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Inflation and distributional impacts: Have mitigation policies been successful for vulnerable and energy poor households?

Rossella Bardazzi [a,*], Francesca Gastaldi [b], Francesca Iafrate [b], Rosaria Vega Pansini [b], Maria Grazia Pazienza [a], Corrado Pollastri [b]

[a] University of Florence, Department of Economics and Management, Italy
[b] Parliamentary Budget Office, Italy

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ABSTRACT

The aim of this paper is to assess the distributional impact of the 2021–23 price increase on Italian household expenditure and energy poverty. Using the microsimulation model developed by the Italian Parliamentary Budget Office, the analysis provides a comprehensive assessment of the uneven impact of inflation across the population and measures how mitigation policies have compensated for this impact. In particular, we focus on vulnerable households to examine whether energy poverty has been affected by the rise in energy prices and to what extent policies have succeeded in protecting these families. Our main findings show that in 2022, mitigation policies have stabilised the impact of inflation by compensating households for almost half of the effect of the price shock on their expenditure. Although not particularly well targeted at energy-poor households, the mitigation policies have protected households from a worsening of their energy vulnerability. However, the reduction of support measures adopted in 2023 is expected to increase the area of vulnerability, including households that are particularly sensitive to high energy costs. Finally, the behavioural response of households was also considered by estimating price elasticities of energy demand and measuring their impact on the simulated scenarios using a sensitivity approach.

1. Introduction

Since the beginning of 2021, EU countries are experiencing unprecedented level of inflation since the creation of the monetary union. Data show that in December 2022 the annual inflation rate measured by the HIPC in the Euro area was 9.2%, falling to 7% in April 2023 (Eurostat, 2023). Looking beyond the aggregate figures, the change in headline HIPC inflation has been mainly driven by energy goods, which recorded the highest increase in December 2022 (25.5%), together with food, alcohol and tobacco (13.8%), followed by non-energy industrial goods (6.4%) and services (4.4%). In a similar way, the slowdown in energy inflation in the first months of 2023 (2.3% in April 2023) has determined a partial reduction in headline inflation. Depending on the composition of the consumption basket, the price surge has been responsible for the sharp increase in the cost faced by households to meet several needs, first and foremost heating, but also transport and food necessities.

The impact of the inflation spike has been uneven across the euro area, with some countries experiencing higher than average inflation, depending on the relative composition of the energy mix, the share of energy imports and the tariff policies and regulations (Varga et al., 2022). In Italy, the annual IPC inflation observed in December 2022 was 11.6%; that related to the cost of housing, water, electricity and fuels reached 54.5%, followed by the inflation related to food items (13.1%) and transport (6.2%). In April 2023, the dramatic fall in energy prices led to a partial correction of the general inflation rate to 8.2%, considering a roughly constant increase of prices of other goods (ISTAT, 2023).

Several causes of the recent energy price surge can be identified. Some are related to cyclical factors linked to both demand and supply components. The outbreak of the Covid-19 crisis and the increase in demand following the end of the restrictions, the bottlenecks in supply chains in the post-pandemic period (given a shift in towards goods rather than services) drove the initial increase in energy prices from the second quarter of 2021 (OECD, 2022b). Rising tensions between Russia and Ukraine and the consequent progressive reduction in Russian gas supplies to Europe since late 2021 further pushed up gas and electricity

* Corresponding author.
E-mail address: rossella.bardazzi@unifi.it (R. Bardazzi).

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prices, given also the marginal pricing mechanism for electricity generation. In addition, inflationary pressures have become more widespread, with energy inflation and higher transport costs being passed on to other non-energy goods. Although expectations for energy price developments, especially for gas, are declining and a partial correction in energy prices has already been observed, the high inflation pressures will not be completely absorbed in the coming months (OECD, 2022a). There are further structural and long-term factors contributing to the rise in energy prices. They include the underinvestment in natural gas and in clean energy sources, the high level of the price of carbon emission permits and the shift in expectations induced by the EU Green Deal. Thus, considering the overlapping contribution of cyclical and structural factors, energy prices are expected to remain volatile and at a higher level in the medium term compared to mid-2021.

Prolonged periods of higher inflation affect households differently along the distribution of expenditure, purchasing power and income. The uneven impact across the population is due to the heterogeneous composition of the consumption basket and the price changes recorded for different categories of goods. Moreover, given that energy prices were the trigger for the inflation spike, aspects related to the increased burden of energy expenditure on household budgets, energy vulnerability and poverty should also be considered together with the distributional effects. Indeed, energy users and households with a relatively higher share of energy and food expenditure have fewer options to reduce expenses in the short run, which increases concerns about energy affordability and the cost of living.

The increasing challenges posed by the impact of rising inflation on households' welfare have led governments to introduce various types of policies to protect households and firms from the sharp rise in energy prices and inflation. The design and the type of measures introduced also contribute to the heterogeneity of the impact of high prices. In assessing the distributional impact of inflation, the institutional setting in terms of tariff structure and regulation in the energy sectors also plays a role.

The aim of this paper is to assess the distributional impact of the unprecedented price increase during the period 2021–23 on Italian households' expenditure and energy vulnerability. We contribute to the debate in several ways. First, the analysis provides a comprehensive assessment of the heterogenous effects of price changes on households spending and of mitigation policies along the entire income and expenditure distribution. Second, we use CPI indices at the highest level of detail to show the heterogeneity in the composition of consumption baskets across categories of goods. Third, the study provides a detailed representation of the structure of energy tariffs in order to take into account the distributional impact also when considering interventions on individual components of the regulated energy price. Fourth, we provide a first assessment of the impact of a prolonged period of inflation on energy poverty and the relative effectiveness of policy measures to prevent it. Finally, we use estimated energy prices elasticities to assess the potential effects of enduring inflation on the household consumption basket.

Our main findings show that the original mitigation measures proved their effectiveness in reducing the regressive impact of inflation. Looking at the distributional impact in 2022, inflation, mainly driven by energy price increases, has a regressive effect that is almost fully offset by the mitigation policies. Such progressive policy effects disappear in 2023 due to a change in the policy mix.

The paper is structured as follows. Section 2 briefly reviews the literature on the impact of energy inflation on household spending and describes the mitigation policies adopted by EU countries to reduce the effects of inflation on household budgets. Section 3 presents the microsimulation model and the results of several simulation scenarios on the distribution of household expenditure in Italy. Section 4 shows the effects on energy poverty and vulnerability under different policy scenarios and the potential impact of estimated demand elasticities on household spending. Conclusions are drawn in Section 5.

2. Energy inflation, distributional impacts and mitigation policies

Inflation and energy price increases can affect households through both direct and indirect channels (ECB, 2010). The first channel concerns consumption. Rising energy inflation hits households directly as they spend a share of their income on energy consumption (heating and electricity) and transport. Heterogeneity in the impact of inflation arises when differences in the households' consumption bundle are taken into account. Heterogeneity leads to differences in the inflation rate perceived by different consumers together with differentiated effects on the purchasing power. As low- and middle-income households spend a high percentage of their income on basic necessities (food and housing), the inflation experienced by poorer households is higher than that of high-income households (ECB, 2022). Inflation also hits households indirectly through the income-generation channel. Since energy is used in the production of other non-energy goods, households may also be indirectly affected by an increase in energy prices even if producers are unable to pass on the increased production costs to final consumers, as producers would reduce wages or profits to be distributed (Battistini et al., 2022). Moreover, the stickiness of nominal wages and pensions may lead to a lag and partial adjustment of income to inflation. A third transmission channel is represented by wealth and debt levels. In periods of high inflation, debtors may benefit from the fact that nominal interest rates do not immediately adjust to inflation. Given that middle-income households hold most of their wealth in bank accounts, these do not provide the necessary protection against real wealth erosion due to increased inflation.

Irrespective to the transmission mechanisms, at the micro level the impact of high and persistent inflation can differ significantly across households (Villani and Vidal Lorda, 2022; Menyhert, 2022). Inflation affects different types of goods and services unevenly, depending on the source of the price spike and the relative production technology. The rise in inflation in 2021, mainly driven by energy goods, initially affected energy and transport expenditure. The persistence of high energy prices causes inflation to be transmitted first to goods for which energy is significant as an input or as a component of the production technology. The data on inflation by type of goods show that services have been barely affected by the price increase after the end of Covid restrictions and by the war crisis. In addition, other sources of heterogeneity can be identified when assessing the effects of inflation on households spending and welfare, and in particular, on energy vulnerability. First, households at the bottom of the distribution tend to devote a higher proportion of their income to the consumption of inelastic goods such as energy and food, than households in the top deciles. Therefore, they are mostly affected by inflation in energy and other necessity goods. The data show that the difference in the inflation rate faced by the lowest and the highest income quintiles is the largest since 2006 (ECB, 2022). Second, heterogeneity can arise from the price and tariff structure in the gas and electricity markets. In the regulated energy markets, tariff components are either proportional to consumption or lump-sum. In such price settings, inflation and the related mitigation policies may generate heterogeneous effects depending on the component affected by the change (e.g. energy transport costs or general system charges). Heterogeneous effects also arise when considering different types of mitigation policies, such as income versus price policies or general versus targeted interventions. Furthermore, distributional effects can be observed when considering the relative response of household consumption and expenditure to periods of high inflation, given the weight of necessity goods in total households' expenditure. Low-income households spend a higher proportion of their income on energy and food items, have a lower or zero savings rate and are therefore less able to cover the increased cost of living or to change the composition of their consumption basket. In fact, households with liquidity and budget constraints may find it difficult to increase their energy and total spending due to inflation. At the same time, energy-poor households with already low energy consumption may find it difficult to further reduce energy costs and demand in the very short term, raising concerns about the affordability of energy expenditure and, more generally, of the increased cost of living. The magnitude of energy inflation may thus have a perverse impact on already energy vulnerable households. The persistence and uncertainty of ongoing price developments may also exacerbate the loss of purchasing power, increase poverty and have serious implications in terms of social exclusion.

This paper focuses on the direct impact of inflation on households and aims at assessing the extent of the transmission of energy and non-energy inflation on households spending along the consumption and income distribution.

