To eat and not to heat? Energy poverty and income inequality in Italian regions



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# To eat and not to heat?
# Energy poverty and income inequality in Italian regions

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**Abstract**

Energy poverty is broadly associated with the more general concept of income poverty. However, this phenomenon is more rarely linked to socio-economic inequalities. Recent works in the related literature are pursuing this line of research to explore if energy poverty is associated with a social vulnerability status with roots in structural inequities (Simcock et al. 2018). These factors are unevenly distributed in space and therefore, determine a geographical variability of energy poverty. Following Galvin (2019), in this paper we study if a relation between economic inequality and energy poverty exists also in the highly heterogeneous context of the Italian territory. We test this relationship on households living in Italian regions controlling for other variables influencing between-regions variation in energy poverty. Moreover, in the empirical analysis we use both consensual and expenditure-based indicators – and also a combination of them – to verify the extent to which the two methods to measure energy poverty contribute to understanding this complex phenomenon, as claimed in some of the literature. Our multivariate analyses confirm that income inequality significantly correlates with energy poverty indicators when Italian regions are the units of analysis. This suggests that strategies to address energy poverty should be comprehensive and spatially implemented.

**Keywords:** Energy poverty; Income inequality; Consensual indicators; Expenditure-based indicators

## 1. Introduction

Regional diversities and disparities are evident in Italy in many respects, including geographical and meteorological variation, differences in economic activities and labour markets, and dissimilarities in institutions, social norms and environmental attitudes. The widely studied Italian north–south poverty divide conceals a coexistence of different forms of deprivation, among which the lack of adequate energy services is possibly the least studied. This paper analyses the distribution of income inequality and energy poverty indicators across the Italian regions and the correlation between these two phenomena and other socio-economic differences.

Energy poverty is a multifaceted phenomenon that asymmetrically affects countries and social groups. Unlike developing countries [1], in advanced contexts energy poverty does not involve a lack of physical infrastructure but instead an "inability to afford adequate warmth in the home" [2]. Although large areas of overlap between income poverty and energy poverty can be expected, the lack of adequate energy services raises specific concerns about the physical and mental health (see, among others, [3], [4], [5], [6], [7], [8]) and educational attainment of those living in too low (or too high) temperatures [9], [10]. This perspective involves on the one hand an in-depth debate on the most suitable indicators to measure this issue [11], [12] and on the other hand an interaction between energy poverty and the characteristics, needs and (re)distribution of different types of resources in society [13].

To analyse the interaction between the availability of energy services and other resources, or lack thereof, factors such as income, housing conditions, technology, lifestyles and demography are crucial [14]. The effects of these elements on energy poverty can be investigated both at the micro (individual) and macro (country) levels. This paper adopts an intermediate level of analysis, namely Italian regions, and from this perspective observes the heterogeneity in the diffusion of energy poverty across different areas and its correlation with other region-level data.

A first contribution of the paper is therefore that it explores whether the nexus between income inequality and energy poverty – identified by Galvin [15], among others – also applies at the subnational level. To tackle this, we control for other determinants that can be associated with energy poverty in the Italian regions between 2004 and 2015. This particular timespan represents an interesting case study to understand the dynamics of energy poverty in a period of economic crisis. An additional original contribution of the paper is that it investigates the extent to which the understanding of this nexus is conditioned by the choice of indicator adopted to measure energy poverty by testing alternative indicators proposed in the literature. In our empirical analysis we adopt both consensual and expenditure-based indicators and our results are robust to the choice of alternative measures.

The remainder of the paper is organised as follows. Section 2 presents the background to the paper, briefly reviewing findings in the literature on energy poverty metrics. Section 3 describes the Italian context and the importance of the regional perspective. Section 4 presents the dataset, the variables selected, the model and the robustness checks adopted. Section 5 reports and discusses the results. Finally, section 6 provides some conclusions and suggests avenues for future research.

## 2. Overlapping deprivations: Inequality and energy poverties

The Italian north–south economic gap has been studied in many respects, but it is striking how differences in income, infrastructure and inequality persist despite the various policies implemented over the past six decades. As Felice [16] stresses, the southern regions are, on average, poorer and exhibit significantly higher inequality, according to the Gini index, than most of the central and northern regions. Since the end of WWII, things have not changed in this respect and socio-institutional factors have been found to be among the most relevant roots of this persistent gap. In a more recent perspective, Ciani and Torrini [17] find that within-area inequality has significantly increased in the last ten years: the economic recession hit the bottom of the income distribution more severely and this gap is mainly attributed to disparities in employment intensity.

Policies to combat poverty and inequality have been introduced at the national and regional levels. Although redistributive policy has been conventionally attributed to central government, the role of the regions has been very important because they have made up for shortcomings in central policy. Indeed, national policies to tackle poverty and social exclusion have traditionally had a minor role and been given limited resources, with their benefits basically addressed to people temporary out of the labour market.[1] It was not until 2017 that the introduction of a nationwide minimum guaranteed

[1] Italy has been traditionally characterised by a welfare state of Bismarckian character in which most resources are devoted to employment-related social protection and categorical needs. Until 2017, a nationwide poverty programme did not exist so that Italy was one of the two countries in the EU-28 without a minimum guaranteed income. Minimum income policy had been experimented with at the local level, especially after the financial crisis, with more than ten

income scheme[2] marked a turnaround in terms of both policy design and the resources employed. Until then, policies to combat poverty had been highly fragmented and very limited in terms of the resources allocated so that local governments (regions and municipalities) played a key supporting role to combat different forms of deprivation and to reduce – also by means of local progressive tax rates – income inequalities. This is why we consider that regional inequalities and energy poverty should be investigated jointly.

Energy poverty,[3] a lack of adequate energy services, has proven very hard to precisely define. Recent EU guidance on energy poverty[4] recognises that, although there is no standard definition, in general "energy poverty results from a combination of low income, high expenditure of disposable income on energy and poor energy efficiency, especially as regards the performance of buildings"(p. 2). It is evident that in this definition causes (like low income) and effects (energy deprivation) coexist and this ambiguity is also evident in the way that definitions and metrics have evolved in recent decades. In developed countries characterised by ample energy infrastructure, income levels and redistribution, preferences and weather conditions can make financial constraints binding. Since the oil shock in the seventies, the effect of increasing energy prices on vulnerable consumers has emerged as a key issue and an 'energy consumption share' was initially employed to identify how many households were suffering from the rapid fuel price increase [18], [2]. In the last four decades, besides raw fuel price variations, all developed countries have seen an escalation in inequality and poverty diffusion.[5] Public policies designed to combat climate change and to incentivise the energy transition have added a specific tax wedge to energy prices,[6] making energy affordability a more important issue. Moreover, the effects of the financial crisis exasperated the situation of the most vulnerable citizens in Italy and

different means-tested social assistance schemes approximating minimum income schemes operating at the sub-national level [57]. At the same time, the European Social Fund (ESF) has played an important role: the ESF financial allocation in Italy for the 2007/2013 cycle assigned 86 per cent to the Italian regions and 14 per cent to the central government. In the current programming cycle (2014–2020) the resources assigned to Italian regions by the ESF and the European Regional Development Fund reach 35.5 billion euros.

[2] See the 'Reddito di Inclusione' and 'Reddito di Cittadinanza' support schemes.

[3] Although some literature distinguishes between energy poverty (lack of access to modern energy sources) and fuel poverty (lack of financial resources to adequately use energy services), in this paper we adopt the term 'energy poverty' to refer to both.

[4] EU Commission Staff Working document accompanying the Commission Recommendation on energy poverty (C (2020) 9600 final).

[5] The dynamics of inequality at the international level came back to international attention following the work of A. Atkinson and T. Piketty (see [58]). In Italy, several analyses show that after a continual decrease in poverty and inequality levels until 1990 the last 30 years have seen a new general worsening according to all indicators. See Cannari and D'Alessio [59] for a long run estimation of poverty incidence and income and wealth inequality in Italy.

[6] See [60].

other Mediterranean countries from several perspectives, including energy poverty [19], [20], [21], and further worsening may be forthcoming because of the coronavirus pandemic [22].

