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Pandemic-era inflation dynamics in the euro area: the role of policy and non-policy demand and energy and non-energy supply factors

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Abstract

We analyze the sources of the pandemic-era inflation surge in the euro area using a Bayesian vector autoregression (BVAR) model. By applying narrative, sign, zero, and inequality restrictions, this study is the first that jointly analyzes the inflationary effects of energy and non-energy supply and policy and non-policy demand factors, including fiscal policy, conventional and unconventional monetary policy. Factoring in that energy price dynamics also responded to aggregate demand conditions, we find that the pandemic-era inflation surge in the euro area was driven by a combination of supply and demand factors. Energy-related supply side constraints, even if less important than often estimated, were a key factor in the run up of inflation. Fiscal and monetary policies were accommodative but not the dominant drivers.

JEL codes: C11, C32, E31, E52.

Keywords: Inflation, monetary policy, fiscal policy, energy supply, pandemic.

Non-technical summary

We examine the drivers of the exceptional inflation surge in the euro area during the Covid-19 pandemic era (2021–2023), particularly in light of central banks' price-stability mandates. After years of low inflation following the global financial crisis, inflation in the euro area surged dramatically, with headline inflation rising from below 1 percent in January 2021 to over 10 percent in October 2022, marking the highest level by far since the European Central Bank's (ECB) establishment. Core inflation also peaked at 5.7 percent in March 2023. Understanding the causes of this unprecedented inflation surge is critical for designing effective monetary policy responses and future strategies.

We identify several potential drivers of the inflation surge: Supply-side factors including global supply chain disruptions and energy supply shocks, particularly due to the Russian invasion of Ukraine; demand-side factors in the form of a rapid post-pandemic rebound in demand, compounded by accommodative fiscal and monetary policies. Considering the latter we investigate whether a potential delay in adjusting monetary policy was responsible for the inflation surge.

Despite extensive research, the academic literature remains inconclusive on the relative importance of these factors. We address this gap by disentangling supply and demand contributions, assessing the role of monetary and fiscal policies, and identifying lessons for future policy trade-offs.

We employ a Bayesian Vector Autoregression (BVAR) model using euro area data from January 2007 to June 2024. The model incorporates a broad range of macroeconomic variables, including inflation, energy prices, GDP growth, short- and long-term interest rates, primary government expenditure, a risk appetite index and metrics of pandemic-era supply-demand imbalances. We identify the following types of shocks: Conventional monetary policy shocks reflected by changes in short-term interest rates; unconventional monetary policy shocks from asset purchase programs affecting long-term interest rates and risk appetite; fiscal policy shocks measured by changes in government expenditure; energy supply and non-energy supply shocks; and finally non-policy demand shocks.

To achieve robust identification, the model combines sign restrictions, zero restrictions, narrative restrictions (based on historical policy decisions), and inequality (magnitude) constraints.

Our model attributes the inflation surge to a combination of demand and supply factors, with no single factor clearly dominating. Key results suggest that accommodative fiscal and monetary policies contributed approximately 1.5 percentage points to the peak in inflation. Thereby, fiscal policy accounted for about 0.6 percentage points and monetary policy for about 0.9 percentage points, the latter with similar contributions from conventional and unconventional monetary policy.

Noting that energy price increases were also driven by demand-side pressures, including post-pandemic demand decompression and policy stimulus, genuine energy-supply shocks are estimated to have added about 2.4 percentage points to peak inflation. Non-policy demand and non-energy supply shocks contributed an additional 3 percentage points.

Seeking to address criticism of a potential delay in adjusting monetary policy and the use of unconventional instruments, we show that, in the counterfactual scenario of an earlier tightening of monetary policy, headline inflation in the euro area would still have peaked at 8.5 percent instead of 10 percent and would have resulted in substantial output losses, with average economic growth falling by 3.6 percentage points, relative to its realized path.

Having peaked at over 10 percent in October 2022, inflation gradually declined to 2.9 percent by December 2023, driven by a tightening of monetary policy, reducing inflation by 1 percentage point, more favorable energy supply conditions (reducing inflation by about 2 percentage points), fiscal tightening (lowering inflation by about 0.6 percentage points) and a gradual fading of supply-and-demand imbalances characteristic to the pandemic environment.

Seeking to highlight that the surge in energy prices did not exclusively reflect cost and supply side factors, we show that genuine energy-supply shortages account for only about 15 percentage points of the 30 percent peak in euro area energy price inflation. The remaining half of the surge was largely driven by demand-side factors, including both policy-induced and non-policy demand forces.

We conclude that the pandemic-era inflation surge in the euro area was driven by a combination of supply and demand factors. Accommodative fiscal and monetary policies played a role but were not the dominant drivers. Energy supply disruptions played a smaller role in driving inflation compared to what other studies that focus on energy prices as production costs have suggested.

1 Introduction

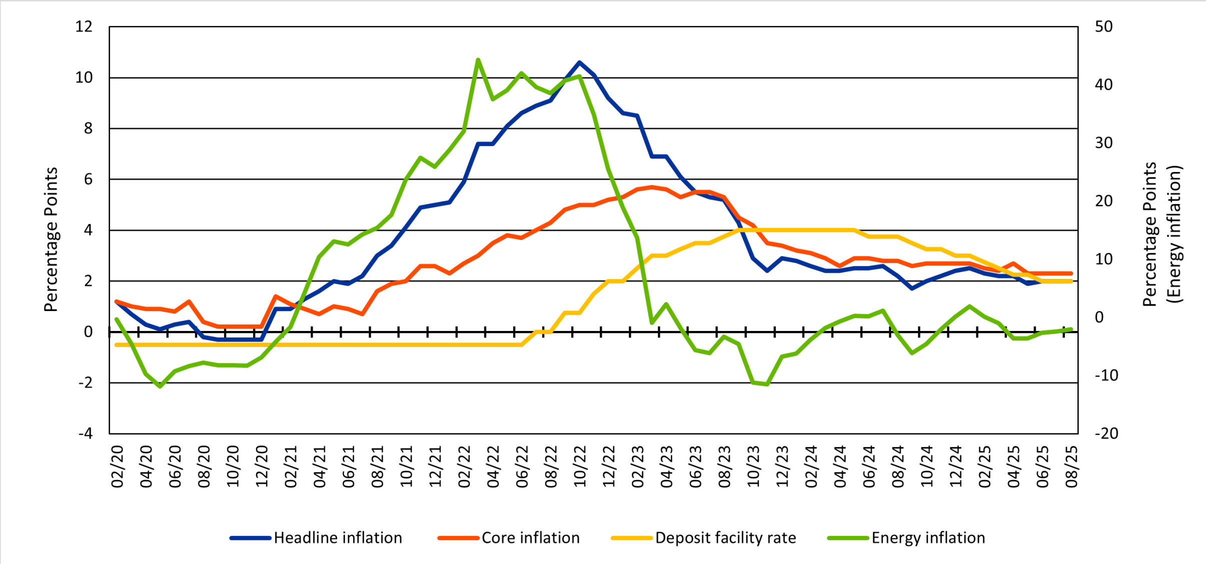
In light of price-stability mandates of central banks, understanding the drivers of the pandemic-era inflation surge is key. In the euro area, after years of low inflation rates in the aftermath of the global financial crisis, following the height of the Covid-19 pandemic, inflation surged to unprecedented levels (Figure 1). Headline inflation rose from below 1 percent in January 2021 to a peak above 10 percent in October 2022—the higest level since the establishment of the ECB—before gradually declining to 2.5 percent by February 2024 (and to the ECB's 2 percent inflation target the following year). Core (HICP excluding food and energy) inflation also surged, though to a lower peak of 5.7 percent in March 2023. The extent of this inflation surge has marked an unprecedented departure of euro area inflation from price stability. Several factors have been considered as the cause behind it. These include disruptions in global supply chains, the Russian war against Ukraine, a fast decompression of demand at the end of the Covid-19 pandemic, accommodative monetary and fiscal policies and tight labor markets.

In 2021, one and a half years into the pandemic, as headline inflation, after many years of shortfalls from 2 percent, was approaching and subsequently exceeding the 2 percent inflation target, monetary policy was highly accommodative, with asset purchases, negative interest rates, targeted longer-term refinancing operations and forward guidance still in place. In autumn 2021, as headline inflation exceeded its target by a significant margin, the ECB started to normalize its monetary policy stance by successively announcing a reduction in net asset purchases in December 2021. In June, with HICP headline inflation running at over 8 percent, it declared that the rate lift-off criteria under its forward guidance had been met and in July 2022 began raising interest rates by 450 basis points until September 2023 (see Figure 1). After having peaked at over 10 percent in October 2022 headline inflation fell to about 2.5 percent by November 2023 so that in June 2024 the ECB began dialing back monetary restraint (see Chapter 2 in ECB, 2025a, for a detailed account).

The literature has overall remained inconclusive in pinning down the relative importance of factors driving the inflation surge, including measuring the importance of monetary policy factors and, specifically, whether that is attributable to monetary policy having responded too late to the rapidly changing environment as unconventional policy instruments such as asset purchase programs remained in place. Accordingly, the literature has been equally inconclusive in gauging policy trade-offs for monetary policy in bringing inflation rates back in line with central bank objectives.

For the conduct of monetary policy and the design of monetary policy instruments it is crucial to quantify the relative importance of monetary policy in the exceptional inflation surge witnessed in

Figure 1
Headline, core and energy price inflation and Deposit facility rate in euro area



Source: Authors' calculations using Eurostat and ECB data.
Note: The figure shows annual percentage changes of headline and core inflation (HICP excluding energy and food, lhs) and energy price inflation (rhs) together with Deposit facility rate (lhs) in the euro area.

2021-2023. This quantification requires a convincing identification strategy, based on a comprehensive set of macro-economic variables, to first identify supply and demand factors behind inflation dynamics. The approach needs to acknowledge that, even though energy is a production input, energy prices respond to both supply and demand factors. While energy-supply disruption triggered a spike in energy prices, one cannot exclude that this spike was also compounded by the fast decompression of demand in the post-pandemic environment and because of policy stimulus. For demand factors it is crucial to distinguish policy and non-policy factors driving the expansion of demand in this specific environment, whereby among policy-related drivers a distinction needs to be made between fiscal and monetary factors. In turn, considering the prominent use of unconventional monetary policy instruments like asset purchases in the run up to the pandemic, their importance relative to the classical interest rate instrument needs to be assessed too, so as to measure the monetary policy impact correctly. Only then can judgment be passed about the extent by which monetary policy was responsible for the extraordinary increase in inflation in this period, whether its response was delayed and whether this delay can be associated with the use of unconventional instruments.

The large and fundamental disagreement in the literature about the relative importance of drivers is not surprising, given that multiple shocks have occurred within a very short time span, impairing a quantification of the relative importance of all factors. Many papers have focussed on a subset of factors only. For the euro area Adolfsen et al. (2024); Alessandri and Gazzani (2025); Bańbura et al. (2023) place emphasis on the sectoral propagation of energy supply and, in particular, gas price shocks. Ascari et al. (2023) identify a combination of both demand and supply factors as drivers. Ascari et al. (2024a) find that demand factors, specifically fiscal stimulus, play a relatively more important role. Giannone and Primiceri (2024) attribute the inflation surge mostly to demand-side factors. As for the evolution in relative importance over time ECB staff finds that initially supply-side constraints and energy-price shocks dominated inflation dynamics and later on an expansion of demand (ECB, 2025b).

We focus on policy factors as demand-side drivers of inflation, while controlling for supply side factors, such as energy supply shocks. Tracing supply and demand side forces through the pandemic period we show that the post-pandemic inflation surge has been due to a fast decompression of demand coinciding with significant supply-side constraints. We find that energy-related supply side constraints, even if less important than often estimated, were initially the dominant factor in the run up of inflation. Subsequently, demand-side factors became more relevant, with public policy stimulus having contributed partly.

We derive our results based on a Bayesian vector autoregression (BVAR) model for the euro area data over the sample January 2007 to June 2024, relying on a combination of i) *sign restrictions* in line with Faust (1998), Canova and De Nicolo (2002), Uhlig (2005) and Rubio-Ramirez et al. (2010), ii) *narrative restrictions* as proposed by Antolín-Díaz and Rubio-Ramírez (2018), iii) *magnitude restrictions* along the lines of Peersman (2005), iv) and *zero restrictions* for identification. Specifically, the baseline model identifies five shocks including conventional (CMP) and unconventional (UMP) monetary policy shocks, fiscal policy shocks, energy supply shocks, and other energy-related shocks. In an extension, we also consider two additional shocks: non-policy demand shocks and non-energy supply shocks that would then allow us to compare the impacts of aggregate demand shocks (including non-policy and policy shocks) and aggregate supply shocks (including energy and non-energy supply shocks) on inflation dynamics during this episode.

Our findings are twofold. First, there is no overall dominance of either supply or demand factors, but rather a combination of them. Thereby, the demand-side drivers were also partly driven by accommodative public policies. Second, tightening monetary policy conditions earlier with the aim of nullifying the monetary policy contribution to the inflation surge would not have prevented the unprecedented extent of the inflation surge and in addition would have incurred significant output losses.

More in detail, we find that the five identified shocks together explain about 60 percent of the 8 percentage point inflation surge between June 2021 and October 2022. Specifically, adverse energy-supply shocks that significantly gained importance since the Russian invasion of Ukraine, are the key factor dragging down economic growth, while contributing about 2.4 percentage points to the inflation surge. Meanwhile, monetary and fiscal policy have played an important role in the economic recovery following the pandemic crisis but also contributed to inflation by 1.5 percentage points, with 0.6 percentage points from fiscal policy and 0.9 percentage points from both unconventional and conventional monetary policy. Other energy-related shocks, interpreted as demand-driven shocks based on its impulse response, contributed about 1 percentage point to inflation.

Extending the model to include other aggregate demand and non-energy supply shocks highlights the importance of demand-driven factors in the inflation surge in the euro area during this episode, explaining a large share of the inflation surge, therefore supporting the findings of Giannone and Primiceri (2024) and Ascari et al. (2023). These demand-side shocks, including expansionary policies supporting the economic recovery, were also important drivers of energy prices. Similarly, for the subsequent disinflation episode after October 2022, our results indicate that tightening monetary policy, both conventional and unconventional, tightening fiscal policy, favorable energy supply conditions and the fading impact of past factors expanding demand have led to a decrease by 4.5 percentage points in inflation. By June 2024, the deviation of inflation from target in December 2023 is caused by factors other than monetary, fiscal, and energy-related shocks.

In the face of the exceptional surge in inflation, assessing the appropriateness of the timing and extent of tightening monetary policy is key. To assess this impact of timing and pace of monetary policy responses, we analyze a counterfactual model scenario in which interest rates are raised six months earlier and follow a similar trajectory. Under this scenario, inflation would have been reduced by 1.6 percentage points, with a peak at 8.5 percent. However, this earlier intervention would have come at the expense of a significantly slower economic recovery, with average year-on-year economic growth falling short by 3.6 percentage points. As for the inflation impact, these figures are comparable with a similar counterfactual exercise conducted in ECB (2025a, p. 13), based on a wide range of macroeconomic models.

The rest of the paper is organized as follows. Section 2 discusses the main similarities and differences between our work and the previous studies. Section 3 introduces the baseline model identifying policy and energy supply shocks, baseline results, as well as counterfactual analyses with different responses of monetary policy. Section 4 presents a refined model separating non-energy from energy related supply side factors and policy from non-policy demand factors. Section 5 illustrates the responsiveness of energy prices to demand factors, during the 2022 energy price spike. Section 6 discusses results from robustness checks, including an alternative measurement of unconventional monetary policy, another measure of economic activity, and different lag structures. Section 7 concludes.

2 Related Literature

Our work contributes to growing research analyzing the origins of the exceptional surge in inflation during the pandemic era. This literature rests on a wide range of modeling classes, including relatively simply dynamic models, structural New Keynesian models with non-linearities or multiple sectors, or BVARs, or a combination of these approaches. This literature overall remains inconclusive as to whether demand or supply factors or policy or non-policy factors are responsible for the exceptional pandemic-era increase in inflation.

In light of pandemic-related supply bottlenecks and the surge in energy prices in the wake of the Russian invasion of Ukraine there is a large body of literature that, for the euro area, emphasizes supply-side and cost factors. These include Arce et al. (2024); Ascari et al. (2024b); Adolfsen et al. (2024); Alessandri and Gazzani (2025); Baba and Lee (2022); Bańbura et al. (2023); De Santis and Tornese (2025). On the other side of the spectrum, studies that find demand and policy factors to have been key drivers include Giannone and Primiceri (2024); Sahuc et al. (2024). Studies that rather emphasize a combination of both supply and demand factors and of policy and non-policy factors include Ascari et al. (2023, 2024a).

The lack of agreement about pandemic-era inflation drivers also concerns the case of the US. Important studies of the inflation surge in the US include e.g. Ball et al. (2022) who point to the quick pass-through of energy price shocks to inflation on account of labor market tightness (with Benigno and Eggertsson, 2023, emphasizing labor shortage propagating along a non-linear Phillips curve), while Bernanke and Blanchard (2025) and Ferrante et al. (2023) emphasize sectoral supply and demand imbalances, rather then aggregate labor market tightness and attribute commodity price increases to strong aggregate demand. At the same time Gagliardone and Gertler (2023), while controlling for demand shocks and labor market tightness, identify a combination of oil price shocks and "easy" monetary policy as drivers. Accordingly, for the US, these researchers all identify different degrees of importance of labor market tightness, monetary policy accommodation, the propagation of sectoral demand-and-supply imbalances, and energy price spikes.

More in detail, for the euro area, among the studies focusing on supply constraints Bańbura et al. (2023) construct a BVAR capturing global supply chain disruptions, oil and gas prices, a wide range of price indicators and monetary policy proxies to identify energy-related supply and demand shocks, non-energy supply shocks, and demand. They find an overall small or negative contribution of monetary policy to the post-pandemic rise in (core) inflation in the post-pandemic period. As a matter of fact, throughout the entire sample period the contribution of monetary policy is negligible (see Figure 7 in Bańbura et al., 2023), a result that may be partially attributable to challenges with capturing all monetary policy instruments fully, including unconventional policies. Also Ascari et al. (2024b) show that shocks to global supply chain pressures were the main drivers of the inflation surge in the euro area.

Given the higher importance of gas (relative to oil) price developments in the euro area during the period Adolfsen et al. (2024) and Alessandri and Gazzani (2025) build BVARs for gas prices. The first study identifies state dependency with high capacity utilisation and low unemployment fostering a strong pass through of gas price shocks to all inflation components. The latter study finds a concentration of the strength of pass through in countries with high gas dependence.