The distributional effects of inflation, ultimately triggered by energy price increases, have been studied extensively since the first energy price crisis in the 1970s. Michael (1979) investigates the distribution of inflation rates across households in the US and finds considerable dispersion and persistence of such differences over time. The author finds that in the early 1970s inflation rates differed by age and income level of the householder with poor households experiencing relatively higher inflation rates. Muellbauer (1974) finds that the estimated cost of living index in the UK rose more for low-income consumers in the late 1960s. In particular, by estimating a linear expenditure system of demand equations and calculating a cost-of-living index for different levels of expenditure, the distributional effects of inflation are analysed considering substitution effects and consumption elasticities. Among the studies on the distributional impact of inflation, the use of the aggregate CPI index has been widely criticized because it can hide large differences in consumption preferences among households along the income-expenditure distribution (Lynes, 1962; Boskin and Hurd, 1986; Hagemann, 1982; Callan et al., 2015). More recently, the effects of inflation triggered by the end of COVID restriction and by the Ukrainian war have been extensively analysed from a distributional perspective. Some studies have described the differentiated effects of price increases for different quintiles of the income-expenditure distribution (see, among others, Battistini et al., 2022; Colabella et al., 2023). Sologon et al. (2022) assess the distributional and welfare effects of the price surge across EU countries using the compensating variation, finding higher inflation in poorer countries but also that the distributional impact is less substantial than expected. Peersman and Wauters (2022) examine the price elasticity of energy demand and find that it is significantly larger for price increases than for price decreases and that the marginal propensity to consume is higher for low-income households.

Following the start of the energy price surge in the second half of 2021, the EU and most OECD countries adopted large and differentiated packages of measures to cushion and, in some cases, to offset the impact of the energy price increase on households and firms (OECD, 2023). Policy support measures can be classified into price and income support policies (OECD, 2022c). The former includes all measures that reduce the after-tax energy price paid by households and firms. They include price controls, reduced general system and transport charges, reduced indirect taxes on energy products (VAT and excise tax rates), subsidies, price controls and social tariffs. Income policies include lump-sum transfers to energy-consuming households and firms to reduce energy costs, as well as other transfers, such as those to poor households to provide a generalized relief to higher inflationary costs. Income and price support measures may be non-targeted or targeted to a specific group of beneficiaries, either through means-tested or on the basis of other characteristics such as age and health status. Information collected on measures implemented in OECD countries between October 2021 and December 2022 shows that non-targeted price support policies dominate over income measures, which are mainly targeted at more vulnerable households (Causa et al., 2022).

In Italy, support measures to protect the economy from higher energy prices were introduced during the COVID crisis and have been extended till the first half of 2023. During this period, the composition of the policy support measures has also changed as some measures have been strengthened, such as social allowances on energy bills for poor households, and others have been reduced or abolished, such as the rebate on excise duties on fuels from December 2022. By April 2023, overall, the measures adopted so far for this purpose amount to €119 billion (6.11 % of GDP) and include, among others, a mix of income and price measures, either untargeted or targeted or means-tested.[1] Measures affecting households can be grouped into two types (OECD, 2022c). First, general non-targeted price support measures, modifying taxes or the regulated components of prices that benefit either households or firms (reductions in excise duties on fuels and VAT on gas, and the reductions in general system charges for both electricity and gas). A second group of policies includes several forms of cash transfers as means-tested measures targeted at relatively poorer households. Some of the measures are specifically targeted at households in financial hardship, such as the expansion of the social allowances for energy, while other more general measures cover a wider range of beneficiaries, such as the one-off allowances, the contribution relief, the revaluation of pensions paid[2] .[3] All the relief measures introduced to cushion the impact of higher prices have been given on a temporary basis.

Similar policies have been implemented in other EU countries (Table 1). In Germany, for example, several one-off means-tested transfers have been introduced to provide an additional support targeted to specific groups. In addition, the German government has announced a €200 billion policy package for 2023–24, including a substantial support to counteract energy inflation. Among the relevant measures of this new policy package, a price cap based on a percentage of previous year consumption has been introduced. Very similar measures with different eligibility criteria have also been introduced in France and Spain (Sgaravatti et al., 2023).

Different policies have different secondary effects. As observed by Varga et al. (2022) and Ari et al. (2022), price support policies reduce the incentive for more efficient energy use. In addition, price policies can have high budgetary costs and, in most cases, are not well targeted. On the other hand, income/transfer measures can be well designed to target more vulnerable households and maintain the incentive to an efficient use of resources. At the same time, they can be difficult to implement and, in some cases, may not reach the intended population.

3. Distributional impact of rising inflation in Italy

3.1. Inflation inequality

The first inflationary tensions in Italy began to emerge in mid-2021 as a result of the recovery of production processes after Covid and were exacerbated by the Ukraine-Russia conflict at the beginning of 2022. In particular, the year 2022 was marked by a sharp rise in prices not seen for around forty years: inflation, as measured by the NIC index, reached 8.1% (from 1.9 in 2021), the highest level since 1985, when it exceeded the 9% threshold. The sharp rise in prices, which started upstream in the production chain as early as spring 2021 as a result of increases in

[1] For details, see Parliamentary Budget Office (2022a, 2022b, 2023). Roughly 35 billion has been allocated to measures specifically benefiting firms; 30 billion to supporting households and 35 billion to measures benefiting households and firms; 16 billion have been allocated to local governments or to investments and 3 billion to the health system.

[2] Considering the eligibility criteria, energy social allowances are granted to households in economic hardship depending on the composition of the household; the one-off allowances and the reduction of social security and welfare contributions are given on the basis of individual income.

[3] Other minor measures in favour of households include: the exclusion of fuel allowances from employees' tax base; vouchers for the purchase of public transport passes; the extension of measures concerning fringe benefits, including the amounts paid for reimbursing employees for the payment of utilities.

Table 1
National support measures to mitigate the effects of energy price increases and inflation.

	Price/Tariff measures			Income/Transfers measures				
Country	Reduced energy tax/VAT	Retail Price regulation	Wholesale price regulation	Transfers to vulnerable groups	Mandate to state-owned firms	Windfall profits tax/regulation	Business support	Other
Austria/Belgium/Czechia/Italy/Sweden	x	x		x		x	x	x
Bulgaria/Croatia/Denmark/Estonia/Germany/Latvia/Luxembourg/Netherlands/Norway/Poland/Romania/UK	x	x		x		x	x	
Cyprus/Greece	x	x		x	x	x	x	
Finland/Ireland/Lithuania	x			x		x	x	x
France	x	x	x	x	x	x	x	x
Hungary	x	x				x	x	
Malta		x	x		x	x	x	x
Portugal	x	x	x	x	x	x	x	
Slovakia		x		x	x	x	x	
Slovenia/Spain	x	x	x	x		x	x	

Source: own elaboration based on Sgaravatti et al. (2023).

commodity prices, subsequently spread to consumer goods, above all foods, with a significant impact on the average consumer's shopping list. In autumn 2022, the prices of gas and other energy goods experienced a reduction, leading to a decline in the inflation rate in the early 2023. However, the high inflation dynamics will be absorbed more gradually as inflation spreads to less volatile prices. As a result, inflationary pressure on household budgets, especially those with lower spending capacity, remains therefore significantly high. Estimates for 2023 suggest that inflation will be around 6.1%, with a rapid decline in energy prices, in part already observed (European Commission, 2023).

Price dynamics from January 2021 to end-April 2023 were highly differentiated across categories of goods (Fig. 1) .[4] The strongest impact was registered on total housing expenditure (+47% in 2023 after +71.3% in December 2022) – which includes utilities such as gas and electricity (which increased by 196 and 207%, respectively) – and, to a lesser extent, on transport expenses (+18.3%), which were affected by the change in fuel prices (+129%). It should be noted that energy and fuel price indices are influenced by price dynamics but also by policy measures on tariffs and other price components (e.g., fuel excise duties). Over the same period, food prices increased by around 20.3% overall. In the second half of 2022, housing costs, mainly energy prices, continued to increase sharply, especially in October before starting to fall by November.

3.2. Modelling approach, data and scenarios

Using the tax–benefit microsimulation framework developed by the Italian Parliamentary Budget Office (PBO) and incorporating inflation forecasts,[5] we estimate both the annual change in household expenditure for 2022 and 2023 due to price dynamics and the impact of mitigation policies on a representative sample of Italian households.[6]

The household tax-benefit microsimulation framework developed by the Italian PBO consists of several modules with different functionalities and powered by different data sources. In order to assess the distributional impact of price shocks and the mitigation measures, we use the Simulation Module of Indirect Taxes (VAT and excise duties) and the Module for simulating Personal Income Taxes. This is a static model (i.e. without behavioural responses) based on the ISTAT Household Budget Survey integrated (with administrative key) with data on personal income taxes, social contributions, pension benefits, and ISEE.[7] The model is very accurate in calculating different types of taxes and social transfers: it estimates VAT and excise duties paid by households on consumption, leveraging a detailed breakdown of VAT rates (COICOP classification of elementary expenditure items). Personal income taxes are estimated on the basis of income data, which also allow an accurate modelling of means-tested social transfers. A weight calibration procedure has been applied to reproduce the main (aggregate) marginal distributions in order to estimate actual revenues with a small margin of error. The last year for which all integrated sources are available is 2017. Expenditure levels for the subsequent periods are obtained by applying the general monthly CPI index to the individual household's consumption basket at a high level of disaggregation (4-digit COICOP, 112 expenditure items), and calibrating the resulting data to match the main consumption aggregates in 2021. For subsequent periods, quantities are assumed to be constant and, using the same approach, we project expenditure using monthly CPI indices, where available, and price forecasts for the second half of 2023.

In order to obtain a more detailed estimate of the dynamics of energy expenditure, we use a specific approach based on quantities and tariffs for fuels, gas and electricity.[8] Prices and tax rates have been applied to an estimate of household consumption in quantities (litres of fuel, kWh of electricity and cubic metres of gas). The estimation of the quantities consumed and the decomposition of prices and tariffs allow taking into

[4] The figure shows the NIC price index (Consumer price index for the whole nation) released by the Italian National Statistical Institute (ISTAT) on a monthly basis and at the COICOP level.

[5] The analysis is based on a prospective scenario of price trends that is consistent with the forecasting framework prepared by the PBO as of June 2023. The inflation projections used in the analysis are also consistent with the EC inflation forecasts for Italy (Parliamentary Budget Office, 2023; European Commission, 2023).

[6] The use of inflation forecasts allows the assessment of the aggregate and distributional impact for the whole year 2023, incorporating hypotheses of a fall in energy prices and alternative mitigation policy packages.

[7] It is the official indicator of the socio-economic situation of households - hereafter ISEE (Indicatore della Situazione Economica Equivalente) – used for means-tested policies in Italy. The model contains a very high level of detail on household consumption (based on the survey data) and on income (thanks to the use of administrative data). Taxable bases are calculated from tax returns, while social security data and sample information are used to estimate non-taxable incomes. Pensions and job-related details for employees (wage, sector of activity, qualification, and type of contract) are taken from pension statements.

