<0.01$) indicates that the programme's mitigating effect is significantly offset for the most vulnerable group. This suggests structural or programme-related barriers may limit the programme's efficacy for households facing extreme poverty, whereas the BSE's relative effectiveness diminishes less markedly for higher-income groups.

Other variables with significant coefficients include education, gender, and household characteristics. For example, higher education levels reduce *EP* (-0.018, $p<0.1$), underscoring the role of awareness and resource access. Female-headed households experience lower *EP* (-0.018, $p<0.05$), which may suggest that women are more proactive in securing resources, such as energy-related investments or efficient budgeting. This finding contrasts with the general narrative that women experience poverty more frequently and intensely than men. However, some studies have previously observed that female-headed households can exhibit a higher quality of life than their male-headed counterparts (see, e.g., Listo, 2018). The number of persons per room (-0.059, $p<0.01$) suggests that overcrowding is associated with lower energy poverty, perhaps due to shared energy resources.

The estimate obtained regarding households' access to information, specifically whether they have a computer, is highly relevant. The finding, in line with the results from Martinez-Jorge et al. (2023), indicate that this factor significantly impacts the reduction of energy poverty rates. This may explain, along with the educational level, why the most vulnerable households (those in the lowest income deciles) do not apply for the BSE due to issues such as the complex bureaucracy involved in the process or even a lack of awareness that they are entitled to receive it. These results suggest that providing more information and resources on how to apply for these benefits could significantly help improve energy poverty levels.

As shown in Equation (9) and based on the conditional mean of *u* proposed by Jondrow et al. (1982), we can compute our *EPGI* using the estimated model. This index quantifies the gap between the observed level of energy poverty and the theoretical minimum that could be achieved by each household, given their available resources. Figure 5 presents the average *EPGI* across income deciles for the total sample. It can be observed that, despite some variability, households in the lowest income deciles exhibit the lowest *EPGI* values. This indicates that these households have the greatest potential for improvement when comparing their current level of energy poverty with the achievable minimum.

Figure 6 further illustrates the average *EPGI* per income decile, distinguishing between recipients and non-recipients of the BSE. Among BSE beneficiaries, particularly those in middle-income households, the *EPGI* tends to be slightly higher, suggesting a potential correlation between receiving the BSE and experiencing reduced energy poverty. However, for the first income decile, households not receiving the BSE show a higher average *EPGI* than their beneficiary counterparts. This finding may highlight the need to enhance the effectiveness of the BSE in addressing energy poverty among the lowest-income households.

Table 3. Parameter estimates

Parameters	*Est.*		*Est./s.e.*
ln income$_{-1}$	-0.013	**	-2.25
year 2022	0.041	***	4.71
year 2023	0.041	***	4.31
AACC (1)	0.049	*	1.73
AACC (2)	0.018		0.66
AACC (3)	0.007		0.28
AACC (4)	0.044		1.49
AACC (5)	0.021		0.72
AACC (6)	0.034		1.30
AACC (7)	0.049	**	2.31
AACC (8)	0.081	***	3.58
AACC (9)	0.071	***	2.90
AACC (10)	-0.100	***	-3.41
AACC (11)	0.037	*	1.96
AACC (12)	-0.001		-0.03
AACC (13)	-0.009		-0.29
AACC (14)	-0.064	***	-2.73
AACC (15)	-0.014		-0.44
AACC (16)	-0.053		-0.81
AACC (17)	-0.086		-1.06
AACC (18)	-0.091	**	-2.23
bono$_{-1}$	-0.234	***	-2.92
t·bono$_{-1}$	0.066	***	5.29
bono$_{-1}$·income decile (1)$_{-1}$	0.230	***	3.28
bono$_{-1}$·income decile (2)$_{-1}$	0.133	*	1.93
bono$_{-1}$·income decile (3)$_{-1}$	0.114		1.65
bono$_{-1}$·income decile (4)$_{-1}$	0.098		1.32
bono$_{-1}$·income decile (5)$_{-1}$	0.081		1.08
bono$_{-1}$·income decile (6)$_{-1}$	0.037		0.47
bono$_{-1}$·income decile (7)$_{-1}$	0.054		0.64
bono$_{-1}$·income decile (8)$_{-1}$	0.058		0.68
bono$_{-1}$·income decile (9)$_{-1}$	0.100		1.11
moderately populated	-0.009		-0.61
densely populated	0.002		0.16
ln education	-0.018	*	-1.81
computer	-0.023	**	-2.40
gender	-0.018	**	-2.11
single	0.092	***	7.47
separated	0.040	*	1.89
widowed	0.022		1.45
divorced	0.059	***	4.23
child benefit$_{-1}$	-0.057	*	-1.96
disability	-0.008		-0.97
ln age	0.044	**	2.22
tenure	0.008		0.79
housing	-0.011		-0.94
ln (persons per room)	-0.058	***	-5.89
intercept	0.192	***	8.47
σ_u	0.147	***	14.09
σ_v	0.180	***	29.59

