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ENERGY PRICES, INFLATION AND THE ECB'S MONETARY POLICY DURING THE 2021-22 ENERGY CRISIS

by Stefano Neri*

Abstract

Adverse shocks to energy prices exert a significant upward impact on euro area consumer prices and lead to a significant and protracted decline in economic activity. The shocks in 2021 and 2022 had a more pronounced and persistent impact on inflation than those in previous years, highlighting the existence of state-dependent effects. If the ECB had adopted a more restrictive monetary policy than implied by the actual policy rate and by the Eurosystem's balance sheet to offset the impact of the shocks on consumer prices, both real GDP and inflation would have been much lower in 2022. A response to inflation excluding energy prices could have reduced the negative impact on output.

JEL Classification: C32, E31, E37.

Keywords: energy price shocks, monetary policy, Bayesian VAR, local projections.

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1 Introduction

How do changes in energy prices affect consumer inflation, and more generally, the economy? This is a question that has been posed since the early 1970s, when the first oil shock led to a global rise in inflation to double-digit levels, and that has given rise to a substantial body of literature. The question has once again become a topic of interest among academics (e.g. Kilian and Zhou, 2023) and policymakers (e.g. Lane, 2024), as inflation reached double-digit levels in 2022 in many countries after the post-pandemic reopening of the economies and Russia's invasion of Ukraine.

This paper addresses the aforementioned question, focusing on the euro area, and provides a quantification of the contribution of energy price shocks to inflation and economic activity using a Bayesian Vector Autoregressive (BVAR) model. The price of the bundle of energy goods represents the cost paid by consumers for all energy products (e.g. gasoline, heating gas and electricity) and it is used to identify the shocks to energy prices. Energy goods are produced not only using oil but also natural gas and renewable resources; the relative importance of these various sources has changed substantially over time.

Two figures illustrate the important role of energy goods in the euro area, especially during the 2021-22 energy crisis. Firstly, the average share of energy goods in the Harmonised Index of Consumer Prices (HICP) over the period 2001-2023 is approximately 10 per cent. Secondly, when inflation peaked in October 2022, the direct contribution of the energy component was 4.5 percentage points out of 10.6 per cent (year-on-year). The total impact of the energy shocks on headline inflation reaches as much as 6 p.p. if indirect effects are taken into account (Corsello and Tagliabracci, 2023).

The study is centred on the euro area for three reasons. Firstly, the euro area was significantly affected by the energy price shocks due to its high dependence on imports of natural gas, particularly from Russia, and of liquefied gas. Secondly, the European Central Bank (ECB) was still pursuing an expansionary monetary policy, with the policy rate in negative territory, when the energy price shocks hit the euro area. Thirdly, the collective bargaining coverage rate in the euro area is high, which gives rise to significant risks of wage-price spirals.

The paper offers a significant contribution to the literature in three distinct ways. Firstly, the paper examines the responses of a small set of macroeconomic variables to energy price shocks using a BVAR in which the shocks are identified by means of sign and narrative restrictions. Secondly, the paper studies the transmission mechanism with local projections (LPs; Jordá, 2005) and the identified shocks, as in Neri (2023). Thirdly, the role of the ECB's monetary policy in the transmission of the shocks is assessed using structural counterfactuals.

The analysis yields three results. Firstly, shocks to energy prices lead to a gradual increase in consumer prices and to a significant and lasting decline in economic activity. In response to the increase in inflation, the ECB raises the policy rate. Secondly, the impact on consumer prices is larger when the estimation sample includes the energy crisis than when it is excluded. This result indicates that energy price shocks exert state-dependent effects induced by the magnitude of the shocks. Thirdly, had the ECB tightened the monetary policy stance more than implied by the actual path of the policy rate and the Eurosystem's balance sheet to counter the impact of the energy shocks on consumer prices, real GDP and inflation would have been much lower in 2022, all else being equal. The impact on real GDP and inflation would have been less pronounced had the ECB tightened monetary policy to offset the indirect impact of the shocks on ex-energy consumer prices (i.e. the price of the consumption bundle that excludes energy goods).

Related literature. – The macroeconomic effects of fluctuations in oil prices have been the subject of considerable research. This research has also focused on the factors behind such price movements, including reductions in oil production or shifts in global demand, and monetary policy.

Kilian (2008) shows that exogenous disruptions in oil production account for a relatively minor fraction of oil price fluctuations, including those observed in the 1970s. Barsky and Kilian (2004) conclude that shifts in global demand for oil are the primary drivers of oil price movements. Caldara et al. (2019) show that both supply and demand shocks are equally important in explaining oil prices and quantities. With regard to the role of monetary policy, Barsky and Kilian (2002, 2004) argue that shifts in monetary regimes were responsible for the oil price increases observed in the 1970s.

The study by Kilian and Zhou (2023) is the closest study to this paper. The authors quantify the impact of energy price shocks on the US and other major economies, including the euro area. The more persistent increase in inflation in the euro area and the UK is due to the stronger impact of the shocks on core consumer prices than in the US, Canada and Japan. The authors also show that energy price shocks in 2021 and 2022 exerted a more pronounced impact on inflation in the euro area than in the US.

In their study on the euro area, Eickmeier and Hofmann (2022) identify a combination of factors that contributed to the increase in inflation in 2021 and 2022. These included exceptionally strong demand and constrained supply. The latter played a more prominent role in the euro area than in the US. Casola et al. (2024) find that the post-pandemic inflation in the euro area was primarily attributable to shocks to the supply of natural gas. Bańbura et al. (2023) show that euro-area core inflation during the post-pandemic recovery was primarily due to supply-side shocks, including disruptions to global supply chains and fluctuations in gas and oil prices. Alessandri and Gazzani (2023) show that gas supply shocks account for a large share of the variance of euro-area core inflation. De Santis and Tornese (2023) find that the impact of energy supply shocks on consumer prices in the euro area is larger in periods of high-inflation, thereby supporting state-dependent models of firms' pricing.

Outline. – The remainder of this paper is structured as follows. Section 2 provides a description of the BVAR and the identification of the shocks. Section 3 presents the results of the impulse response analysis and the local projections, the historical decompositions and the structural counterfactuals. Section 4 assesses the robustness of the results. Section 5 concludes.

2 The macroeconomic effects of shocks to energy prices

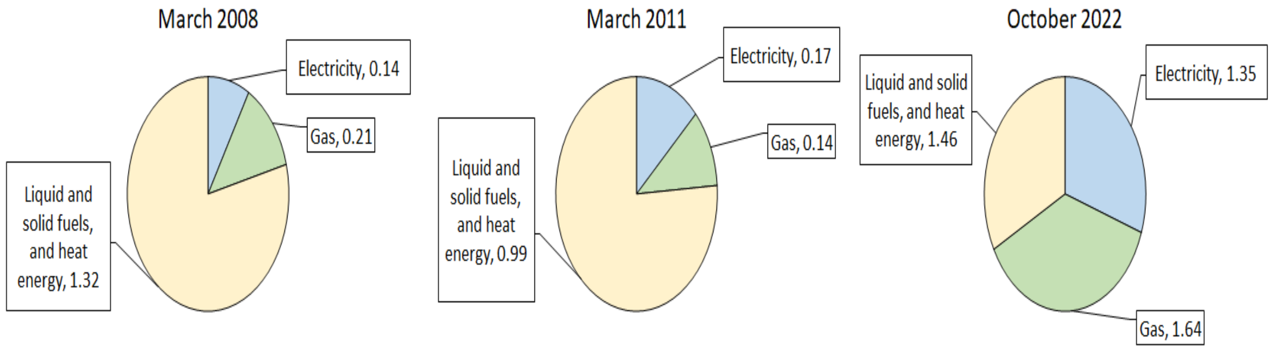
A BVAR is employed to simulate the posterior distribution of the macroeconomic effects of energy price shocks, their contribution to inflation and to carry out a counterfactual to assess the role of the ECB's monetary policy in the transmission of the shocks. For the latter exercise, the identification of shocks to both energy prices and monetary policy is necessary. Peersman (2022) identifies exogenous changes in international food commodity prices and quantifies their role in driving inflation in the euro area. I leave the joint identification of shocks to energy and food prices to future research.

2.1 Energy consumption and prices in the euro area

In this section, I describe the evolution of the consumption weights of the different energy goods between 2001 and 2023 and the role of their prices for inflation, with a particular focus on the energy crisis that began in the summer of 2021. I also compare their contribution to headline inflation during the episodes of rising inflation in 2007-08 and 2011-12.

In 2001, the weight of energy goods in the HICP basket was 9 per cent, with electricity and transport fuels jointly accounting for 7 p.p. In 2022, the weight of the energy goods was almost 11 per cent. Between 2001 and 2022, the share of the consumption of electricity and gas increased by, respectively, 1.1 and 0.8 p.p., reaching 3.1 and 2.2 per cent (Figures C1 and C2). The consumption shares of transport fuels and heating energy, instead, remained broadly stable over the same period.

Figure 1. Contributions to headline inflation of energy goods
(*percentage points*)



Source: ECB.

In October 2022, inflation reached 10.6 per cent, a significant increase from the low figures between 2014 and 2019 (1.0 per cent on average). The increase was to a large extent caused by the energy component, which alone contributed for 4.5 p.p.. However, within the energy goods, the drivers of the increase in 2021-22 were different from the two previous periods (Figure 1). In those episodes, energy inflation was driven by the prices of liquid and solid fuels, which are closely linked to oil prices. In 2021 and 2022, however, gas and electricity prices were the largest contributors to headline inflation. The ratio of the maximum contribution of liquid and solid fuels in October 2022 to that in July 2008 is 1.7, while the same ratio for electricity and gas is 9.6 and 5.5, respectively.

The above-mentioned facts suggest caution in using oil prices to identify the shocks that hit the euro area economy in 2021 and 2022. It is also important to take into account the shocks that have affected the European gas market since the summer of 2021, as the gas price was the marginal price for the production of electricity in these years.

Given the importance of the various components of the energy basket and their relevance for households, I use the time series of the energy component of the HICP to extract the energy price shocks. A similar approach is adopted by Kilian and Zhou (2023) and De Santis and Tornese (2023). The authors justify this choice by arguing that it is necessary to take into account the evolution of natural gas and electricity prices in order to quantify their impact on inflation.