Showing that the main drivers of the recent inflation surge are related to the supply-side initially goes back to Arce et al. (2024) who applied the approach by Bernanke and Blanchard (2025) to the euro area economy. They capture the supply side by energy and food prices and labor market tightness and find an only small role for demand shocks. Yet these studies treat energy prices and wage costs as exogenous, when it is realistic to expect that these also responded to aggregate demand conditions.

In sharp contrast to this strand of literature, among those emphasizing non-policy demand forces as predominant drivers of the inflation surge are Giannone and Primiceri (2024). Their different variants of BVARs for the euro area, distinguishing demand, energy and non-energy supply, suggest that more than half of the rise in inflation is attributable to demand, especially once the pandemic ended and demand outpaced supply. Thereby, they find that non-policy demand forces are predominant drivers of the inflation surge, accountable for more than half of it, relative to supply, both in the US and in the euro area. This qualitative result of demand factors being only partially driven by policy has been validated in a structural model setting in Sahuc et al. (2024), showing that the counterfactual of an earlier tightening of the monetary policy stance would have lowered inflation by less than two percentage points only and would have created substantial output losses.

Ascari et al. (2023) attribute a more balanced impact to both supply and demand on pandemic-era inflation dynamics. They argue that while price pressures were already building before the natural gas shock, an inflationary impulse in one sector (energy) has quickly become broad based because demand remained strong. As the economy was reopened demand increased while supply constraints took longer to resolve. VAR analysis also identifies energy and non-energy supply and demand shocks but does not trace demand factors back to policy factors.

The paper tracing demand dynamics back to policy and non-policy factors and most closely related to our approach is the one by Ascari et al. (2024a). They find that demand shocks were relatively more important than supply shocks in the post-pandemic inflation surge, with fiscal stimulus playing an important role, even if differing across euro area countries. They place emphasis on the fiscal response having been strong, given the suspension of the Stability and Growth Pact and the Next Generation EU program mobilizing 6% of GDP.

Ascari et al. (2024a) identify three types of demand (fiscal, monetary, non-policy) and supply shocks (domestic cost push, global supply, oil price supply shocks). Like Bańbura et al. (2023) they capture the policy stance by including Krippner's shadow rate measure. They include a global supply chain pressure index to capture non-energy supply and allow for temporary surges in the covariances of all shocks for the model to cope with the volatility in pandemic data.

Our approach still differs in several respects.

First, our data selection measures energy more comprehensively, as we capture, not just oil, but also gas and electricity prices, given their importance in the euro area during the period. We also take a different approach to treating Covid-19 related data-outliers. While Ascari et al. (2024a)'s approach can be characterized as 'discounting' Covid-19 era data through volatility in shocks, we also control outliers by attributing them to a Covid-19 indicator, while at the same time controlling for heightened uncertainty during this episode with a measure of macroeconomic uncertainty.

Second, we measure fiscal policy (and accordingly shocks) by focusing on real primary government expenditure growth, as we think this measure is better in capturing the demand side impact. In fact, most Covid-related fiscal support was tied to the expenditure side, as opposed to tax measures.[1]

Third, we aim at a more comprehensive measurement of different instruments and channels of monetary policy transmission, taking into account that the ECB's Pandemic Emergency Purchase Programme aimed at both easing the monetary policy stance along risk-free financial market segments and supporting monetary policy transmission and countering headwinds from large risk reversals, especially at the start of the pandemic. To this end, we make an explicit distinction between conventional and unconventional policies, aiming at a more robust approach to capturing effects of asset purchases

[1]For instance, between 2019-2020, for the euro area, the revenue remains about 46.5 percent of GDP, while expenditure increased sharply from 47 percent of GDP to 53.6 percent of GDP.

compared to the shadow rate measure by Krippner (2013). The latter is subject to assumptions about the level of the effective lower bound that are likely too strong given that the ECB lowered the deposit facility rate into negative territory and maintained scope for lowering it further, thereby never really reaching the effective lower bound. Therefore, to capture financial factors and monetary policy transmission in a more comprehensive manner, we extend asset price information beyond the measures of returns on safe assets and include a risk appetite index.

Fourth, methodologically (apart for identifying energy supply shocks) we do not impose contemporaneous restrictions, but allow for flexibility in the dynamic response of variables to structural shocks, while Ascari et al. (2024a) use contemporaneous restrictions more prominently.

Fifth, in terms of overall results we find a more balanced importance of supply and demand shocks.

Overall, methodologically, our paper also adopts a novel approach to combining traditional sign restrictions with narrative, zero, and inequality (or magnitude) restrictions in Bayesian VAR models. We thereby extend the sign-restriction approaches for identifying macro-economic shocks in the euro area by, for instance Gambetti and Musso (2017), Gonçalves and Koester (2022), Giannone and Primiceri (2024), Ascari et al. (2023), just to name a few. This extension from the traditional sign restrictions is first motivated by Antolín-Díaz and Rubio-Ramírez (2018) who argue that combining sign restrictions and narrative restrictions would significantly sharpen the inference of VAR-based models identified via traditional sign restrictions. Additionally, we show that the use of zero and inequality restrictions is necessary to separate the conventional and unconventional monetary policy shocks as well as to distinguish the energy supply shocks from other supply shocks.

Finally, our approach places additional emphasis on capturing distinct channels of monetary policy, including through risk taking, not least as concerns about monetary policy transmission have scored high in the conduct of monetary policy in the euro area. To enhance the sign-restriction-based identification of these shocks, we incorporate narrative information on the timing and direction of key policy events from Akkaya et al. (2024) who decompose the high-frequency movements of EA's risk-free yields into policy factors (target, path, and QE i.e. quantitative easing). Our paper is therefore related to the studies using high-frequency data for the identification of monetary policy shocks, such as Jarociński and Karadi (2020). Specifically, we incorporate a euro-area measure of risk appetite developed in Akkaya et al. (2024), to explicitly account for the risk-taking channel, as emphasized by Bauer et al. (2023), therefore further capturing a highly important policy dimension and refining the identification of euro area monetary policy shocks. Specifically, noting that our synthetic measure of the euro-area long-term interest rate captures credit and liquidity risk premia, in addition to the term premium, the inclusion of the risk appetite index into the model helps us trace the broader risk dimension of monetary policy instruments, in particular of central bank asset purchases.

3 Model

3.1 Baseline model and data

To study the drivers of inflation dynamics, we use a VAR model as follows:

$$A_0 X_t = B_0 + \sum_{i=1}^{q} B_i X_{t-i} + \epsilon_t, \tag{1}$$

where X_t is the vector of endogenous variables at monthly frequency, q is the lag length, B_0 deterministic terms, B_i a matrix of parameters, A_0 a matrix of parameters capturing the contemporaneous relationships between the endogenous variables, and ϵ_t a vector of orthogonal structural shocks with a Gaussian distribution of mean zero and identity covariance matrix.

Vector X_t is composed of nine variables, measured at monthly frequency:[2] inflation (first log difference of headline HICP), HICP energy inflation (first log difference of energy prices in the HICP), real GDP growth (first log difference of real GDP), a short-term interest rate (3-month interbank lending rate), a long-term interest rate (the synthetic euro area 10-year government bond yield), real government expenditure growth (first log difference of government expenditure), an indicator of risk appetite, an index of macroeconomic uncertainty, and a Covid-19 indicator. HICP inflation and output growth are two key macroeconomic variables. The short-term interest rate, long-term interest rate, and government expenditure are included to model conventional monetary policy, unconventional monetary policy, and fiscal policy.

In addition, the Covid-19 shock has created challenges for modeling economic time series because it created unprecedented large changes in key macroeconomic variables, especially in GDP, due to lockdown and reopening measures. We address this issue by following Ng (2021) to include a Covid-19 indicator—which is the monthly log difference of newly reported Covid-19 cases aggregated for euro area countries. Furthermore, to capture the high economic uncertainty during this episode, we include the euro area macroeconomic uncertainty index developed by Comunale and Nguyen (2025).[3]

[2] See Appendices A and B for detailed information on the data, including the construction of monthly data for real GDP and real government expenditure. These data are interpolated from quarterly data using information available at the monthly frequency.

[3] An alternative approach is to dummy out the Covid-19-related outliers as in, for instance, Bernanke and Blanchard (2024). However, as argued by Ng (2021), these extreme values are not void of economic content and should not be "dummied out".

The reduced-form representation implied by the structural model (1) is

$$X_t = C_0 + \sum_{i=1}^{q} C_i X_{t-i} + u_t, \tag{2}$$

where $C_0 = A_0^{-1}B_0$, $C_i = A_0^{-1}B_i$ and $u_t = A_0^{-1}\epsilon_t$. It is known that the reduced-form estimation does not provide enough information to identify even one column of A_0. To overcome this, we follow Faust (1998), Canova and De Nicolo (2002), Uhlig (2005) and Rubio-Ramirez et al. (2010) and apply sign restrictions for identifications. Moreover, to strengthen shocks identification we impose additional magnitude restrictions along the lines of Peersman (2005), use narrative restrictions as proposed by Antolín-Díaz and Rubio-Ramírez (2018), and rely on zero restrictions.

In line with the literature on sign-identified VAR models, we apply Bayesian methods for inference. The baseline model is estimated with two lags with the data from January 2007 to June 2023.[4] We set priors using dummy observations, as in Banbura et al. (2010). We use a Gibbs sampling approach and draw A_0^{-1} directly in each iteration by using the efficient algorithm proposed by Rubio-Ramirez et al. (2010). In a nutshell, given the draw of $\text{cov}(u_t) = \Omega$, the Cholesky decomposition of $\Omega = \tilde{A}_0'\tilde{A}_0$ is computed. This matrix $\tilde{A}_0$ is multiplied by an orthogonal rotation matrix Q_t, generating a draw of $A_0^{-1} = Q_t\tilde{A}_0$. We retain only those draws that satisfy all specified restrictions.

3.2 Identification of structural shocks

The baseline model identifies five structural shocks of interest: conventional and unconventional monetary policy shocks, a fiscal policy shock, an energy supply shock, and another energy-related shock. In the subsequent Section 4, we discuss an extension of the baseline model with two additional shocks: non-policy aggregate demand and non-energy aggregate supply shocks.

Table 1 provides an overview of how we combine sign-restrictions on contemporaneous and accumulated effects, zero instantaneous-impact restrictions, and magnitude restrictions to identify these shocks. Signs ($+$ / $-$) denote restrictions on the direction of the impact of structural shocks on observed variables, accumulated over time. Exclusively contemporaneous sign restrictions are marked by 'C:$+$'/'C:$-$', zero instantaneous restrictions by 0 and magnitude restrictions imposing a relatively *higher* absolute instantaneous impact of a shock on comparable macroeconomic variables (marked by $*$) are denoted by 'C:$++$ '.

[4]The lag is selected by BIC. We also conduct robustness check with different lag structures as discussed in Section 6.

Table 1
Sign restrictions in the baseline model

Shocks (Row) /Variable (Column)	Tightening CMP shock	Tightening UMP shock	Tightening fiscal policy shock	Negative Energy supply shock	Other Energy related shock
Uncertainty					
HICP	−	−	−	$+^*$	
Energy price	0	0	0	C:++*	C:+
RGDP	−	−	−	−	
Short-term interest rate	C:++*	$*$			
Long-term interest rate	C:+*	C:++*	C:−		
Government expenditure			C:−		
Risk appetite	C:−	C:−			
Covid-19 indicator	0	0	0	0	0

Note: The table lists signs of responses of endogenous variables (in the first column) to tightening conventional MP, unconventional MP, and fiscal shocks as well as negative energy supply shock and other energy related shock. Signs (+ / −) denote restrictions on the direction of the impact of structural shocks on observed variables, accumulated over time. Exclusively contemporaneous sign restrictions are marked by 'C:+'/'C:−', zero instantaneous restrictions by 0 and magnitude restrictions imposing a relatively *higher* absolute instantaneous impact of a shock on comparable macroeconomic variables (marked by $*$) are denoted by 'C:++ '.

3.2.1 Sign restrictions

Sign restrictions, as summarized in Table 1, reflect standard impacts documented in the literature. An unexpected contractionary conventional monetary policy shock is assumed to increase short- and long-term interest rates and lower risk appetite instantaneously[5] while cumulatively reducing output and prices with a lag. As the short-term interest rate serves as the instrument for conventional monetary policy, it responds contemporaneously to a conventional monetary policy shock. Likewise long-term interest rates and risk appetite respond immediately, as these financial data, at monthly frequency, will also respond instantaneously.

A contractionary unconventional monetary policy shock is expected to raise the long-term interest rate and lower risk appetite contemporaneously, and subsequently decrease output and prices with a lag.

A fiscal tightening shock contemporaneously lowers government expenditure and long-term interest rates, causing output and prices to fall eventually, akin to a contractionary demand-side shock.

[5] Bauer et al. (2023) provide empirical evidence on the immediate response of risk appetite at daily frequency in the occurrence of a surprise monetary tightening shock.

Given that the long-term interest rate is the synthetic euro area 10-year government bond yield which includes both the term premium and credit risk, a fiscal policy consolidation also lowers long term rates because it reduces inflationary risk—due to unfunded fiscal shocks as documented in Bianchi et al. (2023)—as well as risk of sovereign stress.

An unfavorable energy supply shock is assumed to increase energy prices contemporaneously and headline consumer prices with a lag, while reducing real output. In addition, we allow another energy-related shock to affect energy prices contemporaneously. Unlike the energy supply shock, we do not assign ex-ante interpretation in terms of sign restrictions to the impact of this shock on key macroeconomic variables and instead rely on its impulse responses for ex-post interpretation. Such energy shocks could be: aggregate demand shocks which cause contemporaneous effects on energy prices; the specific oil-related energy-market demand shocks; or a combination of these shocks. The latter could be shifts in the price of energy driven by higher precautionary demand associated with market concerns about the availability of future energy supplies (Kilian, 2009).

Because the model is estimated at monthly frequency, we do not strictly assign contemporaneous restrictions on output and prices, as often assumed in the literature estimated using quarterly data. Instead, we allow flexibility by assuming that responses of output and prices satisfy the specified restrictions in either quarter 1 (the sum of first 3 months) *or* quarter 2 (the sum of first 6 months) after the occurrence of the corresponding shock. In other words, restrictions do not require output and prices to respond immediately. They rather let the data speak on the average time of the first effect of shocks on output and prices. In terms of impact on prices, we only allow energy supply and other energy related shocks to affect energy prices instantaneously.

3.2.2 Zero restrictions

We additionally rely on zero restrictions for identification, as shown in Equation 3. As previously mentioned, we include Covid-19 cases in our model to account for Covid-19-related outliers. Specifically, one shock (ϵ_t^9), distinct from other economic shocks, constitutes a health shock that affects all economic and financial variables. Conversely, we assume that none of the remaining eight economic, financial or policy shocks influence Covid-19 cases.

Although energy supply shocks and other energy-related shocks are assumed to influence energy prices contemporaneously, none of the policy shocks is assumed to affect energy prices immediately. This assumption reflects the euro area's status as an energy price taker in the short run. Another shock that could affect energy prices contemporaneously is the Covid-19-related shock (ϵ_t^9), as evidenced by the collapse in oil prices during the early phase of the pandemic. Finally, the non-identified economic shocks ϵ_t^6, ϵ_t^7, and ϵ_t^8 are assumed not to impact energy prices contemporaneously.

$$\begin{pmatrix} u_t^{\Delta Energy\,price} \\ u_t^{Uncertainty} \\ u_t^{\Delta HICP} \\ u_t^{\Delta RGDP} \\ u_t^{Short\,rate} \\ u_t^{Long\,rate} \\ u_t^{\Delta GovExp} \\ u_t^{Risk\,appetite} \\ u_t^{Covid-19\,cases} \end{pmatrix} = \begin{pmatrix} * & * & 0 & 0 & 0 & 0 & 0 & 0 & * \\ * & * & * & * & * & * & * & * & * \\ * & * & * & * & * & * & * & * & * \\ * & * & * & * & * & * & * & * & * \\ * & * & * & * & * & * & * & * & * \\ * & * & * & * & * & * & * & * & * \\ * & * & * & * & * & * & * & * & * \\ * & * & * & * & * & * & * & * & * \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & * \end{pmatrix} \begin{pmatrix} \epsilon_t^{Energy\,supply} \\ \epsilon_t^{Otherenergy-related} \\ \epsilon_t^{Conventional\,MP} \\ \epsilon_t^{Unconeventional\,MP} \\ \epsilon_t^{Fiscal policy} \\ \epsilon_t^6 \\ \epsilon_t^7 \\ \epsilon_t^8 \\ \epsilon_t^9 \end{pmatrix} \quad (3)$$

3.2.3 Inequality (magnitude) restrictions

Standard sign restrictions alone may not be sufficient to identify the shocks of interest. This concern applies specifically to the distinction of conventional and unconventional monetary policy and to the identification of genuine energy-supply shocks. Therefore, we impose additional magnitude restrictions, as indicated in Table 1 above. First, given that conventional monetary policy has a larger effect at the short end of the yield curve, a conventional monetary policy shock is assumed to have a larger contemporaneous (absolute) impact on the short-term interest rate than on the long-term rate (indicated by 'C:++' and '∗' in the first column of Table 1 in the rows corresponding to the short-term and long-term interest rate accordingly). Specifically, the (absolute) response of the long-term rate is assumed to be less than half that of the short-term rate. Conversely, the long-term rate is expected to respond more strongly to an unconventional monetary policy shock than the short-term rate. In particular, the (absolute) response of the short-term rate is assumed to be less than half that of the long-term rate. These assumptions are consistent with the identification strategy proposed by Altavilla et al. (2019) and are supported by the findings in Akkaya et al. (2024).

To support the distinction of the specific energy-supply related effect on consumer prices relative to other sources, we also assume that an energy supply shock has a larger contemporaneous impact on energy prices than on headline consumer prices. Specifically, the (absolute) response of energy prices is assumed to be larger than that of headline consumer prices. Importantly, these magnitude restrictions are only imposed on the instantaneous impact, leaving the responses in subsequent periods to be determined by the data.

As we are modeling euro area macroeconomic dynamics in the context of *global* developments in both pandemic-related supply and demand imbalances and energy prices, it is important to ensure that these global factors are not misconstrued to be overly responsive to domestic economic developments.

Our combination of zero, sign, and magnitude restrictions seeks to preserve this global dimension of macroeconomic dynamics against the background of global health developments and geopolitical tensions.