Significance code: * p<0.1, ** p<0.05, *** p<0.01
Note: $_{-1}$ indicates that the variable is lagged by one period

Figure 5. Average household *EPGI* by income deciles

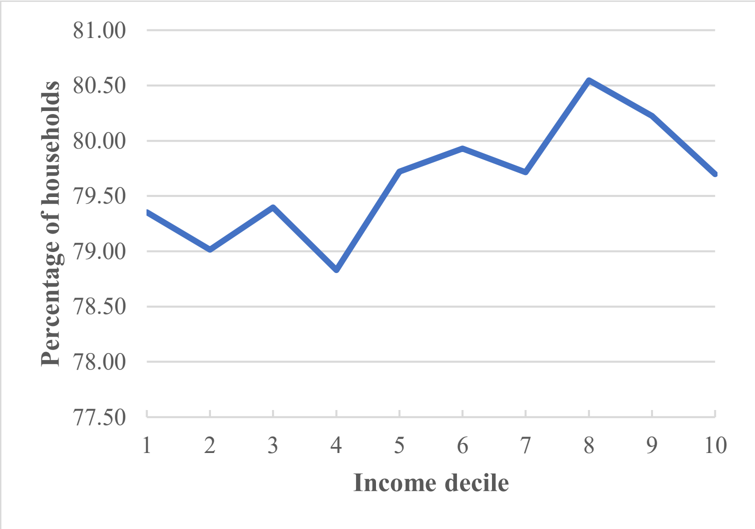
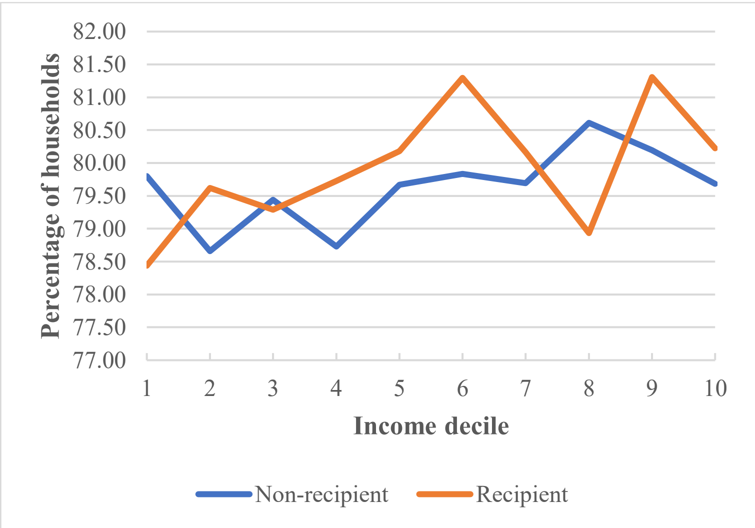
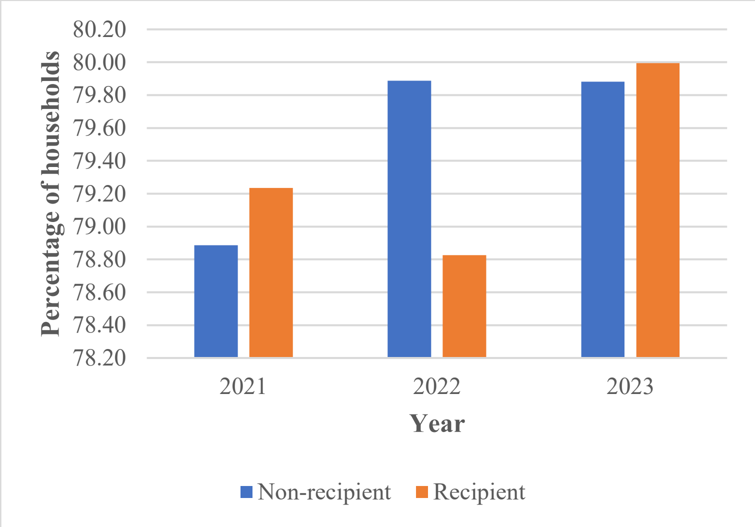