2.2 Specification of the BVAR

The model consists of four variables, all in levels: the (log of the) energy component of the Harmonised Index of Consumer Prices (HICP), the (log of the) HICP excluding the energy component, (the log of) real GDP and the policy rate. These variables are selected to identify the minimum set of shocks that explain inflation developments. The consumer prices and real GDP series are seasonally adjusted. Appendix A provides details on the data. Kilian and Zhou (2023) estimate a 3-variable VAR that includes energy price inflation, and core and headline inflation using monthly data over the period 1997 and 2023. The model in this paper differs from that in Kilian and Zhou (2023) as it includes a measure of real activity and the policy rate. The former variable allows me to study the impact of energy price shocks on the real economy while the latter is used to conduct counterfactual simulations to shed light on the role of monetary policy in the transmission of the energy shocks.

To consider the effects of unconventional measures adopted by the ECB since the outbreak of the Global Financial Crisis, I use the EONIA rate up to 2008:Q3 and the shadow short-term rate computed by Krippner (2013, 2020) afterwards as policy rate. The justification for using a shadow rate after autumn 2008 and before the adoption of asset purchases in late 2014 is that the ECB introduced the fixed-rate full-allotment procedure in all refinancing operations in October 2008, which allowed banks to obtain unlimited liquidity. The resulting excess liquidity pushed the EONIA rate close to the Eurosystem's deposit facility rate . The shadow rate also captures the impact of asset purchases on the term structure of interest rates.

The estimation period goes from 1999:Q1 to 2023:Q4. The unprecedented increase in gas prices in 2021 and 2022 suggests that the transmission of shocks to energy prices may have been stronger than in the past. To account for these potentially non-linear effects, I compare the impulse responses of the BVAR estimated using the period ending in 2021:Q2 and that in 2023:Q4.

The model is specified with four lags, which is the minimum number required to yield serially uncorrelated residuals. To account for the unprecedented collapse of output after the outbreak of the Covid-19 pandemic, I include a dummy variable with a value of one in 2020:Q2. Section 4 shows the results obtained with employment replacing real GDP, which fell by much less during the pandemic.

I use Bayesian methods for inference. The prior for the coefficients is normal with a Minnesota structure (Litterman, 1986 and Doan et al., 1983). The mean prior is set to one for each variable's own first lag and zero for all the other coefficients; the prior for the covariance matrix of the error terms is diffuse. The overall tightness is set to 0.20, a standard value used in the literature. The variance of the prior coefficients for each variable's lags follows a harmonic decay ($l^{-0.5}$), while the tightness of the variance of each variable's prior lags relative to the other variables is set to 0.5. The priors for the constant is normal with a zero mean and a standard deviation of 1000.

2.3 Identification of the shocks

The identification of the structural shocks combines the sign restrictions proposed by Canova and De Nicolò (2002) and Uhlig (2005), which were later refined by Rubio-Ramírez et al. (2010), with the narrative restrictions proposed by Antolín-Díaz and Rubio-Ramírez (2018). The narrative restrictions complement the traditional sign restrictions by constraining the structural parameters so that the structural shocks or their contribution to selected variables agree with a narrative on specific events. The difference between the narrative restrictions and the method based on external instruments for the structural shocks (Mertens and Ravn, 2013) is that the former relies on a small number of key historical events, whereas the latter exploits the whole time series of the instruments.

I identify four shocks: aggregate demand and aggregate supply shocks, energy price shocks and monetary policy shocks. Identifying aggregate demand and supply shocks improves inference on the impact of the shock of interest, as shown by Canova and Paustian (2011). I identify the monetary policy shocks in order to conduct the counterfactual simulations aimed at evaluating the role of monetary policy in the transmission of the shocks to energy prices. Table 1 presents the sign restrictions, which I impose on impact following Canova and Paustian (2011). The table defines the matrix A_0 mapping the structural shocks ε_t onto the reduced-form residuals u_t, i.e. $u_t = A_0^{-1}\varepsilon_t$.

Table 1. Sign restrictions

Variable / shock	Aggregate demand	Aggregate supply	Energy prices	Monetary policy
Ex-energy consumer prices	+	+	+	-
Energy prices	+	-	+	?
Policy rate	+	?	?	+
Real GDP	+	-	-	-

Note: a ? means that the impact response is not restricted.

A positive aggregate demand shock increases both ex-energy and energy consumer prices, and economic activity. The ECB responds to the shock by raising the policy rate. A negative (adverse) aggregate supply shock raises consumer prices and lowers economic activity and the demand for energy, which in turn lowers its prices. A positive shock to energy prices raises both energy and ex-energy consumer prices and lowers activity.[1] In this sense, I assume these shocks affect the supply of energy goods. This is a reasonable choice given the focus of the paper on the 2021-22 high inflation. Finally, a positive (contractionary) monetary policy shock raises the policy rate and causes a decline in (ex-energy) consumer prices and output. The response of energy prices is unrestricted.

Table 2 presents the narrative restrictions, which I use to sharpen the identification of the shocks needed for the counterfactual scenarios.

Table 2. Narrative restrictions

Restriction	Narrative	Implementation
Narrative restriction 1 (NR1)	Cut in ECB's policy rate further into negative territory	Shock to monetary policy is negative (expansionary) in 2014:Q3
Narrative restriction 2 (NR2)	Sharp increase in energy prices following Russia's invasion of Ukraine	Absolute value of contribution of energy shock in 2022:Q1 larger than absolute value of the sum of those of other shocks

Firstly, the monetary policy shock is negative in 2014:Q3 (NR1), when the ECB unexpectedly reduced the rate on the deposit facility by 10 basis points to -0.20 per cent. When the ECB brought the rate on the deposit facility into negative territory in June 2014, the President of the ECB said in the press conference that "[…] *from all practical purposes, I would consider having reached the lower bound today*", without excluding the possibility of "*some little technical adjustments*". Prior to the September meeting, only 7 per cent of the analysts surveyed by Reuters the week before the meeting had anticipated a reduction in the deposit facility rate. Secondly, I assume that the contribution of shocks to energy prices to these prices in 2022:Q1, when Russia invaded Ukraine and gas and diesel prices increased sharply amidst fears of massive supply disruptions, is larger in absolute value than the contribution of all the other shocks (NR2).[2] De Santis and Tornese (2023) impose the restriction that the shock to energy prices is positive in March 2022.

[1] Kilian and Zhou (2023) allow core consumer prices to respond on impact to an energy price shock. The magnitude and timing of the pass-through from energy prices to non-energy prices is an empirical question. Therefore, I prefer to leave the response of the latter prices unrestricted.
[2] Russia was the largest exporter of natural gas and diesel to Europe in 2022. When Russia invaded Ukraine, fears of massive supply disruptions emerged rapidly causing a surge in their prices.

3 Results

Inference is based on 10,000 draws from the posterior distribution of the reduced form BVAR parameters and 5,000 draws from the unitary sphere for each draw from the posterior.[3] I discard the draws from the posterior distribution for which the maximum eigenvalue of the associated companion matrix is larger than one, which implies explosive dynamics. These dynamics could be problematic when simulating the model over a long period. A total of 15,000 draws is retained for inference. As for the importance sampling step of the Gibbs sampling, I use 15,000 draws to approximate the importance weights (Antolín-Díaz and Rubio-Ramírez, 2018).[4]

In computing the summary statistics from the posterior distribution, I follow Inoue and Kilian (2022). The authors derive the Bayes estimator of the vectors of impulse responses under a range of alternative loss functions and show that conventional impulse response estimators such as the posterior median or mean are not the Bayes estimator of the response vector. The authors also show that conventional pointwise quantile error bands ignore the mutual dependence of the responses and that they also tend to substantially underestimate the uncertainty. In this paper, I construct the Bayes estimate under the expected absolute loss.[5]

In the next sections, I first present the results of the impulse response analysis. Then, in order to extend the analysis to the main components of headline inflation and to a small set of macroeconomic variables, I use local projections.

3.1 The impact of energy price shocks: an impulse response analysis

Figure 2 reports the impulse responses to a shock to energy prices. The black solid lines denote the Bayes estimate. The red lines refer to all the impulse responses falling within the 0.68 joint credible set. The black dotted lines denote the median, the 0.16 and 0.84 percentiles.

A positive shock to energy prices raises them by 2 per cent on impact. The probability that the response is positive after two years is close to 1, suggesting that the shock is very persistent. The shock causes a gradual increase in ex-energy consumer prices, whose response remains positive with a probability larger than 0.80 until the end of the fourth year. Kilian and Zhou (2023) also find that core consumer prices increase gradually after a shock to energy prices. Real GDP falls persistently, reaching a minimum at the end of the second year. Throughout the whole horizon, the probability that the response is negative is larger than 0.80. In response to the persistent increase in ex-energy consumer prices, the ECB raises the policy rate, which reaches a peak after one year. After two years, the probability that the policy rate is above its baseline is 0.80.

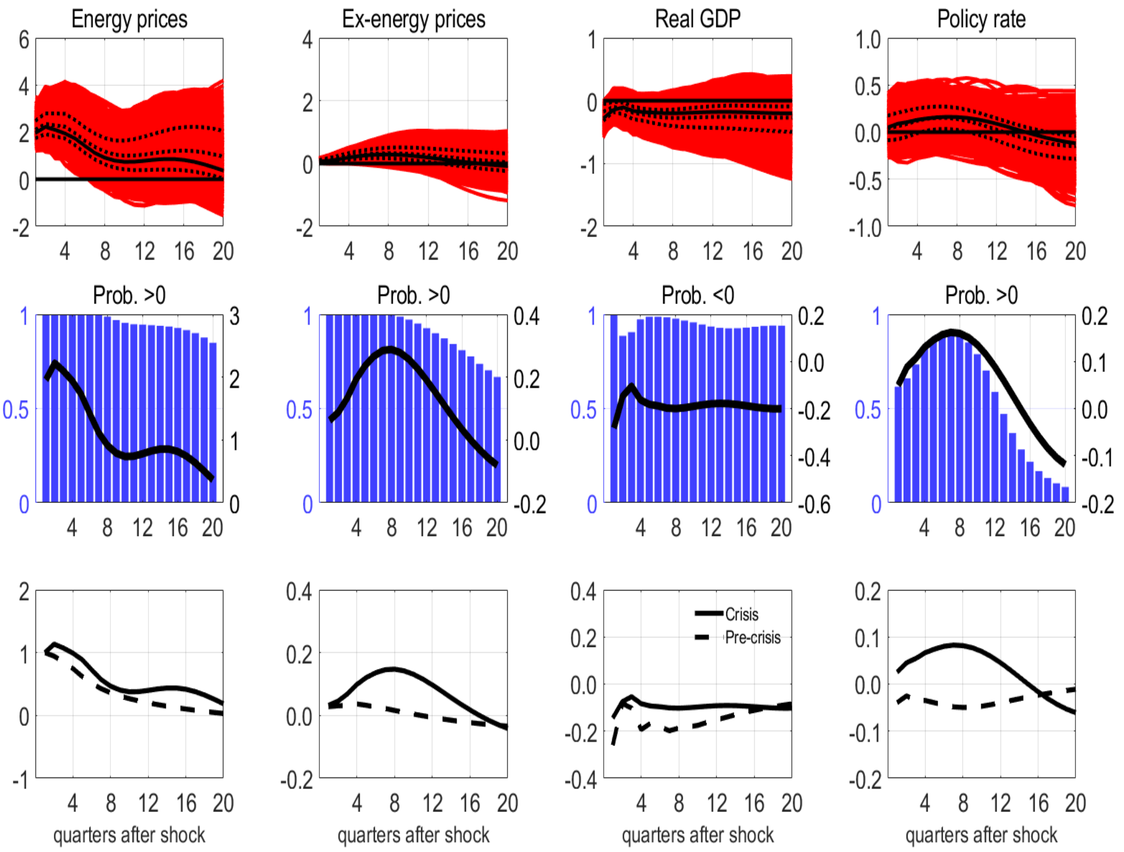
[3] The complete set of impulse responses and the historical decompositions is available upon request.