[8] In relation to both electricity and gas, this approach is limited to users in the protected market ("Mercato tutelato"). For users in the unregulated (free) market, whose bills are not necessarily linked to quantities and tariffs, the change in expenditure was calculated by applying the Istat price index referred to this specific market segment. We identify the subset of households on the free market using a Monte Carlo technique.

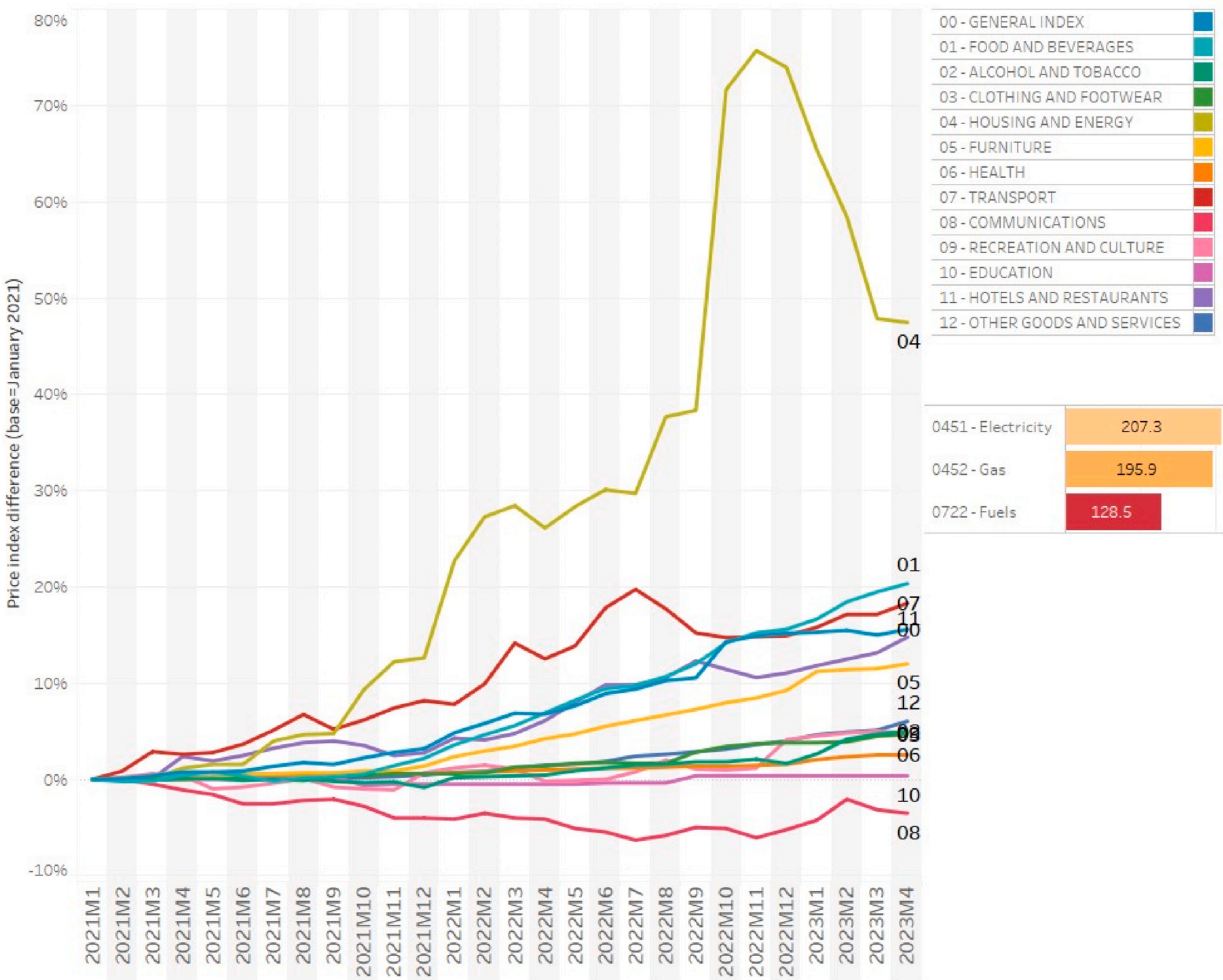

Fig. 1. Price changes in Italy by consumption item
(index; January 2021 = 100).
Source: own elaboration based on Istat, general CPI index.

account the differentiated incidence of the components of the prices of energy goods, as they are linked to the level of consumption.[9] Similarly, the decomposition of price components makes it possible to analyse the distributional impact that mitigation policies acting on these components have had.

In order to estimate the impact of mitigation measures, we compare household expenditure in different scenarios. The 'baseline scenario' considers household expenditure in 2021; the 'theoretical scenarios' estimate the expenditure that would have been incurred if mitigation measures had not been fully applied. The 'full scenario' estimates expenditure considering the complete policy mix introduced in 2022 and then revised in 2023. To this end, the analysis includes the simulation of the effects of the main price policies and monetary transfers. Price policies include the reduction of fuel excise duties and general system charges for electricity and gas, and the reduction of VAT on gas. In the second group we consider social allowances for electricity and gas, the two one-off allowances (€200 and €150), the relief from social contribution and the revaluation of pensions. The specific benefits for each household have been estimated on the basis of the financial situation (employment status and ISEE level) and of the expenditure basket.

3.3. *Simulation results: distributional impacts of inflation and mitigation policies*

Fig. 2 shows (white circles) the change in annual household expenditure, for 2022 and 2023, due to the interplay of price increases and policies. For 2022, the impact of price increases on household expenditure is around 9.6% (of which around 7 percentage points due to energy price increases and 2.7 to inflation in other goods), but mitigation policies helped to alleviate it by about 4.5 points, bringing it down to 5.1%. In detail, price-related policies contributed to the reduction of household expenditure by 1.6 percentage points, whereas monetary transfers by additional 2.9. Considering the same consumption basket composition, the gross impact of price increases in 2023 amounted to 4.8%, as a consequence of the increase in non-energy goods prices

[9] Inflation has a differentiated impact on expenditure because the level of consumption varies for two reasons. First, as the level of expenditure increases, the share of expenditure allocated to the various items of consumption changes. Second, for energy and fuel bills, changes in rates and taxes are not proportional to consumption: since the weight of the different tariff components (energy, transport, system charges, taxes) is not uniform as the quantities consumed vary, the change in each of them has a different impact on the bills of users who consume different amounts of energy.

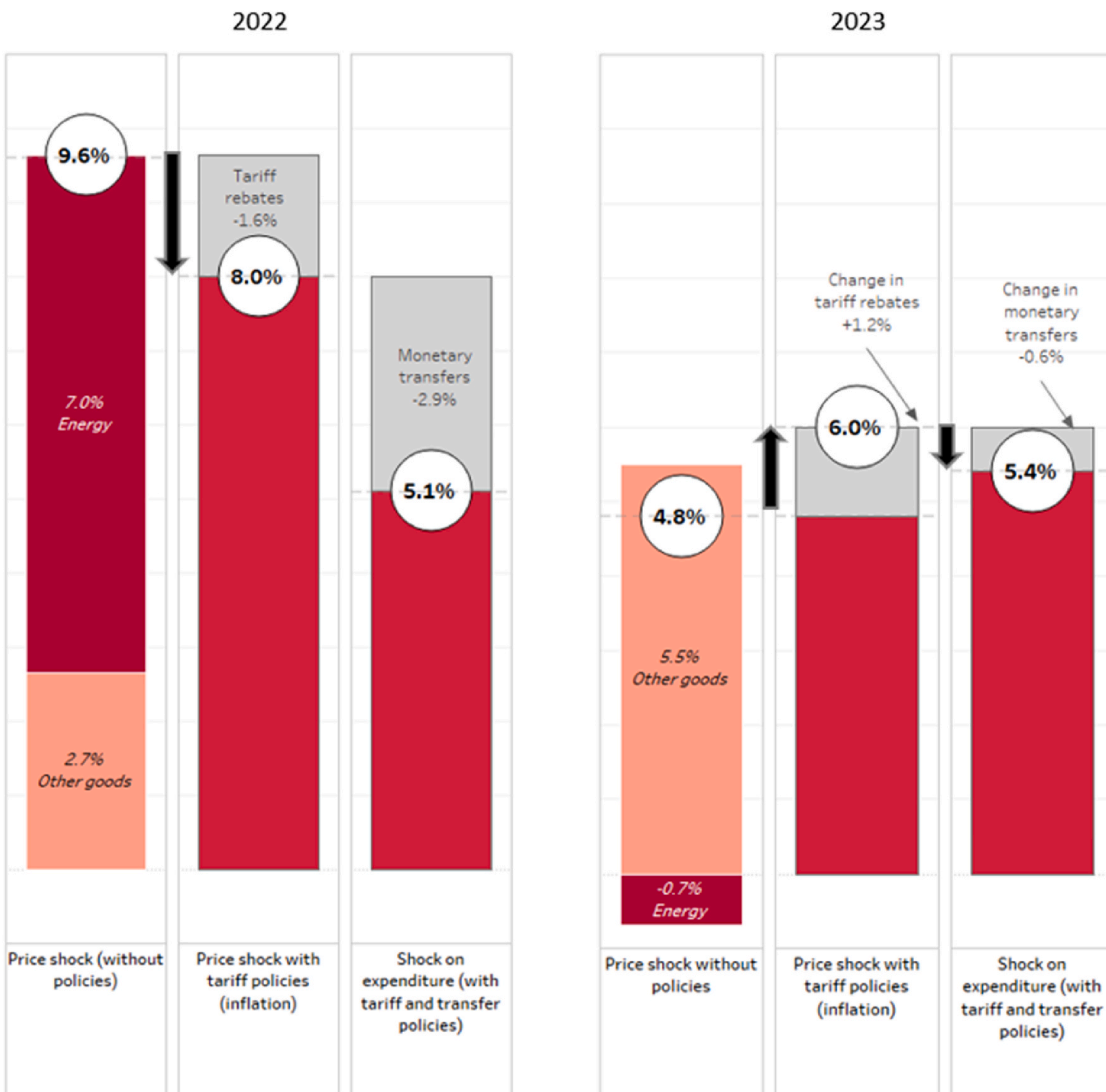

Fig. 2. – Changes in Italian household expenditure as a result of price dynamics in 2022 and 2023, before and after state support measures (*).
Source: PBO microsimulation model.(*) Totals may not match due to decimal point rounding.