Figure 6. Average *EPGI* for recipients and non-recipients of the BSE by income deciles



Finally, Figure 7 illustrates temporal trends, indicating marginal improvements in the *EPGI* over time for non-recipients of the BSE, alongside a decrease in the average index for recipients in 2022. This decline may be attributed to an ineffective policy adjustment in response to rising energy prices, driven by the post-pandemic recovery and the Russia-Ukraine conflict.

Figure 7. Average *EPGI* for recipients and non-recipients of the BSE per year



To conclude, in summary our analysis highlights two key dimensions related to the impact of the BSE: effectiveness and equity. In terms of effectiveness, we find that the BSE does contribute to reducing energy poverty. On average, recipients show lower energy poverty levels compared to non-recipients. However, this impact is not uniform across the income distribution. Specifically, the programme is significantly less effective for households in the lowest income decile, which points to a deeper issue of equity. These are the households facing the greatest vulnerability. However, our estimates suggest that the support they receive is not sufficient to significantly reduce their energy poverty. This raises concerns about how the BSE is designed and whether it is adequately tailored to address the needs of those most at risk. For the policy to be both impactful and fair, improvements in how support is structured and delivered are clearly needed.

6. Conclusion

This study presents an evaluation of the *Bono Social Eléctrico* (BSE), a Spanish social electricity voucher aimed at alleviating energy poverty. By employing a novel microeconomic framework and a Stochastic Frontier Analysis (SFA) approach, we assessed the gap between observed and potential energy poverty levels and evaluated the programme's effectiveness. Our findings highlight the BSE's role in mitigating energy poverty, although its impact is constrained by inefficiencies in targeting and coverage.

Our results show an inverse relationship between household income and energy poverty, reaffirming that lower-income households face greater challenges in achieving energy security. Temporal analysis suggests that energy poverty worsened in recent years, likely due to increased energy prices following the post-pandemic economic recovery and the geopolitical effects of the Russia-Ukraine conflict. The BSE has proven effective in reducing energy poverty for beneficiaries, but its impact has diminished over time and varies across income groups. Notably, the programme's mitigating effect is significantly lower for the lowest-income households, suggesting that structural or programme-related barriers may prevent the most vulnerable from fully benefiting. This raises concerns about inequities in the targeting mechanism.

Additionally, our results indicate that vulnerable households with better access to information (e.g., owning a computer or having higher education levels) can reduce their poverty more effectively. To address these challenges, we propose reconsidering the BSE's design to better reach its target audience. Key recommendations include shifting the application process to public administrations, utilising household data they already possess to notify eligible households and streamlining the application process. This would help reduce bureaucratic hurdles and simplify documentation management, ensuring that aid is less diverted to higher-income households and more effectively reaches low-income families.

Our study also identifies significant inefficiencies in the BSE's impact. Vulnerable households in the lowest income decile are underrepresented among recipients, while higher-income households disproportionately benefit. Additionally, non-recipients in the lowest income decile exhibit lower Energy Poverty Gap Index (*EPGI*) values than beneficiaries, suggesting an 'energy poverty trap' where some recipients remain unable to overcome structural vulnerabilities despite receiving aid.

Regional disparities in energy poverty further complicate the issue, with some regions exhibiting higher levels of energy poverty due to varying climatic conditions, energy prices, and housing characteristics. These disparities highlight the need for geographically customised policies to ensure equitable outcomes. In addition, the temporal trends in *EPGI* reveal that while non-recipients showed slight improvements, recipients experienced a setback in 2022, likely due to the BSE's failure to adapt to escalating energy costs. This underscores the need for a more responsive policy framework.