[4] Antolín-Díaz and Rubio-Ramírez (2018) show that narrative restrictions truncate the support of the likelihood function. This truncation implies a reweighting of the likelihood function, with weights that are inversely proportional to the probability of satisfying the narrative restrictions.

[5] Inoue and Kilian (2022) consider also quadratic and Dirac losses. The results in their paper are very similar.

Figure 2. Impulse response to a positive shock to energy prices

(*per cent and percentage points; deviation from unshocked paths*)



Notes: Top row: the black solid line denotes the Bayes estimate based on the expected absolute loss. The black dotted lines denote the median, the 0.16 and 0.84 percentiles. The red areas show all the impulse responses within the 0.68 joint credible set. Middle row: the black lines denote the Bayes estimate based on the expected absolute loss; the blue bars represent the posterior probabilities of the responses being either positive or negative (see title to each panel). Bottom row: Bayes estimate of the impulse responses for the crisis (solid lines) and the pre-crisis (dashed lines) sample periods.

The comparison between the red and the black dotted lines confirm the findings in Inoue and Kilian (2022): conventional pointwise quantile error bands are not a valid measure of the estimation uncertainty as they tend to substantially underestimate it.

As discussed in Section 2, I also consider two sample periods in order to uncover potential non-linearities and state-dependence related to the size of the energy price shocks, and therefore to the level of inflation. The first sample ends in 2021:Q2 (pre-crisis sample), just before the inflation surge, the second (crisis sample) ends in 2023:Q4. Theory and empirical evidence suggest that firms' price-setting may be state-dependent rather than time-dependent as in workhorse New Keynesian models. Cavallo et al. (2024) show, using granular datasets, that the frequency of price changes increased sharply after the unprecedented shocks in 2022. In a parsimonious New Keynesian model that is consistent with the empirical findings, firms adjust their prices more rapidly in response to large increases in marginal costs than to small increases: "*large shocks travel fast*".

A comparison of the impulse responses over the two periods (bottom row in Figure 1) reveals that a shock to energy prices, whose persistence is similar in the two estimation samples, has a more pronounced and sustained impact on ex-energy consumer prices in the sample that includes the energy crisis, during which larger shocks occurred and inflation reached much higher levels than before. This result is in line with the findings in De Santis and Tornese (2023).[6] While the impact on real GDP is comparable, the ECB increases the policy rate by more and keeps it at a higher level for longer in the crisis sample.

3.2 The broader impact of energy shocks: local projections

In this section, I investigate the transmission of energy price shocks using local projections, focusing on selected variables that are relevant to unveil the transmission of these shocks.

Following Ramey (2016), I estimate the equation:

$$z_{t+h} = \alpha_h^z + D_t^{Covid} + \sum_{l=1}^{L} \varphi_l^z \, z_{t-l} + \beta_h^z \hat{\epsilon}_t^{p^e} + \eta_{t+h} \qquad (1)$$

where $h = 1, \ldots, H$ is the horizon for the responses, z_{t+h} the variable of interest at horizon $t + h$, L is the number of lags of the same variable, $\hat{\epsilon}_t^{p^e}$ the shock to energy prices identified with the BVAR, D_t^{Covid} is the Covid dummy (Section 2.2) and η_{t+h} the error term. The number of lags L is set to 4. The equation is estimated for each accepted draw of the Gibbs sampling using the time series of the shocks to energy prices implied by the draw of the reduced-form parameters and the identification matrix A_0. I assume that all the coefficients of eq. (1) have a flat prior. The collection of the parameters β_h^z provides the response of variable z to the shock. I consider the following variables: the main component of the HICP (energy, non-energy industrial goods, services, processed and unprocessed food), (year-on-year) negotiated wages, the long-term inflation (year-on-year) expectations from the ECB Survey of Professional Forecasters, employment and real consumption. Consistent with the majority of the applied works and in line with the results in Sims, Stock and Watson (1990), all but negotiated wages enter eq. (1) in level. Moreover, within a Bayesian framework, the presence of unit roots in some variables is not a concern for the inference (Sims and Uhlig, 1991).

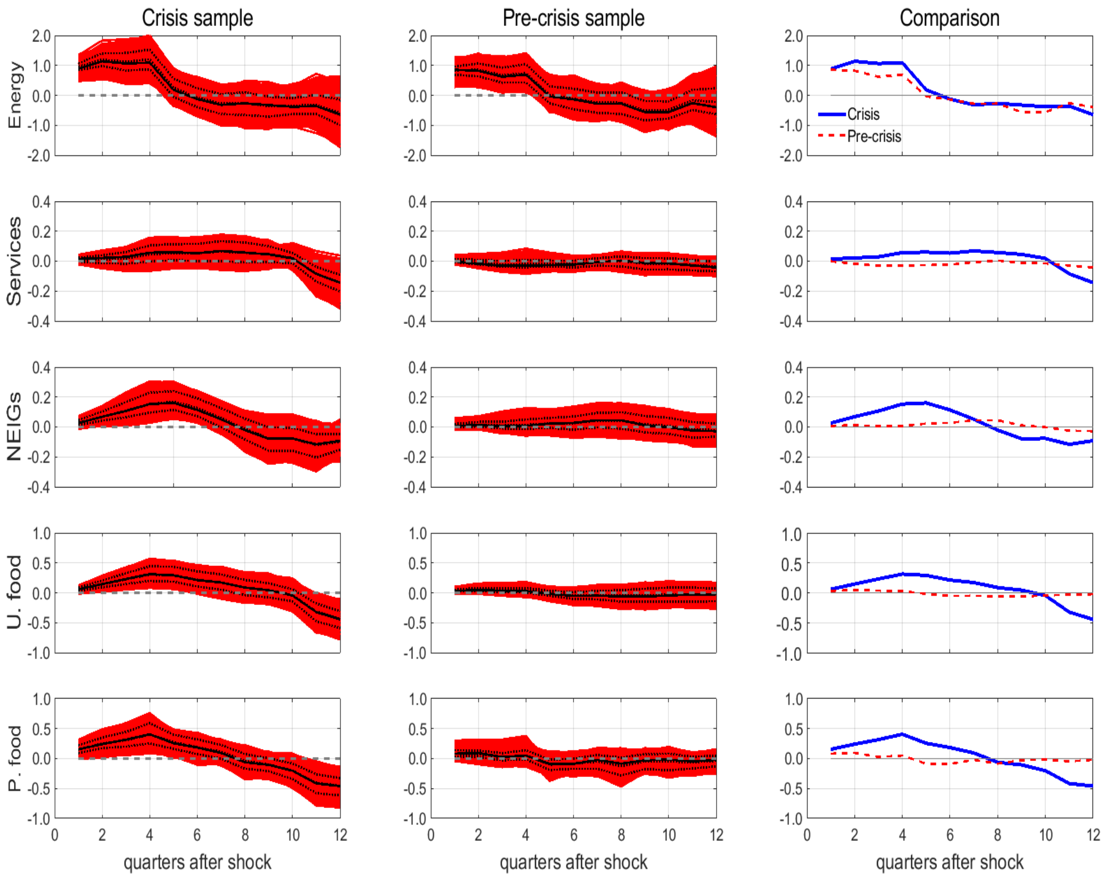
The comparison between the two estimation periods suggests that the shocks to energy prices that occurred in 2021 and 2022 had a larger impact on some items of the consumption basket than in the pre-crisis period. This finding provides additional evidence of state-dependence in firms' pricing

[6] A complementary explanation to the role of the size of the shocks could be that composition of the energy shocks has changed in the most recent years. While before 2021, movements in energy prices were mainly due to oil prices, in the most recent years natural gas prices were the main driver of the surge in energy prices (Alessandri and Gazzani, 2023).

(Cavallo et al., 2024) and highlights the importance of non-linear empirical methods (De Santis and Tornese, 2023).