Scholars have periodically produced new energy poverty indexes, competing to identify the most efficient ones and producing an overwhelming amount of empirical literature [23], [24], [25], [26].[7] The contest for the most efficient indicator, however, risks obscuring the complex nature of energy poverty and recalls the general debate on unidimensional vs multidimensional general poverty indicators. As Alkire and Foster [27] stress, "How we measure poverty can importantly influence how we come to understand it, how we analyse it, and how we create policies to influence it. For this reason, measurement methodologies can be of tremendous practical relevance."[8]

In the flourishing literature on energy poverty measurement, two broad families of unidimensional and multidimensional indicators and a third group of direct measures can be identified. The unidimensional branch focuses on a specific domain, which is usually the relationship between energy expenditure and total expenditure or income (total or residual after deducting energy expenditure), and tends to highlight the affordability perspective and the strict link with income poverty. These expenditure-based indicators are occasionally labelled 'objective' because they are not influenced by personal opinions and self-perceptions and, as they mainly focus on income and expenditure, they represent the affordability approach.

On the other hand, multidimensional indicators aim to consider various forms of deprivation associated with a lack of adequate energy services and are largely based on combinations of household self-reported judgments.[9] In this group, we find *subjective* perceptions of inability to adequately heat the house and more *neutral* measures such as the presence of damp walls or roof problems. This deprivation approach avoids the loss of information that is typical of the income/expenditure approach [28]. As is usual with multidimensional indicators, key choices are how to assign weights (equal weights or in accordance with indicator relevance) and how to aggregate the reported deprivations. In other words, there is a choice between considering at least one indicator to reveal energy poverty status (a union approach) and a stricter approach in which only the simultaneous presence of all types of deprivation can identify energy-poor households (intersection

[7] The harsh debate comparing different properties and drawbacks of these indexes probably produced an information overload and several countries and institutions have still not chosen a reference indicator.
[8] [27] p.1.
[9] These kinds of indicators belong to the consensual-based approach, which uses surveys or focus groups to set what goods or services families should be able to afford. Inability to afford these items identifies deprivation.

approach). Delugas and Brau [29], for example, build several multidimensional energy poverty indexes to assess their impact on self-reported satisfaction in Italy in 2013. Their results stress that energy poverty is an important driver of subjective wellbeing, and composite indicators seem particularly useful to capture the complex nature of energy poverty.[10]

The last group, which refers to the standard amount of energy needed to obtain an adequate internal temperature in houses, would be promising but it is hindered by a lack of reliable data [30], [11]. In this case, the metric would be linked to real energy needs and not to actual energy expenditure.[11]

Recent works, [31], [12], [32], [33] among others, excellently discuss all the most important indicators and their properties.[12] However, some general remarks are useful to introduce the specific indicators used in this paper. Since Boardman's systematisation of the concept, it has been widely recognised that, besides income poverty, energy poverty is a result of a lack of capital investment in housing stock as opposed to a lack of income, and therefore specific policies should be designed to modernise equipment, to improve energy efficiency and prevent an insurgence of energy deprivation. Bouzarovski and Petrova [34] identify several dimensions of vulnerability besides affordability – energy-related practices, specific household needs, inflexibility, energy inefficiency – that render individuals, households or social groups less likely to be able to access socially and materially necessary energy services. Marchand et al. [35] analyse the correlation between general deprivation and energy poverty in the UK using multi-dimensional indexes. Miniaci et al. [19], who analyse the Italian eligibility criteria to claim energy-related support with reference to general income poverty, investigate this problem too. They find that income-related eligibility criteria do not efficiently target households with energy poverty status or ones close to becoming energy-poor.

At the core of the twofold nature of energy poverty there is a comparison between consensual and expenditure-based approaches. The latter – which focus on the energy budget share or are based on residual income – are usually favoured by policymakers for their link to income poverty and for their alleged neutrality. However, these metrics are based on actual expenditure and therefore on revealed consumption preferences and usually do not consider households that ration their energy consumption to overcome budget constraints (the 'heating or eating' dilemma). Because of this, the difficulties of

[10] See also Awaworyi Churchill et al. [61] on the link between energy poverty and subjective wellbeing in Australia.
[11] See [33] and [43] for recent empirical analyses of Italian data.
[12] Faiella and Lavecchia [37] compare how different indexes maintain the desired property of observing a drop in poverty among richer deciles. In this respect, measures such as the share of income devoted to energy expenditure are more effective than measures of absolute poverty or housing conditions.

the very poorest households can be overlooked by the traditional expenditure-based indicators. Furthermore, in most cases expenditure-based indexes are relative measures and therefore are influenced by average population income and consumption choices. On the other hand, consensual indicators give direct information on the deprivation status perceived by the family – overcoming the dilemma – and better reflect the idea that inadequate energy use is related to other forms of deprivation such as health fragility and social exclusion. However, the fact that demographic and cultural characteristics of respondents affect perceptions of 'adequate' temperature (lower expectations by the poor or denial of reality) is considered in some literature an important limitation which prevents the use of this indicator as a basis for policy. As Tirado Herrero [11] stresses, this kind of drawback of consensual indicators also has a positive side. Indeed, subjective measures can adjust over time to reflect changes in socially perceived basic needs, resulting therefore in a more flexible tool to catch the context-specific characteristics of poverty.

For the purposes of this paper, in Table 1 we rapidly review the subset of indicators used in the empirical analysis. The first two indicators are the most widely used consensual indicators and are drawn from two questions in the EU harmonised Survey on Income and Living Conditions (EU-SILC). The indicator $\mathbf{P_1}$ is purely based on self-perception of the adequateness of the internal temperature in wintertime, whereas $\mathbf{P_2}$ is more similar to a declaration of household financial distress with respect to energy costs. The latter, although it is more limited, is nevertheless deemed more 'objective' and easier to compare at the international level.[13]

As for the income/expenditure category, we consider the ten percent rule ($\mathbf{P_3}$), the first indicator with which energy poverty was brought to the attention of policymakers after the oil shocks in the seventies [2]. This particular threshold, 10 per cent, which gained widespread consensus because of its easy-to-communicate nature, was originally matched to empirical values in the UK during the eighties.[14] It is evident that the 10% threshold does not have any normative value and does not generally correspond to the actual energy expenditure share at the international level. However, it has been adopted – uncritically – by several countries and it is always one of the bundle of indicators shown when dealing with energy poverty. The fourth indicator, $\mathbf{P_4}$, is a composite measure, an energy-poor classification metric considering high energy costs and at the same time residual disposable income (after the costs are deducted) below the official poverty line (Low-Income, High-Costs – LIHC).

[13] However, it should be noted that households can be ashamed to reveal financial distress.
[14] Indeed, 10% was twice the median energy expenditure as a share of income and at the same time the average share of households belonging to the first three income deciles. The UK officially adopted this metric until 2013.

**Table 1. Selected energy poverty indicators**

| Variable | Family | Poverty Definition | Reference |
|---|---|---|---|
| **$P_1$** | Consensual approach | The household cannot afford to keep its home adequately warm | EU-Silc |
| **$P_2$** | Consensual approach | In the last twelve months, the household has been in arrears, i.e. has been unable to pay utility bills (heating, electricity, gas, water, etc.) for the main dwelling on time due to financial difficulties | EU-Silc |
| **$P_3$** | Expenditure-based: Ten per cent rule | $P_3 = \frac{1}{n}\sum_{i=1}^{n} w_i I\left(\frac{s_{ie}}{y_i} > 0.1\right)$ | Boardman [2] |
| **$P_4$** | Expenditure-based: Low Income, High Cost | $P_4 = \frac{1}{n}\sum_{i=1}^{n} w_i \left(I\left(s_{ie}^{eq} > P50_t(s_{ie})\right) \times I\left(\left(y_i^{eq} - s_{ie}^{eq}\right) < y_j^*\right)\right)$ | Hills [36] |
| **$P_5$** | Expenditure-based: Modified Low Income, High Cost | $P_4 = \frac{1}{n}\sum_{i=1}^{n} w_i \left(I\left(\frac{s_{ie}^{eq}}{S_i} > 2 \times \left(\frac{\sum_{i=1}^{n} s_{ie}^{eq}}{\sum_{i=1}^{n} S_{eqi}}\right)\right) \times I\left((s_i - s_{ie}) < s_j^*\right) \cup \left(I(s_i^r = 0) \times I\left(S_i^{eq} < P50_t\left(S_i^{eq}\right)\right)\right)\right)$ | Faiella and Lavecchia [37] |