First, to attenuate a potential overestimation of the endogeneity of energy prices to domestic macroeconomic developments, especially domestic policy factors, in addition to allowing energy prices to respond with a larger instantaneous magnitude to genuine energy-related shocks than headline inflation, we let energy prices respond to domestic policy factors—but only with a lag.

Second, we allow for a non-domestic, non-energy supply-related shock and explicitly control for a Covid-19-specific health shock to account for the global nature of the pandemic.

This combination of assumptions ensures that euro-area energy price developments can also be explained by global factors and are not misattributed to domestic euro-area policy factors.

3.2.4 Narrative restrictions

Seeking to refine shock identification further, we finally follow Antolín-Díaz and Rubio-Ramírez (2018) to further improve shock identification by adding narrative restrictions as presented in Table 2. The arrows ↑ (↓) indicate that the identified shocks are positive (negative) in a specific month or period of time. Narrative sign restrictions for both monetary policy shocks are selected based on monetary policy factors identified in Akkaya et al. (2024) and Altavilla et al. (2019)—specifically, the *Target* factor for conventional monetary policy, and the *QE* and *Path* factors for unconventional monetary policy.[6]

The narrative for the conventional monetary policy shock corresponds to a positive surprise in October 2011, which is one of the largest *Target* surprises (in absolute value) documented in Akkaya et al. (2024). This surprise occurred when the Governing Council of the ECB kept interest rates unchanged against market expectations of policy easing amid slowing growth and financial market tensions.

Among the three largest *Target*-related surprises (in absolute terms), only the October 2011 event is associated with a positive surprise in the 3-month OIS and a negative surprise in stock prices, further reinforcing its classification as a monetary policy shock (see also Jarociński and Karadi, 2020).[7]

[6] The narrative events are selected by identifying the largest (absolute) factors associated with unconventional and conventional monetary policies.

[7] The other two large *Target* surprises occurred on 16 March 2023 and 3 November 2011. However, on these dates, the 3-month OIS and stock price surprises moved in the same direction, which weakens their characterization as monetary policy

Table 2
Narrative sign restrictions in the baseline model

Shocks/date	Conventional MP shock	Unconventional MP shock	Fiscal policy shock	Energy supply shock
Oct 2011	↑			
Dec 2015		↑		
Jan-Dec 2011			↓	
March 2022				↓

Note: The table lists narrative sign restrictions used in the baseline model for CMP, UMP, Fiscal policy and Energy supply shocks.

Narrative information for identifying unconventional monetary policy can be gleaned from the ECB Governing Council's decision in December 2025 to lower the interest rate on the deposit facility by 10 basis points to -0.30 percent and to extend the Asset Purchase Programme (APP) by six months. As this decision was less accommodative than expected, it generated a large (positively signed) tightening in unconventional monetary policy. This event represents the largest *QE* component identified in Akkaya et al. (2024). It is associated with a positive surprise in the 10-year OIS, a positive surprise in the 10-year synthetic euro area government bond yield, and a negative surprise in stock prices.

Regarding narrative sign restrictions to identify fiscal shocks, we assume that total fiscal shocks in 2011 were negative, reflecting fiscal consolidation in the euro area (see ECB, 2016).

A narrative approach to identifying genuine energy supply shocks can naturally rely on instances of major geopolitical crises (see also the discussions in De Santis and Tornese, 2025). In this vein we associate an adverse energy-supply shock from the Russian invasion of Ukraine, dating its instantaneous impact to March 2022 (the month after the invasion).

In summary, we combine sign, zero, inequality, and narrative restrictions to strengthen the identification of the shocks of interest. Robustness checks of this identification approach, also allowing for a richer set of structural shocks, are presented in Sections 4 and 6.

3.2.5 Impulse-responses from the baseline model

We estimate the baseline model to analyze the relative importance of five identified shocks of interest for inflation dynamics in the euro area using data over the sample period from January 2007 to June 2024. This period includes the surge in inflation from June 2021 to October 2022 and the subsequent

shocks.

disinflation episode. Annex C, Figures C.1–C.5, shows the impulse-responses from estimating this baseline model, together with their corresponding 68 percent confidence bands. These point to risk appetite constituting an important channel of monetary policy transmission in the euro area, for both conventional and unconventional monetary policy. Conversely, fiscal policy and energy-related shocks do not affect risk appetite. The estimated accumulated impact of fiscal policy suggests a multiplier in the range of 1-2 over a two-year horizon. Finally, the estimated profiles of the two energy-related shocks distinguish energy-supply from energy demand shocks, as the other, less restricted, energy-related shock is estimated to move output and inflation in the same direction.

The dynamic responses to monetary policy shocks generated by this baseline model broadly align with those from ECB models that are widely used for regular policy analysis and forecasting, including the New Area-Wide Model, the New Multi-Country Model, the ECB-BASE model, and the FRB-US model. While our baseline BVAR features a more frontloaded but weaker impact of monetary policy on inflation than the New Area-Wide Model and ECB-BASE, estimated responses in output are stronger than in these two models. Yet, overall, Figure C.6 in Annex C demonstrates that the output and price responses from our baseline model to shocks in short-term interest rates fall within the range estimated in all models.

3.2.6 Inflation surge between June 2021 and October 2022

Having largely fallen short of 2 percent since the global financial crisis, year-on-year euro area HICP inflation rose above the ECB's 2 percent inflation target in July 2021 and subsequently surged by 8 percentage points to over 10 percent by October 2022. The BVAR analysis of this episode offers the following insights on the relative importance of drivers and the nature of energy price shocks.

First, the decomposition of the 8 percentage point surge in inflation into contributing factors suggests that the five identified shocks account for more than 60 percent of the inflation surge—approximately 5 percentage points (Figure 2a, the October-2022 bar). This finding underscores the significant role played by these shocks, while also highlighting the importance of other supply and demand-side forces, beyond energy supply and policy-related demand factors, in explaining the remaining 3 percentage points, and to be revisited using the more refined model in the subsequent Section 4.[8]

Second, as expected, energy supply shocks contributed negatively to economic growth and positively to inflation. Adverse energy supply factors are estimated to have contributed 2.4 percentage

[8]This cumulative impact encompasses both the contemporaneous effects of current shocks and the lagged effects of past shocks.

points to the inflation surge (Figure 2a), i.e. the largest of all contributions, and the only factor driving down economic growth (Figure 2b). Specifically, following the Russian invasion of Ukraine, the contribution of energy supply shocks to headline inflation increased by 0.8 percentage points in March 2022. This result highlights a large but not dominant contribution of energy supply shocks to the inflation surge and is to some extent consistent with the findings in Giannone and Primiceri (2024) and Baumeister (2023).

Third, energy price related factors in the inflation surge are not entirely supply driven. The decomposition suggests that other energy-related shocks contribute approximately 1 percentage point to the inflation surge. This shock can be interpreted as a demand-driven disturbance, as the impulse responses in Figure C.5 indicate that both prices and real GDP increase following the shock. Such a demand shock may originate either domestically within the euro area or externally from global sources, with the latter capturing global demand shocks that increase energy prices while simultaneously stimulating euro area economic activity.

Fourth, expansionary fiscal and monetary policies played important roles in the economic recovery following the pandemic crisis (Figure 2b) while also contributing to inflation. Specifically, approximately 1.5 percentage points of the inflation surge during this period are attributable to expansionary fiscal and monetary demand shocks—0.6 percentage points from fiscal policy and 0.9 percentage points from monetary policy. The positive contribution of fiscal policy aligns with the expansionary fiscal stance in the euro area during 2021–2022 (Bischl et al., 2022; Cepparulo et al., 2024). Regarding monetary policy, our findings indicate an expansionary stance during the post-pandemic period, consistent with Darracq Pariès et al. (2024), which is based on the ECB's workhorse DSGE model.

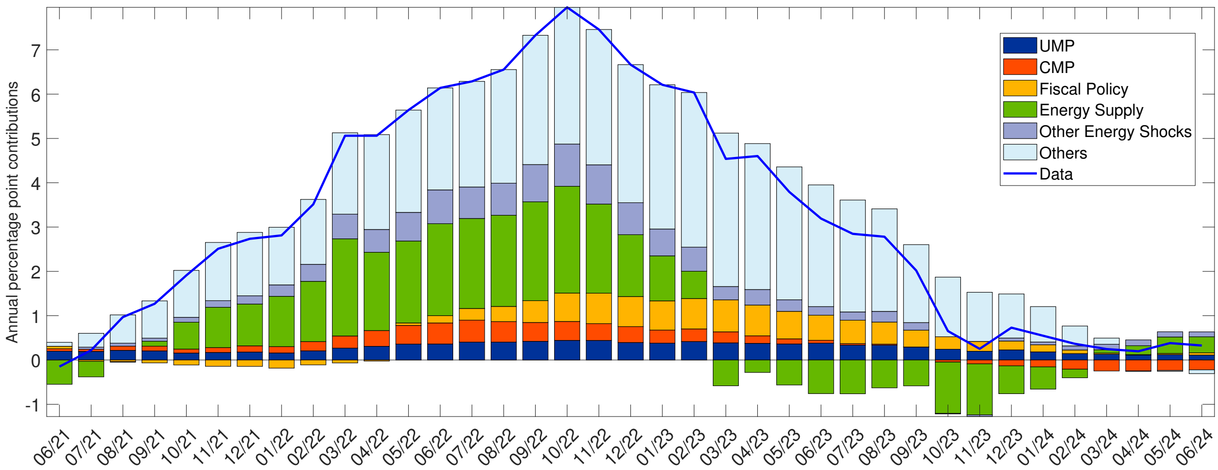
We observe that the majority of monetary policy's contribution to inflation occurred between June 2021 and July 2022, a period during which monetary policy primarily supported economic growth. Conventional and unconventional monetary policy contributed approximately equally to inflation dynamics, each accounting for about 0.45 percentage points at its peak. Interestingly, the peak contribution of conventional monetary policy occurred in July 2022 and declined sharply thereafter, coinciding with the start of the ECB's rate-hike cycle.

3.2.7 Disinflation since October 2022

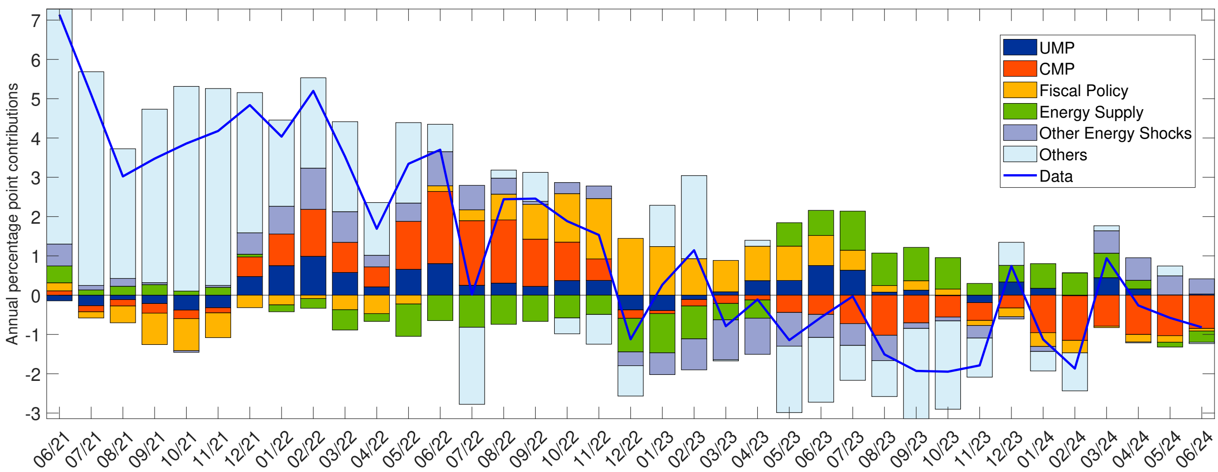
Having peaked at over 10 percent in October 2022, inflation declined to 2.9 percent by December 2023 (and decreased further to reach the 2 percent inflation target by 2025). This 7-percentage-point disinflation reflects negative contributions from all five identified shocks (Figure 3). In addition to policy

Figure 2
Historical decomposition of inflation and output growth

(a) Inflation



(b) Output growth



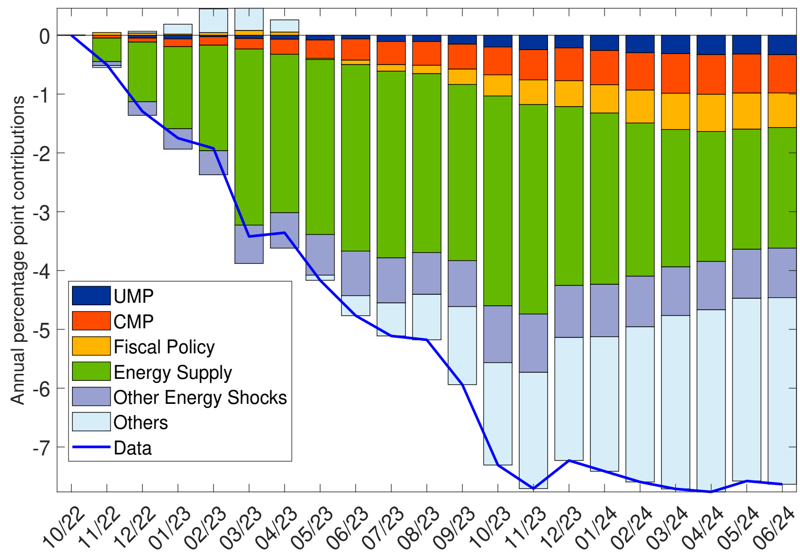
Note: The figure shows the historical decomposition of year-on-year inflation and output growth, excluding the corresponding deterministic components.

tightening and receding energy supply constraints, inflation also abated, to a significant extent, due to factors independent of these shocks.

Quantitatively, monetary policy accounted for a reduction in inflation of 1 percentage point. This reduction encompasses both the diminishing impact of past expansionary shocks and the effects of policy tightening, with conventional monetary policy playing a more prominent role.

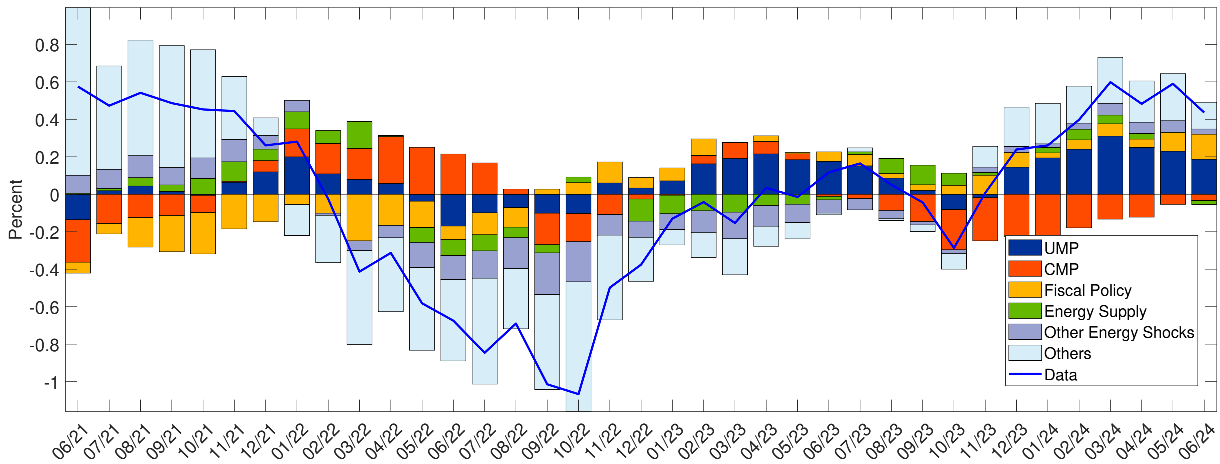
While the ECB tightened monetary policy using the standard interest rate instrument to curb inflation, its unconventional tools supported financial market confidence. This effect can be seen in the decomposition of the risk appetite index during this episode (Figure 4). Several studies, including

Figure 3
Historical decomposition of disinflation between October 2022 and June 2024



Note: The figure shows the historical decomposition of year-on-year disinflation, excluding the corresponding deterministic component.

Figure 4
Historical decomposition of risk appetite



Note: The figure shows the historical decomposition of risk appetite, excluding the corresponding deterministic component.

Bauer et al. (2023) and Akkaya et al. (2024), provide significant evidence of the risk-taking channel of monetary policy. This channel is confirmed by the persistent decrease in risk appetite in response to tightening monetary policy shocks, both conventional and unconventional (as depicted in Annex C, Figures C.1 and C.2). Figure 4 suggests that conventional monetary policy tightening since mid-2022 curbed risk-taking. Conversely, unconventional monetary policy remained broadly accommodative, sustaining risk appetite and safeguarding financial market confidence. So with unconventional monetary policy remaining in place, the ECB supported financial intermediation and prevented a sharper economic contraction.

Similarly, fiscal policy contributed negatively to inflation, accounting for a reduction of 0.6 percentage points. This finding points to a swifter reversal in fiscal policy compared to the IMF's estimate for the US which attributes a cumulative reduction in inflation from fiscal policy of approximately 0.5 percentage points in 2023 (IMF, 2024).

Improved energy supply conditions further reduced inflation by 2 percentage points, while demand-driven energy shocks contributed an additional 1 percentage point reduction in euro area inflation.

Overall, the five structural factors collectively lowered inflation by more than 4.5 percentage points (or 60 percent) between October 2022 and December 2023. This result highlights the effectiveness of monetary and fiscal policies, favorable energy supply conditions, and weaker energy demand in curbing inflation. In sum, the inflationary contributions of these five shocks appear to have been almost fully reversed. The deviation of inflation from target that remained in December 2023 is attributed to factors other than monetary, fiscal, and energy-related shocks.

3.3 Counterfactual analysis of the response of monetary policy

We have demonstrated that monetary policy played a pivotal role in driving the strong post-pandemic economic recovery, while also having some influence on inflationary pressures. How would output and inflation have evolved under an earlier tightening of monetary policy? We address this question using counterfactual scenarios that focus on the path of short-term interest rates. Specifically, we design two scenarios. In the first scenario, the short-term interest rate is raised six months earlier, in January 2022, instead of July 2022, but follows a similar trajectory to reach a peak of 4 percent in the deposit facility rate by March 2023. In the second scenario, the short-term interest rate is raised six months later, in December 2022, also following the same pace and reaching the same peak level.