Figure 3. Impulse responses of the main inflation components

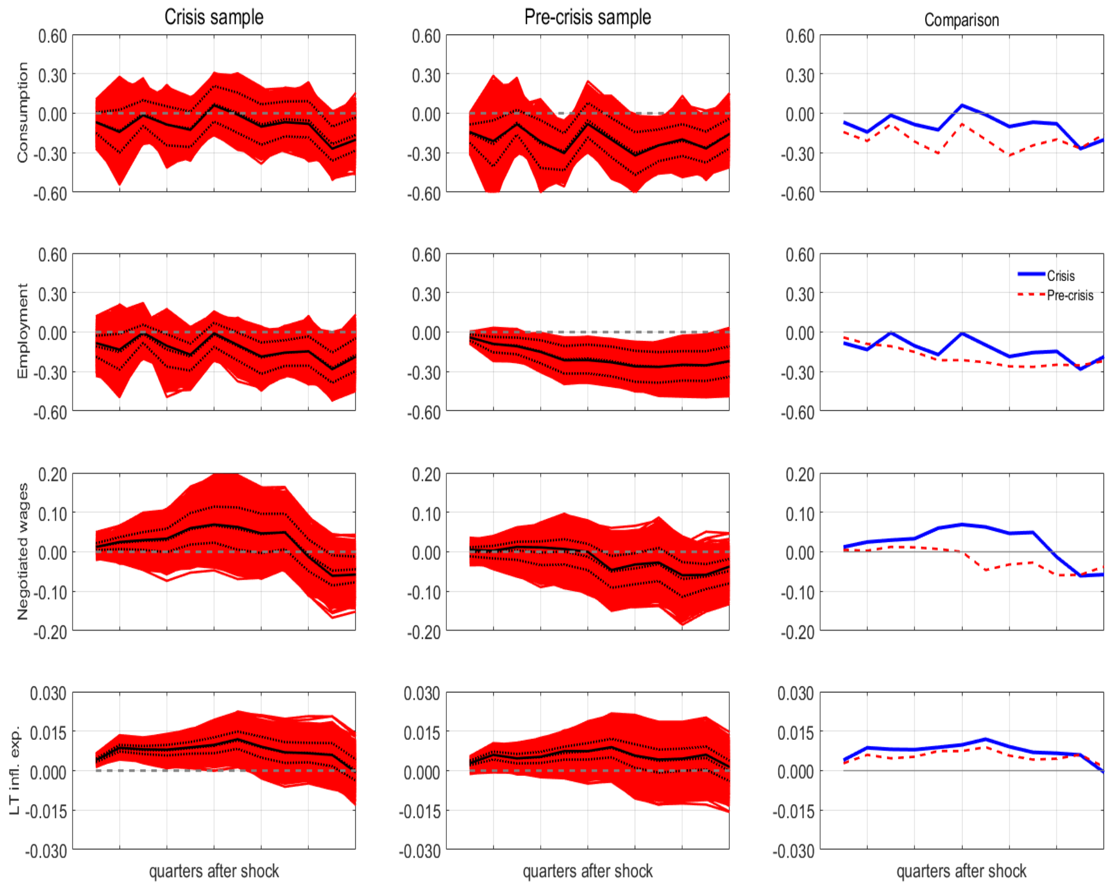
(*percentage points*)



Notes: left column: impulse responses based on the crisis sample; mid column: impulse responses based on the pre-crisis sample. The black dotted lines denote the median, the 0.16 and the 0.84 percentiles. Right column: comparison of the Bayes estimates in the two sample periods. The red lines the denote the responses within the 0.68 joint credible set.

The response of real consumption is somewhat smaller in the crisis sample, while that of employment is not different (Figure 4). A possible explanation is that after the energy crisis, the adoption of measures to support households' consumption and of job-retention schemes by the governments of euro-area countries may have reduced the impact of the large shocks to energy prices in 2021 and 2022. The response of negotiated wages in the crisis sample is somewhat larger than in the pre-crisis one, suggesting that workers obtained larger salary increases due to their loss of purchasing power after the unprecedented inflationary shocks.

Figure 4. Responses of selected macroeconomic variables
(*percentage points*)



Note: see Figure 3.

Finally, the response of long-term inflation expectations is similar across the two estimation periods. The clarification of the ECB's inflation target in July 2021 may have contributed to containing the upward pressure of energy price shocks on long-term inflation expectations.[7]

3.3 How important were energy price shocks during the energy crisis?

This section presents the historical decomposition of (y-on-y) energy inflation, ex-energy and headline inflation focusing on 2021 and 2022. I group together aggregate demand, aggregate supply and monetary policy shocks (green bars) and leave alone those to energy prices (red bars) to better highlight their role. The historical decomposition of headline inflation is computed as the weighted sum of the decompositions of ex-energy (weight = 0.89) and energy inflation (weight = 0.11). The contributions of the shocks to all yearly inflation rates are computed within the Gibbs sampling as

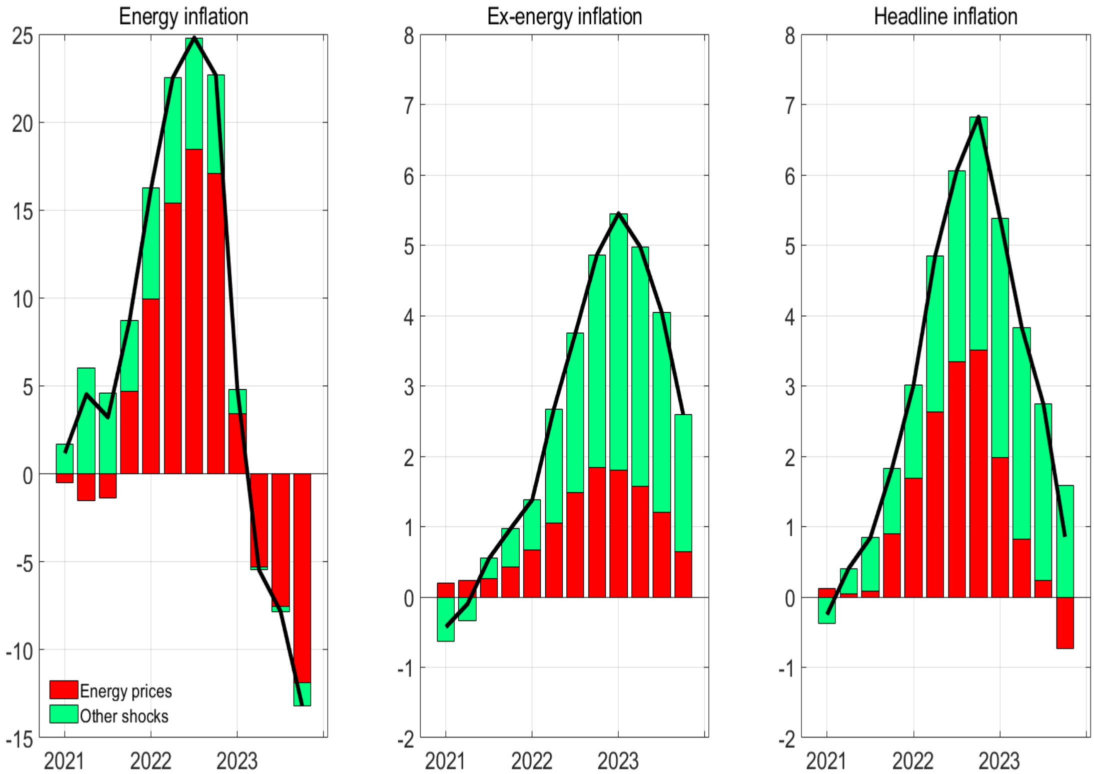
[7] Boeck and Zörner (2024) use a structural counterfactual with a VAR to assess the role of second round effects of shocks to gas prices through inflation expectations.

four-quarter differences of the contributions to the corresponding price series. Figures 5 shows the Bayes estimates.

Since the third quarter of 2021, positive shocks to energy prices have pushed these prices to unprecedented levels. In the first quarter of 2022, when Russia invaded Ukraine, these shocks account for 14 p.p. of a total deviation from the baseline of 16 p.p. (Figure 5, left panel). The maximum contribution is reached in the third quarter of 2022, amounting to 20 out p.p. of a total deviation of 25. Within the other shocks, those to aggregate demand have exerted upward pressure on energy inflation in both 2022 and 2023.

Figure 5. Historical decomposition: energy, ex-energy and headline inflation

(*percentage points; deviations from the baseline*)



Note: the bar denotes the Bayes estimate of the contribution of the identified shocks to the deviations of the inflation rates from their respective baseline levels. The contributions are computed within the Gibbs sampling as the year-on-year changes in the contributions to the corresponding price series.

The maximum contribution of energy shocks to ex-energy inflation is reached in the first quarter of 2023, when they account for 1.4 p.p. out of a total deviation of 6 (Figure 5, mid panel), thereby confirming that energy price shocks exert significant indirect effects on the prices of food, non-energy industrial goods and services. Monetary policy and aggregate demand shocks explain the largest part of the deviation of ex-energy inflation from the baseline: their maximum contribution is around 2.0 p.p. each between late 2022 and early 2023. The reopening after the most acute phase of the Covid-

19 pandemic and the ECB's expansionary monetary policy during this period contributed to raising ex-energy inflation. The contribution of aggregate supply shocks is, overall, nil.

The contribution of energy shocks to headline inflation increases gradually throughout 2021 and 2022, reaching a maximum of 3 p.p. out of a deviation of 7 in the last quarter of 2022 (Figure 5, right panel). This result is in line with that in Kilian and Zhou (2023), who find that shocks to energy prices explain a significant part of the increase in euro-area headline inflation in 2022. Aggregate demand and monetary policy shocks together account for 1.7 p.p., on average, in 2021 and 2022.

Turning to real GDP growth, the impact of adverse shocks to energy prices reached -1.7 p.p. in in the last quarter of 2022 (Figure B1 in Appendix B). These shocks exert a large and persistent downward pressure on economic activity between the beginning of 2022 and the end of the sample. The strong growth after the pandemic is explained by shocks to aggregate demand and monetary policy, which together account for 1.5 p.p., on average, between mid-2022 and mid-2023. The deviations of the policy rate (Figure B1) from the baseline are primarily due to shocks to energy prices and to aggregate demand, which together account for almost 6 p.p., on average, between the last quarter of 2022 and the third quarter of 2023. Monetary policy shocks exert upward pressure on the policy rate from the second quarter of 2023 onwards. The ECB responded to the adverse shocks to energy prices and to positive aggregate demand shocks by tightening the monetary policy stance.

To sum up, adverse shocks to energy prices were major drivers of inflation and economic activity in 2021 and 2022 in the euro area. In response to these shocks, the ECB gradually reduced the degree of monetary accommodation and brought the monetary policy stance into restrictive territory in the course of 2023.

3.4 The role of the ECB's monetary policy: a counterfactual analysis

In this section, I employ a structural counterfactual to assess the role of the ECB's monetary policy on the transmission of shocks to energy prices during the 2021-22 period of high inflation. The counterfactual enables an evaluation of how inflation and real GDP growth would have evolved in the absence of a restrictive monetary policy aimed at offsetting the impact of energy shocks on headline inflation. Theory suggests that a tightening of monetary policy in response to a shock to the price of energy would lower output and counter the increase in inflation, *ceteris paribus*. The contribution of the counterfactual is to quantify the effectiveness of monetary policy in countering the effects of the shocks on inflation and the adverse impact on economic activity.