$i$ household index (1…n); $s_{ie}$ energy expenditure of the i[th] hh; $s_{ie}^{eq}$ equivalent expenditure of the i[th] hh; $s_i^r$ heating expenditure of the i[th] hh; $y_i^{eq}$ equivalent income of the i[th] hh; $y_j^*$ and $s_j^*$ income or expenditure poverty thresholds;

Source*:* Authors'

The LIHC measure was proposed by Hills [36] with the aim of also considering the vulnerability of household budgets to moving below the poverty threshold. It is currently the official UK reference indicator. The last indicator, $\mathbf{P_5}$, is an adaptation of LIHC proposed by Faiella and Lavecchia [37] which considers hidden energy poverty by adding under-consumption.[15] In detail, this indicator includes vulnerable households (with equivalent expenditure below the median) with no heating expenditure to detect 'hidden energy-poor households', which are impossible to identify with indicators $\mathbf{P_3}$ and $\mathbf{P_4}$.

While the theoretical differences among these measures have been deeply explored, the empirical consequences of the choice of one specific indicator have been less discussed. Generally speaking, different approaches give dissimilar results concerning how many energy-poor households are present in a given country and cross-country comparisons are even more difficult.[16] We can therefore say that even in the area of energy poverty there are no measurements that meet all the indicator efficiency requirements and are exempt from value judgements. Considering energy poverty measurement simply as the share of energy costs in total expenditure or taking into account an equivalence scale to adjust for different household compositions reveals different value judgements and different degrees of attention to socio-demographic groups in society. Indeed, after four decades of research on the topic it is evident that a universal set of metrics is not viable and looking at a single indicator appears to be of limited relevance because of both a lack of real comparable data [12] and the importance of local culture and context-specificity [11]. This is why in the empirical analysis we consider both expenditure-based and consensual-based indicators to explore the link between energy poverty, income inequality and socio-economic factors at the regional level.

To the best of our knowledge, except for the theoretical and empirical analyses by Galvin [15] and Galvin and Sunikka-Blank [38], the effects of income inequality on energy poverty are largely unexplored. Indeed, most of the literature on the relationship between justice and energy poverty focuses on how specific groups can be more vulnerable to energy consumption difficulties within or between countries [39], [40], [41], [20]. Our aim is to shed light on another side of the justice-energy poverty nexus, i.e. how the level of income inequality recorded in a territory can correlate with energy poverty.

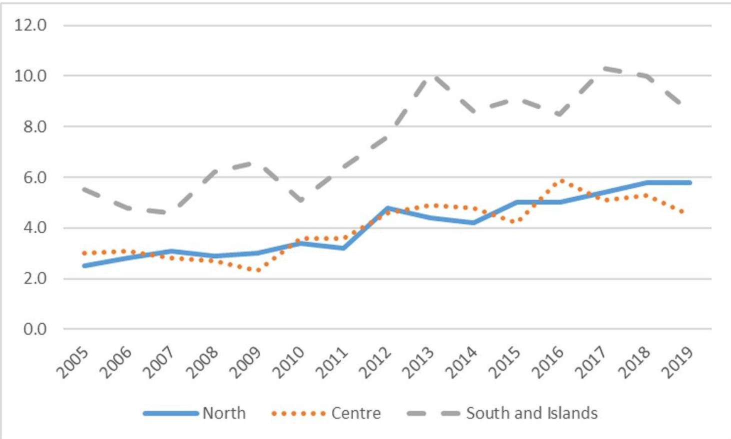
[15] The indicator used in this paper is different from the one originally proposed by Faiella and Lavecchia [37] because we replace household total expenditure with household income as the total expenditure variable is not available in the EU SILC dataset.

[16] See [62] for a cross-country comparison.

### 3. Poverty, energy vulnerability and inequality: The Italian case

The previously mentioned Italian north–south divide is relevant to many social and economic phenomena. In particular, if we focus on the general issue of income poverty, the latest data show that in 2019 on average almost 1.7 million households lived in absolute poverty,[17] with an incidence of 6.4 per cent of the total. As Figure 1 shows, the percentage of poor households is very heterogeneous across geographical macro areas, with the highest value in the southern regions: 8.6 per cent in 2019. An increase in the share of poor households in the south can be noted in the wake of the economic crises in 2008 and 2011–2012. Central and northern Italy show similar values in the period 2005–2017, with a divergent trend in the latest years (4.5 and 5.8 per cent respectively in 2019).

**Figure 1. Absolute poverty incidence by Italian geographical area (%)**




Source: ISTAT

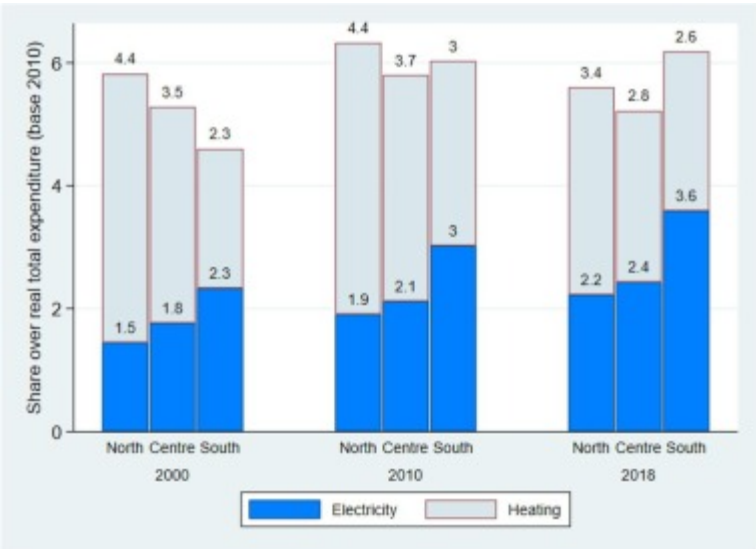
In general, absolute poverty is higher in larger households and decreases as the age of the household head increases: young householders have lower spending capacity and were more severely hit by the recent economic crisis. As expected, poverty is more widespread than average among single-parent households.

To analyse how energy expenditure impacts on the budgets of Italian households, some descriptive evidence provides relevant hints. According to the latest Eurostat data, the share of residential energy expenditure in total household expenditure in Italy was about 4.3 percent in 2015, well above the EU-

[17] Households are classified as absolutely poor if they have a monthly expenditure equal to or less than the value of the absolute poverty threshold computed by the Italian Statistical Office (ISTAT). The threshold differs in size and composition by age of the household, by geographical distribution and by type of municipality of residence.

27 average (3.7 percent).[18] During the last two decades energy price indexes have been increasing more than the overall consumption price index and the financial crisis adversely affected household disposable income [37]. On the other hand, milder weather conditions have reduced consumption of heating fuels, particularly in southern Italy. Figure 2 presents the shares of electricity and heating real expenditure in total household expenditure in 3 selected years by geographical area.[19] In general, the gap at the beginning of the century between northern and southern Italy in terms of total residential energy share had been reversed by 2018. Several factors can explain this: the increase in temperature drove greater use of cooling and rapid population ageing increased the average consumption of residential energy, with the new elderly adapting their lifestyles to a more energy-intensive consumer standard, as is discussed in Bardazzi and Pazienza [42].