From a policy perspective, several improvements are necessary. Enhancing the programme's targeting mechanism, automating income verification through direct links to tax or welfare records, and utilising real-time digital data could improve the precision of subsidy allocation. Complementary measures, such as integrating the BSE with energy efficiency initiatives and retrofitting housing, could provide more sustainable solutions. Furthermore, simplifying administrative procedures and increasing outreach to vulnerable groups (e.g., the elderly, disabled, and rural populations) would improve programme accessibility.

Tailoring policies to regional characteristics is crucial. Addressing energy poverty disparities requires adjusting subsidy levels based on local energy prices, climatic conditions, and housing needs. Finally, the BSE's inability to respond dynamically to external shocks, such as the 2022 energy price surge, highlights the importance of building flexibility into policy design. Regular reviews and indexation of subsidies to energy prices could ensure continued effectiveness.

Ultimately, it is insufficient for the BSE to only partially reach its intended recipients. One of the primary barriers to aid distribution is the lack of information and the complex administration surrounding the application process. For the greater good, legislators must adapt these regulations to better meet the social needs of the most vulnerable families, ensuring that the BSE fulfils its purpose of providing essential energy security.

In conclusion, while the BSE has contributed to reducing energy poverty in Spain, its limitations call for targeted reforms. Improving targeting mechanisms, integrating complementary structural measures, simplifying administrative processes, and adopting a flexible, regionally adaptive approach are essential for ensuring equitable energy access. These findings provide valuable insights for policymakers seeking to strengthen energy poverty alleviation strategies and promote energy justice in the face of future challenges.

References

Aristondo, O., Onaindia, E., 2018. Counting energy poverty in Spain between 2004 and 2015. Energy Policy 113, 420-429. https://doi.org/10.1016/j.enpol.2017.11.027.

Bagnoli, L., Bertoméu-Sánchez, S., 2022. How effective has the electricity social rate been in reducing energy poverty in Spain? Energy Economics 106, 105792. https://doi.org/10.1016/j.eneco.2021.105792.

Bashford-Fernández, J.M., Rodríguez-Álvarez, A., 2024. Measuring local employment multipliers and informal employment: A stochastic frontier approach. Regional Studies 58(1), 78-90. https://doi.org/10.1080/00343404.2023.2189014.

Cadaval, M., Regueiro-Ferreira, R.M., Calvo, S., 2022. The role of the public sector in the mitigation of fuel poverty in Spain (2008-2019): Modeling the contribution of the *Bono Social de Electricidad*. Energy 258, 124717. https://doi.org/10.1016/j.energy.2022.124717.

Carfora, A., Scandurra, G., 2024. Boosting green energy transition to tackle energy poverty in Europe. Energy Research & Social Science 110, 103451. https://doi.org/10.1016/j.erss.2024.103451.

Costa-Campi, M.T., Jove-Llopís, E., Trujillo-Baute, E., 2021. Cómo abordar la pobreza energética en España (Working Paper), Center for Economic Policy - EsadeEcPol. Madrid.

Filippini, M., Hunt, L.C., 2011. Energy demand and energy efficiency in the OECD countries: A stochastic demand frontier approach. The Energy Journal 32(2), 59-80. https://doi-org.esc-web.lib.cbs.dk/10.5547/ISSN0195-6574-EJ-Vol32-No2-3.

Garcia Alvarez, G., Tol, R.S.J., 2021. The impact of the Bono Social de Electricidad on energy poverty in Spain. Energy Economics 103, 105554. https://doi.org/10.1016/j.eneco.2021.105554.

Hausman, J.A., 1978. Specification tests in econometrics. Econometrica 46(6), 1251-1271. https://doi.org/10.2307/1913827.

He, X. and Reiner, D., 2016. Electricity demand and basic needs: Empirical evidence from China's households. Energy Policy 90, 212-221. https://doi.org/10.1016/j.enpol.2015.12.033.

Heindl, P., 2015. Measuring Fuel Poverty: General Considerations and Application to German Household Data. FA 71, 178. https://doi.org/10.1628/001522115X14285723527593.

Hills, J., 2011. Fuel poverty: The problem and its measurement. Interim Report of the Fuel Poverty Review. Centre for the Analysis of Social Exclusion, London School of Economics and Political Science, London, UK.

Jondrow, J., Lovell, K., Materov, I., Schmidt, P., 1982. On the estimation of technical inefficiency in the stochastic frontier production function model. Journal of Econometrics 19(2-3), 233-238. https://doi.org/10.1016/0304-4076(82)90004-5.