(+5.5%) and the decrease in energy costs (−0.7%). However, the gradual rebalancing of support policies (lower tariff rebates only partly offset by higher monetary transfers) led to a further increase in expenditure of 0.6 percentage points: the final net effect on household spending is therefore estimated at 5.4%, +0.3% from 2022.

In order to consider the distributional profile of inflation, Fig. 3 shows the change in household spending in 2022 by equivalent expenditure deciles. The bars, which represent the contributions to the increase in expenditure, show the impact of the developments in the prices of energy goods (fuel, electricity and gas) and of the other goods included in the basket that would have occurred in the absence of support policies (red bars) and the impact of these policies (blue bars), highlighting the associated distribution.

Looking at the distributional profile of inflation, it appears that in 2022 the impact of price increases, mainly due to energy inflation, on expenditure would have been higher for households with lower consumption levels (pure theoretical scenario). In general, inflation has a regressive impact: the burden on the lower deciles of equivalent expenditure has been significantly higher than for the rest of the population. For the first decile, in the absence of support policies, inflation would have increased expenditure by about 19%, 9.3 points above the national average and more than three times the impact experienced by the tenth decile. This is a consequence of the fact that the largest price increases involved basic necessities (electricity, gas and food), which account for a larger share of the expenditure for the poorest. In particular, this result is linked to the decreasing contribution of the increase in energy prices between expenditure deciles (+16.3% for the first and 3.7% for the tenth). Quite the opposite, the contribution of other goods price increase is homogeneous along the distribution of expenditure, explaining 2.7% of the increase in the expenditure of the first decile and 2.9% of the tenth.

For this same reason, energy price mitigation measures (reductions of excise duties, system charges and VAT) can be considered progressive. They help to reduce the expenditure of the first decile by 2.8 percentage points and that of the last by 0.9. Net of tariff compensations, the expenditure of households in the first decile would have increased by 16.2% versus 5.7% for the last decile. Support measures implemented in the form of transfers, which are subject to various forms of means testing

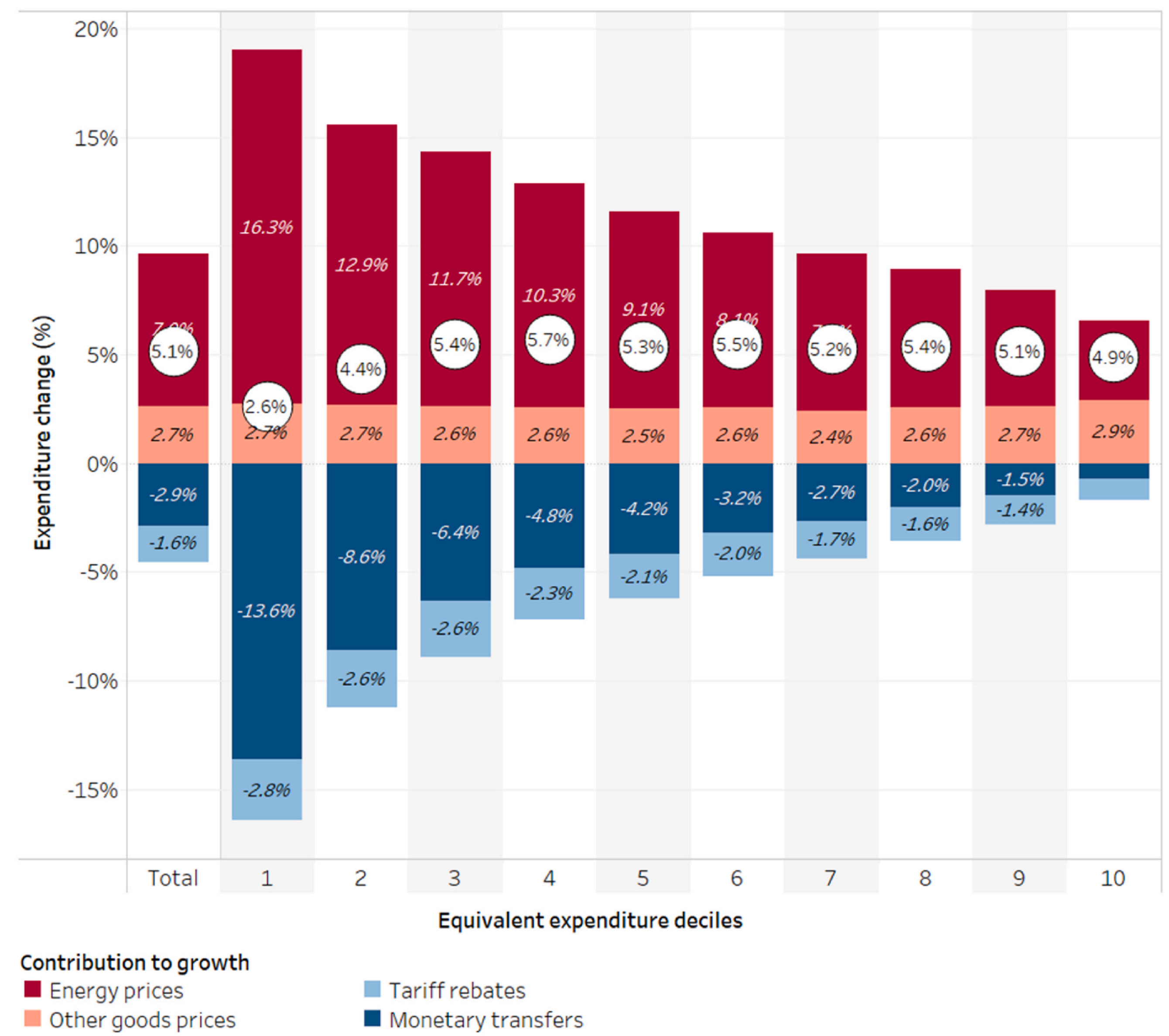

Fig. 3. Changes in Italian household expenditure as a result of price dynamics between 2021 and 2022 by equivalent expense deciles before and after public support measures.
Source: PBO microsimulation model.

and are largely paid as a lump-sum, are even more markedly progressive. For the first decile, cash transfer measures almost offset the increasing dynamics of energy prices. Overall, the combined effect of the support measures more than offsets the regressive impact of inflation, leading to a redistribution across deciles. Therefore, the final net impact in 2022 was progressive, being significantly lower for the first two expenditure deciles than for the highest deciles (2.6 and 4.4%, respectively, compared to an average of 5.1%).

Fig. 4 shows the results of the distributional impact for 2023, taking into account the inflation forecast (Parliamentary Budget Office, 2023) and the price mitigation measures introduced in the first half of the year, which differ in amount and composition from those introduced in 2022. The increase in the prices of non-energy goods and the rebalancing of the policy mix result in a small overall regressive impact on expenditure in 2023. The net increase in expenditure in 2023 is higher for the first two deciles compared to the last one (6.9 and 6.1%, respectively, compared to 5.6%). Several factors contribute to the regressive profile in 2023: the increase in energy expenditure induced by the reduction in tariff support measures, which is higher for the lowest deciles; the smaller effect of the reduction of energy prices, which has a relatively smaller impact on poorer households, as it only leads to a reduction in the variable component of the tariff; the write-off in 2023 of monetary transfers (such as on-off allowances), which are particularly relevant for low-income households that are not compensated by other benefits targeted at the same population, such as increased contribution relief and pension revaluation.

4. Energy vulnerability in a high inflation period

4.1. Energy poverty definition and indicators

In this new context of high inequality and rising inflation, the energy poverty (EP) issue has become of major concern and identifying vulnerable households to this type of deprivation has become

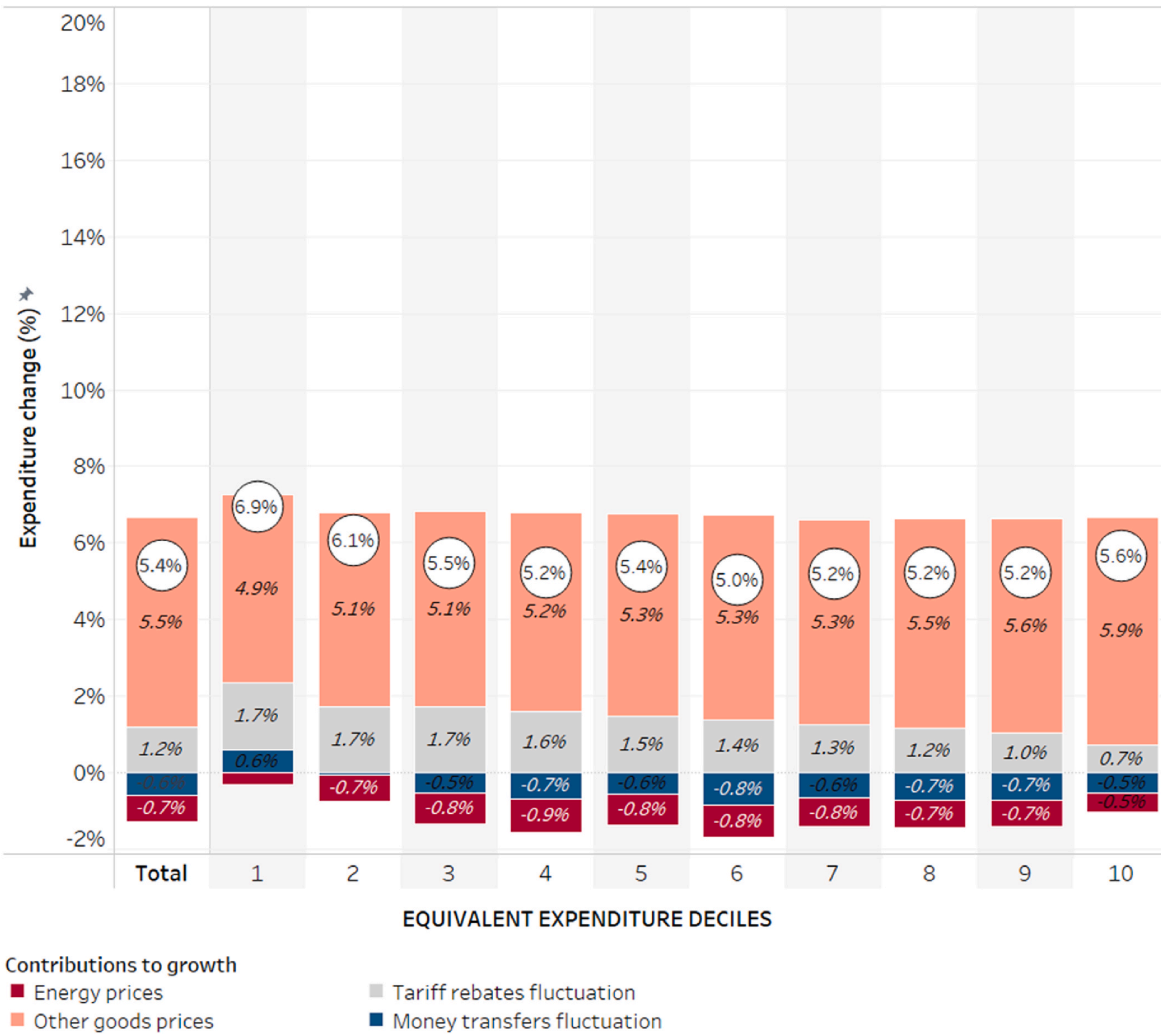

Fig. 4. – Changes in Italian household expenditure due to price dynamics between 2022 and 2023 by equivalent expense deciles before and after public support measures.
Source: PBO microsimulation model.

fundamental to policy making. Given the current crisis, with its high volatility of energy prices, this issue and its measurement are expected to become increasingly relevant in the near future. Unfortunately, the empirical literature has not produced a standard metric: on the contrary, there is a large number of EP indices available, although there are some key features on which most researchers agree, such as multidimensionality and the difficulty of finding accurate data.