**Figure 2. Shares of household electricity and heating expenditure (%)**




Source: Italian Household Budget Surveys (ISTAT)

Indeed, climate is a relevant element that can affect energy poverty through direct and indirect channels. The direct effect is that households increase their energy expenditure in colder periods. The indirect effect is that colder areas may have adopted "more stringent thermal building regulations and practices" ([15] p.4). This heterogeneity in regulation and practice can also operate in Italy, the

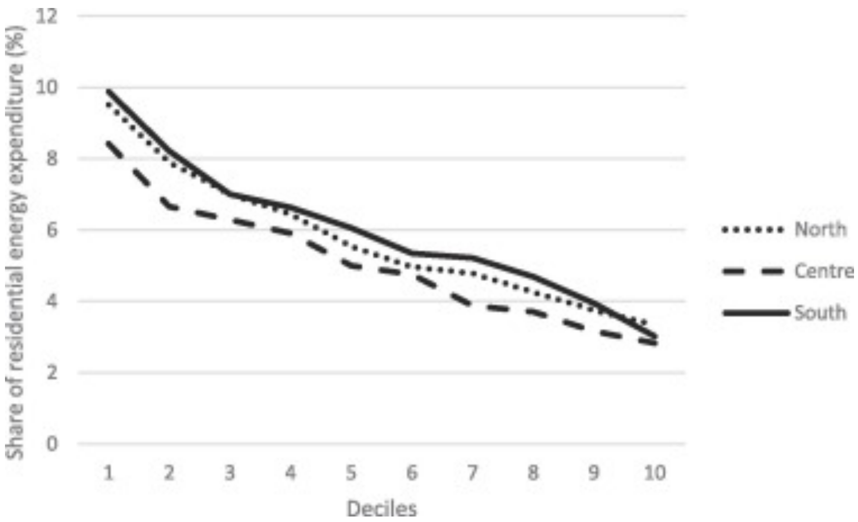
[18] Data from the 'Mean consumption expenditure per household by COICOP consumption purpose' database.
[19] The data used in Figure 2, Figure 3 are from the ISTAT 'Household Budget Survey.' This annual survey collects data on household expenditure and other socio-demographic characteristics. The electricity and heating expenditures are deflated using commodity-specific price indexes (base year 2010). The years selected are those with the lowest (2000), highest (2010) and latest (2018) statistics considering the national territory as benchmark.

territory of which has been classified in six different climate areas since 1993.[20] The direct effect is probably the most intuitive one, yet empirically it seems inverted by the indirect effect, which associates higher energy poverty with less cold areas in both Europe [15] and within Italy [43].

The share of heating expenditure in Figure 2 reflects the difference in average weather conditions, with the temperature decreasing from the south to the north of the peninsula, and therefore an increasing use of heating fuel following the same direction and a decreasing electricity demand for cooling. Indeed, in the same timespan the share of households with air conditioning in the south increased from 8 per cent – below the national average of 9.5 per cent – to 43 per cent, 2 points above the national average.

If we look at the distribution by a tenth of equivalent total expenditure in the year 2018 (Figure 3), Italian households in the bottom part of the distribution have a higher share of residential energy expenditure, with similar values in northern and southern Italy because of greater heating and cooling needs respectively.

**Figure 3. Shares of residential energy expenditure by decile of equivalent total expenditure (2018)**




Source: Italian Household Budget Survey (ISTAT)

This descriptive evidence suggests that some households are more vulnerable than others to the burden of energy expenditure to get access to residential energy services, as is also acknowledged in

[20] In the 'Regulation containing rules for the design, installation, operation and maintenance of building heating systems for the purpose of limiting energy consumption' (DPR 412 of 26 August 1993). It can be retrieved (in Italian) from the following link: https://www.gazzettaufficiale.it/eli/id/1993/10/14/093G0451/sg

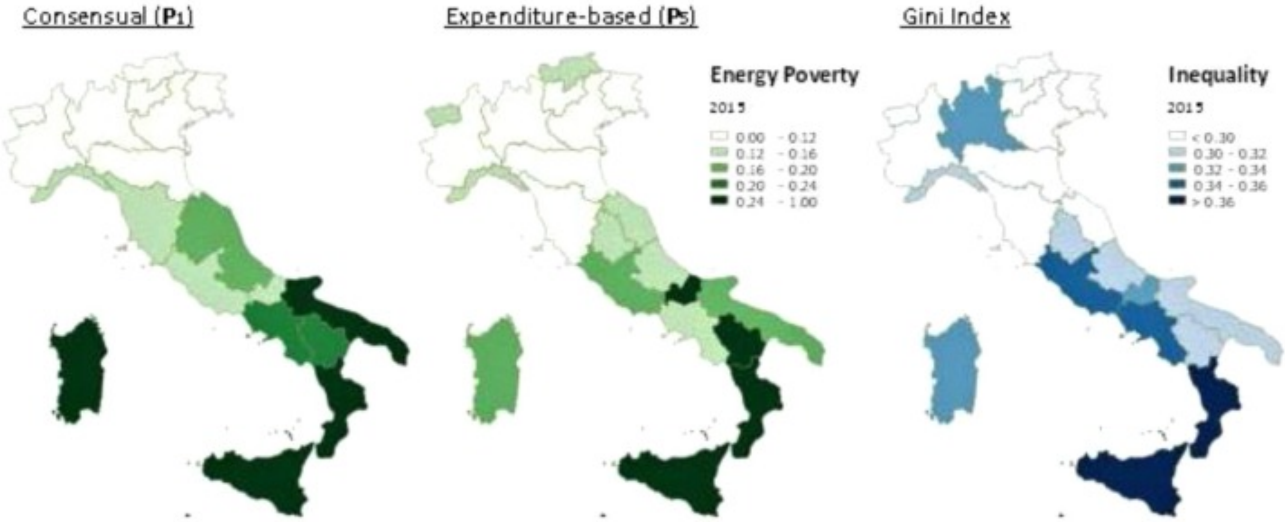
the recent Integrated National Energy and Climate Plan (INECP), which was submitted by the Italian government to the European Commission in January 2020.[21] Energy poverty has progressively gained the attention of EU institutions and member states and also that of the scientific literature. Several recent studies have measured energy poverty in Italy and discussed its main characteristics, mainly from a microeconomic perspective [37], [43], [44]. Several factors are thought to affect the future path of energy poverty in Italy: demographic changes in the population [42], energy price dynamics and the overall trend in household total expenditure. The Covid-19 pandemic is going to exacerbate energy poverty and increase the number of vulnerable families: higher residential energy consumption due to the lockdown and lower income to pay bills could push many families into energy poverty, notwithstanding the emergency measures already adopted in many countries [22].[22]

Italy does not have an official definition of energy poverty. Therefore, several indicators can be used, as was discussed in the previous section. According to the indicator adopted in [45] – the $\mathbf{P_5}$ indicator as originally designed by Faiella and Lavecchia [37] – more than 2.2 million households were in energy poverty in 2016. The consensual approach[23] adopted by the European Commission [46] estimates that about 14 percent of households were not able to keep their homes adequately warm in 2018. However, a divide between the centre-northern and southern regions can be confirmed and corresponds to lower and higher incidences of energy poverty. Interestingly, the regional variability of the intensity of these indicators can be gauged from Figure 4, where geographical maps show energy poverty measured with consensual ($\mathbf{P_1}$) and expenditure-based ($\mathbf{P_5}$) indicators and the Gini index to measure regional income inequality. Although the concentration of energy poverty in the south is clear according to both indicators, some differences between the two maps can be detected:

[21] National plans are available at the following link: https://ec.europa.eu/info/energy-climate-change-environment/overall-targets/national-energy-and-climate-plans-necps_en
[22] A mapping of these emergency measures to energy services is available on the website of ENGAGER COST Action: http://www.engager-energy.net/covid19/
[23] The "Energy poor are considered those with arrears on utility bills and/or unable to keep their homes adequately warm," [46], p.16.

some regions with a higher share of energy-poor households according to one indicator are ranked with a lower intensity if the alternative indicator is adopted and vice versa.

**Figure 4. Indicators of energy poverty (consensual and expenditure-based) and inequality (2015)**




Source: EU-SILC (2015)

An aim of this paper is to assess whether this geographical variability in energy poverty is linked to income inequality, particularly across Italian regions. Indeed, inequality is itself a key concern of the global community[24] because of its detrimental effect on other aspects of development, and to better understand this phenomenon the academic community is exploring how it can be observed at different scales [47]. In Italy, measures of inequality at the local level have recently gained increasing attention, even though most of the literature has only focused on between-region inequality [48], [49], [50]. Using the Gini index to assess income inequality, we observe that in 2015 the value for Italy was 0.33, higher than the average value for the EU-28 (0.31). Looking at the regional map in Figure 4, the familiar north–south divide emerges once again: income inequality is structurally higher in southern Italy and the economic crises of 2008–09 and 2011–12 worsened the situation with poorer regions being most hit by austerity measures [49]. In particular, Ciani and Torrini [17] show that while the component of income inequality between the Italian macro areas has been more stable in recent years, the within-area component – which reflects the dispersion of income around the average inside each area – increased in the south after the recession and during the recovery.