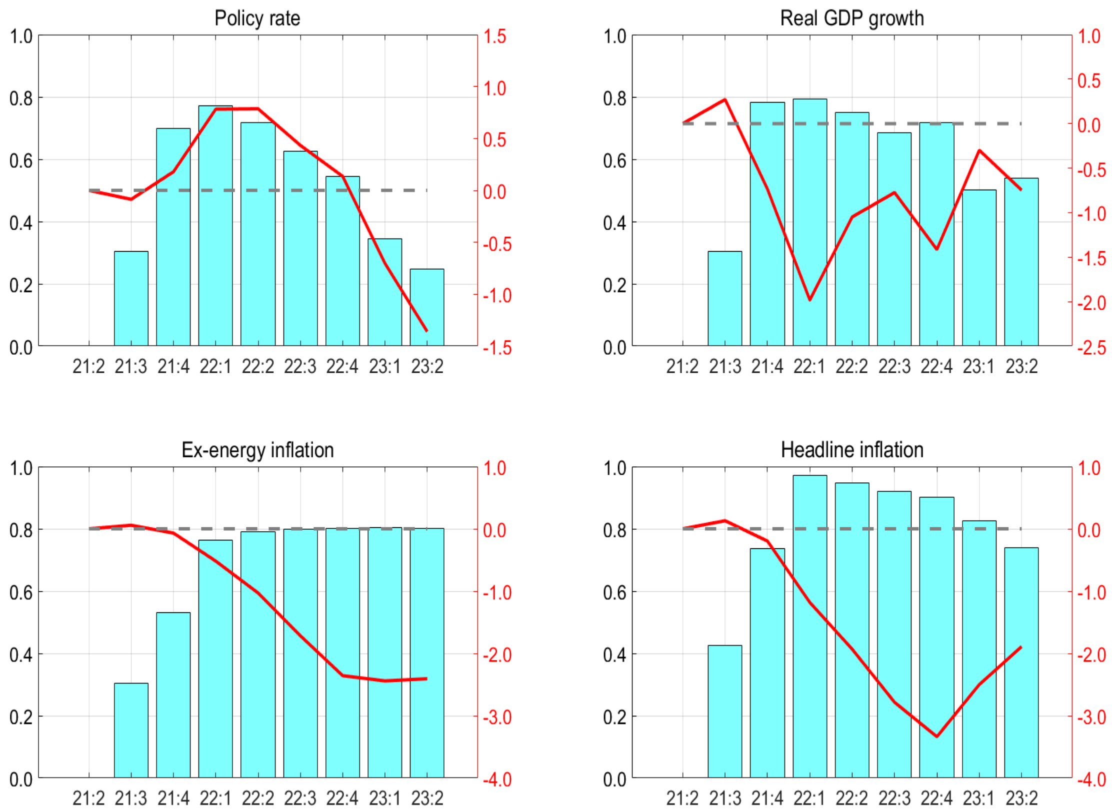
The simulation is computed as follows. Conditional on an accepted draw from the posterior distribution of the parameters of the BVAR, I calibrate the monetary policy shocks in order to offset the impact of the energy shocks on headline inflation in each quarter between 2021:3 and 2023:2.[8] In

[8] The monetary policy shock, ε_t^{mp}, that offsets impact of the shock to energy prices, ε_t^{en}, on headline consumer prices is $\varepsilon_t^{mp} = -\left[\frac{\omega_{NE}A_0(1,3)+\omega_E A_0(2,3)}{\omega_{NE}A_0(1,4)+\omega_E A_0(2,4)}\right]\varepsilon_t^{en}$, where $A_0(1,3)$ is the impact of the shock to energy prices on the ex-energy consumer

the baseline simulation, the BVAR is fed only with identified shocks to energy prices. Figure 6 shows the Bayes estimate of the differences between the baseline and the counterfactual simulations together with the posterior probabilities that in each quarter these differences are either positive or negative.

Figure 6. Structural counterfactual simulations

(*percentage points*)



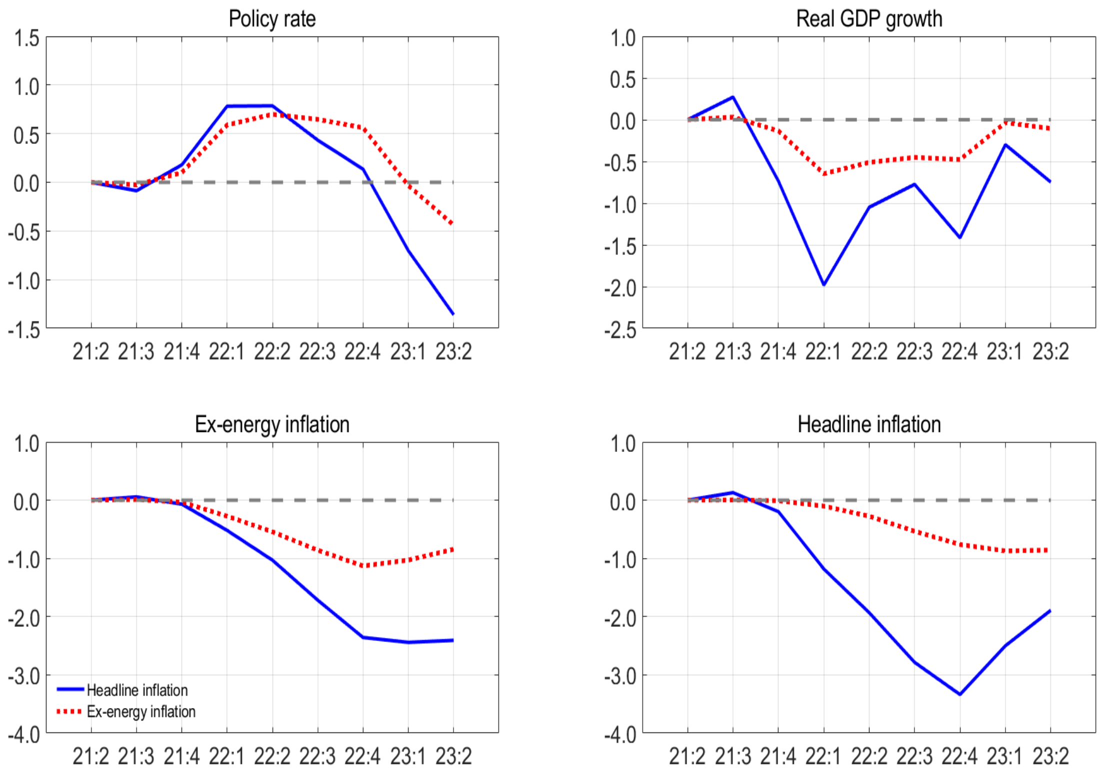
Note: the red solid line denotes the Bayes estimate based on the expected absolute loss; the grey dashed line is the zero line. The light blue bars measure the probability that in each quarter the variable is either negative (real GDP growth, ex-energy and headline inflation) or positive (policy rate).

The posterior probability that the path of ex-energy in the counterfactual is below that baseline reaches 0.8 in 2022:Q1 and then remains at that level. In the case of headline inflation, the posterior probability is above 0.8 between 2022:Q1 and 2023:Q1. Real GDP growth is negative between 2021:Q4 and the end of the simulation. Finally, the counterfactual policy rate is above the baseline with a probability of 0.7, on average, between 2021:Q4 and 2022:Q3.

prices, $A_0(3,4)$ is the impact on energy prices, $A_0(1,4)$ the impact of the monetary policy shock on ex-energy prices and $A_0(2,4)$ its impact on energy prices. The parameters ω_{NE} and ω_E measure, respectively, the weights of non-energy goods and energy goods in the HICP (see Section 3.2).

Figure 7. Structural counterfactual: targeting headline vs. ex-energy inflation

(*percentage points*)



Note: the blue solid lines denote the Bayes estimate of the counterfactual in which the ECB adjusts the policy rate to offset the impact of the shocks to energy prices on headline inflation; the red dotted lines denote the Bayes estimate of the counterfactual in which the ECB adjusts the policy rate to offset the impact of the energy shocks on ex-energy inflation. The grey dashed line is the zero line.

It is interesting to compare the results of the counterfactual with those obtained assuming that the monetary policy shocks offset the direct impact of the energy shocks on ex-energy rather than on headline inflation.[9] In this case, the ECB looks through the impact of energy prices on headline inflation and responds only to the extent that the shocks give rise to indirect effects.

Figure 7 compares the results of the two counterfactuals.[10] If the ECB tightens monetary policy to offset the impact of the energy price shocks on headline inflation, real GDP growth and inflation fall by more compared with the case in which the central bank aims at offsetting the indirect impact on ex-energy inflation. In the latter case, the impact on real GDP growth would have been lower by 0.8 p.p., on average, in 2022; that on headline and ex-energy inflation by, respectively, 1.1 and 0.6.

[9] In this case, the monetary policy shock is $\varepsilon_t^{mp} = -\frac{A_0(1,3)}{A_0(1,4)}\varepsilon_t^{en}$.

[10] The magnitude of the shocks in the first counterfactual ("Headline inflation" in Figure 7) is larger than that of past shocks (Figure B2). In accordance with the terminology in Leeper and Zha (2003), the policy interventions are not regarded as "modest", indicating that they give rise to expectation-formation effects and that they are not in line with the past behaviour of the ECB. This is not the case in the second counterfactual ("Ex-energy inflation" in Figure 7), as the corresponding policy interventions are "modest" (within ±2) and, therefore, in line with the past behaviour of the ECB.

The ECB raises the policy rate by less when it responds to ex-energy inflation compared with the case in which it aims at stabilizing headline inflation. However, the ECB starts reducing the policy rate later in the former case, implementing a "higher-for-longer" monetary restriction. Overall, in the counterfactual in which monetary policy aims at stabilizing ex-energy inflation, output and headline inflation fall by less, and the policy rate is raised by less compared with the other counterfactual.

4 Robustness analysis

The robustness of the findings is tested along two dimensions: the specification of the BVAR and the narrative restrictions for identifying the energy price and monetary policy shocks.[11] The first exercise aims to assess whether the use of employment data, which exhibited a much smaller decline than real GDP in 2020:Q2 (-3 per cent, compared with -11) due to the extensive implementation of job retention schemes, influences the results of the paper. The second robustness check assesses the extent to which the findings depend on the use of the narrative restrictions. It is important to recall that these restrictions enhance the identification of the shocks to monetary policy and to energy prices, which are necessary for conducting the counterfactual analysis.

Replacing real GDP with total employment yields qualitatively similar results (Figures B4 to B6). Removing the narrative restrictions on energy price shocks and monetary policy also do not affect the findings (Figures B7 to B9). With regard to the contribution of energy price shocks to headline inflation, this is somewhat lower than in the baseline case (Figures 5 and B8).