The classic triad of determining factors includes low income, low energy efficiency and high energy prices. However, these commonly identified causes overlook other determinants that contribute to a condition of vulnerability to energy poverty: health, age, household composition, social and cultural characteristics, can create a mismatch between the energy requirements of the family and the available energy services that goes beyond the three main factors. Furthermore, urban/rural location or climate characteristics and preferences or different social norms concerning indoor comfort interact with other determinants in a dynamic framework. Within this broader perspective it is interesting to consider not only the identification of the energy poor, but also those groups that are at risk of falling into energy poverty in the future because of a particular sensibility to vulnerability factors.

The empirical literature has produced a large number of binary EP indices and properly identifying pros and cons of each metric, as well as the complementarity and redundancy between them, has become very important (EPAH, 2022; Sareen et al., 2020; Tirado Herrero, 2017). In a nutshell, these metrics can be classified into three groups: 1) consensual indicators based on self-reported assessments of thermal comfort, housing conditions and ability to pay energy bills; 2) expenditure-based indicators where household energy expenditure is compared to household income (or total expenditure) or to the median values of the entire distribution; 3) direct measurement of energy requirements which monitors parameters such as humidity and temperature and consider the energy efficiency status of the dwellings. The three approaches have several pros and cons and, generally speaking, a dashboard of different types of indicators – or a composite indicator - seems to be the most promising way of analyzing energy poverty[10]. In this paper we use the most well-known composite indicator, the Low Income High Cost indicator (LIHC), which identifies EP when, at the same time, high energy costs (HC component) and a below the official poverty line residual disposable income (net of energy expenditure) occur (LI component). Looking at the residual income helps in detecting vulnerable households, which are at risk of falling into poverty due to energy expenditure increase. A variation of the LIHC indicator, proposed for the Italian case by Faiella and Lavecchia (2015, 2023), combines the two above-mentioned components with the hidden EP, which considers both the poor households with too high a share of expenditure on energy and those under-consuming, i.e. with low total energy expenditure and no expenditure on heating. The modified-LIHC (henceforth M-LIHC) aims at identifying also subjects presumably bound by the 'eat or heat' dilemma, who are difficult to detect with the other expenditure-based indicators. Although there are peculiar aspects of this indicator which may distance it from others generally used in the literature (see the formula in Appendix A), it is nevertheless the only indicator officially adopted in Italy in the Integrated National Energy and Climate Plan and therefore it is a relevant measure for national policies aimed at fighting EP. Moreover, the modified-LIHC indicator has the characteristic of being decomposable in a way that makes it possible to highlight the area of vulnerability.

Table 2
M-LIHC indicator in alternative simulation scenarios (% of total households).

	Overall M-LIHC index	Breakdown	
		First component	*Second component*
2021			
Base Scenario	11.42	*8.75*	*2.67*
2022			
Theoretical scenario - no policies	22.47	*19.80*	*2.67*
Theoretical scenario - price related policies only	21.26	*18.59*	*2.67*
Full scenario - price & income policies	11.91	*9.24*	*2.67*
2023			
Theoretical scenario - no policies	22.79	*20.12*	*2.67*
Theoretical scenario - price related policies only	22.15	*19.48*	*2.67*
Full scenario - price & income policies	13.27	*10.60*	*2.67*

Source: PBO microsimulation model.

4.2. The impact of high energy prices on energy poverty

The increase in the general price level and the exceptional rise in energy commodity prices have certainly exacerbated energy poverty, putting a significant proportion of households in a marginal position. To analyse this effect, the M-LIHC indicator of energy poverty has been considered, initially without any behavioural reaction of households. In other words, we observe the short-term effect in the absence of substitution effects and without any reduction in the quantities consumed. Table 2 shows how, on the basis of this indicator, 11.42% of households are identified as energy poor in 2021, our Base Scenario. This particular metric can be split into two parts (see the formula in Appendix A). The first component measures the share of vulnerable households in terms of low income and high costs (8.75% of households), while the second component identifies those who do not heat their homes due to a tight budget constraint (2.67%). In this framework, our results show that the price increase between 2021 and 2023 almost doubles the share of households in EP (from 11.42% in 2021 prices to 22.47% in 2022 and 22.79 in 2023 in the theoretical no-policy scenario) as a consequence of the burst in expenditure on energy products and the sharp reduction in residual disposable income.[11]

As already shown in Fig. 4, the compensatory measures in place between the end of 2021 and the first half of 2023 were partially effective in reducing the impact, leading to a decrease in the number of energy-poor households compared to the theoretical scenario with no policies, lowering their expenditure (measures reducing some tariff components) and, above all, increasing their disposable income (direct transfers). Taking policies into account (full scenario) and focusing on the first component of the M-LIHC index, the share of energy poor households slightly increases by 0.5 percentage points over the course of 2022 (9.24%) but more than halves with respect to a no-policy scenario (19.8). However, in the absence of a refinancing of transfers in 2023 or in the presence of only partial indexation of pensions and wages, the share of households in EP increases further by 1.4 percentage points (10.6).[12] To this end, it is useful to consider both the distributional effects by socio-demographic characteristics and the areas of vulnerability, i.e. to identify those households that are not yet in energy poverty but whose incomes are very close to the poverty line or whose costs are close to being unaffordable. Fig. 5 depicts, in the baseline scenario, the share of household in energy poverty (in dark red), the vulnerability area (in orange and dark blue) and those households that are certainly not energy poor (in light blue) in terms of income and cost adequacy, with respect to the first component of the index shown in Table 2. On a national average, non-energy poor and non-vulnerable households (HI-LC) accounted for 69.28%, energy poor (characterized by low income and high energy costs, LIHC) for 8.75%, while 22% could be considered vulnerable either because of income just above the poverty line (LI-LC) or because of high energy expenditure (HI-HC). Interestingly, the share of households that are definitely not poor is considerably lower for the over-65s (60.44%), for residents with foreign citizenship (50.89%) and for households living in the southern regions (57.7%). In the case of the over-65s, vulnerability is due to high energy expenditure rather than low income, while the opposite is true for foreign residents, where the share of households with income net of energy expenditure close to the poverty line is over 21%.

[10] Given the multidimensionality of EP, a single indicator can hardly capture multiple aspects and drivers, while a combination of metrics could be more helpful to reflect the complexity of the phenomenon. Therefore, multidimensional indexes have been proposed by several authors (Charlier and Legendre, 2019; Gouveia et al., 2019) where several metrics have been composed to compute a complex indicator. However, even this approach is not without criticisms, as an ad-hoc system of weights must be chosen to combine the various elements of the index and the lack of comparable data makes it less suitable for replication in different national settings. See Bardazzi et al. (2023a, 2023b) on the use of a dashboard or a combination of different indicators.

[11] It's worth emphasizing that the indicator refers to dynamic thresholds that shift endogenously as total expenditure increases. This endogeneity risks bringing vulnerable households out of the EP area without any improvement of the households' purchasing power. Therefore, we have frozen the thresholds to the base scenario of the indicator so to avoid vulnerable households being moved out of the EP area solely on the basis of the movements in the overall energy expenditure distribution. A similar assumption has been made by Menyhert (2022).

[12] It's worth noting that the second part of the M-LIHC indicator is not affected by the different scenarios. As shown in the formula in Appendix A, this component identifies those households with a zero heating expenditure and a low income level. Indeed, this kind of extreme self-constraint is not affected by a further increase in prices.