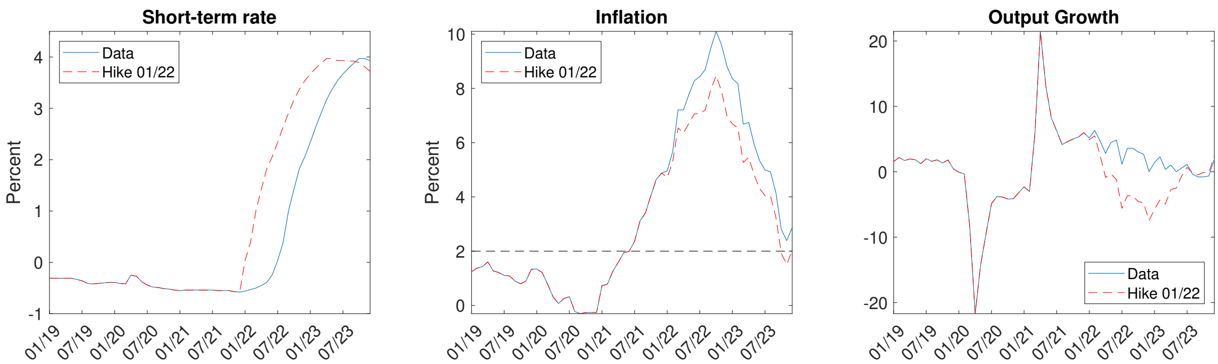
In both scenarios, all other shocks, except for conventional monetary policy shocks, are held constant, including unconventional monetary policy shocks. Conventional monetary policy shocks are adjusted to achieve the targeted short-term rate path. The results of these scenarios are presented in Figure 5.

Raising the interest rate six months earlier would have reduced the peak of inflation by 2 percentage points. Consequently, inflation would have peaked at 8.5 percent instead of 10 percent. However, this earlier tightening would not only have derailed the economic recovery, it would have resulted in a contraction of the economy by 1.6 percentage points between January 2022 and December 2023, compared to the actual 2 percent growth during this period. Conversely, delaying the rate hike until the end of 2022 would have significantly overheated the economy, with inflation reaching 11 percent in October 2022 and generating a 3.7 percentage point higher growth rate.

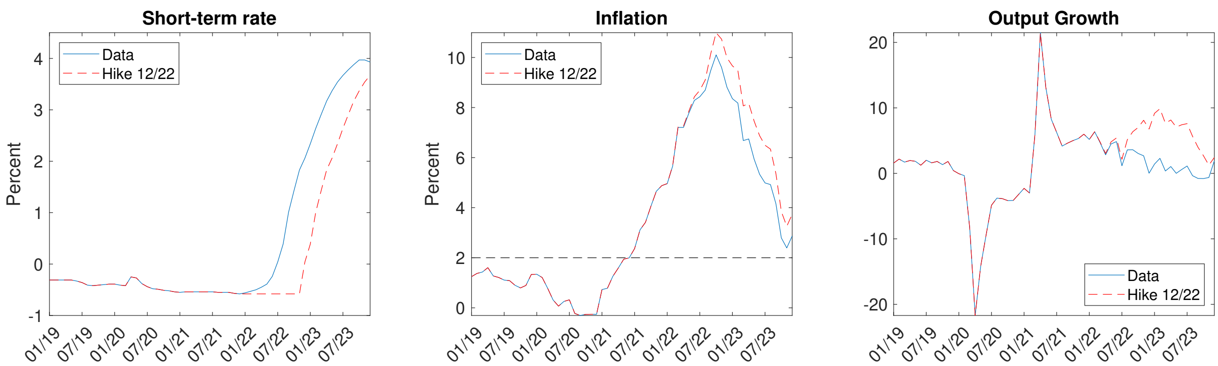
These comparisons illustrate the substantial trade-offs between output growth and inflation control in conducting monetary policy during the inflation surge.

Figure 5
Counterfactual scenarios

(a) Scenario 1: Hiking rate in January 2022



(b) Scenario 2: Hiking rate in December 2022



Note: The figure shows the counterfactual analysis using the estimated baseline model. The simulation assumes that other shocks different from the conventional monetary policy shocks are the same, while changing the conventional monetary policy shocks to achieve that targeted short-term rate path. Both inflation and output growth are year-on-year log differences of headline HICP and real output.

4 Extended model version

4.1 Extension with non-policy aggregate demand and non-energy aggregate supply shocks

The preceding analysis leaves three percentage points of the peak in inflation surge unexplained. Specifically, the baseline model is silent about the role of supply-demand imbalances caused by the pandemic and how these affected growth and inflation. To address this gap, we extend the baseline model, originally comprising five shocks, to further identify general non-energy aggregate supply shocks (AS) and non-policy aggregate demand shocks (AD). The latter excludes demand shocks that simultaneously raise energy prices, as these are already captured by the other energy-related shocks.

This more comprehensive specification allows us to ascertain that the identified policy demand shocks—conventional monetary policy, unconventional monetary policy, and fiscal policy—are not influenced by non-policy demand factors, and that energy supply shocks are not affected by non-energy supply factors. As argued by Paustian (2007), identifying other shocks helps to improve the identification of the shocks of interest. Furthermore, separating policy-related factors from non-policy factors allows us to better analyze growth and inflation developments. This approach helps identify imbalances in demand and supply that can be directly linked to the pandemic period.

To identify the additional shocks, we employ a combination of sign and zero restrictions. These sign restrictions are detailed in the last two columns of Table 3.

Specifically, a negative non-policy aggregate demand shock is assumed to reduce output growth and inflation instantaneously and the short-term interest rate only with a lag. The latter restriction helps to distinguish this shock from the conventional monetary policy shock. Without explicit restriction a non-policy aggregate demand shock causes the long-term interest rate to move in the same direction as output, inflation, and short-term interest rate, as indicated by impulse-response functions (see Appendix D, Figure D.7), therefore distinguishing it from the unconventional monetary policy shock. Additionally, the narrative restrictions on monetary and fiscal policy shocks, reapplied as in subsection 3.2.4, help to differentiate non-policy aggregate demand shocks from identified policy shocks. We further distinguish non-policy aggregate demand shocks from energy-demand shocks by assuming that the former have *no immediate* impact on energy prices. The latter are captured by other energy-related shocks, as described in Section 3.

We assume non-energy aggregate supply shocks, which may have played an important role through different phases of the pandemic, to move inflation and output growth in opposite directions. A favorable shock reduces inflation while increasing output growth, whereas an unfavorable shock raises

Table 3
Sign restrictions in the model with non-policy AD and non-energy AS shocks

Shocks (Row) /Variable (Column)	Tightening CMP shock	Tightening UMP shock	Tightening fiscal policy shock	Negative Energy supply shock	Other Energy related shock	Other AD shock	Other AS shock
Uncertainty							
HICP	−	−	−	+*		C:−	C:+
Energy price	0	0	0	C:++*	C:+	0	0
RGDP	−	−	−	−		C:−	C:−
Short-term interest rate	C:++*	*				−	
Long-term interest rate	C:+*	C:++*	C:−				
Government expenditure			C:−				
Risk appetite	C:−	C:−					
Covid-19 indicator	0	0	0	0	0	0	0

Note: The table lists signs of responses of endogenous variables (in the first column) to tightening conventional MP, unconventional MP, fiscal shocks as well as negative energy supply, other energy related shocks, and non-policy aggregate demand ("Other AD shock") and non-energy aggregate supply ("Other AS shock") shocks. Signs (+ / −) denote restrictions on the direction of the impact of structural shocks on observed variables, accumulated over time. Exclusively contemporaneous sign restrictions are marked by 'C:+'/'C:−', zero instantaneous restrictions by 0 and magnitude restrictions imposing a relatively *higher* absolute instantaneous impact of a shock on comparable macroeconomic variables (marked by ∗) are denoted by 'C:++'.

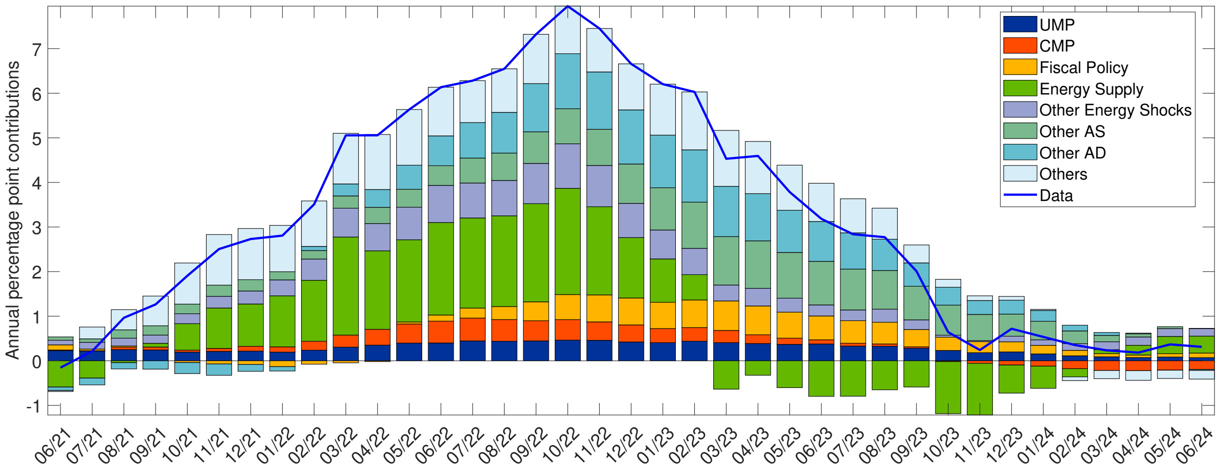
inflation and lowers output growth. While these sign restrictions are similar to those on energy supply shocks, we separate the two shocks by imposing contemporaneous zero restriction for non-energy aggregate supply shocks on energy prices. However, we do not impose restrictions beyond the contemporaneous period, allowing for the possibility of a larger energy price response in subsequent periods.

Annex D shows the estimated impulse responses to the seven identified shocks in this extended model version. Non-policy demand shocks move output, inflation and interest rates in the same direction. Non-energy supply shocks move output and inflation in opposite directions and lead to an increase in interest rates.

4.2 Results from extended model version

This model extension does not alter the decomposition of the relative roles of the previously identified shocks (monetary policy, fiscal policy, and two energy-related shocks) and therefore corroborates our baseline identification and findings (Figure 6). The contribution of monetary and fiscal policy shocks to inflation surge, as measured in the baseline model, does not capture effects caused by non-policy demand shocks. Moreover, energy supply shocks are not influenced by non-energy supply factors as

Figure 6
Model with non-policy AD and non-energy AS shocks: Historical decomposition of inflation



Note: The figure shows the historical decomposition of year-on-year headline inflation, excluding the corresponding deterministic component, from the extended model with non-policy aggregate demand and non-energy aggregate supply shocks.

well.

The two newly identified shocks account for 2 percentage points of the increase in inflation between June 2021 and October 2022. Thereby the non-policy aggregate demand shocks account for 1.2 percentage points, and the remaining 0.8 percentage point increase is caused by the non-energy aggregate supply shocks (Figure 6, October 2022 bar). Consequently, supply and demand imbalances, genuinely related to the pandemic period, account measurably for the inflation surge.

All seven identified shocks explain about 87 percent of the 8 percentage points surge in inflation, leaving 1 percentage point unexplained due to (a combination of) unidentified factors. Supply-side shocks, including energy supply and non-energy aggregate supply shocks, contributed about 3.2 percentage points to inflation surge during this period. Meanwhile, demand-side shocks, including all policy-related shocks, non-policy aggregate demand shocks, and other energy-related shocks, contributed about 3.7 percentage points. These results indicate an important contribution of demand factors to the recent inflation surge, a finding that is in line with Giannone and Primiceri (2024). However, the size of demand-driven contribution to inflation in our model is smaller than their findings, which could be attributable to the unexplained residual in our model (i.e. it may be caused by other unidentified shocks).[9] Regardless of this difference, both studies highlight the importance of demand factors,

[9]Note that in Giannone and Primiceri (2024), inflation is explained fully by demand and supply disturbances in their bi-variate VAR model with GDP and HICP. Meanwhile, we identify seven shocks in a model with nine variables. These reduced-form residual shocks unidentified in our model could act as a buffer and capture the effects of omitted variables and

including non-policy demand factors, to the inflation surge in the euro area during this episode, as demand expanded faster than supply could keep up with.

Finally, regarding the disinflation episode, we find that the contribution of non-policy aggregate demand shocks to inflation dropped gradually to almost zero by March 2024. Likewise, the contribution from non-energy aggregate supply shocks fell from 0.8 percentage points to almost zero by May 2024. These results can be read as reflecting the dissipation of pandemic-related supply-demand imbalances at the time.

5 Drivers of energy prices through the lens of the extended model

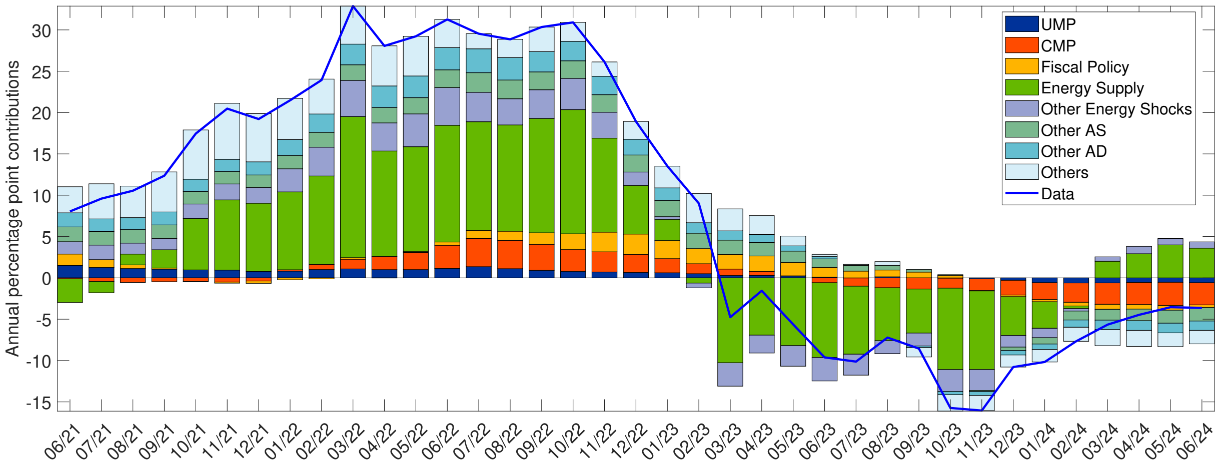
So far we have argued that demand factors also have importantly contributed to inflation development in the euro area. This result seems at odds with findings that the euro area inflation surge was largely driven by supply disturbances associated with the rise in energy prices. For instance, Arce et al. (2024), part of a broader project by Bernanke and Blanchard (2024), find that more than 60 percent of inflation surge was largely due to energy and food prices, which are assumed to be exogenous variables in the price equation. Yet, as these prices may also respond to aggregate demand and policy factors, Giannone and Primiceri (2024) argue that energy and food prices had a demand-related endogenous component. Motivated by this debate, this section assesses demand and supply factors using the extended model with non-policy aggregate demand and non-energy aggregate supply shocks.

The historical decomposition of HICP energy inflation, as shown in Figure 7, suggests that the seven identified shocks explain a large share of the fluctuations in energy inflation, therefore facilitating a meaningful comparison of the role of various shocks to energy inflation. In more detail, adverse energy supply shocks constitute the most important component and increased substantially in March 2022 in the context of the Russian invasion of Ukraine. During the period from March to October 2022, as expected, adverse energy supply shocks were key drivers of energy prices, accounting for about 46 percent of the surge in energy prices. The contribution from policy and non-policy demand shocks is not trivial as well, explaining about 40 percent of the energy-price surge. Accordingly, and in contrast to many studies on the pandemic-era inflation surge, we find that accommodative policies and the post-pandemic decompression of demand were also significant contributors to the energy-price spike. These factors played a role alongside the commonly assumed energy supply disruptions.

Similarly, energy price deflation in 2023 was also largely driven by both, negative demand shocks

other shocks which are different from the seven identified shocks.

Figure 7
Model with non-policy AD and non-energy AS shocks: Energy inflation



Note: The figure shows the historical decomposition of year-on-year energy inflation, excluding the corresponding deterministic component, from the extended model with non-policy aggregate demand and non-energy aggregate supply shocks.

and favorable energy supply conditions. Year-on-year energy inflation decreased by about 34 percentage points between October 2022 and June 2024, with an 11.5 percentage point reduction coming from energy supply shocks and a 15.5 percentage point reduction from all demand-side shocks.

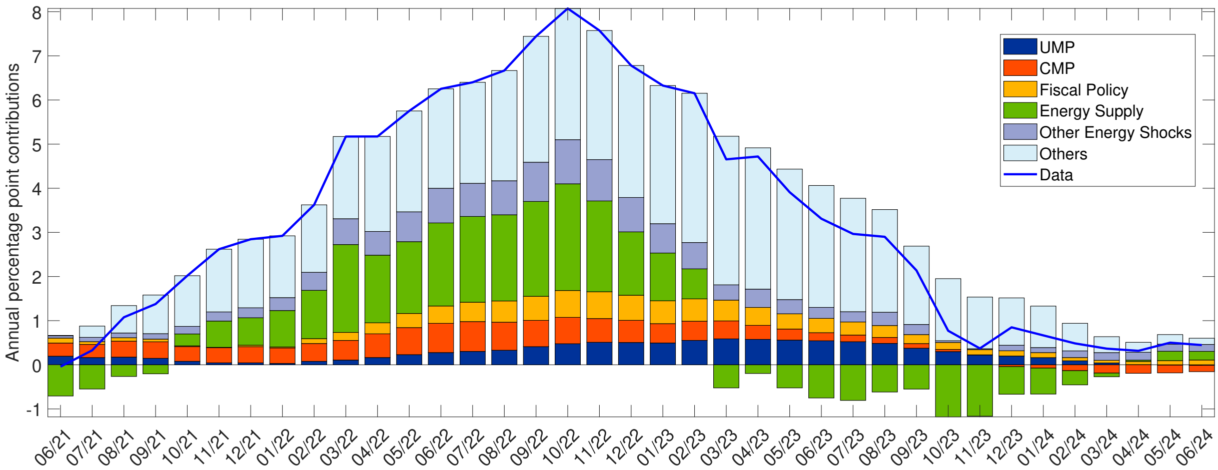
These findings therefore indicate that energy inflation was not only driven by energy supply disruptions but, to some extent, also by demand factors. Our findings further suggest that expansionary policies, supporting the economic recovery, were likely the key contributors to increasing energy demand, which in turn pushed up energy prices, explaining about 30 percent of the energy inflation surge. Conversely, the subsequent tightening policies to combat inflation contained demand and lowered energy price inflation. While these results underscore the importance of energy price inflation for euro-area inflation dynamics during this period, they also highlight that energy price dynamics are not exogenous factors, but need to be understood in the light of broader aggregate demand and supply imbalances.