[24] Sustainable Development Goal #10 is particularly worth mentioning: “Reduce inequality within and among countries.”

## 4. Data and methodology

### 4.1. Dataset and relevant variables

Our dataset is built mainly on the Italian module of the EU Statistics on Income and Living Conditions (EU-SILC) established by European Union Regulation 177/2003, which is a survey collecting a large set of qualitative and quantitative information at the individual and household levels in EU member countries. It provides some crucial indicators of income, poverty and social exclusion in the European Union through yearly household and personal interviews (with individuals over 16).[25] Concerning energy poverty, following the consensual approach the survey collects information on households unable to keep their homes adequately warm (**$P_1$**) and those with arrears in paying utility bills (**$P_2$**). Additional information on household residential energy expenditure is collected in the national module of SILC by the Italian Statistical Office (ISTAT) and is available to users for the period 2004–2015.[26] These national data allow expenditure-based energy poverty indicators to be built: the 10 percent rule (**$P_3$**), LIHC (**$P_4$**) and the **$P_5$** indicator. All these indicators are computed for 19 Italian regions and 2 provinces (NUTS 2) as our model aims to explore the geographical dimension of the relationship between energy poverty, income inequality and other determinants within the country. The microdata are therefore collapsed at the regional level to create a pooled dataset over the 12 years (2004–2015) with variables for a panel of 21 regions, corresponding to 252 region-year statistical observations available for this study.

The explanatory variables considered in our model relate to the socio-economic situation of the area, heating system characteristics and weather conditions. Income level and income inequality are respectively measured with household equivalent income in real terms (base year 2010)[27] and the Gini index.[28] Furthermore, we control for the diffusion of single-parent households, which is considered a proxy for unfavourable demographic conditions [49]. This proxy is even more accurate when dealing with energy poverty because of the higher heating costs in cases of households with children paired with the fewer economic resources of single earners. On the other hand, the availability of central heating systems could be a positive factor reducing energy expenditure – and poverty – among Italian

[25] Italy, like most EU countries, adopted a rotational sample design composed of four groups, each to be followed up for 4 years. Each year a quarter of the sample is renewed. The overall sample is statistically representative of the population residing in Italy and consists of about 20,000 households a year.

[26] The database is identified as ITSILC XUDB 2004–2015.

[27] We use the Carbonaro equivalence scale and a logarithmic transformation of the variable.

[28] ISTAT computes the Gini index on net incomes and excludes imputed rents. The panel data is publicly available at: http://dati.istat.it/

households [51].[29] As climate has been proven to be a relevant factor in residential energy use, regional weather variables are included in the dataset. We use the heating degree days (HDDs) from an EU Commission Joint Research Centre database.[30] Furthermore, considering the difference between the indicators of energy poverty, we expect that different indicators will react in dissimilar ways as HDDs increase. More specifically, it is possible that the correlation between HDDs and energy poverty will be more negatively skewed when adopting a consensual specification than an expenditure-based one, as in warmer contexts expectations and different reference benchmarks can influence the perception of an 'adequately warm home' irrespectively of actual spending.

Table 2 summarises the data used in the empirical analysis and presents the different energy-poverty indicators $\mathbf{P_1}$, $\mathbf{P_2}$, $\mathbf{P_3}$, $\mathbf{P_4}$, and $\mathbf{P_5}$ introduced in Section 2 and the poverty rates computed with the union and the intersection of indicators $\mathbf{P_1}$ and $\mathbf{P_5}$ ($\mathbf{P_U}$ and $\mathbf{P_I}$). The regional Gini index, average real income, HDDs, single-parent families and central heating systems are also reported, representing the independent variables selected for this study.

[29] Both these variables are drawn from the Italian Household Budget Survey released by ISTAT.

[30] Heating degree days (HDD) are weather-based technical indexes designed to estimate the heating energy requirements of buildings. They are measures of how much the outside air temperature was lower than a specific 'base temperature.'" For heating the base temperature is 15°. HDD data are presented as C˚ temperature sums. The data used in this paper are provided on the EU Commission Joint Research Centre Agri4Cast Resources Portal. See https://agri4cast.jrc.ec.europa.eu/DataPortal/Index.aspx?o=d

**Table 2. Descriptive statistics (2004–2015)**

| Variable | Description | Obs. | Mean | St. Dev. | Min | Max |
|---|---|---|---|---|---|---|
| **$P_1$** | Share of energy-poor households according to **$P_1$** | 252 | 0.14 | 0.10 | 0.01 | 0.54 |
| **$P_2$** | Share of energy-poor households according to **$P_2$** | 252 | 0.09 | 0.05 | 0.00 | 0.23 |
| **$P_3$** | Share of energy-poor households according to **$P_3$** | 252 | 0.19 | 0.05 | 0.06 | 0.37 |
| **$P_4$** | Share of energy-poor households according to **$P_4$** | 252 | 0.11 | 0.04 | 0.02 | 0.24 |
| **$P_5$** | Share of energy-poor households according to **$P_5$** | 252 | 0.15 | 0.05 | 0.09 | 0.35 |
| **$P_U$** | Share of energy-poor households according to **$P_1$** or **$P_5$** | 252 | 0.25 | 0.11 | 0.11 | 0.63 |
| **$P_I$** | Share of energy-poor households according to both **$P_1$** and **$P_5$** | 252 | 0.04 | 0.04 | 0.00 | 0.25 |
| Gini | Gini index | 252 | 0.31 | 0.03 | 0.26 | 0.40 |
| Income | Logarithm of equivalent income deflated with 2010 prices | 252 | 10.14 | 0.16 | 9.80 | 10.37 |
| HDD | Heating Degree Days | 252 | 2139 | 943 | 921 | 4895 |
| Single Parents | Share of single-parent households | 252 | 0.01 | 0.01 | 0.00 | 0.04 |
| Central Heating | Share of households with a central heating system | 252 | 0.20 | 0.13 | 0.01 | 0.47 |
| South | South Italy Regions | 252 | 0.38 | 0.49 | 0.00 | 1.00 |

## 4.2. Methodology

Our variable of interest, the share of households that are energy-poor, $y$, is within (0,1) by construction. The usual linear regression model is not appropriate for bounded dependent variables since the model's predictions can be outside the boundary limits. A beta regression model is used to acknowledge the bounded nature of our variable of interest. This is achieved via a transformation of the data assuming a beta distribution, which makes the estimates more accurate and forces the result to range within (0,1). The transformation is done by using a link function $g(.)$ to keep the conditional mean of the model inside the interval. We use a logit link function, which is commonly found in applications in economic analysis. The parametrisation of the beta distribution is defined in terms of its mean $\mu$ and a precision (scale) parameter $\varphi$. The mean value of $y$ conditional on the independent variable(s) $x$ is $E(y|x) = \mu_y$ and the link function allows $g(\mu_y) = x\beta$ so that $\mu_y = g^{-1}(x\beta)$ is bounded in (0,1). Using the logit function, $ln\left(\frac{\mu_y}{1-\mu_y}\right) = x\beta$ so that $\mu_y = \frac{exp(x\beta)}{1+exp(x\beta)}$. The conditional variance of the beta distribution is $Var(y|x) = \frac{\mu_y(1-\mu_y)}{1+\emptyset}$ and it decreases as the scale parameter ▫ increases. A scale-link function is used to ensure that $\emptyset > 0$. Here we have assumed the log link for the conditional scale. Finally, maximum likelihood estimators are used for the regressions.