Jové-Llopis, E., Trujillo-Baute, E., 2024a. Escaping the Energy Poverty Trap: Policy Assessment. Environ and Resource Economics. https://doi.org/10.1007/s10640-024-00918-2.

Jové-Llopis, E., Trujillo-Baute, E., 2024b. The effect of regional factors on energy poverty. Applied Economic Analysis 32(95), 167-185. https://doi.org/10.1108/AEA-01-2024-0019.

Kumbhakar, S.C., Lovell, C.A.K., 2000. Stochastic Frontier Analysis, 1st ed. Cambridge University Press. https://doi.org/10.1017/CBO9781139174411.

Linares, P., Romero, J.C., Lopez-Otero, X., 2017. Pobreza Energética en España y posibles soluciones (Working Paper No. 1/2017). Economics for Energy, Vigo.

Linares-Llamas, P., Romero-Mora, J.C., 2015. Resumen y principales conclusiones sobre el Estudio de Pobreza Energética. Cuadernos de Energia 46, 68-75.

Listo, R., 2018. Gender myths in energy poverty literature: A critical discourse analysis, Energy Research & Social Science 38, 9-18. https://doi.org/10.1016/j.erss.2018.01.010.

Llorca, M., Rodriguez-Alvarez, A., Jamasb, T., 2020. Objective vs. subjective fuel poverty and self-assessed health. Energy Economics 87. https://doi.org/10.1016/j.eneco.2020.104736.

Martinez-Jorge, A., Collado Van-Baumberghen, N., Galindo, J., 2023. A quién llegan los bonos energéticos: un análisis por nivel de renta y tipos de familia (Working Paper No. 47). Center for Economic Policy - EsadeEcPol, Madrid.

Millimet D.L, Parmeter, C.F., 2022. COVID-19 severity: A new approach to quantifying global cases and deaths. Journal of the Royal Statistical Society Series A: Statistics in Society 185(3), 1178-1215. https://doi-org.esc-web.lib.cbs.dk/10.1111/rssa.12826.

Moore, R., 2012. Definitions of fuel poverty: Implications for policy. Energy Policy 49, 19-26. https://doi.org/10.1016/j.enpol.2012.01.057.

Mundlak, Y., 1978. On the pooling of time series and cross section data. Econometrica 46(1), 69-85. https://doi.org/10.2307/1913646.

Orea, L., Llorca, M., Filippini, M., 2015. A new approach to measuring the rebound effect associated to energy efficiency improvements: An application to the US residential energy demand. Energy Economics 49, 599-609. https://doi.org/10.1016/j.eneco.2015.03.016.

Palma, P., Barrella, R., Gouveia, J.P., Romero, J.C., 2024. Comparative analysis of energy poverty definition and measurement in Portugal and Spain. Utilities Policy 90, 101770. https://doi.org/10.1016/j.jup.2024.101770.

Phimister, E., Vera-Toscano, E., Roberts, D., 2015. The dynamics of energy poverty: Evidence from Spain. Economics of Energy & Environmental Policy 4(1), 153-166. https://doi.org/10.5547/2160-5890.4.1.ephi.

Pitt, M.M., Lee, L-F., 1981. The measurement and sources of technical inefficiency in the Indonesian weaving industry. Journal of Development Economics 9(1), 43-64, https://doi.org/10.1016/0304-3878(81)90004-3.

Qiu, H., Sha, Y., Zhang, Y., 2024. Energy affordability and subjective well-being in China: Causal inference, heterogeneity, and the mediating role of disaster risk. Energy Economics 129, 107180. https://doi.org/10.1016/j.eneco.2023.107180.

Rodriguez-Alvarez, A., Llorca, M., Jamasb, T., 2021. Alleviating energy poverty in Europe: Front-runners and laggards. Energy Economics 103, 105575. https://doi.org/10.1016/j.eneco.2021.105575.

Rodriguez-Alvarez, A., Orea, L., Jamasb, T., 2019. Fuel poverty and Well-Being:A consumer theory and stochastic frontier approach. Energy Policy 131, 22-32. https://doi.org/10.1016/j.enpol.2019.04.031.

Romero, J.C., Linares, P., Lopez-Otero, X., 2014. Pobreza Energética en España. Análisis económico y propuestas de actuación (Working Paper), Economics for Energy. Economics for Energy, Vigo.