6 Robustness checks

6.1 Alternative measurement of unconventional policies

Unconventional monetary policy shocks have so far been identified based on the *price* channel, i.e., long term interest rate, together with sign restrictions on output, price, and risk appetite. We conduct a robustness check by considering the quantity channel via the ECB's total assets, following Gambacorta et al. (2014) and Weale and Wieladek (2016). Basically, we replace the long term rate in the baseline model by the ECB's total assets. We adjust the sign restriction that a tightening unconventional monetary policy shock would reduce total assets in either three months or six months after the shock, while keeping sign restrictions on other variables as in the baseline. Also, we replace the inequality restriction between short-term rates and long-term rates to distinguish between conventional and unconventional monetary policy shock by a zero restriction that conventional monetary policy does not raise the ECB's assets simultaneously. This extension leads to a similar result (Figure 8), therefore corroborating our findings.

Figure 8
Model with ECB's total assets: Historical decomposition of inflation



Note: The figure shows the historical decomposition of year-on-year headline inflation, excluding the corresponding deterministic component, from the extended model with ECB's total assets.

6.2 Other robustness checks

We also conduct other robustness checks. First, we use industrial production as a measure of economic activity instead of monthly real GDP. Second, we consider different lag structures, with three and four lags.

Last, we so far exclude all energy-related fiscal support from government expenditure. Prior to Russia's invasion of Ukraine, such support was relatively limited. Following the surge in energy prices in 2022, however, euro area countries adopted a broad range of energy support measures, including both price suppressing and non-price suppressing measures (Checherita-Westphal and Dorrucci, 2023;

Dao et al., 2023). Price-suppressing measures, possibly expansionary, can lower inflation at least in the short run, therefore differing from conventional expansionary fiscal expenditure shocks. However, this effect can be also offset by the non-price suppressing components, such as disposable income support to households (including subsidies and transfers). Owing to the limited sample period for these measures, we cannot separate the inflationary versus deflationary-energy support fiscal shocks. In the baseline version of our model, we therefore exclude all energy-related expenditure support (transfers and subsidies to households and support to firms) from Jan 2022, interpolated from quarterly energy support as documented in Checherita-Westphal and Dorrucci (2023). Alternatively, in a sensitivity analysis we use total government expenditure, which also encompasses energy-related support measures.

As shown in Annex E, for all these cases we obtain similar historical decompositions, therefore corroborating our findings.

7 Conclusion

For the conduct of monetary policy and the design of monetary policy instruments it is crucial to understand the drivers behind the exceptional pandemic-era inflation surge of 2021-2023. This quantification requires a convincing identification strategy, based on a comprehensive set of macro-economic variables, to identify supply and demand factors behind inflation dynamics, acknowledging that, even though energy is a production input, energy prices respond to both supply and demand factors. Energy-supply disruptions in the wake of the Russian invasion of Ukraine triggered a spike in energy prices, but one cannot exclude that this spike was also compounded by demand expanding faster than supply in the post-pandemic environment and because of policy stimulus. For demand factors in turn, we need to further distinguish non-policy and policy factors, including the role fiscal policy, of the standard interest rate instrument of monetary policy and of unconventional monetary policy instruments.

Accordingly, our Bayesian vector autoregression (BVAR) model identifies non-energy supply and policy and non-policy demand factors, including fiscal policy, conventional monetary policy and unconventional monetary policy to understand the sources of the exceptional pandemic-era inflation surge in the euro area. We find that policy-related demand, while being the main driver of economic recovery, contributed about 1.5 percentage points to the headline inflation surge, with a contribution of 0.6 percentage points from fiscal policy, and about 0.9 percentage points from conventional monetary policy and unconventional monetary policy, with broadly equal contributions from both components. The contribution of energy supply shocks added about 2.4 percentage points to headline inflation leaving measurable scope for non-energy supply disruptions to act as inflation drivers.

In total, genuine supply side constraints, reflecting mostly energy supply disruptions but also pandemic-related supply constraints, were key drivers in the initial run up of inflation. Subsequently, aggregate demand factors, including both policy and non-policy factors, caught up, thereby explaining a large share of the surge in headline inflation and a significant part of the energy inflation surge as well.

Many observers argued that policy makers were too slow to react to the inflation surge. Our findings suggest that the contribution from policy, especially from monetary policy, to the inflation surge has been relatively limited. In our counterfactual model-based exercise we show that raising interest rates earlier would have shaved only about 1.6 percentage points of the over 10 percent peak in headline inflation, so it would not have arrested the inflation outbreak, and would have generated substantial output losses.

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Appendix

A Data

We combine datasets from different sources as presented in Table A.1. The sample period of monthly data ranges from January 2007 to June 2024.

Table A.1
Data Description

Variable	Source
Macro Uncertainty	Comunale and Nguyen (2025)
HICP	ECB SDW
HICP Energy	ECB SDW
Real GDP	Eurostat, Interpolation
Short-term rate	ECB SDW
Long-term rate	ECB SDW
Government Expenditure	Eurostat, Interpolation
Risk Appetite Index	Akkaya et al. (2024)
ECB's Total Assets	ECB
Industrial Production	Eurostat
Economic Sentiment Indicator	European Commission
Covid-19 cases	European Centre for Disease Prevention and Control

Additional information:

- *Real GDP*: The quarterly data is available from Eurostat. The monthly real GDP is interpolated from quarterly real GDP as discussed in Online Annex B).
- *Short-term rate*: Euribor 3-month - Historical close, average of observations through period, Euro area (changing composition), Monthly
- *Long-term rate*: Synthetic Euro Area 10 Years Government Benchmark Bond - Yield, Euro area (changing composition), Monthly
- *Government Expenditure*: The quarterly data (as percent of GDP) is from Eurostat. The monthly ratio of government expenditure to GDP is obtained by cubic interpolation from its quarterly

ratio, which is then multiplied with monthly real GDP to obtain monthly real government expenditure. It excludes the energy expenditure support from January 2022 to the end of the sample. The monthly energy expenditure support is interpolated based on quarterly data reported in Checherita-Westphal and Dorrucci (2023).

- Data of Real GDP, prices, and government expenditure are working day and seasonally adjusted.
- The risk appetite index for the Euro Area is taken from Akkaya et al. (2024), following the measure constructed for the US by Bauer et al. (2023) to capture the risk-taking channel of monetary policy.

B Construction of Monthly Real GDP

The monthly real GDP is interpolated from quarterly real GDP using two monthly series: industrial production and the economic sentiment indicator. The following interpolation is based on the process proposed by Stock and Watson (2010).

Specifically, quarterly GDP values Q_t are linked to monthly values as follows:

$$Q_t = \frac{q_{1t} + q_{2t} + q_{3t}}{3} \tag{B.1}$$

where q_{it} is the monthly value in the $i-th$ month of quarter t.

Both Q_t and q_{it} are trending variables. Let V_t and v_{it} denote trends for Q_t and q_{it}, respectively. Define $\hat{Q}_t = \frac{Q_t}{V_t}$ and $\hat{q}_{it} = \frac{q_{it}}{v_{it}}$, then we can rewrite Eq B.1 as:

$$\hat{Q}_t = \frac{1}{3V_t} \begin{bmatrix} v_{3t} & v_{2t} & v_{1t} \end{bmatrix} \begin{bmatrix} \hat{q}_{3t} \\ \hat{q}_{2t} \\ \hat{q}_{1t} \end{bmatrix} \tag{B.2}$$

Let X_{it} denotes a set of observed (de-trended) indicators in the $i-th$ month which are used for the interpolation: industrial production and the economic sentiment indicator. Then we model $\hat{q}_{1t}$ as follows:

$$\hat{q}_{it} = \beta_0 + BX_{it} + u_{it} \tag{B.3}$$

in which

$$u_{it} = \rho u_{it-1} + \epsilon_{it} \quad \text{where} \quad \epsilon_{it} \sim \mathcal{N}(0, \sigma_\epsilon^2) \tag{B.4}$$

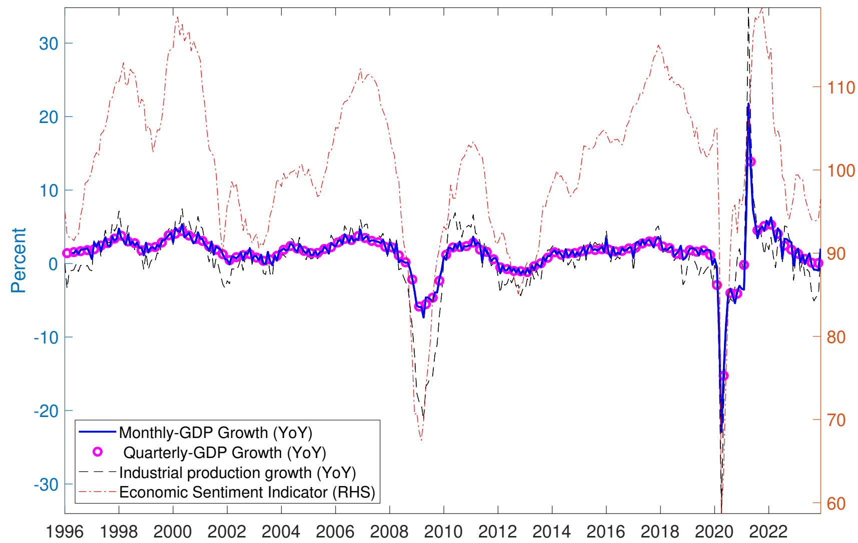
Following Stock and Watson (2010), the quarterly trend V_t is obtained from a cubic trend, while the monthly trend v_{it} is computed by using cubic spline data interpolation from the quarterly trend. The system *B*.2, *B*.3, and *B*.4 forms a linear state-space model with *B*.2 being the measurement equation and *B*.3, and *B*.4 being the transition equations. Hence, the system includes one observable variable and four state variables.

Conditional on the trends V_t and v_{it}, parameters $\beta_0,\ B,\ \rho,\ \sigma_\epsilon$, and the initial values of state variables, $\hat{q}_{it}$ can be estimated by the Kalman smoother, which is then multiplied by the corresponding trend value to generate the monthly value of GDP.

We estimate $\beta_0,\ B,\ \rho,\ \sigma_\epsilon$, and the initial values of state variables $[\hat{q}_{30}, \hat{q}_{20}, \hat{q}_{10}, u_0]$ using maximum a posteriori estimation. based on the quarterly real GDP data and two (detrended) monthly series: industrial production and the economic sentiment indicator.

For the prior distribution, we assume a normal distribution for β_0 and B, with mean and standard deviation obtained from an OLS estimation of (detrended) monthly GDP, which is constructed from a simple spline data interpolation, on a constant term and industrial production and the economic sentiment indicator. For ρ, a beta distribution is used with a mean of 0.5 and a standard deviation of 0.2. The initial state variables $[\hat{q}_{30}, \hat{q}_{20}, \hat{q}_{10}]$ share the same prior distribution with a mean of 1 and a standard deviation of 0.2, while being bounded between 0.8 and 1.2. The prior distribution for u_0 is a normal distribution with a mean of 0 and a standard deviation of 1. Lastly, the prior distribution for σ_ϵ^2 is an inverse gamma 2 distribution with a mean of 0.01 and an infinite standard deviation.

Figure B.1
Constructed monthly-GDP series



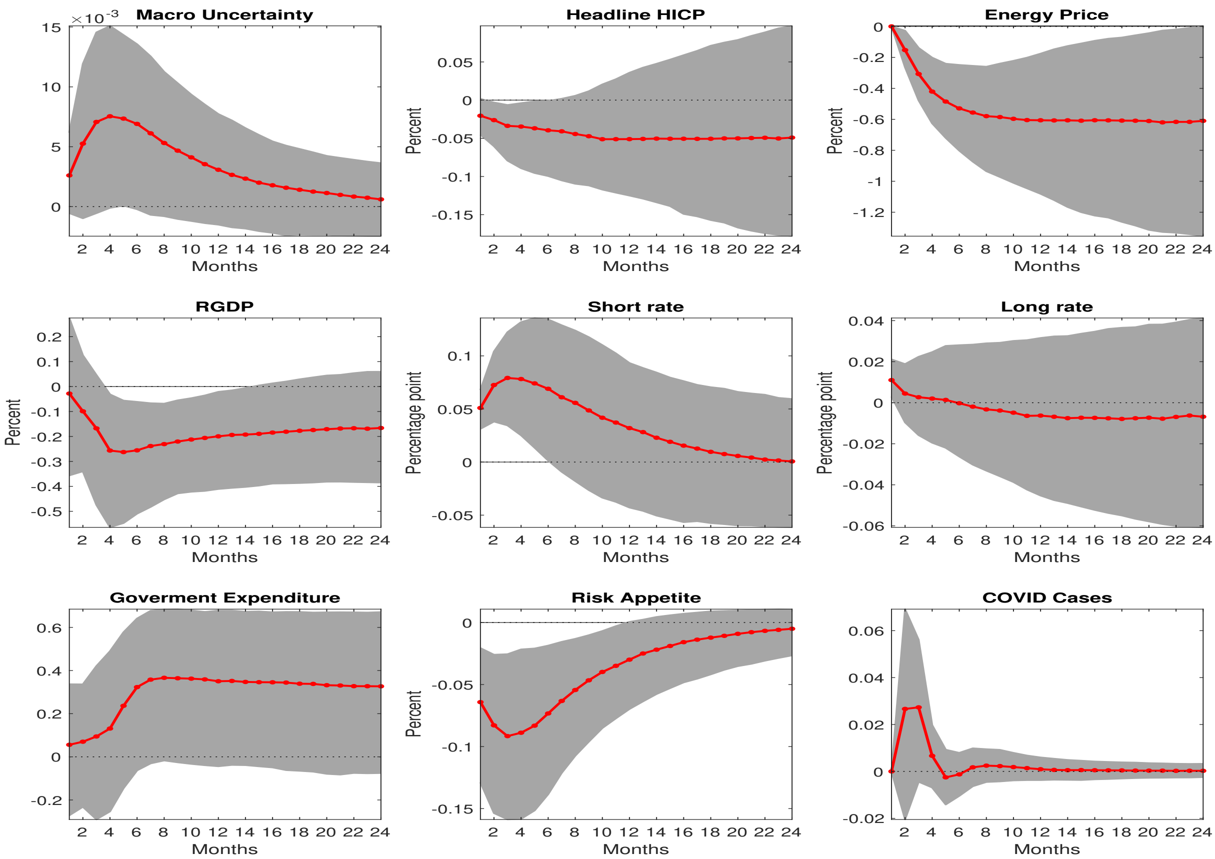
Note: The figure shows the year-on-year growth rate of the constructed monthly real GDP series together with the year-on-year growth rate of quarterly-GDP-series, the year-on-year growth of the industrial production and the economic sentiment indicator (right axis).

C Results from baseline model

We begin by reviewing the responses to five identified shocks. Impulse-response functions are shown with their corresponding 68 percent confidence bands.

First, a positive standard deviation shock to conventional monetary policy, raising the short term rate contemporaneously by 5 basis points, induces a contraction in demand, lowering both prices and output. Prices gradually fall, reaching a reduction of about 0.05 percent after two years (see Figure C.1). Output falls more sharply, with a trough of 0.25 percent in the fourth month and remains significantly negative through the end of the first year. While the response of energy prices is restricted to zero on impact, it subsequently decreases by more than 0.5 percent after one year, consistent with weaker aggregate demand. Meanwhile, government expenditure increases, with credible intervals marginally including zero, likely reflecting the automatic stabilizers. Risk appetite declines on impact, as expected, due to the contemporaneous sign restriction. It continues declining, reaching its trough at 0.1 (which is about 10 percent of its standard deviation) after three months, and remaining significant even a year after the shock. This result aligns with the risk-taking channel of monetary policy transmission as also documented for the euro area (see Leombroni et al., 2021; Akkaya et al., 2024). As expected, Covid-19 cases show little responses, compared to its standard deviation of 0.4, due to its exogenous nature. After an initial slight increase partly due to the sign restriction, the long term interest rate edges down gradually following the economic contraction; however, the intervals indicate high uncertainty. Finally, the short term rate gradually reverts back towards baseline in the second quarter after the shocks in response to weaker demand conditions.