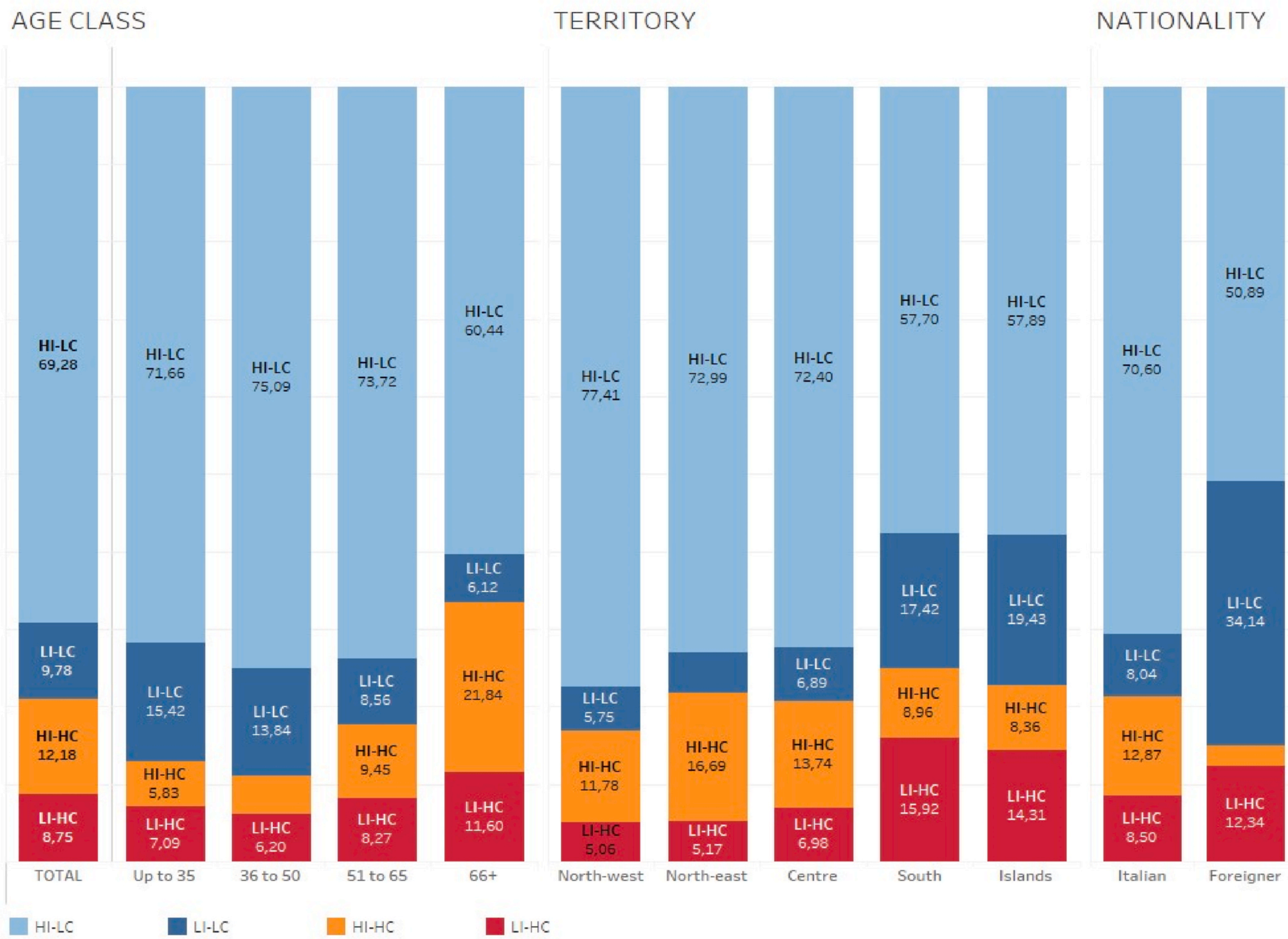

Fig. 5. - Breakdown of the first component of the M-LIHC index by socio-demographic characteristics: baseline scenario 2021
HI-LC: High Income Low Cost (not energy poor); LI-LC: Low Income Low Cost (income related vulnerabilities); HI-HC: High Income High Cost (energy expenditure vulnerabilities); LI-HC: Low Income High Cost (energy poor).
Source: PBO microsimulation model.

Although policy measures have been able to mitigate the level of inflation, Fig. 6 shows an overall negative impact of the price increase (including counteracting policies) on energy poverty risks in 2022, with the non-vulnerability area decreasing by almost 10 points (from 69.38% to 59.76%) and with different impacts depending on the age, location and residence of households. Households whose income is not very low, but whose energy expenditure is close to being unsustainable increase in all age or location areas: if at a geographical level the increase in the HI-HC segment is more evident in the central north, in the southern regions energy poverty reaches 16.44% of households. Households headed by over-65s show greater vulnerability: the share of those who are definitely not poor falls to 49%, while the share of households showing unsustainable levels of energy expenditure rises from 21.84 to 32.31%.

Although mitigation policies have only slightly changed the overall energy poverty, Fig. 7 shows how the composition of energy poverty and vulnerability has evolved in 2023. Energy inflation has indeed led to an increase in the area of poverty measured by the LI-HC component (from 8.8 to 10.6%) and an even more dramatic increase in the area of vulnerability (from 22 to 28.4%), due to the increased proportion of households with high costs (from 12.2 to 19.8%). Such increase is not concentrated among older headed households, as in 2022, but is spread across all age groups. The same effect can also be seen for foreign headed households, for whom the area of vulnerability due to high costs increases more than the area linked to low income.

4.3. *Including partial consumer reaction: household energy demand elasticities*

The results discussed above include only the (short-term) impact effect of inflation and support measures and do not take into account changes in household energy consumption or general cross substitution effects. To consider the first direct consumer reaction related to energy consumption, it is necessary to estimate the price elasticity of demand, which is a difficult task as several components and factors may interact in a confounding way (different energy products, different uses and users and non-homogeneous incidence of carbon pricing). In addition, technological innovation, product availability and binding regulation may alter the time trend, making the distinction between the short and long run essential. Furthermore, as highlighted by several meta-analyses, the estimation of elasticities varies according to the characteristics of the data, with estimates based on macro-data showing lower values than those based on micro-data.[13]

When focusing on household energy demand, other non-economic factors are essential: most of the international economic literature analysing residential energy consumption agrees that household energy demand is a combination of non-human (such as housing and weather

[13] Indeed, Miller and Alberini (2016) highlight that data aggregation reduces price variation and masks the heterogeneity across more disaggregated units.

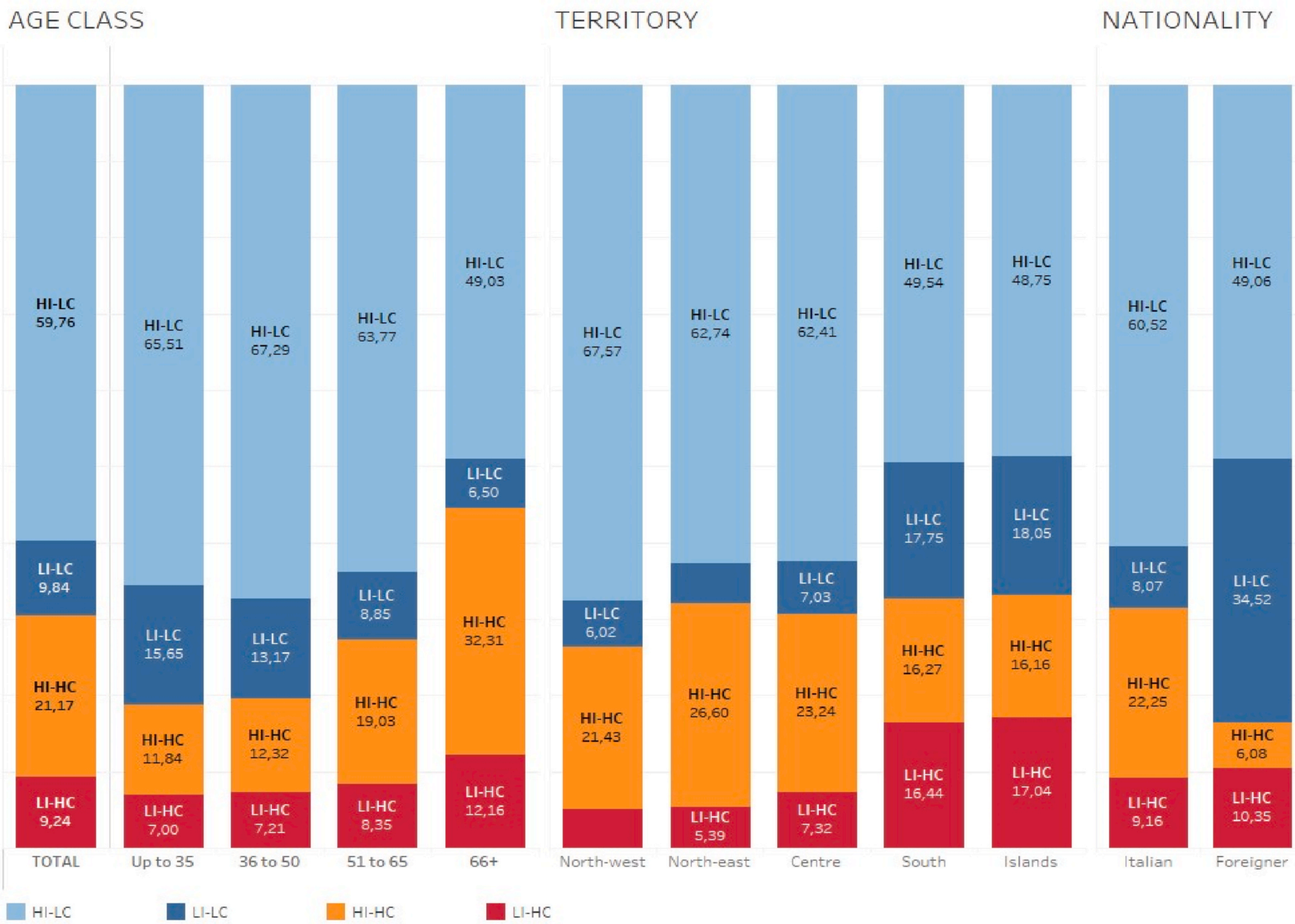

Fig. 6. - Breakdown of the first component of the M-LIHC indicator by socio-demographic characteristics: full scenario with policies 2022
HI-LC: High Income Low Cost (not poor); LI-LC: Low Income Low Cost (income related vulnerabilities); HI-HC: High Income High Cost (energy expenditure vulnerabilities); LI-HC: Low Income High Cost (energy poor).
Source: PBO microsimulation model

conditions) and human characteristics, the latter including demographic, psychological and cultural elements. These factors add considerable variability to the estimates so it is useful to refer to meta-analyses to get a general idea. As a general finding, long-run elasticities are higher than the corresponding short-run estimate, because time is needed to adjust the demand for relatively inelastic goods. Estimates are generally higher for heating-related than electricity expenditures and higher for gasoline with respect to diesel. As an example, Gillingham et al. (2009) report own-price elasticities for residential use ranging between −0.14 and −0.44 for electricity and between −0.32 and −1.89 for natural gas in the short-run. Labandeira et al. (2017)'s meta-analysis reports a short run price elasticity of −0.126 (−0.365 in the long run) for electricity, −0.180 (−0.684) for natural gas, −0.293 (−0.773) for gasoline and −0.153 (−0.443) for diesel. Long-run elasticities below 1 are also confirmed by Pellini (2021) using macro-data for several EU countries. Focusing on Italy, Bardazzi and Pazienza (2020) use a pseudo panel built on the Italian HBS survey (Bardazzi and Pazienza, 2017) to estimate price elasticities considering age and cohort effects. They find that households living in central and southern Italy are more responsive than northern families to changes in energy prices and this effect can be traced both for electricity and for natural gas. More recently, Faiella and Lavecchia (2023) and Bonfatti and Giarda (2023) use the same pseudo-panel technique to estimate short and long-run elasticities. In details, Faiella and Lavecchia report values between −0.29 and −0.40 (−1.17 in the long run) for electricity and −0.40 and −0.0.44 for natural gas (−1,23 in the long run), depending on the estimation method. Bonfatti and Giarda (2023) reports an average estimate of −0.38 for electricity and −0.64 for gas in the short-run and income quartile estimates with a higher value for the first quartile above the richest group for electricity consumption and the opposite for natural gas.