5 Concluding remarks

Adverse shocks to energy prices exert a significant upward impact on euro area consumer prices and lead to a significant and protracted decline in economic activity. The effects on prices are state-dependent: they are large when large shocks, as those that hit the euro area in 2021 and 2022, occur. Energy price shocks account for a large part of the increase in headline inflation and the decline in real GDP growth between 2021 and 2023.

The ECB's monetary policy played a significant role in the transmission of the energy price shocks. If the central bank had adopted a more restrictive monetary policy than implied by the actual policy rate and the Eurosystem's balance sheet to offset the impact of the shocks on consumer prices, both real GDP and inflation would have been much lower in 2022. A response to ex-energy consumer prices would have resulted in a smaller cost in terms of output.

Further research could estimate a medium-scale New Keynesian model, in which long-term inflation expectations can become unanchored (Carvalho et al., 2023 and Gáti, 2023), and derive the optimal monetary policy when the economy is hit by energy price shocks and nominal wages are partly indexed to inflation.

[11] In the previous version of the paper, the BVAR included also the long-term inflation expectations from the ECB Survey of Professional Forecasters. The results are very similar to those presented in this version.

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Appendix A – Data

HICP – All-items excluding energy, working day and seasonally adjusted

Source: ECB Statistical Data Warehouse

Series key: ICP.M.U2.Y.XE0000.3.INX

HICP – Energy, neither seasonally nor working day adjusted

Source: ECB Statistical Data Warehouse

Series key: ICP.M.U2.N.NRGY00.4.INX

Gross domestic product at market prices, calendar and seasonally adjusted data

Source: ECB Statistical Data Warehouse

Series key: MNA.Q.Y.I8.W2.S1.S1.B.B1GQ._Z._Z._Z.EUR.LR.N

Policy rate: combination of the Euro OverNight Index Average, EONIA, rate and the shadow rate computed by Krippner (2013). See: https://www.ljkmfa.com/visitors/

Source: ECB Statistical Data Warehouse

Series key for EONIA: FM.Q.U2.EUR.4F.MM.EONIA.HSTA

HICP – Industrial goods excluding energy, working day and seasonally adjusted

Source: ECB Statistical Data Warehouse

Series key: ICP.M.U2.Y.IGXE00.3.INX

HICP – Services, working day and seasonally adjusted

Source: ECB Statistical Data Warehouse

Series key: ICP.M.U2.Y.SERV00.3.INX

HICP – Processed food incl. alcohol and tobacco, working day and seasonally adjusted

Source: ECB Statistical Data Warehouse

Series key: ICP.M.U2.Y.FOODPR.3.INX

HICP – Unprocessed food, working day and seasonally adjusted

Source: ECB Statistical Data Warehouse

Series key: ICP.M.U2.Y.FOODUN.3.INX

Private final consumption, calendar and seasonally adjusted data

Source: ECB Statistical Data Warehouse

Series key: MNA.Q.Y.I9.W0.S1M.S1.D.P31._Z._Z._T.EUR.LR.N

Employment (in thousands of persons)

Source: ECB Statistical Data Warehouse

Series key: MNA.Q.Y.I9.W2.S1.S1._Z.EMP._Z._T._Z.PS._Z.N

Negotiated wages (year-on-year percentage changes)

Source: ECB Statistical Data Warehouse

Series key: MNA.Q.Y.I9.W2.S1.S1._Z.EMP._Z._T._Z.PS._Z.N

Long-term inflation expectations (2.5 per cent trimmed mean)

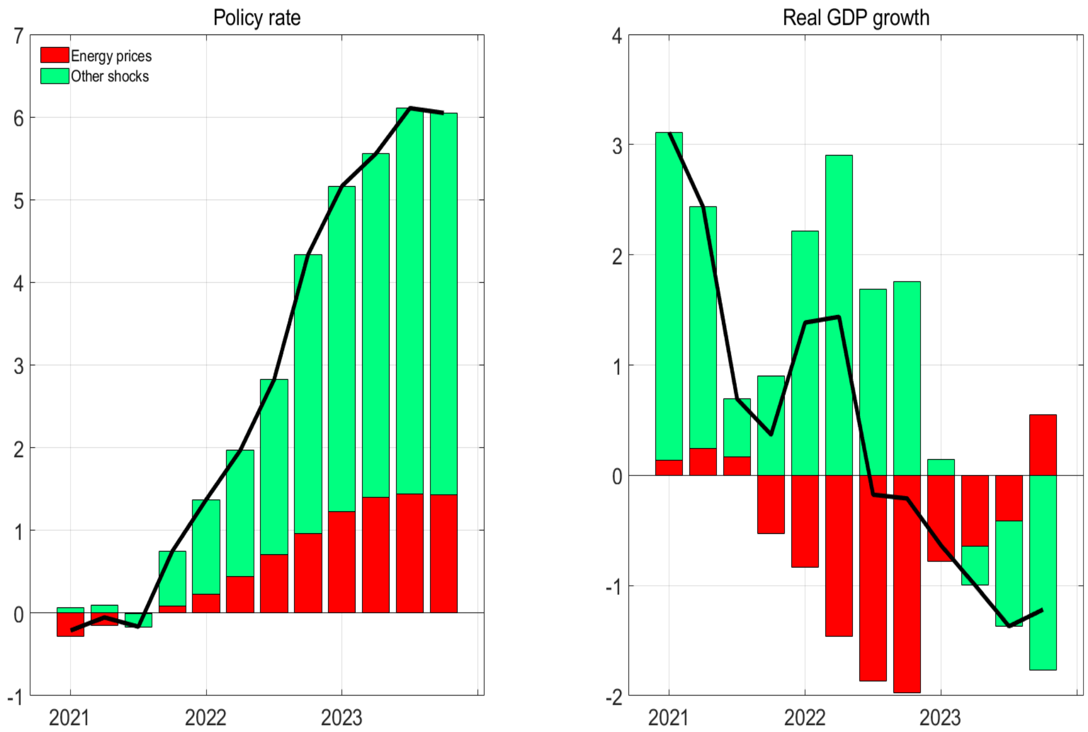
Source: ECB Statistical Data Warehouse

Series key: SPF.Q.U2.HICP.POINT.LT.Q.AVG

Appendix B – Additional results and robustness checks

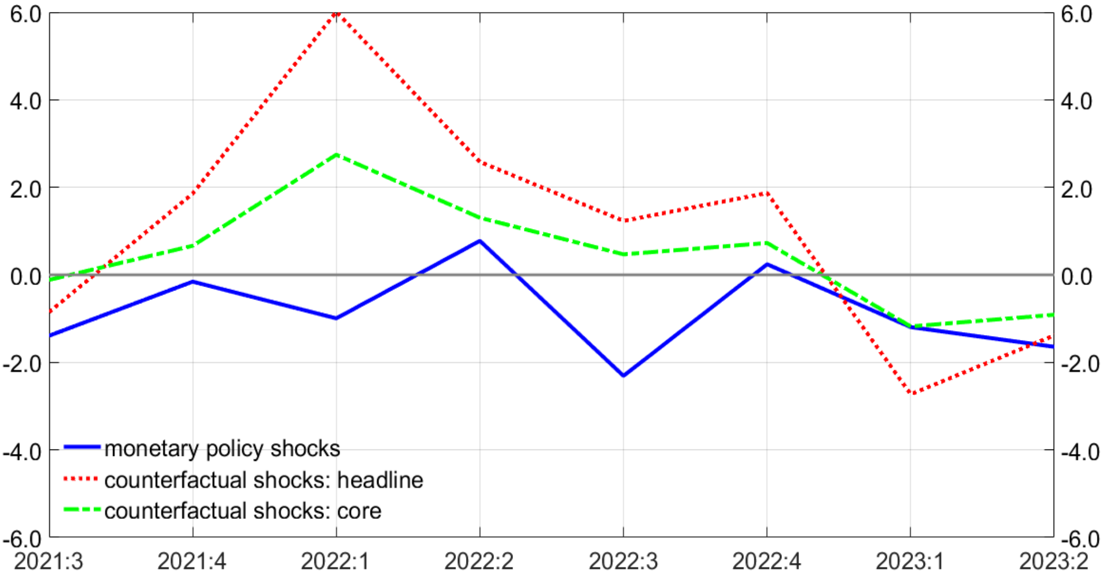
Figure B1. Historical decomposition: real GDP growth and policy rate

(*percentage points; deviations from the baseline*)



Note: the bar denotes the Bayes estimate of the contribution of the identified shocks to the deviations of the policy rate and real GDP growth from their respective baseline levels. The contributions to GDP growth are computed within the Gibbs sampling as the year-on-year changes in the contributions to the corresponding level of real GDP.