The beta regression model is applied to the pooled dataset described above.[31] Because of the initial transformation, the coefficient estimates are not directly interpretable and to obtain the effect of the regressors on the dependent variable it is necessary to compute the marginal effects which are a function of the parameters. Moreover, Likelihood Ratio (LR) statistics with a $\chi^2$distribution are more reliable in providing an evaluation of how much the regression fits compared to $R^2$ and adjusted $R^2$ (which is generally used in Ordinary Least Square (OLS) regressions).

## 5. Results and discussion

Following the model suggested by Galvin [15], we start by considering consensual indicators of energy poverty.[32] As previously discussed, these indicators have interesting characteristics because they provide direct information on the deprivation status perceived by the family, and so overcome the heating-eating dilemma, and also include rationed consumers. Using the **$P_1$** indicator (households unable to keep their homes adequately warm) as the dependent variable, alternative models are

[31] An analysis of the data variability over time is presented in Appendix A.

[32] Table B1 in the appendix reproduces Galvin's specification in the context of Italian regions between 2004 and 2015: subjective energy poverty as measured by $P_1$ is associated with inequality, income level, HDD and two other subjective indicators, $P_2$ (arrears in utility bills) and households' self-reported problems ("leaking roof, damp walls/floors/foundation, or rot in window frames or floor"). We confirm that the correlation between energy poverty and inequality remains robust, and the other variables maintains their signs too.

selected with a progressive inclusion of controls, subject to the constraint of the degrees of freedom provided by our limited number of observations. Besides the Gini index, income levels and climatic conditions, we gradually introduce controls which affect energy poverty and are heterogeneously distributed within the country. Table 3 reports the estimated coefficients for three models with their p-values and standard errors in parentheses. In the bottom part of the table, the scale parameter $\varphi$ is presented[33] along with LR $\chi^2$ and its p-value.

**Table 3. Estimation results for energy poverty according to indicator $P_1$**

| | (1) | | (2) | | (3) | |
|---|---|---|---|---|---|---|
| | **Coefficients** | **p-values** | **Coefficients** | **p-values** | **Coefficients** | **p-values** |
| **Gini** | 3.844 (1.243) | 0.002 | 3.776 (1.322) | 0.004 | 3.776 (1.322) | 0.004 |
| **Income** | −2.354 (0.216) | 0.000 | −2.401 (0.267) | 0.000 | −2.487 (0.409) | 0.000 |
| **HDD** | −0.000387 (0.00006) | 0.000 | −0.000350 (0.00006) | 0.000 | −0.000350 (0.00006) | 0.000 |
| **Single Parents** | | | 20.72 (4.483) | 0.000 | 20.53 (4.535) | 0.000 |
| **Central Heating** | | | −0.690 (0.353) | 0.051 | −0.695 (0.353) | 0.049 |
| **South** | | | | | −0.0327 (0.118) | 0.782 |
| **Constant** | 21.48 (2.279) | 0.000 | 21.73 (2.863) | 0.000 | 22.61 (4.287) | 0.000 |
| **Scale Constant** | 3.933 (0.0898) | | 4.020 (0.0898) | | 4.020 (0.0898) | |
| **Observations** | 252 | | 252 | | 252 | |
| **chi²** | 334.5 | | 355.8 | | 355.9 | |
| **p** | 0.000 | | 0.000 | | 0.000 | |

Standard errors in parentheses

Source: Authors' elaboration

[33] The scale parameter is given by the log link function so, for example, in the first column, $\widehat{\emptyset} = exp(3.9) = 49.4$. This parameter should be used to compute the conditional variance of the beta regression according to the formula presented in the text.

In column (1), the baseline model shows coefficients coherent with our expectations and previous literature,[34] i.e. energy poverty, ceteris paribus, is positively correlated with increases in income inequality and negatively with (the logarithm of) equivalent income. Cooler meteorological conditions (as proxied by HDDs) also negatively affect energy poverty measured with $\mathbf{P_1}$ with a statistically significant coefficient. This counterintuitive result is consistent with the literature and can be due to the above-mentioned indirect links between HDDs and energy poverty [15] and to different perceptions about what is socially adequate in subjective indexes [11]. Moreover, the $\mathbf{P_1}$ indicator appears to fluctuate according to the business cycle and therefore is more sensitive to negative expectations and general economic conditions.

Exploiting the availability of other information on characteristics which vary widely across Italian regions, it is possible to enrich our model with new variables to obtain a more accurate description of the channels that may affect energy poverty. In the second column, the incidence of single-parent families and central heating are added. The previous explanatory variables maintain their signs and significance levels, while single parents and central heating systems result as respectively positively and negatively related to energy poverty, consistently with our expectations. The coefficient for single-parent families, which is significant at the 1% level, confirms that single-parent families are economically disadvantaged, especially in southern European countries like Italy [49]. This disadvantage is likely to apply to energy poverty too, considering the need for higher heating and cooling expenditure and the lower incomes of this family type. The presence of central heating systems is another possible driver of energy poverty reduction [51]. Finally, in the third column, the dummy variable 'South' has been added to control for an eventual additional fixed effect linked to the geographical location but in this model it is non-significant, probably because the regional divide is well captured by the other covariates. This result contributes to reinforcing the robustness of the estimation.

Alternative indicators can be selected to measure energy poverty, as a vast and far from undisputed literature suggests [37], [24], [25], [21]. Therefore, we apply the previous model to different measures of energy poverty to verify the robustness of its relationship with income inequality in Italy. In the results, differences emerge not only between consensual and expenditure-based indicators but also within these groups.

[34] See Galvin [15] and the results obtained applying his approach to our dataset presented in Table B1 in the appendix.

Table 4 compares the results for the main consensual (**$P_1$** and **$P_2$**) and expenditure-based (**$P_3$**, **$P_4$** and **$P_5$**) measures. The results in the first two columns show almost identical coefficients, albeit with different magnitudes and an overall weaker predictability of **$P_2$**. Indeed, the estimated coefficients remain similar irrespectively of which consensual indicator is adopted to measure energy poverty. The only difference is a slightly more significant coefficient for central heating systems (maintaining the negative sign as expected). This confirms that inequality, low incomes, single parent households and an absence of central heating systems are all associated with perceptions of energy poverty and a lower capacity to pay gas and electricity bills. *Ceteris paribus*, no other systematic difference is observed between southern and northern regions.

The columns on the right of the table present the results with expenditure-based measures: the ten percent rule (**$P_3$**), the Low Income, High Costs measure (**$P_4$**) and the vulnerability indicator (**$P_5$**). While the consensual indicators produce similar outcomes, the results for the expenditure-based energy poverty measures are more heterogeneous: **$P_3$** and **$P_4$** both depart from the consensual energy poverty results, while the vulnerability indicator **$P_5$** produces estimates more closely related to the consensual-based models. Indeed, using indicators **$P_3$** and **$P_4$**, there appears to be a reversal in the sign of the Gini coefficient, while HDDs, single-parent households and central heating systems lose their significance. These regressions have weaker explanatory power (although the chi-squared test still confirms a significance level well beyond the 1% level). Strikingly, the significant and negative sign of the Gini coefficient suggests that increases in income inequality lead to lower energy poverty. This counterintuitive result could be partly biased by the incapacity of the ten percent rule and LIHC indicators to capture the energy poverty of individuals who are at the very bottom of the distribution, being unable to afford any heating expenditure and therefore ignored by these energy poverty definitions. This problem does not arise with consensual poverty measures and with measures that explicitly consider under-consumption (**$P_5$**).