In this paper, as in Bardazzi and Pazienza (2020), residential energy demand elasticities are estimated on a pseudo-panel dataset and then included into the PBO model as exogenous parameters for a sensitivity analysis of behavioural reactions to the price increase. The pseudopanel technique consists in grouping observations on the basis of an invariant characteristic and tracking cohorts over time so to estimate a dynamic demand model (a Partial Adjustment Model). The results of our estimates for electricity and natural gas by quartiles of total expenditure are shown in Table 3.[14]

These elasticities appear to be lower than those estimated in the international literature, but not far from other recent Italian estimates (Faiella and Lavecchia (2023) and Bonfatti and Giarda, 2023). In particular, they are lower for electricity and higher for natural gas and slightly larger for the first quartile. In assessing the role that elasticities can play in influencing consumer behaviour in a price shock framework, it is important to stress that the empirical literature has found an asymmetry between different price trends and changes in the ordinary values of elasticities when large price fluctuations occur. In particular,

[14] See Appendix B for details of the methodology. Estimations refer to equation (B.2).

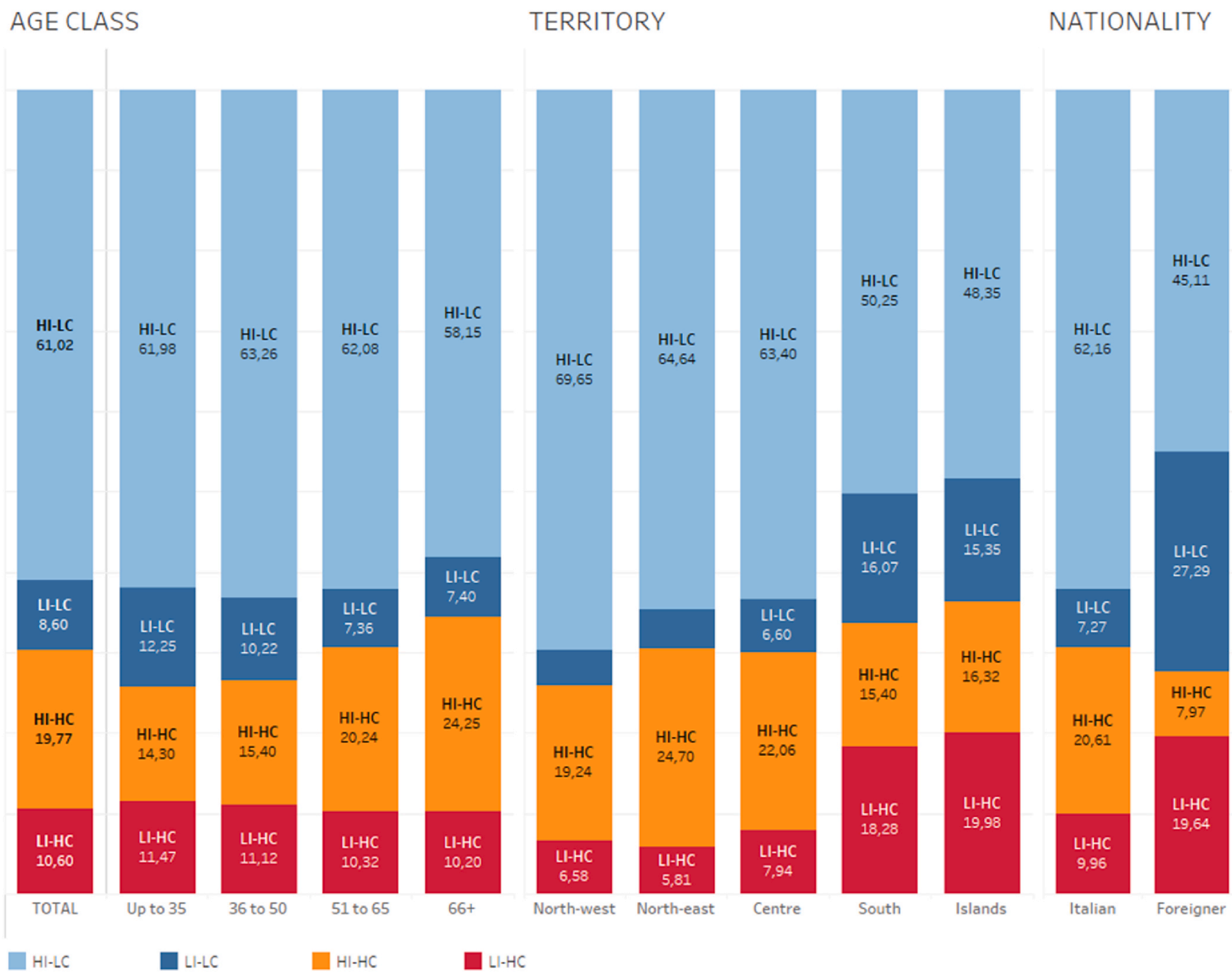

Fig. 7. - Breakdown of the first component of the M-LIHC indicator by socio-demographic characteristics: full policy scenario 2023
HI-LC: High Income Low Cost (not poor); LI-LC: Low Income Low Cost (income related vulnerabilities); HI-HC: High Income High Cost (energy expenditure vulnerabilities); LI-HC: Low Income High Cost (energy poor).
Source: PBO microsimulation model

Table 3
Estimates of short-run price elasticities for Italian households.

Quartile	Electricity		Natural gas	
	Coefficient	p-value	Coefficient	p-value
First	−0.597	0.000	−0.751	0.000
Second	−0.524	0.000	−0.577	0.000
Third	−0.529	0.000	−0.639	0.000
Fourth	−0.553	0.000	−0.622	0.000

Source: Authors' elaboration.

Miller and Alberini (2016) note that "households might be more sensitive to price changes if or where prices are especially high, implying a causal relationship between price levels and responsiveness to price". More recently, Peersman and Wauters (2022), using Belgian consumer survey data, confirm the asymmetry of elasticities in the upward and downward phases of prices, with the elasticity of upward periods being higher than that of downward periods (three times higher). Furthermore, the authors note that "the price elasticity crucially depends on the magnitude of the price shift; that is, the elasticity decreases heavily for larger energy price increases. For example, households report an elasticity of −0.38 when the monthly energy bill at constant consumption would increase by EUR 20, and -0.19 when the bill would increase by EUR 100 (p. 4)".

Unfortunately, the impact of the huge energy price shock experienced in 2022 cannot yet be estimated with official statistics at the household level and therefore we cannot assess how the shock might have affected the estimated elasticities. Using historically estimated elasticities in the context of the recent peak in energy prices would imply a huge reduction in energy consumption that cannot be considered sustainable, so leading to misleading results. Looking at the elasticity estimation results, we can expect the distributional impact to be larger

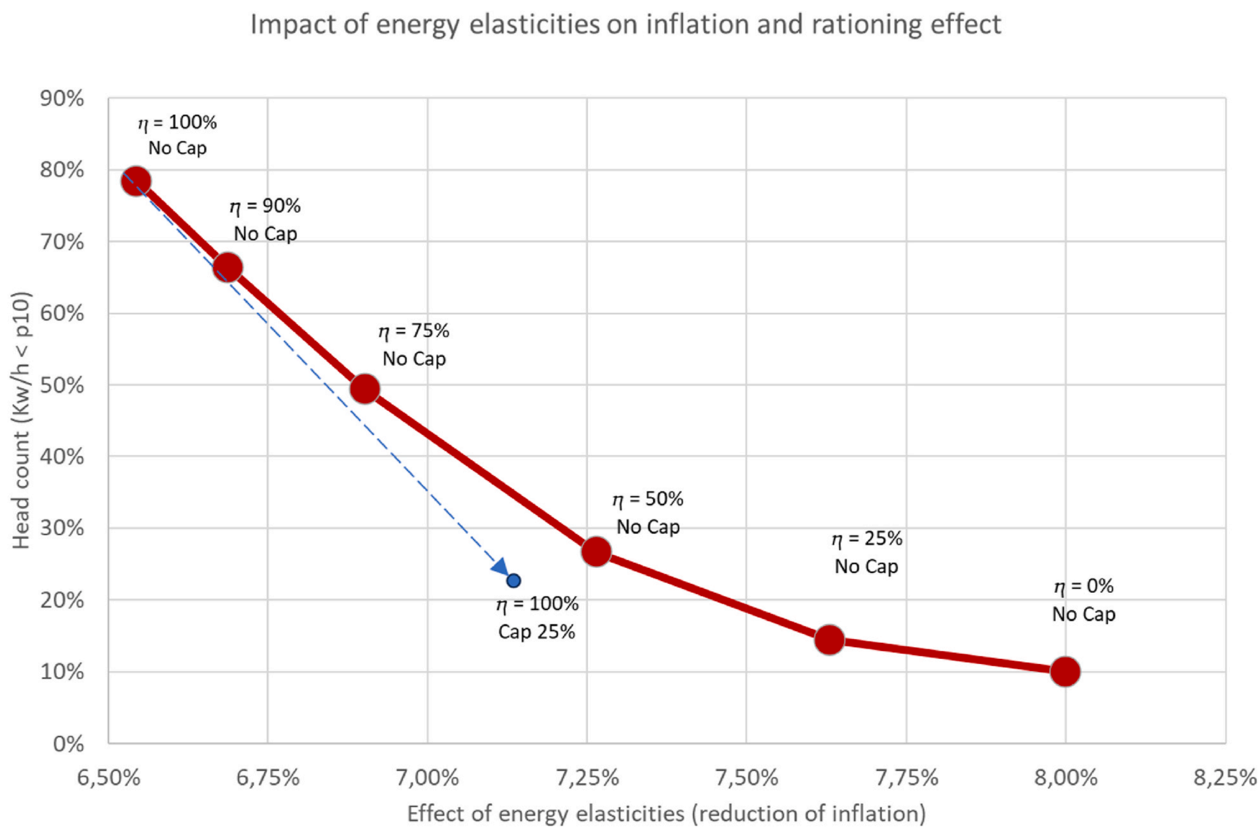

Fig. 8. Energy elasticities, inflation and rationing effects.
Source: PBO microsimulation model

for the first two deciles compared to the case of no behavioural reaction. A decrease in the quantities consumed by households that already ration their energy consumption may signal the risk that price shocks may have had an important impact on energy consumption through further self-rationing.