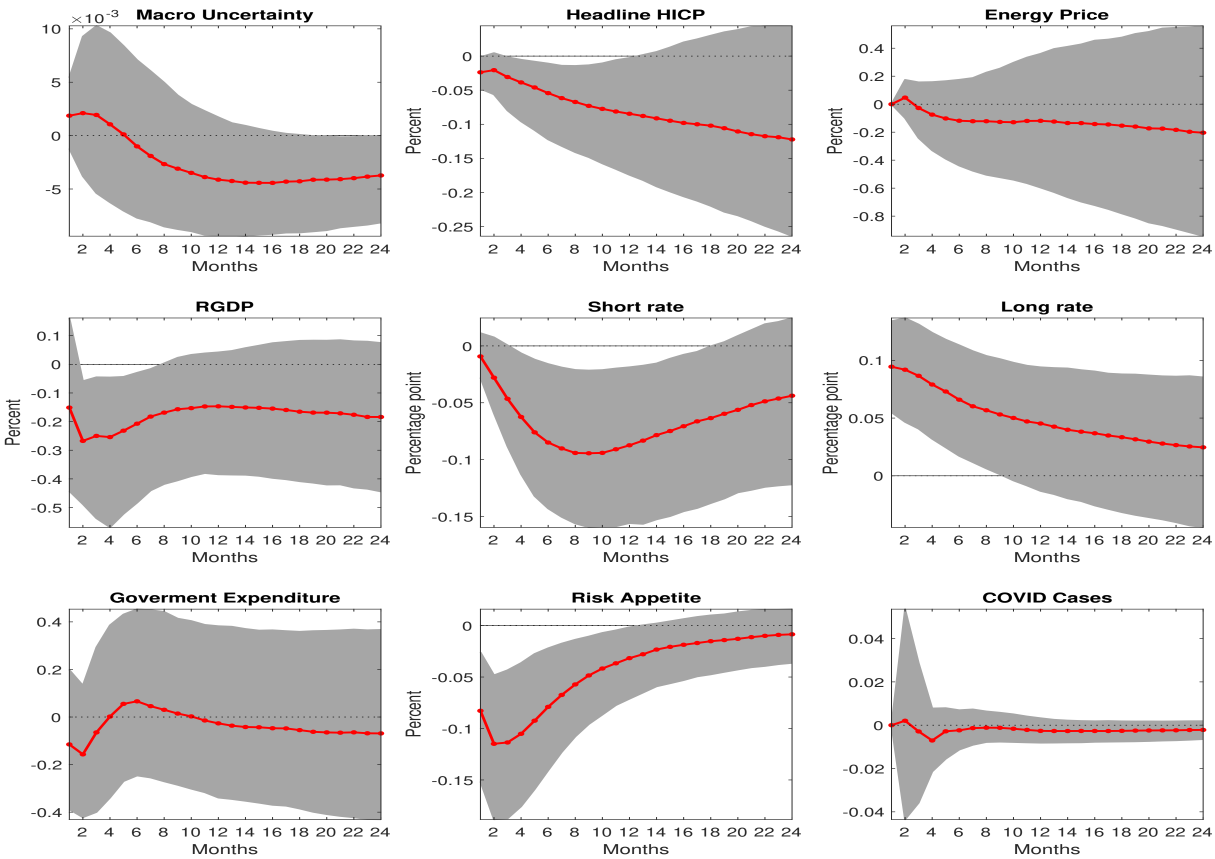
Figure C.1
Impulse responses to a one standard error tightening conventional monetary policy shock



Note: Impulse responses to a one standard deviation tightening conventional monetary policy shock. The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

Similarly, a tightening unconventional monetary policy also leads to an economic slowdown, reducing output and price (see Figure C.2). The response of output is also similar with that of a conventional monetary policy shock. In contrast, prices appear to drop more over the medium term, although the effect is not significant beyond one year. The responses of output and prices are broadly in line with those documented in Kabaca and Tuzcuoglu (2024) on US and Canada for a similar size of drop in 10-year interest rate. The short rate falls in response to these drops in output and price. Interestingly, we do not find a significant response of energy price as in the case with conventional monetary policy. Compared with the conventional monetary policy, we find that the response of risk appetite is somewhat stronger in terms of magnitude, but similar in persistence, again confirming the role of risk taking channel in the transmission of monetary policy shocks, particularly in ECB asset purchases, noting that our long-term interest rate measure is the synthetic yield across euro area sovereign debt, thereby reflecting liquidity and credit risk premia on top of term premia. Specifically, in response to an unconventional monetary policy shock that raises long term rates 10 basis points, risk appetite decreases by about 0.1 percentage points at trough (in the second month) and remains statistically significant one year after the shock—closely mirroring the response to a conventional monetary policy shock. Interestingly, we find that government expenditure contracts in response to a tightening unconventional monetary policy, likely due to higher borrowing costs when issuing debt to finance for those expenditure—although this effect is not statistically significant.

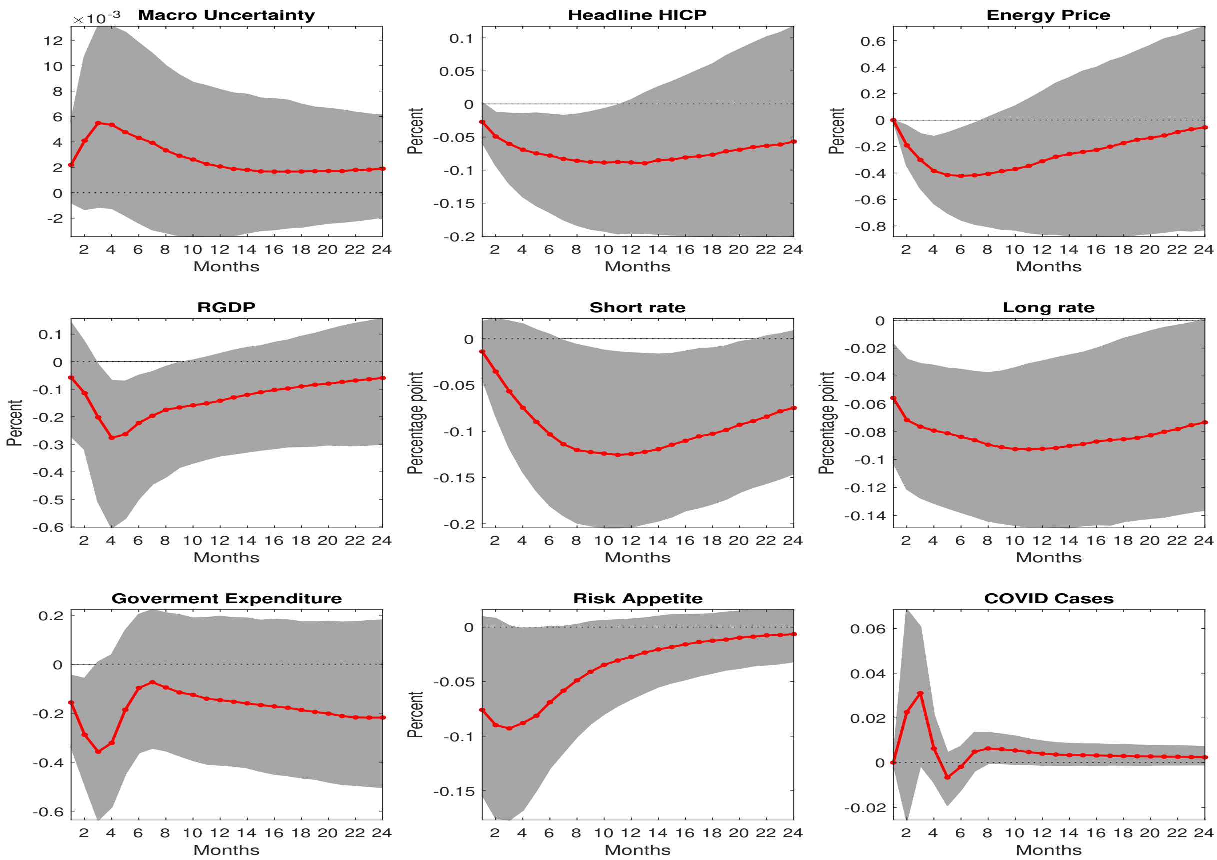
Figure C.2
Impulse responses to a one standard deviation tightening unconventional monetary policy shock



Note: Impulse responses to a one standard deviation tightening unconventional monetary policy shock. The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

A reduction in government expenditure causes a recessionary effect (Figure C.3), which is expected given the sign restrictions. Nevertheless, beyond the restricted horizons the impacts on long term rate, output and price are significant. While the on-impact multiplier is about 0.8, the cumulative multiplier over the 24-month horizon is in between 1 and 2, which is in the usual range reported in the literature. For instance, Amendola et al. (2020) find that the cumulative multiplier for 1-2 year horizon in the euro area is about 1.1 under the normal condition times and 1.6 under the effective lower bound. In addition, long term rates fall by 6 basis points on impact, reaching almost 10 basis points at trough about 1 year after the shock and remaining significantly.

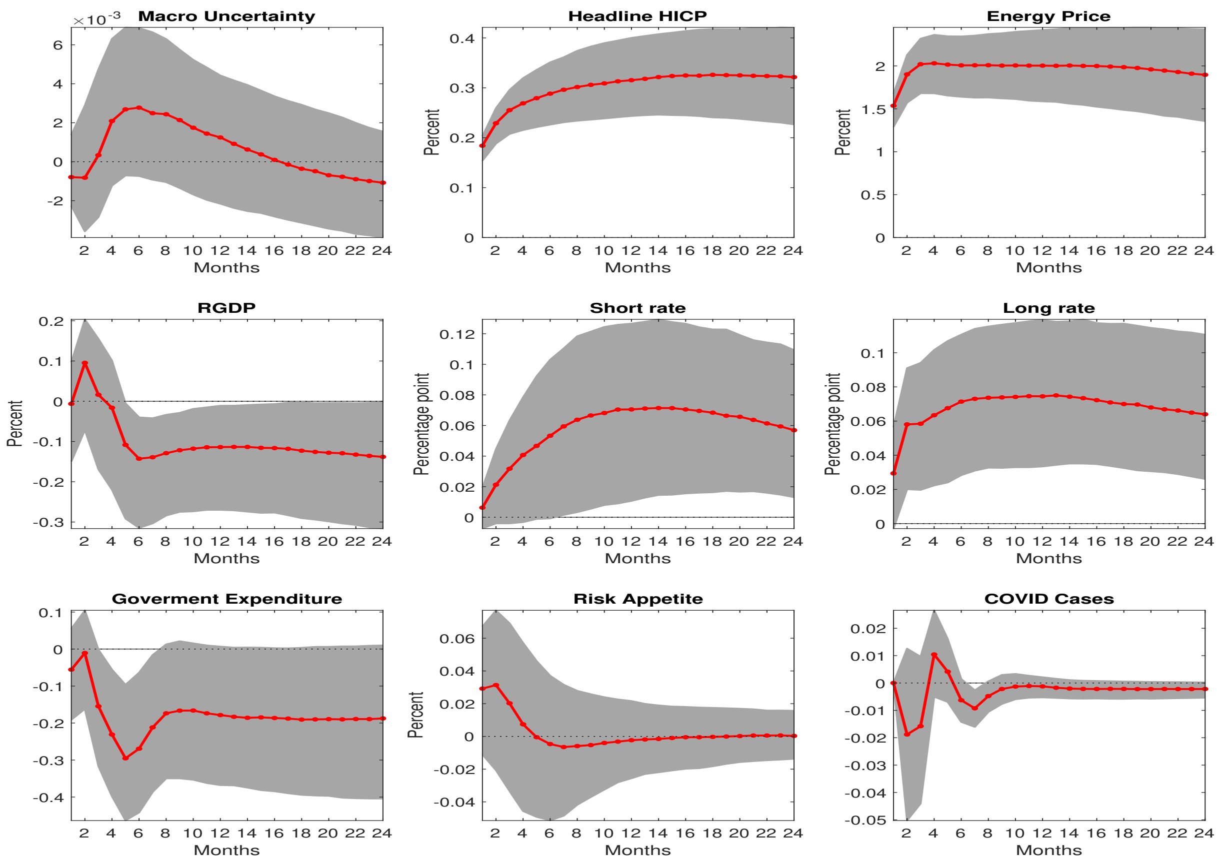
Figure C.3
Impulse responses to a negative one standard deviation government expenditure shock



Note: Impulse responses to a negative one standard deviation government expenditure shock. The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

In response to a negative energy price shock (Figure C.4), energy prices rise by 1.5 percentage points on impact, passing through to the HICP with an increase by 0.2 percentage points on impact and by 0.3 percentage points at peak. This supply shock lowers GDP by 0.15 percentage points six months after the shocks. Short term rates increase in response to higher inflation. Long term rates go up, likely due to the persistent inflationary impact of the shock, which leads to a decrease in government expenditure due to higher borrowing cost for the government. The response of risk appetite to energy price shocks is small and not significant.

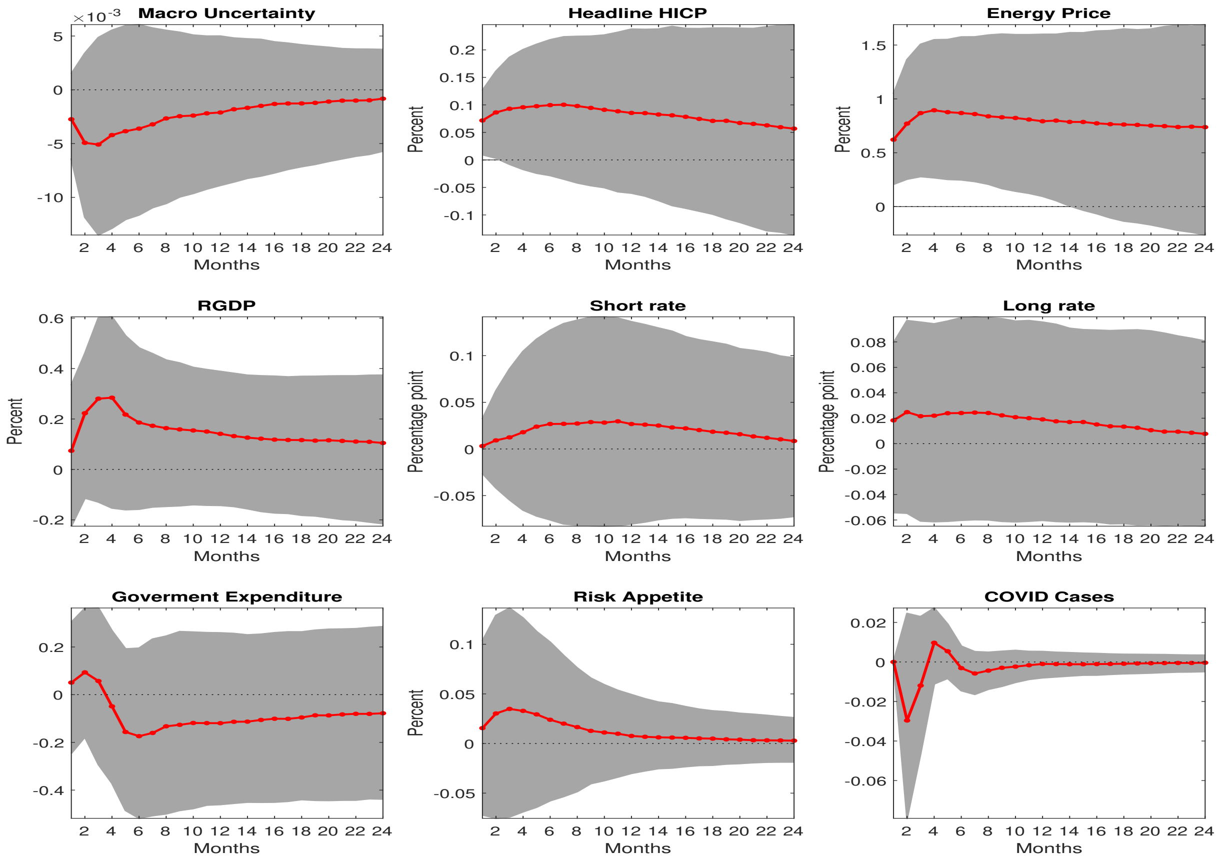
Figure C.4
Impulse responses to a negative one standard deviation energy supply shock



Note: Impulse responses to a negative one standard deviation energy supply shock. The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

Last but not least, we also identify other energy-related shocks, capturing all shocks that affect energy prices contemporaneously, differing from energy supply shocks, such as aggregate demand or energy-specific demand shocks (Kilian, 2009). In response to this shock, energy prices increase as expected and remain persistent, while both HICP and real GDP rise even without any specific restrictions on these variables (Figure C.5). Therefore, these dynamics suggest that the shock primarily reflects stronger demand, which drives up energy prices.

Figure C.5
Impulse responses to a one standard deviation to other energy-related shock

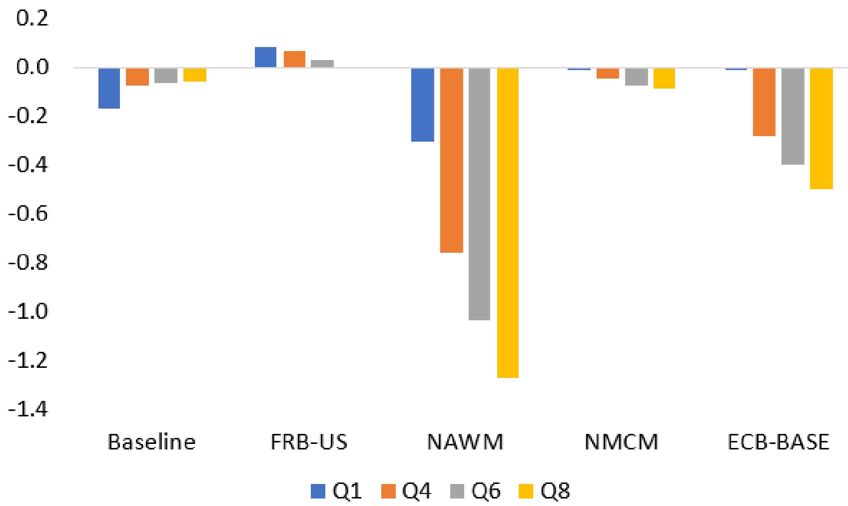


Note: Impulse responses to a one standard deviation other energy-related shock. The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

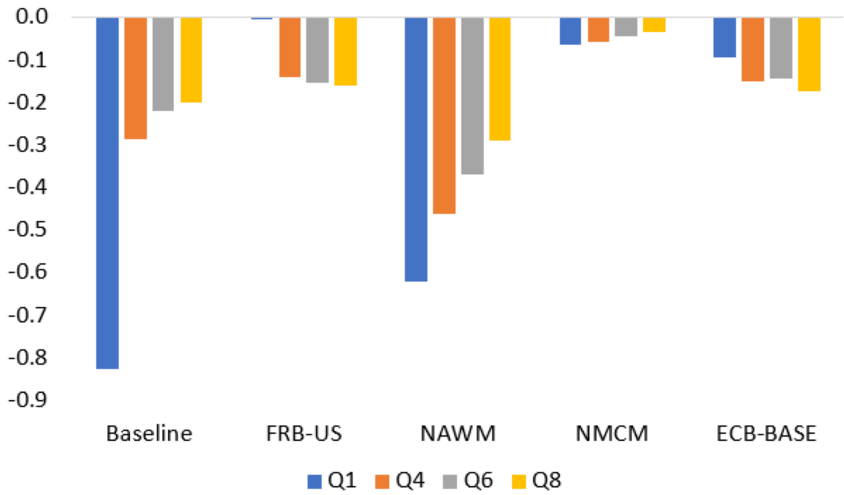
Quantitatively, these impulse-responses align broadly with that of other central-bank workhorse models for monetary policy analysis. In Figure C.6 we compare the impulse-responses of our baseline model version with those from three widely used ECB models—the New Area Wide Model (Coenen et al., 2018), the New Multi Country Model (Dieppe et al., 2011), and the ECB-BASE model (Angelini et al., 2019)—as well as the FRB-US model (Brayton and Tinsley, 1996). While these models are specified at a quarterly frequency, our responses are monthly. To facilitate the comparison, for all models, we first rescale the responses of output and prices at each horizon by the cumulative change in the short-term interest rate up to that point. The quarterly response in the baseline model is taken as the rescaled value in the last month of the quarter which is then compared with the quarterly responses from the other models, as illustrated in Figure C.6. The interpretation is then straightforward, reflecting the responses to a cumulative increase by one percentage point in the short-term rate. Overall, the output and prices responses from our baseline model lie within the range of these models.