**Table 4. Estimation results for energy poverty according to selected indicators**

| | $P_1$ | | $P_2$ | | $P_3$ | | $P_4$ | | $P_5$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Coeff.** | **p-values** | **Coeff.** | **p-values** | **Coeff.** | **p-values** | **Coeff.** | **p-values** | **Coeff.** | **p-values** |
| **Gini** | 3.776 (1.322) | 0.004 | 5.702 (1.050) | 0.000 | −3.409 (0.925) | 0.000 | −4.221 (0.979) | 0.000 | 1.395 (0.630) | 0.027 |
| **Income** | −2.487 (0.409) | 0.000 | −1.109 (0.330) | 0.001 | −1.162 (0.281) | 0.000 | −0.654 (0.291) | 0.024 | −1.788 (0.194) | 0.000 |
| **HDD** | −0.00035 (0.00005) | 0.000 | −0.00014 (0.00004) | 0.000 | 0.000005 (0.00003) | 0.856 | −0.00006 (0.00003) | 0.061 | 0.0001 (0.00002) | 0.000 |
| **Single Parents** | 20.53 (4.535) | 0.000 | 11.24 (3.661) | 0.002 | −3.100 (3.144) | 0.324 | −4.914 (3.457) | 0.155 | 2.788 (2.190) | 0.203 |
| **Central Heating** | −0.695 (0.353) | 0.049 | −1.038 (0.287) | 0.000 | 0.100 (0.235) | 0.669 | −0.102 (0.256) | 0.691 | 0.00282 (0.165) | 0.986 |
| **South** | −0.0327 (0.118) | 0.782 | −0.0295 (0.0933) | 0.752 | 0.0977 (0.0806) | 0.226 | 0.299 (0.0837) | 0.000 | 0.174 (0.0564) | 0.002 |
| **Constant** | 22.61 (4.287) | 0.000 | 7.451 (3.470) | 0.032 | 11.35 (2.939) | 0.000 | 5.923 (3.054) | 0.052 | 15.60 (2.037) | 0.000 |
| **Scale Constant** | 4.020 (0.0898) | | 4.774 (0.0894) | | 4.507 (0.0888) | | 4.845 (0.0892) | | 5.436 (0.0890) | |
| **Obs** | 252 | | 252 | | 252 | | 252 | | 252 | |
| **chi²** | 355.9 | | 285.8 | | 104.9 | | 156.5 | | 353.2 | |
| **p** | 0.000 | | 0.000 | | 0.000 | | 0.000 | | 0.000 | |

Standard errors in parentheses

Source: Authors' elaboration

Indeed, the indicator P5 produces estimates more closely related to the $\mathbf{P_1}$ and $\mathbf{P_2}$ models: the Gini coefficient has a positive sign, while income has a significant effect in reducing energy poverty; single-parent families and central heating systems are not statistically significant while living in the south is detrimental. A notable difference instead involves HDD, which appears here with a significant and positive coefficient. While in colder areas there are fewer cases of self-reported inability to warm houses and unpaid bills, the model with the $\mathbf{P_5}$ indicator shows that these areas are characterised by higher vulnerability to energy costs, as was generally expected. Indeed, the $\mathbf{P_5}$ indicator has a 'high cost' component – proxied by the share of energy cost in income – and it is therefore responsive to the higher energy expenditure in northern regions.

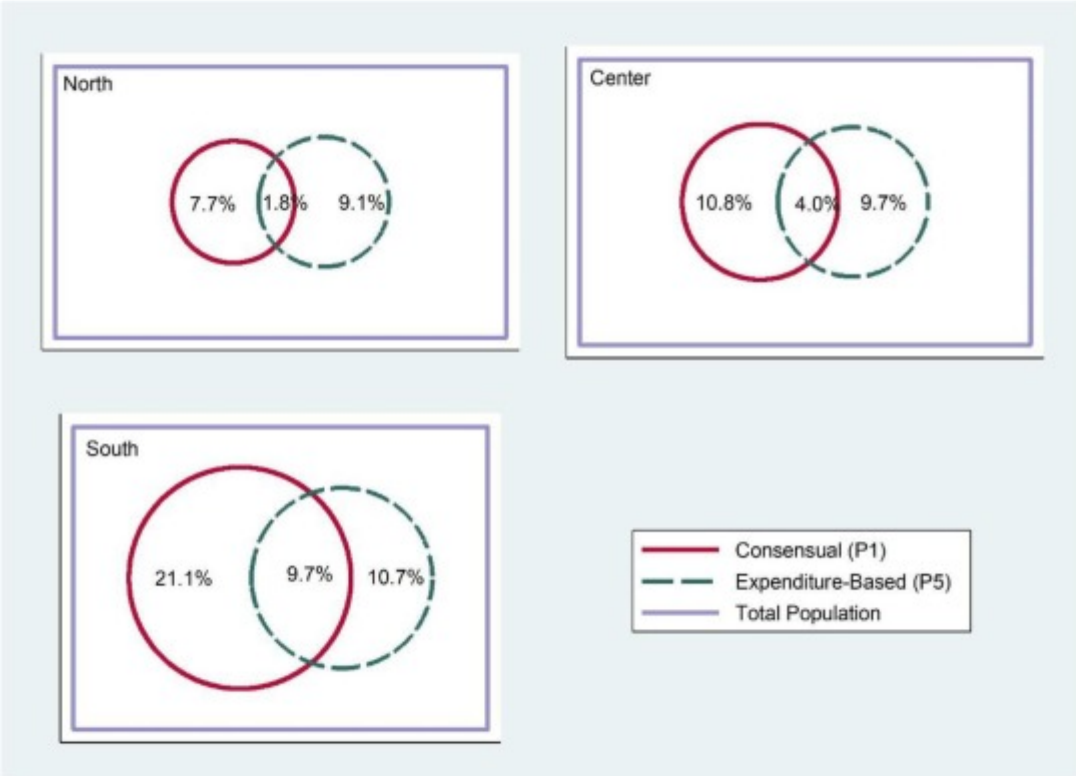
As a sensitivity analysis of our findings on the link between energy poverty and income inequality, we ran additional regressions using alternative inequality indexes commonly used in poverty analysis. Our results prove to be robust to these alternative specifications (see Appendix C) and confirm the direct correlation between energy poverty – measured either with consensual or expenditure-based indicators – and income inequality – measured with inequality indexes that are more sensitive to the top of the income distribution (Theil index) or to the bottom of the income distribution (Atkinson index) with respect to the Gini index.

Finally, we apply our empirical analysis to composite measures of energy poverty: energy-poor households are considered those selected by at least one of the $\mathbf{P_1}$ and $\mathbf{P_5}$ indicators (union approach, $\mathbf{P_U}$) or by both indicators (intersection approach, $\mathbf{P_I}$).[35] Therefore, these multidimensional indicators take into account self-perceived heating needs and actual residential energy expenditure, including hidden poverty situations. The overlap between the different measures is graphically explored in Figure 5, which juxtaposes Venn diagrams of consensual and expenditure-based energy poverty indexes for northern, central and southern Italy separately.[36]

[35] Among the three expenditure-based indicators, $\mathbf{P_5}$ is chosen to compute a multidimensional energy poverty index because of its theoretical [33] and empirical soundness in individuating energy poor households paying attention to the 'heating or eating' dilemma.

[36] See [25] for a similar analysis for Belgium.

**Figure 5. Overlap between $P_1$ and $P_5$ in northern, central and southern Italy (2015)**




Source: EU-SILC (2015)

The bigger circles for the southern area confirm the very high incidence of energy poverty according to the consensual metric (**$P_1$**). Indeed, in southern Italy in 2015 there were slightly more than 30 (**$P_1$**) and 20 per cent (**$P_5$**) of energy-poor families. In central Italy households in energy poverty were always below 15 per cent and in northern Italy it was around 10 per cent according to both definitions. In the north the **$P_1$**-energy-poor are fewer than the **$P_5$**-energy poor. This relation is the reverse in the south. Finally, the overlap area – multidimensional poverty according to the intersection approach **$P_I$** [27] – is also larger for the south, while the two types of poverty are less correlated in central and northern Italy. This means that the two metrics mostly identify different energy-poor households, notwithstanding very similar regression results (Table 4).

Using the combined measures **$P_I$** and **$P_U$**, we replicate the previous estimation as a robustness check. The results for these models are presented in Table 5 with estimation coefficients and their p-values. As expected, we obtain an intermediate picture between columns **$P_1$** and **$P_5$** in Table 4. Low household income is confirmed as a significant determinant of energy poverty, as are the diffusion of single-parent households and living in southern regions. The diffusion of central heating systems, although statistically non-significant, keeps its negative sign.