Nevertheless, the analysis of energy own-price elasticities is a useful exercise, as it provides some hints on the adjustment process that European consumers have actually shown in their energy consumption choices during this particular emergency period. However, as we acknowledge that simply applying energy elasticities estimated on the basis of historical data to the recent exceptional energy price increases may lead to disproportionate results, we prefer to present a sensitivity analysis of the potential effects on total expenditure and on self-rationing of energy consumption using different energy elasticities. Fig. 8 illustrates this point using the second theoretical scenario for 2022 as an example (price shock with tariff policy in Fig. 2), highlighting the impact of different energy elasticity levels (η) on the expenditure and on the electricity consumption to emphasise the implicit reduction in energy use. Indeed, the chart plots the percentage change in total expenditure on the x-axis and the share of households with electricity consumption below the first decile of the distribution on the y-axis. The first point on the bottom right of the graph shows the zero elasticity impact: an 8% increase in total expenditure and, tautologically, 10% of households consuming at the level of the first decile. Applying only 50% of the estimated price elasticities (Table 3), we obtain a lower increase in household expenditure (7.25%) due to a reduction in demand, but at the cost of a severe under-consumption: the share of households with very low electricity consumption (below the actual consumption of the first decile) would more than double. Considering the full impact of the estimated elasticities ($\eta = 100\%$), we have a further reduction in total expenditure but, at the same time, 80% of households consume less than the first decile in 2022. An alternative path can be obtained by using the full value of the price elasticities but limiting the change in household expenditure to 25% (point on the dotted line): this would imply a smaller reduction in total expenditure but also a smaller proportion of households with severe underconsumption. In conclusion, while it is important to consider the behavioural response of economic agents, in the current situation of very high price increases it is better to visualise a range of possible effects than to consider a point estimate that may be meaningless in terms of quantities consumed. [15]

5. Conclusions and policy implications

The increase in energy prices that has occurred in Italy since mid-2021 is also being transmitted to the other household consumption goods, creating a secondary effect on the inflation rate that may persist in the near future. The pass-through of price increases from essential goods - energy and food - to the other expenditure items in the household basket is associated with a loss of purchasing power in terms of real income and wealth. By using the PBO microsimulation model, we measure the relative heavier burden on households in the lower income brackets and the effectiveness of the policies adopted to offset these effects. The policy mix employed in Italy includes both price-reducing measures (fully untargeted) and income-related measures (partially targeted). Our simulations confirm that the targeted measures are by far more effective in reducing the regressive impact on household budgets,

[15] Regarding the impact of the inflation on Italian households' decisions, Colabella et al. (2023) analyse the importance of behavioural responses in assessing the impact on financial vulnerability, i.e. the ability of households to continue paying their mortgages. They find that taking elasticities into account may reduce financial vulnerability, but at the same time may increase energy poverty as households reduce their energy consumption to compensate for the increase in energy prices.

as highlighted by the economic literature and by other European experiences. Beyond the general regressive effect of energy price increases on household budget, the current situation raises concerns about the specific energy poverty issue. The combination of declining real income and rising energy costs, may push a non-negligible number of households from a state of vulnerability to that of outright energy poverty, with a severe self-limitation of energy consumption. To measure these changes, we use a modified Low Income High Cost indicator, which is also used in some official documents in Italy. By using the decomposition of this index in our simulations, we identify those households exposed to this risk, according to several demographic characteristics, including the age, the family type and the geographical location. These findings should help in targeting the policy measures in order to focus the financial resources and interventions to limit further increases of energy poverty and possibly provide relief to those already in need. These results do not include consumers' behavioral reactions and can be considered as a kind of pessimistic scenario, because the adapting ability of households is not taken into account. Indeed, families normally adapt their energy consumption in response to price changes, thus we estimate historical price elasticities of the energy demand by income quartiles. However, historically estimated elasticities cannot be applied in a period of huge price changes, such as the current one (Fig. 1), because elasticities are lower when prices have exceptional fluctuations. We therefore prefer to use elasticities with a sensitivity approach to highlight that the behavioural reaction may help to limit the increase in total expenditure but, at the same time, may push the energy use of all vulnerable households below the level of the bottom 10% of the overall distribution. Policies designed to address the current energy price crisis and the issue of energy poverty should target the vulnerable households, but also some specific group who, even with an average income level, are vulnerable due to specific sociodemographic characteristics or exposed to specific risks. Policies should ensure an adequate level of energy use because under consumption and self-rationing may affect wellbeing, health and growth opportunities. These findings are of utmost importance not only with a focus on the present, but also in view of the future energy transition towards a decarbonisation path and of the planned energy and environmental policy of the European Union, which implies, among other things, an increase in energy prices affecting vulnerable households, which need to be supported with appropriate policies to access the benefits of the transition.

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CRediT authorship contribution statement

Rossella Bardazzi: Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Francesca Gastaldi:** Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Francesca Iafrate:** Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Rosaria Vega Pansini:** Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Maria Grazia Pazienza:** Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing. **Corrado Pollastri:** Conceptualization, Data curation, Investigation, Methodology, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

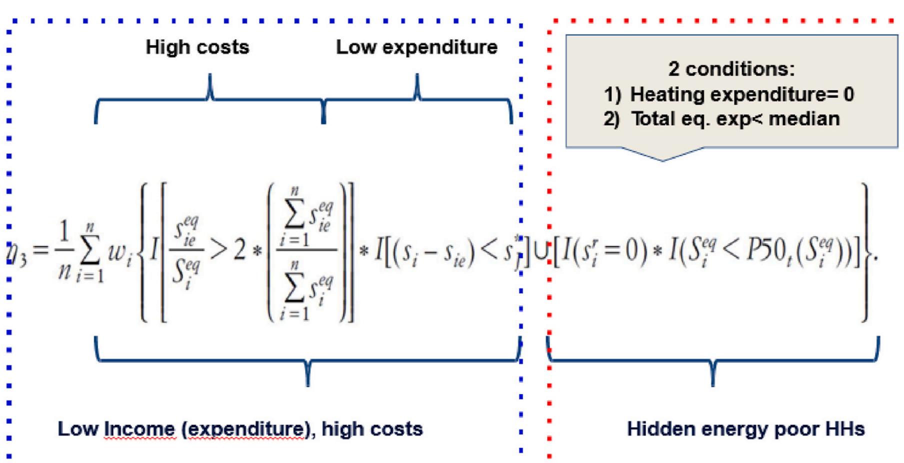
Data availability

The authors do not have permission to share data.

Appendix A

The Modified LIHC indicator

The M-LIHC indicator used in this paper has two main components. The first part is a low-income, high-cost indicator, and the second part is dedicated to detecting hidden energy poverty. To this end, this second part seeks to disentangle the low level of consumption linked to limited income resources from the low level of consumption due to preferences or very high energy efficiency. The UPB model reduces the share of zero heating consumption households by considering the zero expenditure due to the social bonus for low income families, which signal low consumption level without any monetary payment.



$$\eta_3 = \frac{1}{n}\sum_{i=1}^{n} w_i \left\{ I\left[\frac{s_{ie}^{eq}}{S_i^{eq}} > 2 * \left(\frac{\sum_{i=1}^{n} s_{ie}^{eq}}{\sum_{i=1}^{n} s_i^{eq}} \right) \right] * I[(s_i - s_{ie}) < s_i^*] \cup [I(s_i^r = 0) * I(S_i^{eq} < P50_t(S_i^{eq}))] \right\}.$$

* Faiella, I. and Lavecchia, L. (2015), "Energy Poverty in Italy" Politica economica, Società editrice il Mulino, issue 1, pages 27-76.

Appendix B

The main assumption behind the construction of a pseudo-panel is that units sharing the same time-invariant characteristics such as the birth year – and therefore allocated to the same cohort – behave similarly and can consequently be treated as a single unit (Deaton, 1985). We use data collected through the Italian Household Budget Survey (IHBS) as in the microsimulation model. To build the pseudo-panel we use annual observations of these independent cross sections for the period 1997–2019 and we match these data with information on energy prices and related tax components. First, extreme and unreliable values are cleaned from the dataset, then pseudo-household means of all the relevant variables according to the age of the householder and year are computed. For this specific exercise, we have used as additional characteristic the quartile of the total equivalent expenditure (as a proxy for income).

We estimate a simple dynamic demand model for electricity and gas. A Partial Adjustment Model (PAM) consider that individuals adjust their stock of appliances and make energy-efficiency investments. Therefore, it assumes that the change in the log of demand between two periods is only a fraction θ of the difference between the log demand at time t-1 and the log of the desired long-run demand E^*. If we define E as the quantity of energy demanded, P as its price and X as a set of variables including income and sociodemographic characteristics influencing demand, we obtain the following equation:

$$\log E_t = \theta\alpha_0 + \theta\alpha_1 \log P_t + \theta\alpha_2 \log X_t + (1-\theta)\log E_{t-1} + \varepsilon$$

which can be rewritten as

$$\log E_t = \beta_0 + \beta_1 \log P_t + \beta_2 \log X_t + \varphi \log E_{t-1} + \varepsilon \tag{B.1}$$

Equation (1) is the partial adjustment model where the short-run elasticities are obtained from the coefficients β, while the long-run elasticities (α) are given by dividing the estimated parameters by the estimate of θ. The latter is easily obtained as $(1-\varphi)$. The PAM is considered a first-generation type dynamic model as originally applied by Houthakker et al. (1974) to estimate gasoline and electricity demand in the US.

We apply this model to our pseudo-panel to estimate demand elasticities of cohort c in time t for each fuel j, electricity and natural gas. Therefore, our basic estimated equation is:

$$\log Fuel^j_{c,t} = \beta_0 + \beta_1 TE_{c,t} + \beta_2 \log P_t + \beta_3 \log X_{c,t} + \varphi \log Fuel^j_{c,t-1} + \varepsilon_{c,t} \tag{B.2}$$

where β_2 is the short-term price elasticity while the long-run elasticity is obtained as the estimated parameter divided by (1 - φ). In equation (2), the left-hand-side variable is either the logarithm of average consumption of electricity in kilowatt-hours (kWh) or the logarithm of natural gas in cubic metres.[16] TE is the total equivalent expenditure in real terms[17] as a proxy for income, which is not available in our data.[18] Some control variables are included in $X_{c,t}$: the educational level, the presence of children in the family and the generation of the householder have been found in the literature to be relevant for residential energy consumption and are among the few variables that are meaningful at the cohort level.

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[16] As the marginal prices of the utilities faced by each household are not available, we obtain the physical fuel use by dividing the total fuel expenditure at the household level by the appropriate annual block prices (including taxes and other cost components) of electricity and natural gas provided by Eurostat.

[17] The total equivalent expenditure is computed using the square-root equivalence scale.

[18] All monetary variables are deflated using the consumption deflator, base year 2015.

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