Figure B2. Monetary policy and counterfactual shocks

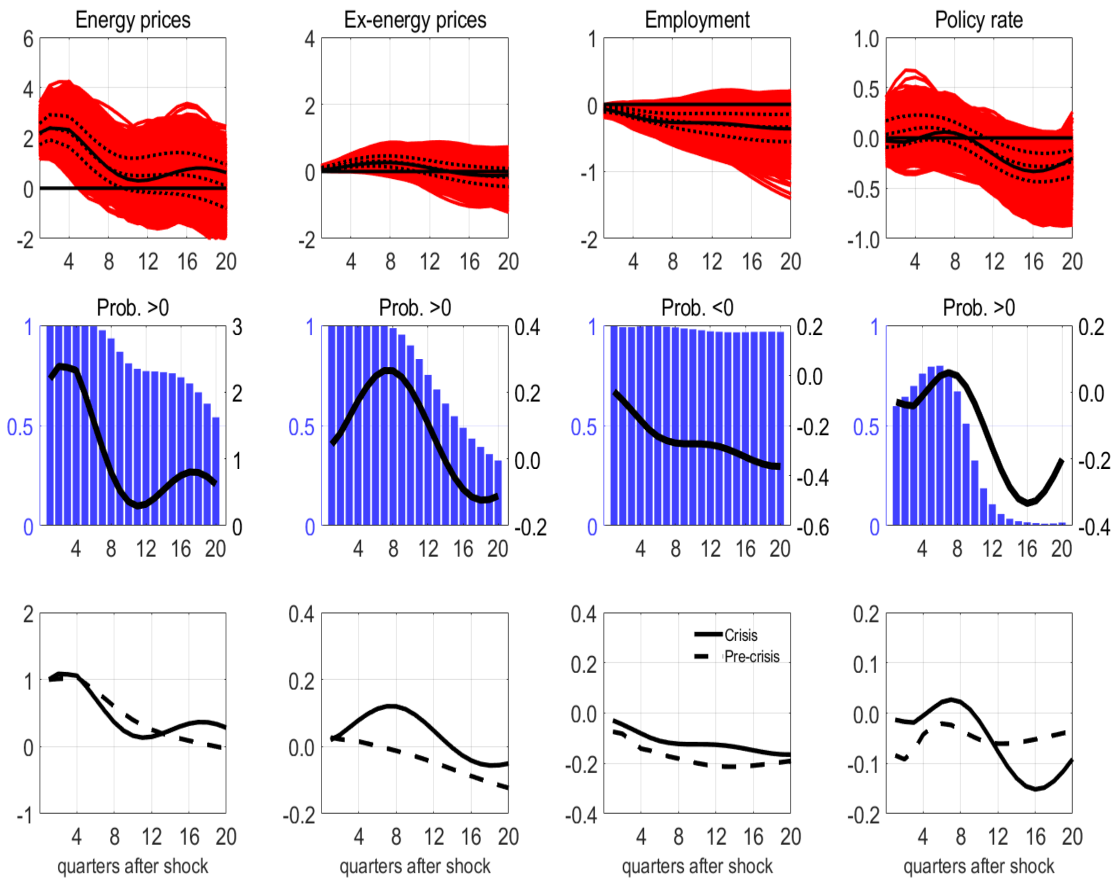


Note: Bayes estimates of the monetary policy shocks (blue solid line) and the counterfactual shocks that offset the impact of the shocks to energy prices on headline inflation (red dotted line) and ex-energy inflation (dashed-dotted green line).

BVAR with employment replacing real GDP

Figure B4. Impulse response to a positive shock to energy prices

(*per cent and percentage points; deviation from unshocked path*)



Notes: Top row: the black solid line denotes the Bayes estimate based on the expected absolute loss. The black dotted lines denote the median, the 0.16 and 0.84 percentiles. The red areas show all the impulse responses within the 0.68 joint credible set. Middle row: the black lines denote the Bayes estimate based on the expected absolute loss; the blue bars represent the posterior probabilities of the responses being either positive or negative (see title to each panel). Bottom row: Bayes estimate of the impulse responses for the crisis (solid lines) and the pre-crisis (dashed lines) sample periods.

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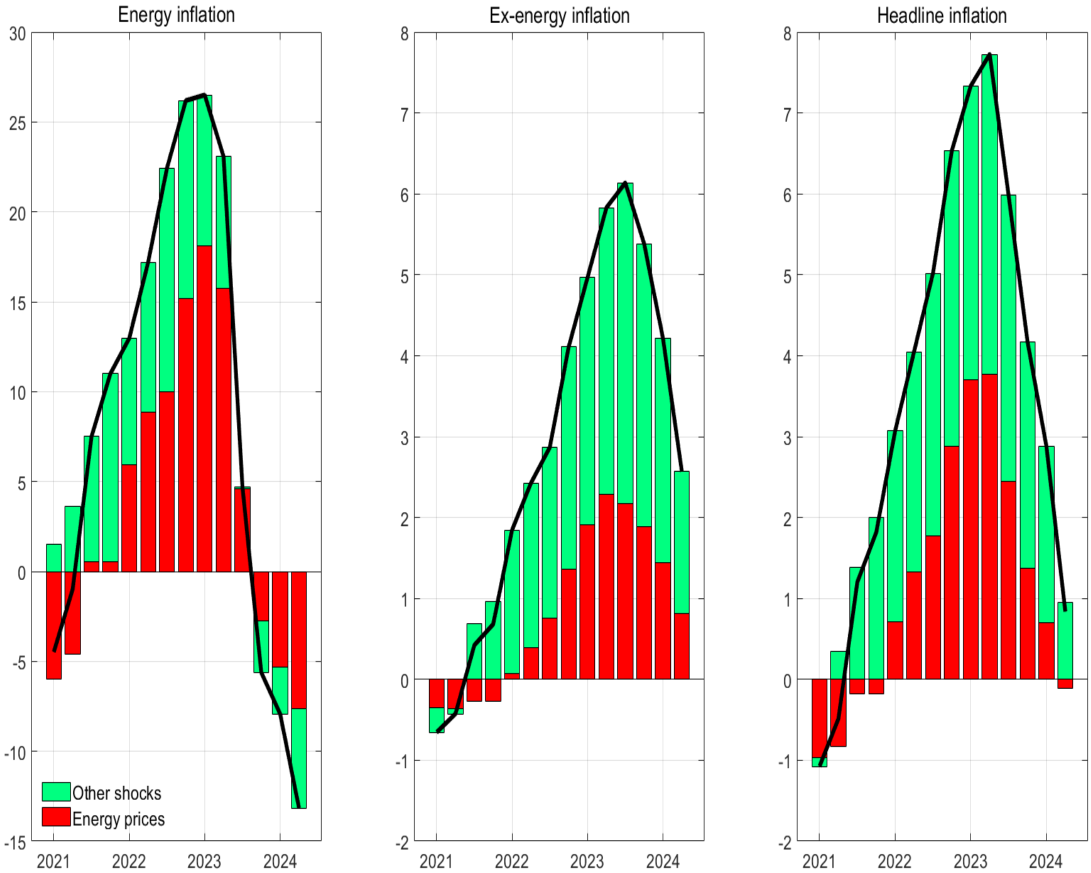
Figure B5. Historical decomposition: energy and ex-energy and headline inflation

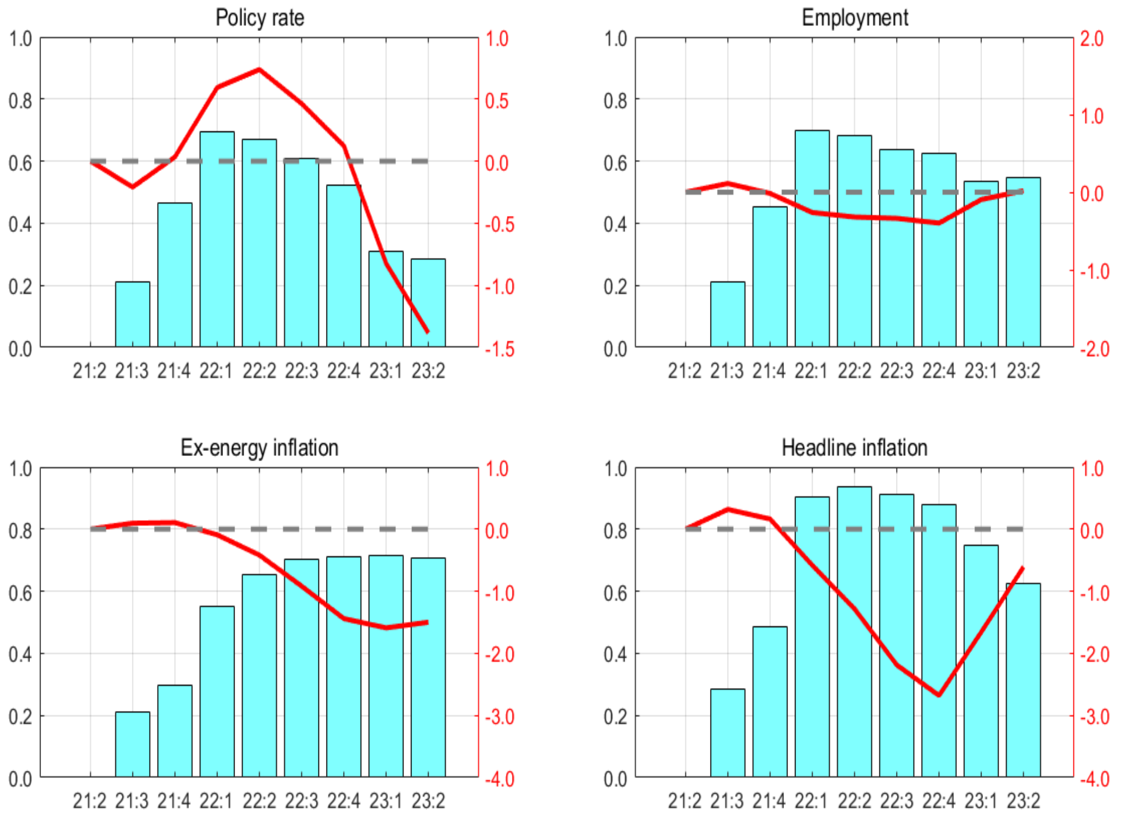
(*percentage points; deviations from the baseline*)



Note: the bar denotes the Bayes estimate of the contribution of the identified shocks to the deviations of the inflation rates from their respective baseline levels. The contributions are computed within the Gibbs sampling as the year-on-year changes in the contributions to the corresponding consumer price series.

Figure B6. Structural counterfactual simulations

(*percentage points*)