Figure C.6
Responses to monetary policy shock across models

(a) Panel A: Price responses



(b) Panel B: Output responses



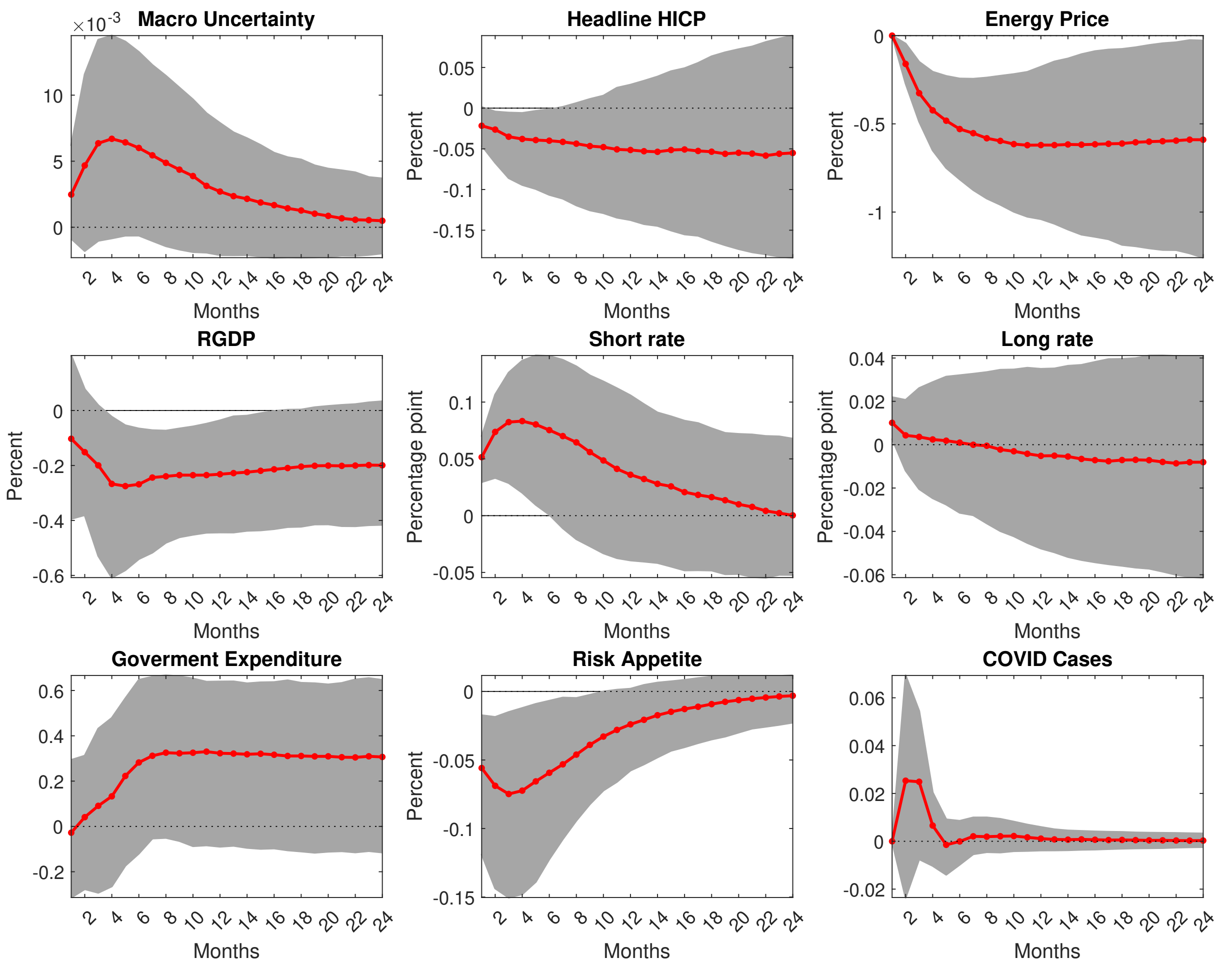
Note: This Figure compares the responses of output and prices, scaled by the cumulative change in the short-term interest rate up to selected quarters. It reflects the responses to a cumulative increase by one percentage point in the short-term rate. NAWM: New Area Wide Model, NMCM: New Multi Country Model, the ECB-BASE model, and the FRB-US model.

D Extension with non-policy aggregate demand and non-energy aggregate supply shocks

The extended model further identities two additional shocks: other non-policy aggregate demand and non-energy aggregate supply shocks. This extension also serves as a robustness check for the baseline response. In this annex, we plot the impulse reposes to the shocks identified in the extended model. Impulse-response functions are shown with their corresponding 68 percent confidence bands.

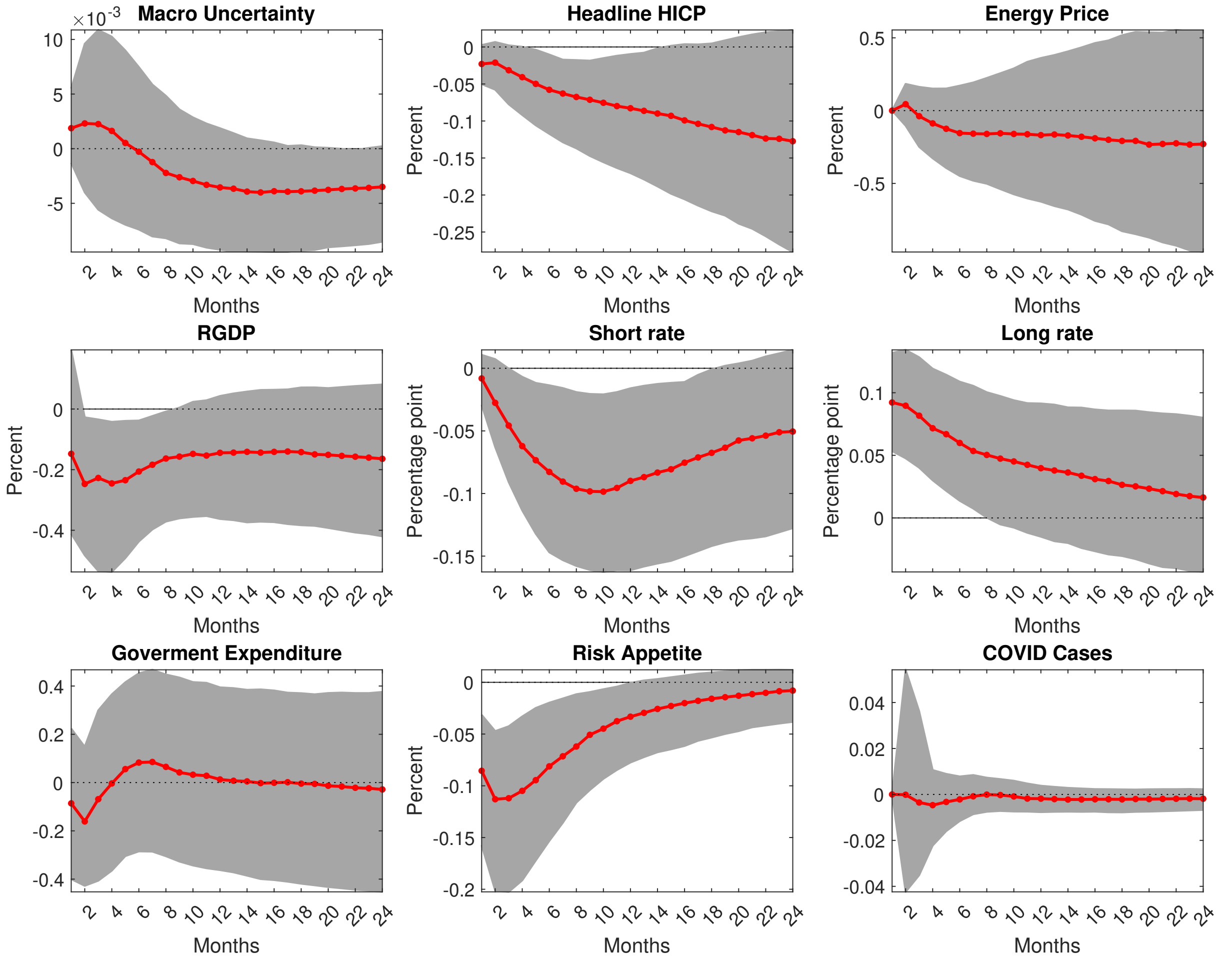
The responses for the five shocks, including conventional monetary policy, unconventional monetary policy, fiscal policy, energy supply, and other energy-related shocks (as plotted in Figures D.1-D.5) are similar to the baseline, therefore corroborate our findings. Furthermore, D.6 and D.7 show additional impulse responses of other aggregate demand and non-energy aggregate supply shocks, confirming their impacts as expected. An aggregate demand shock leads to a decrease in both headline HICP and real GDP contemporaneously, while aggregate supply moves these variables in the opposite directions. In both cases, the shocks have a persistent impact on headline HICP (see Figures D.6 and D.7).

Figure D.1
Impulse responses to a one standard deviation tightening conventional monetary policy shock



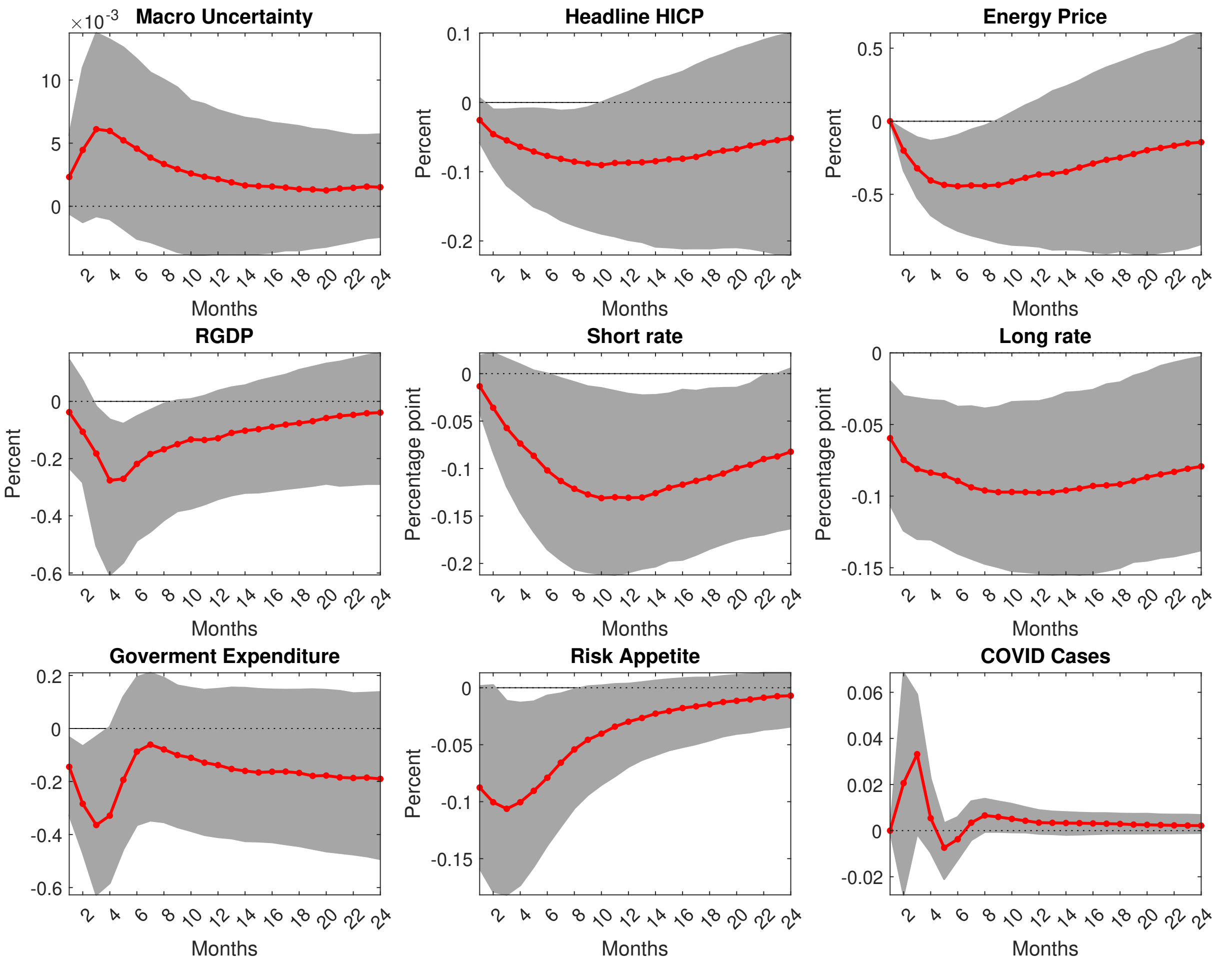
Note: The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

Figure D.2
Impulse responses to a one standard deviation tightening unconventional monetary policy shock



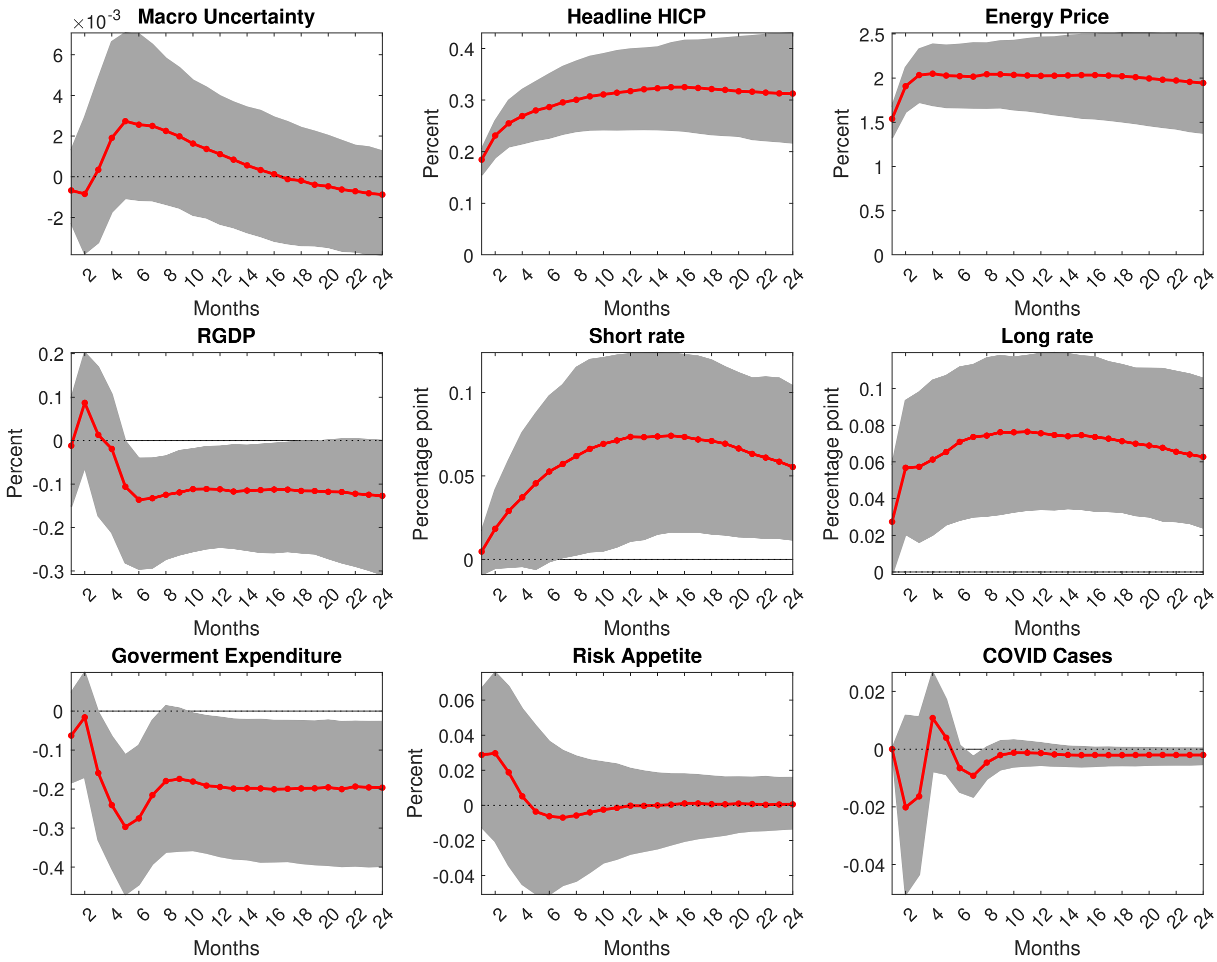
Note: The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

Figure D.3
Impulse responses to a negative one standard deviation government expenditure shock