**Table 5. Estimation results for energy poverty according to composite indicators**

| | $P_U$ | | $P_I$ | |
|---|---|---|---|---|
| | **Coefficients** | **p-values** | **Coefficients** | **p-values** |
| **Gini** | 2.786 (0.756) | 0.000 | 4.376 (1.194) | 0.000 |
| **Income** | −2.263 (0.231) | 0.000 | −3.231 (0.386) | 0.000 |
| **HDD** | −0.0000298 (0.00003) | 0.282 | −0.000238 (0.00006) | 0.000 |
| **Single Parents** | 10.03 (2.597) | 0.000 | 24.53 (4.219) | 0.000 |
| **Central Heating** | −0.253 (0.194) | 0.193 | −0.490 (0.345) | 0.155 |
| **South** | 0.142 (0.0667) | 0.034 | 0.00982 (0.114) | 0.931 |
| **Constant** | 20.85 (2.420) | 0.000 | 28.17 (4.040) | 0.000 |
| **Scale Constant** | 4.738 (0.0888) | | 5.279 (0.0910) | |
| **Observations** | 252 | | 251 | |
| **chi²** | 458.2 | | 386.0 | |
| **p** | 0.000 | | 0.000 | |

Standard errors in parentheses

Source: Authors' elaboration

As mentioned in Section 4.2, the size effects of the covariates are not directly interpretable from the estimated coefficients. Therefore, average marginal effects are computed to show the change in the independent variable due to a change in the covariates (Table 6).[37] As a general finding we can see that the marginal effects of the indicator $\mathbf{P_U}$ are similar to those of $\mathbf{P_1}$ and the same can be said for $\mathbf{P_I}$ and $\mathbf{P_5}$. This is not surprising because with the union approach the consensual indicator tends to prevail, whereas in the intersection approach the more selective $\mathbf{P_5}$ plays a key role.

[37] In the table standard errors estimated with the delta method are presented, while the p-values of the marginal effects are omitted because they are the same as reported with their respective regression results in Table 4, Table 5.

**Table 4. Estimation results for energy poverty according to selected indicators**

| | $P_1$ | $P_5$ | $P_U$ | $P_I$ |
|---|---|---|---|---|
| **Gini** | 0.421<br>(0.147) | 0.179<br>(0.081) | 0.500<br>(0.136) | 0.160<br>(0.044) |
| **Income** | −0.277<br>(0.045) | −0.230<br>(0.025) | −0.406<br>(0.041) | −0.118<br>(0.014) |
| **HDD** | −0.00004<br>(0.000) | 0.00001<br>(0.000) | −0.00001<br>(0.000) | −0.00001<br>(0.000) |
| **Single Parents** | 2.286<br>(0.505) | 0.358<br>(0.281) | 1.801<br>(0.466) | 0.895<br>(0.155) |
| **Central Heating** | −0.077<br>(0.039) | 0.000<br>(0.021) | −0.045<br>(0.035) | −0.018<br>(0.013) |
| **South** | −0.004<br>(0.013) | 0.022<br>(0.007) | 0.025<br>(0.012) | 0.000<br>(0.004) |

Standard errors in parentheses

Source: Authors' elaboration

As an example, the value in the first row of the first column indicates that an increase in regional income inequality of 1 Gini point corresponds to an increase of 0.421 in the share of energy-poor households according to $\mathbf{P_1}$ and of 0.5 according to $\mathbf{P_U}$. It is interesting to notice that these values are more than twice that of the marginal effect of the Gini index on the share of energy-poor households according to the $\mathbf{P_5}$ and $\mathbf{P_I}$ indicators. The effect of a change in income, on the contrary, is much more similar between $\mathbf{P_1}$ and $\mathbf{P_5}$ and the results of $\mathbf{P_U}$ and $\mathbf{P_I}$ are at the two extremes of the variation range.

## 6. Conclusions

According to the UN definition, poverty involves more than a lack of income and malnutrition: it comprises limited access to basic services, social exclusion and restricted active citizenship. The relationships between the various forms of deprivation and the role of inequality in income and wealth are widely studied in the economics literature, but it is certainly still difficult to capture their various facets and consequently to set appropriate policies. The specific phenomenon of energy poverty is even more difficult to identify and quantify. As discussed above, on the one hand identification is very unbalanced in terms of heating needs and the problem of cooling is still very underestimated; on the other hand, there is no agreement on the metric and on the superiority of subjective or objective indicators.

The Italian context provides a very stimulating field of investigation: the north–south economic divide and the variability of climatic conditions provide interesting factors to assess whether this geographical variability of energy poverty is linked to income inequality, particularly among the Italian regions. Following Galvin's [15] study on the link between income inequality and energy poverty at the European level, we have investigated this research question at the subnational level, taking advantage of the heterogeneous economic and climatic conditions along the peninsula. In the empirical analysis we have used both consensual and expenditure-based indicators and also a combination of them to verify the extent to which the two methods of measurement contribute to understanding the complex phenomenon of energy poverty and its link with inequality.

Our multivariate analyses confirm that income inequality – whatever the inequality index selected – significantly correlates with both energy poverty indicators when Italian regions are the units of analysis. This suggests that income redistribution policies could drive a reduction in energy poverty even at the local level, not just at the national level. This finding is particularly relevant for the Italian case, where within-region inequality can deteriorate particularly in areas lagging behind – with impacts not only on energy poverty but also on other related dimensions [52]. Other factors that significantly drive the energy poverty rate are income levels, the presence of specific fragile households (e.g. single-parent households) and the heating technology (with less energy poverty in regions where central heating systems are more widespread). In all the models estimated, climatic conditions (as approximated by heating degree days) and a south dummy (for the general north–south divide) have been used as general controls. These findings are confirmed – with different degrees of magnitude – for all the consensual indicators and for the expenditure-based indicator drawing from [37], which combines the low income-high cost approach and the identification of under-consumers. On the contrary, for the ten percent rule – the most widely adopted measure of objective energy poverty – and LIHC, the results are not satisfactory because these indicators fail to capture the households at the very bottom of the distribution who face the heating-eating dilemma, a situation that seems to be relevant in the Italian context. A relevant finding from our empirical analysis is the suggestion that adopting techniques typical in the computation of multidimensional indexes provides a valuable alternative to considering simultaneously different facets of energy poverty. This is even more important because the overlap area between different indicators is limited and both approaches are vital to identify households that cannot command adequate energy services. Regressions on combined indicators, computed following both the union and intersection approaches, strengthen the previous results.

The importance of a joint analysis of consensual and expenditure-based indicators highlights the need to design policies to combat energy poverty that take into account the complex nature of the phenomenon. As Miniaci et al. [19] note for the Italian case, an income threshold – even if the size of the family is considered – does not seem to be an adequate way to identify families in need of help. More recently, Alvarez and Tol [53] have shown similar findings for Spain: subsidies for household electricity expenditure introduced in 2009 did not contribute to alleviating energy poverty. The authors suggest that complementary policies are needed as social and structural energy poverty factors are not likely to be tackled by an income transfer.

From a policy point of view, our work suggests that measures oriented to reducing inequalities – going beyond income support to generate opportunities for the poor – could help to combat various form of deprivation, among which energy poverty is very important, given the link with health and education. Moreover, social and cultural factors can prove very important: public subsidies to incentivise energy efficiency are usually more convenient for top income earners and for families living in their own homes. Indeed, data from the Italian Revenue Agency for 2018 show that taxpayers in the southern regions, representing 29 per cent of total taxpayers, count for only 13 per cent of energy-efficiency incentive applications.[38] This evidence show that subsidies are concentrated among more affluent households, thus exacerbating income and energy expenditure inequalities. In our view, the higher inequality and the higher incidence of absolute and relative income poverty in the south of Italy can trap energy-poor families into energy inefficiency and into an inadequate command of energy-related services. It is well known that low income families are expected to be more strongly inhibited by behavioural and informational barriers and so are less aware of the benefits of energy efficiency investments and of the saving potentials of the houses in which they live [54]. Our suggestion that energy poverty is a phenomenon related to wider spatial and economic inequalities opens the way to the conclusion that technical policy solutions are not the only ones to be contemplated as they do not take into account social aspects [13], [55], and that a broader set of policies, also spatially localised and aimed at limiting structural inequalities in particular contexts, can be more effective in combating energy poverty.

[38] The ongoing Italian energy efficiency incentives are not specifically related to climatic areas as they support the purchase of both heating equipment and air conditioning equipment.

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