Scarpellini, S., Rivera-Torres, P., Suárez-Perales, I., Aranda-Usón, A., 2015. Analysis of energy poverty intensity from the perspective of the regional administration: Empirical evidence from households in southern Europe. Energy Policy 86, 729-738. https://doi.org/10.1016/j.enpol.2015.08.009.

Tirado-Herrero, S., Jimenez-Meneses, L., Lopez-Fernandez, J.L., Perero-Van Hove, E., Irigoren-Hidalgo, V., Savary, P., 2016. Pobreza, vulnerabilidad y desigualdad energética. Nuevos enfoques de análisis (Working Paper). Asociacion de Ciencias Ambientales, Madrid.

Tirado-Herrero, S., Lopez-Fernandez, J.L., Martin-Garcia, P., 2012. Pobreza energética en España. Potencial de generación de empleo directo de la pobreza derivado de la rehabilitación energética de viviendas (Working Paper), Asociacion de Ciencias Ambientales. Asociacion de Ciencias Ambientales, Madrid.

Waddams Price, C., Brazier, K., Wang, W., 2012. Objective and subjective measures of fuel poverty. Energy Policy 49, 33-39. https://doi.org/10.1016/j.enpol.2011.11.095.

Welsch, H., Biermann, P., 2017. Energy Affordability and Subjective Well-Being: Evidence for European Countries. The Energy Journal 38, 159-176. https://doi.org/10.5547/01956574.38.3.hwel.

Annex I. Types of Vulnerable Consumers, Requirements to Obtain the Social Bonus, and Applicable Discounts

Broadly speaking, a vulnerable consumer can be defined as "an electricity or thermal energy consumer in a situation of energy poverty, who may be eligible for support measures established by the administration," according to the Ministry for Ecological Transition in its National Strategy Against Energy Poverty 2019-2024 (Ministry for Ecological Transition, 2019, p.6).

In RD 897/2017, Article 3, the definition of a vulnerable consumer is specified as: "a vulnerable consumer shall be considered as any natural person who is the registered holder of an electricity supply point in their primary residence, who is subscribed to the Voluntary Price for Small Consumers (PVPC) and meets the other requirements set forth in this article."

Thus, as previously stated in previous regulations, legal entities cannot benefit from the social bonus, as it is exclusively reserved for individuals. The request must also be for the primary residence, and the subscriber must be under the PVPC rate. The PVPC, as defined by the Ministry for Ecological Transition on its website, is the "electricity contract established by the Government where the amount paid for consumed electricity is directly the market price of energy, plus taxes and fees, without including any additional products or services." During the COVID-19 pandemic, a new type of consumer entitled to the social bonus was created: self-employed individuals who experienced cessation or significant reduction of their activity during the confinement and pandemic. This category was valid only up to one month after the confinement period ended.

A.1 General Requirements

In section 2 of Article 3 of RD 897/2017, specific requirements for social bonus applicants are outlined, some of which are inherent in the definition of a vulnerable consumer. These requirements are as follows:

- Being a natural person
- Being the holder of the supply point
- Ensuring that the supply point constitutes their primary residence
- Being subscribed to the PVPC rate

- For PVPC eligibility, contracted power must be below 10 kW
- Not exceeding the maximum consumption limits set for each type of family unit:
  - Individual or two-person household: 1,587 kWh
  - Three-person household, pensioners receiving minimum pension, single-parent family: 2,222 kWh
  - Four-person household, three persons, two of whom are minors: 2,698 kWh
  - Five or more persons, four persons, two of whom are minors, large families: 4,761 kWh

Additionally, further requirements must be met to classify the consumer into one of the protected consumer categories. These requirements will be presented in the subsections below in order of increasing severity, i.e., from lower to higher levels of protection required.