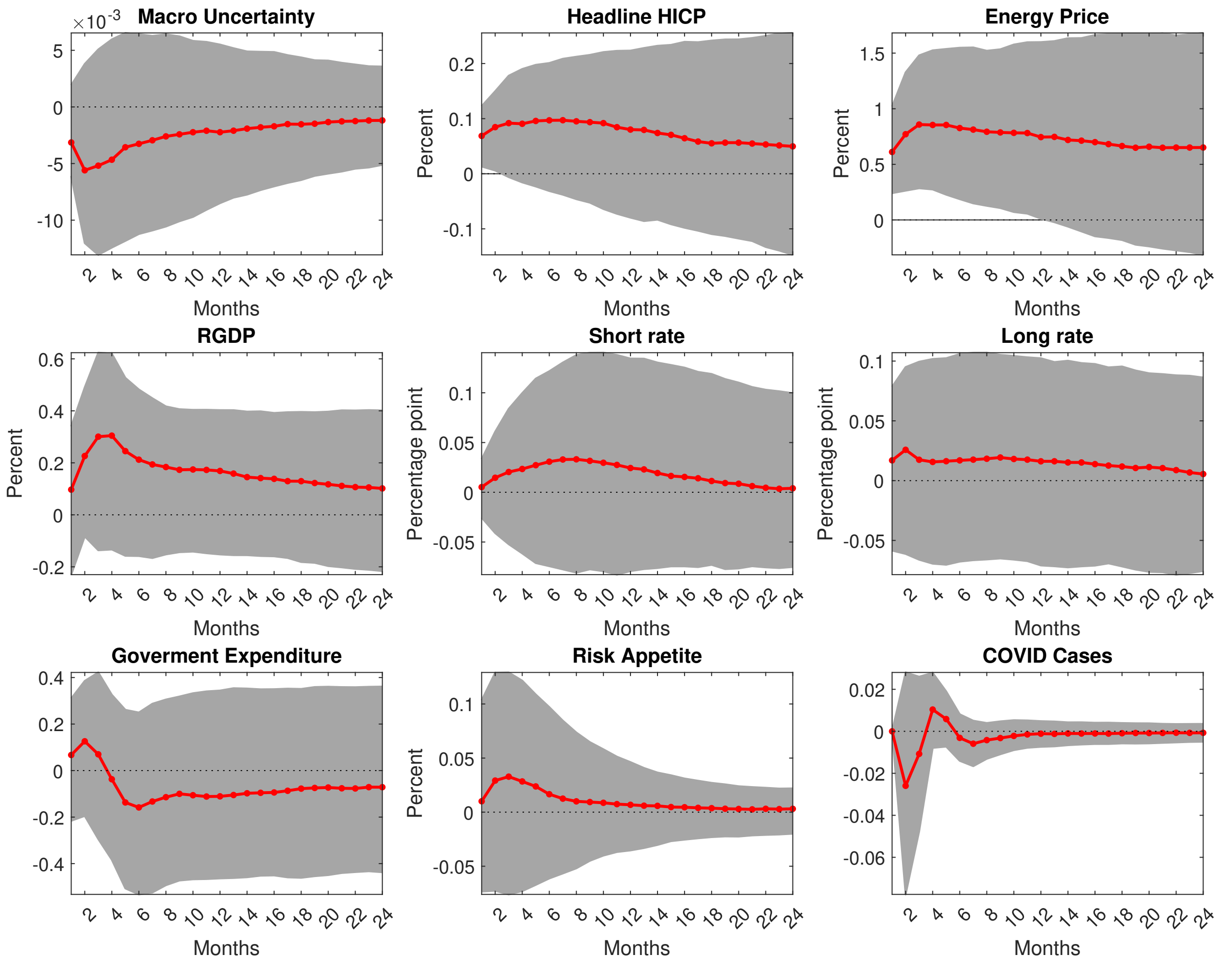
Note: The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

Figure D.4
Impulse responses to a one standard deviation negative energy price shock



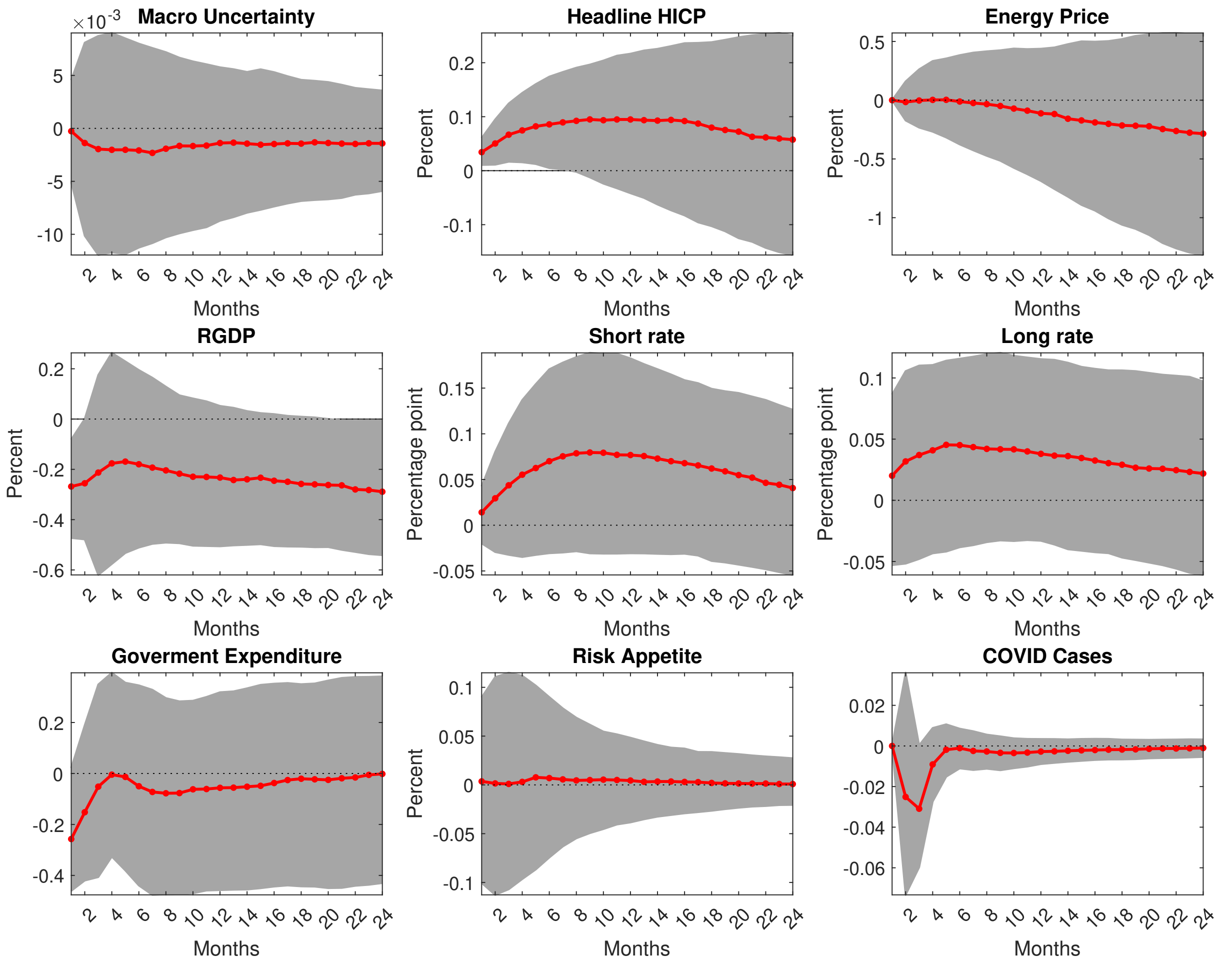
Note: The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

Figure D.5
Impulse responses to a one standard deviation other energy-related shock



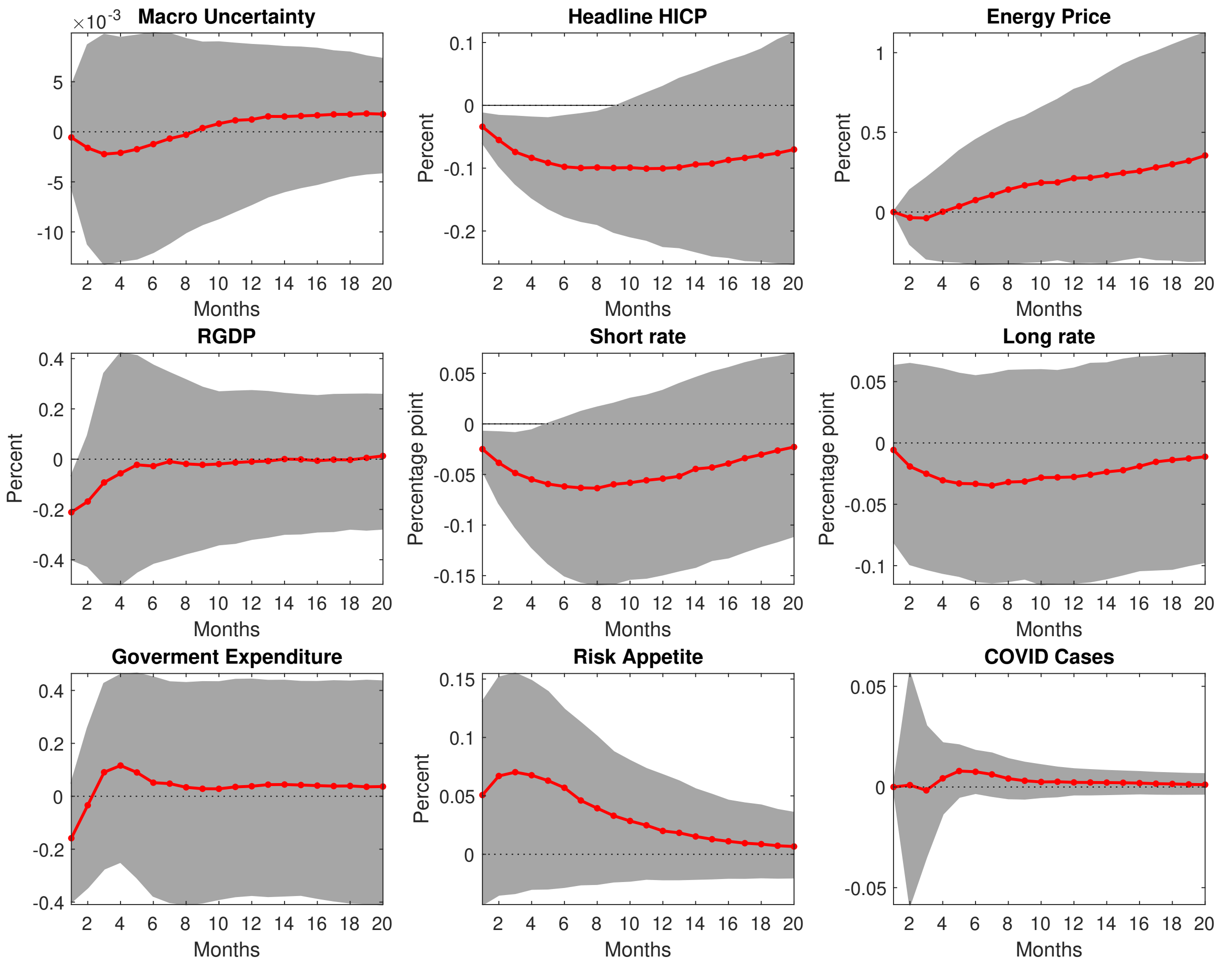
Note: The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

Figure D.6
Impulse responses to an unfavorable one standard deviation non-energy aggregate supply shock



Note: The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

Figure D.7
Impulse responses to a negative one standard deviation non-policy aggregate demand shock

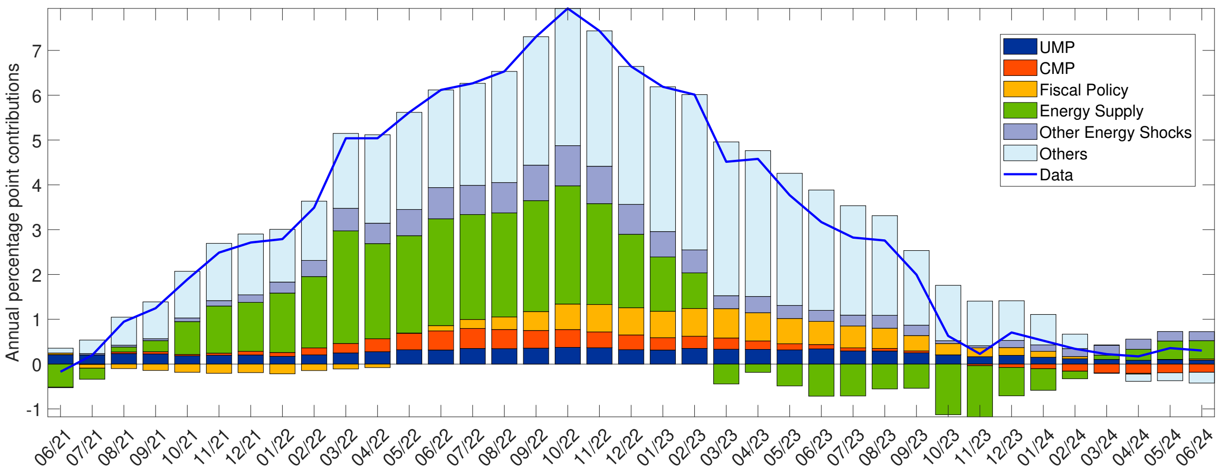


Note: The responses of output, prices, and energy prices are the cumulated responses of GDP growth, inflation, and energy inflation, respectively.

E Other Robustness Checks

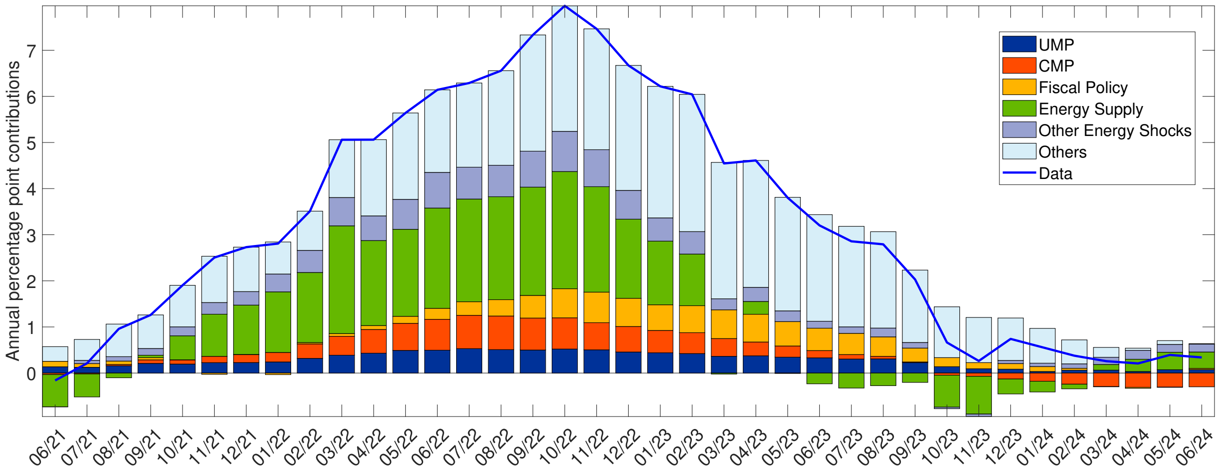
This Annex shows the decomposition of headline inflation for different robustness checks: using industrial production as a measure of economic activity (Figure E.1), considering different lag structures (Figures E.2- E.3), and analyzing with total government expenditure—including energy support (Figure E.4). The results from these analyses are consistent with the baseline model, therefore supporting the robustness of our findings.

Figure E.1
Model with Industrial Production: Historical decomposition of inflation



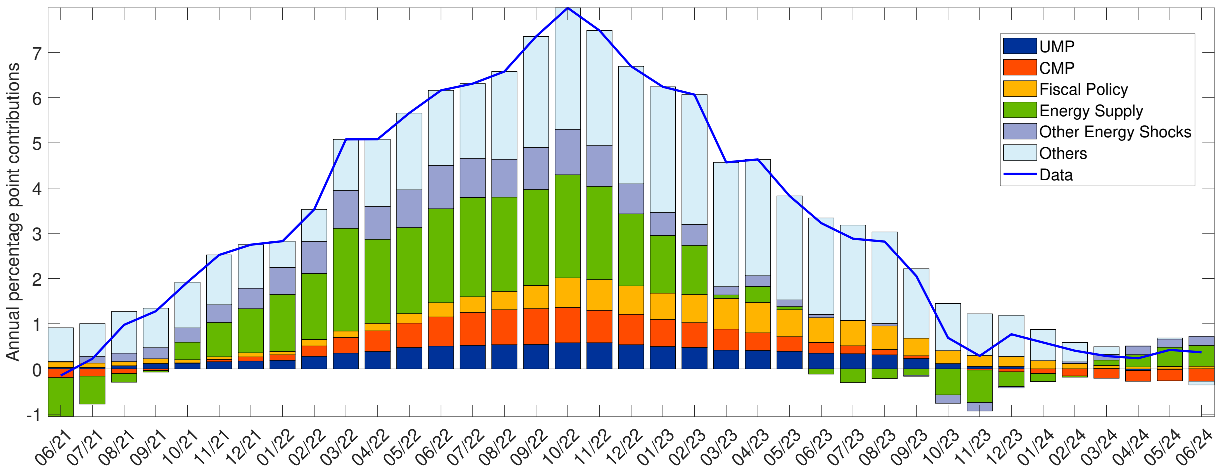
Note: The figure shows the historical decomposition of year-on-year headline inflation, excluding the corresponding deterministic component.

Figure E.2
Model with three lags: Historical decomposition of inflation



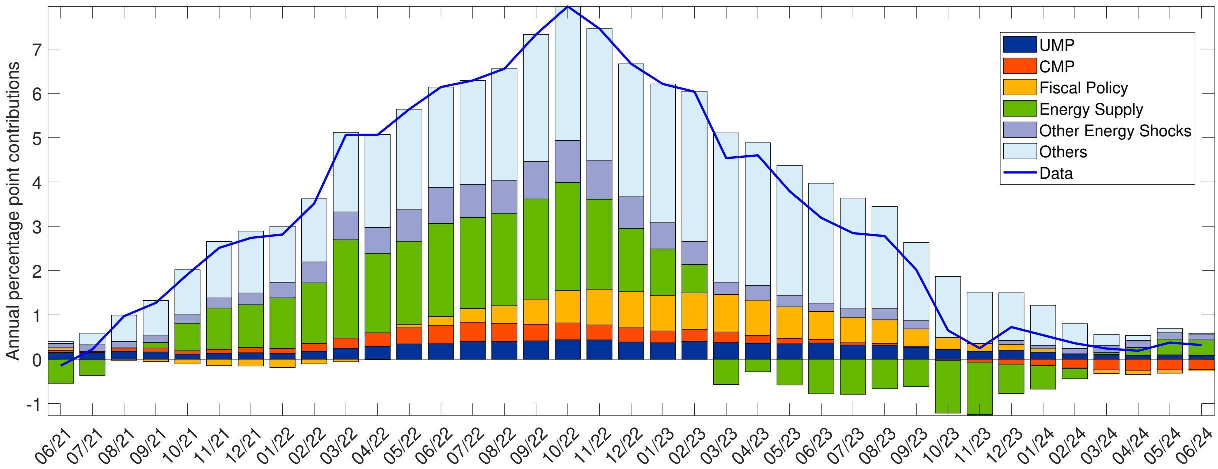
Note: The figure shows the historical decomposition of year-on-year headline inflation, excluding the corresponding deterministic component.

Figure E.3
Model with four lags: Historical decomposition of inflation



Note: The figure shows the historical decomposition of year-on-year headline inflation, excluding the corresponding deterministic component.

Figure E.4
No exclusion of energy support from government expenditure: Historical decomposition of inflation



Note: The figure shows the historical decomposition of year-on-year headline inflation, excluding the corresponding deterministic component.

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