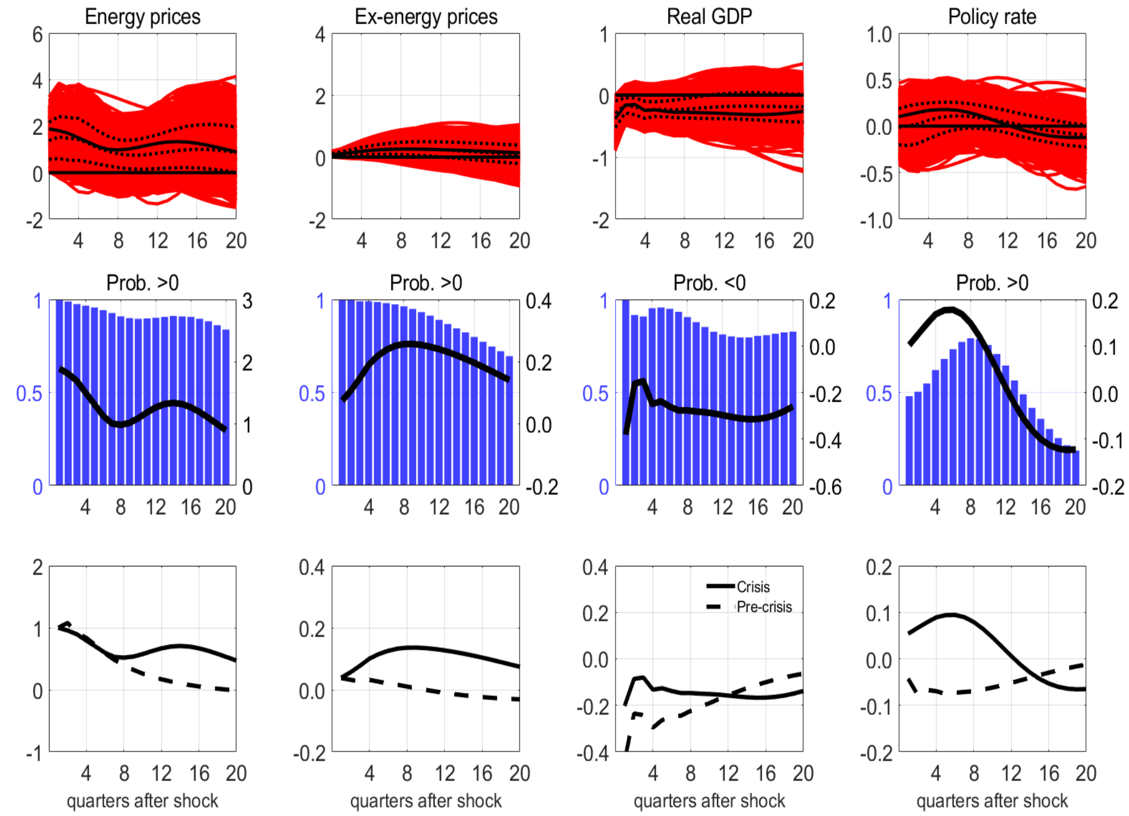


Note: the red solid line denotes the Bayes estimate based on the expected absolute loss; the grey dashed line is the zero line. The light blue bars measure the probability that in each quarter the variable is either negative (real GDP growth, ex-energy and headline inflation rates) or positive (policy rate).

BVAR with no narrative restrictions

Figure B7. Impulse response to a positive shock to energy prices

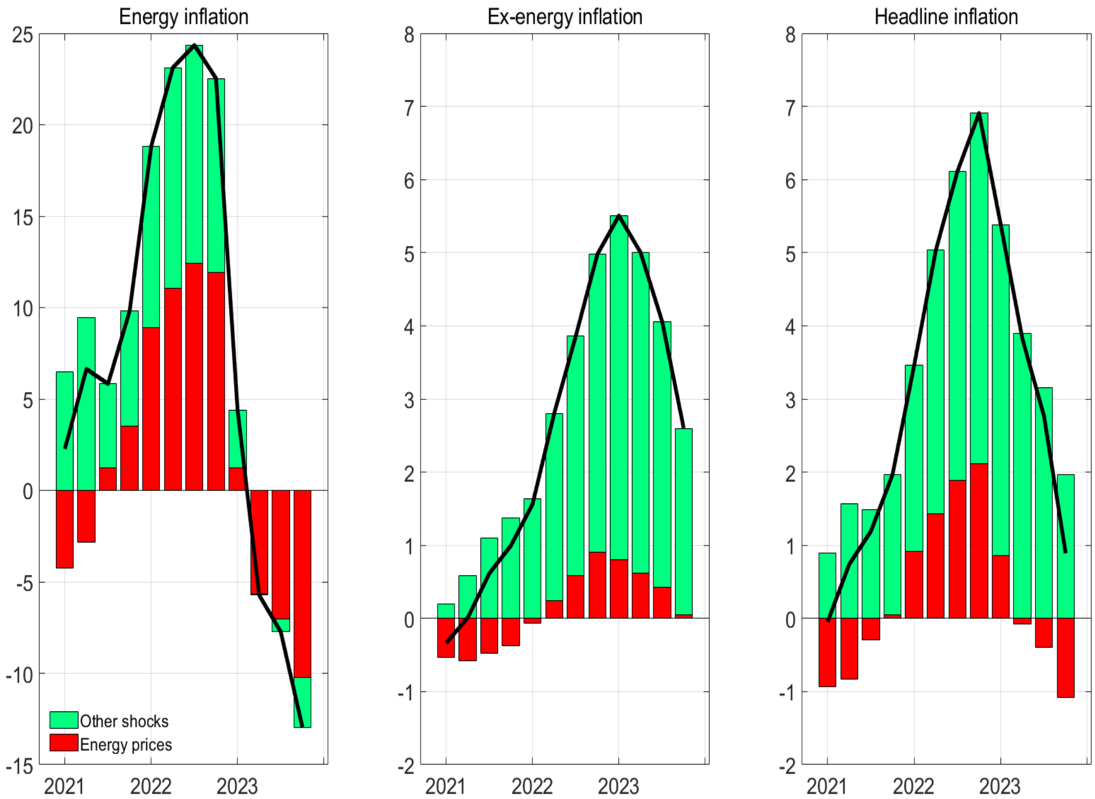
(*per cent and percentage points; deviation from unshocked path*)



Notes: Top row: the black solid line denotes the Bayes estimate based on the expected absolute loss. The black dotted lines denote the median, the 0.16 and 0.84 percentiles. The red areas show the set of impulse responses within the 0.68 joint credible set. Middle row: the black lines denote the Bayes estimate based on the expected absolute loss; the blue bars represent the posterior probabilities of the responses being either positive or negative (see title to each panel). Bottom row: Bayes estimate of the impulse responses for the crisis (solid lines) and the pre-crisis (dashed lines) sample periods.

Figure B8. Historical decomposition: energy and ex-energy and headline inflation

(*percentage points; deviations from the baseline*)



Note: the bar denotes the Bayes estimate of the contribution of the identified shocks to the deviations of the inflation rates from their respective baseline levels. The contributions are computed within the Gibbs sampling as the year-on-year changes in the contributions to the corresponding consumer price series.

Figure B9. Structural counterfactual simulations

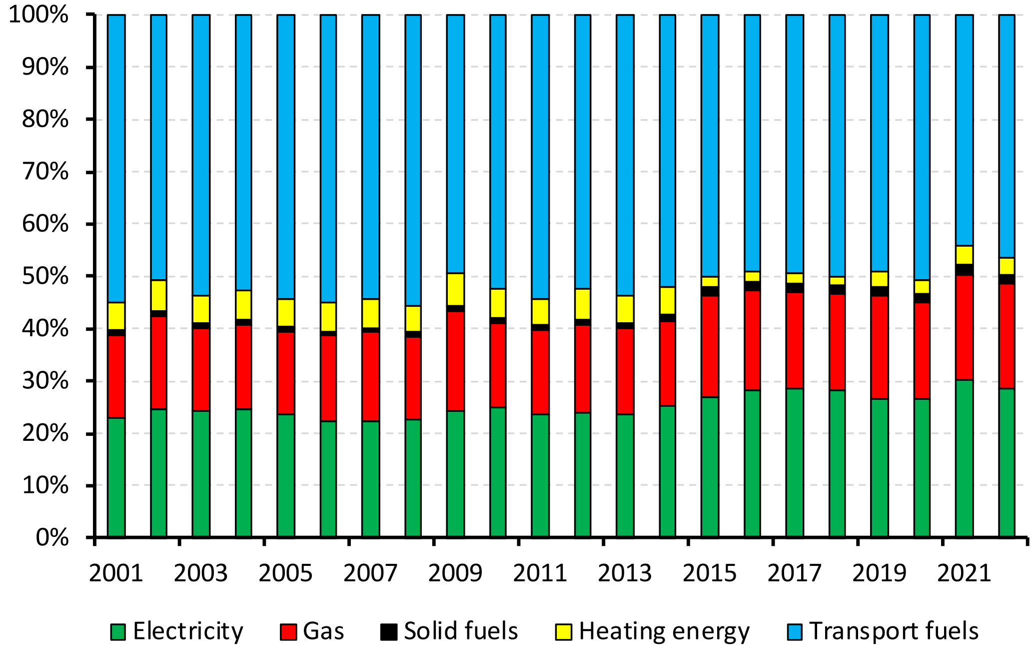
(*percentage points*)

Note: the red solid line denotes the Bayes estimate based on the expected absolute loss; the grey dashed line is the zero line. The light blue bars measure the probability that in each quarter the variable is either negative (real GDP growth, ex-energy and headline inflation rates) or positive (policy rate).

Appendix C - Additional charts

Figure C1. Weights of energy-related items in energy bundle

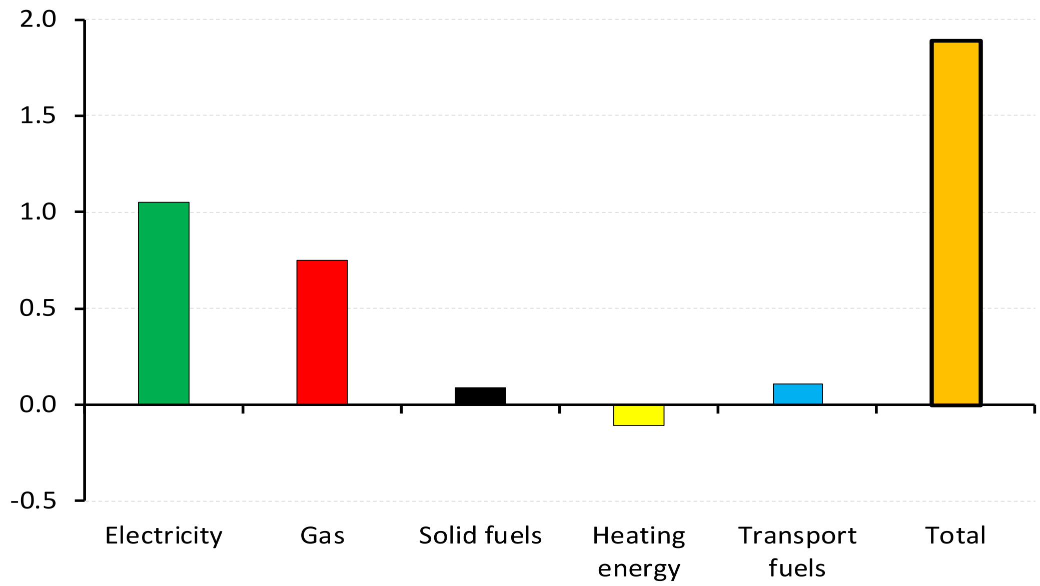
(*per cent*)



Source: Eurostat. *Note*: weights of energy items in the energy bundle. Last observation: 2022.

Figure C2. Weights of energy-related items in energy bundle: changes between 2001 and 2022

(*percentage points*)



Source: Eurostat. *Note*: changes in weight of energy items in the HICP between 2001 and 2022.

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