A.2 Vulnerable Consumer (Art. 3.2 RD 897/2017)

In addition to the general requirements mentioned, at least one of the following must apply:

- Annual income, or, if part of a family unit, the combined annual income must be equal to or lower than:
  - 1.5 times the IPREM for 14 payments if not part of a family unit or if no minors are present (12,600€) The IPREM (*Indicador Público de Renta de Efectos Múltiples*) is a benchmark index in Spain used to assess eligibility for public benefits and subsidies based on income thresholds.
  - Twice the IPREM for 14 payments if there is one minor (16,800€)
  - 2.5 times the IPREM if there are two minors (21,000€) If the household consists of more than one person, the IPREM threshold is increased as follows:
  - By 0.3 for each additional adult
  - By 0.5 for each additional minor
- Holding a large family certificate

- If all family members receiving income are Social Security pensioners (due to retirement or permanent disability) and receive the minimum pension, with additional income not exceeding an aggregate annual total of 500€
- Being a recipient of the Minimum Vital Income (IMV, *Ingreso Mínimo Vital*)

A vulnerable consumer is entitled to a 25% discount on their electricity bill, although this discount was exceptionally 65% until 30 June, 2024.

A.3 Severe Vulnerable Consumer (Art. 3.4 RD 897/2017)

To qualify as a severely vulnerable consumer, the consumer or their family unit must meet one of the following requirements:

- Annual income is less than 50% of the income thresholds set for vulnerable consumers, including, if applicable, special circumstances allowances
- In cases of large families, incomes are equal to or below twice the IPREM for 14 payments (16,800€)
- If the consumer or all household members receive the minimum pension and additional income does not exceed an aggregate annual total of 500€, the household income must not exceed the IPREM for 14 payments, i.e., 8,400€
- For IMV recipients, the income criteria for vulnerable consumers apply, that is, the income or combined household income must be equal to or below:
    - 1.5 times the IPREM for 14 payments if not part of a family unit or if no minors are present (12,600€)
    - Twice the IPREM for 14 payments if there is one minor (16,800€)
    - 2.5 times the IPREM if there are two minors (21,000€)

Severely vulnerable consumers benefit from a 40% discount on their bill, which, until 30 June 2024, was exceptionally 80%.

A.4 Consumers at Risk of Social Exclusion (Art. 4 RD 897/2017)

The category of consumers at risk of social exclusion is the most precarious, with the strictest requirements. In this case, the consumer must meet the requirements for a severely vulnerable consumer and also be assisted by the social services of a Public Administration, whether regional or local. This administration must finance at least 50%

of the PVPC bill. Additionally, in the event of temporary inability to make payment, the electricity supply may not be interrupted.

A.5 Energy Justice Social Bonus (Art. 10 RD 18/2022)

This type of social bonus was created temporarily, until December 31, 2023, to mitigate the effects of the energy crisis on low-income households particularly affected by it.

To qualify for this bonus, the family's income must be equal to or below twice the IPREM but above 1.5 times the IPREM, meaning between 16,800€ and 12,600€. The IPREM multipliers of 0.3 per additional adult and 0.5 per additional minor also apply.

Recipients of this type of bonus are not eligible for the thermal social bonus. The discount applicable was 40% until 30 June, 2024.

A.6 Special Circumstances (Art. 5 RD 8/2021)

If the following special circumstances apply, the IPREM thresholds are increased by 1 point:

- Recognised disability of 33% or more for the consumer or any household member
- Documentation of gender-based violence against the consumer or any household member
- The consumer or any household member is a recognised victim of terrorism
- The consumer or any household member has recognised dependency status of Grade I or II
- Documentation that the household is single-parent (one parent and at least one minor)

Annex II. Computation of $\overline{E}^{z}$

Table B.1. Average for each region, distinguishing between rural and urban areas

Region	rural	urban
Galicia	1,411.02	1,281.74
Asturias	1,562.44	1,433.17
Cantabria	1,479.55	1,350.28
Basque Country	1,383.85	1,254.57
Navarre	1,613.60	1,484.33
La Rioja	1,589.05	1,459.78
Aragón	1,627.91	1,498.64
Madrid	1,517.43	1,388.16
Castile and León	1,717.69	1,588.41
Castilla-La Mancha	1,670.41	1,541.14
Extremadura	1,320.23	1,190.96
Catalonia	1,472.90	1,343.63
Valencia	1,202.49	1,073.22
Balearic Islands	1,375.91	1,246.64
Andalusia	1,226.64	1,097.37
Murcia	1,268.44	1,139.17
Ceuta*	912.64	783.36
Melilla*	934.82	805.55
Canary Islands	924.19	794.91

Note: Ceuta and Melilla, highlighted with *, are two autonomous cities located on the north coast of Africa