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Monetary policy transmission: a reference guide through ESCB models and empirical benchmarks

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Abstract

This paper serves as a reference guide on the effects of "standard" monetary policy shocks on output and prices, based on harmonised simulation exercises conducted across models of the European System of Central Banks (ESCB), meta-analysis of existing empirical literature for the euro area, and selected works on heterogeneity and non-linearities in the monetary transmission mechanism as captured by empirical models. Our analysis starts by comparing the effects of monetary policy shocks as estimated by structural, semi-structural and dynamic stochastic general equilibrium (DSGE) models, and identifying the main sources of heterogeneity – most notably via the specification of monetary policy rules, the slope of the Phillips curve, the role of real rigidities and financial frictions, and the expectations formation mechanism. While DSGE models tend to produce sharper responses, semi-structural models often reveal more gradual and persistent effects, in line with backward-looking empirical models. The second chapter presents a meta-analysis of estimated effects based on the empirical literature, which are broadly consistent with the results obtained from the ESCB models, although differences might appear when correcting for publication bias, or accounting for different identification frameworks. The study is then complemented by selected works on heterogeneity and non-linearities in the monetary transmission mechanism as captured by empirical models. Our analysis in the final chapter shows that monetary policy transmission is heterogeneous across countries, sectors, demand components, and time. It also reveals important non-linear and state-dependent dynamics: in high-inflation periods, greater price and wage flexibility amplifies the response of inflation while dampening output effects, thereby lowering the sacrifice ratio. Overall, the findings underscore the value of combining model-based results with empirically grounded judgement to capture the full range of transmission channels relevant for monetary policy assessment.

JEL codes: C22, C52, D58, E31, E52, E58, F45

Keywords: monetary policy, inflation, output, semi-structural, structural models, meta-analysis, empirical models, heterogeneity

Executive summary

This paper functions as a reference guide for the impact of "standard" monetary policy shocks on output and prices, as analysed through the lens of the available models in the European System of Central Banks (ESCB) and the average findings of existing empirical literature.

The analysis is based on harmonised simulation exercises performed with ESCB models that are routinely used for policy analysis, with the aim of casting light on the range of impacts and sources of heterogeneity in the transmission of "standard" monetary policy shocks across models. The simulation results are compared with those obtained from a meta-analysis of empirical works focusing on the euro area. The study is complemented by selected works on heterogeneity and non-linearities in the monetary transmission mechanism as captured by empirical models.

The main conclusions of the paper can be summarised as follows:

1. Within ESCB models, structural and semi-structural models provide a coherent and relatively homogeneous set of responses of output and prices to a standard monetary policy shock. DSGE models, due to their forward-looking nature, tend to deliver sharper responses due to intertemporal optimisation by agents. In contrast, semi-structural models, which may not fully incorporate forward-looking behaviour, often exhibit more gradual and persistent responses. This is reflected in the behaviour of consumption: while under DSGE models it reflects strong intertemporal substitution, as portrayed by the Euler equation, under semi-structural models it is mainly driven by permanent income, with a relatively low estimated elasticity of substitution.

2. Two critical factors in determining the degree of heterogeneity across responses within each model category are the specification of the monetary policy rule and the Phillips curve slope. Once the same rule – both in terms of variables and parameter values – is adopted throughout, the variability of inflation and output responses shrinks substantially. Moreover, the underlying supply-side dynamics captured by the Phillips curve are crucial in determining the transmission.

3. Other factors are also important in understanding the transmission mechanism. The role of financial frictions, while important in specific models to capture the role of the financial sector both as a source of disturbances and as an amplification mechanism, appears less clear when comparing the transmission of monetary policy across models when the financial channel is active or – to the extent possible – deactivated. Real rigidities also affect the response of nominal and real variables: reducing parameters such as habit persistence and investment adjustment costs is akin to removing the sluggishness in output response. As a result, in response to an unexpected increase in the policy rate, the fall in output is larger while the response in terms of inflation does not change significantly. Lastly, the role of the expectation formation mechanism is

key in determining the transmission of a monetary impulse. Departures from rational expectations under DSGE models affect the transmission of monetary policy shocks, making the responses closer to those observed in semi-structural models. Some dampening of anticipation effects would appear necessary to obtain empirically plausible results.

4. The distribution of estimated monetary policy effects derived from hundreds of empirical analyses using alternative identification schemes is centred around values that are in line with those obtained from the ESCB models, with no activity or price puzzles, and with average (median) responses peaking at around -0.25 (-0.15) percent after two years for output and at around -0.18 (-0.11) percent after four years for price levels, following an unexpected 25 basis point increase in the policy rate. Both distributions are left-skewed, with the mean absolute value being larger than the median responses for the same interest rate shock.

5. Evidence on meta-averages provides useful insights but should be interpreted with caution, as it is often inflated due to publication bias. Corrected estimates suggest smaller impacts, highlighting the importance of addressing biases in empirical studies. Moreover, the results suggest that the responses of output and prices published in leading journals show stronger dampening effects of contractionary monetary policy than the estimates published elsewhere. In contrast, there is no marked difference between papers authored by central-bank-affiliated researchers and those penned by authors who have no central bank affiliations when it comes to the average and median responses of output and prices to conventional monetary policy shocks. Correcting the estimates would yield final average (median) effects that peak at -0.14 (-0.08) percent for output and -0.08 (-0.05) percent for price level at the same horizons as for non-corrected estimates. Significant differences also exist depending on the identification approach employed, with high frequency and narrative identification schemes reporting the greatest effects.

6. ESCB models yield results that are very much in line with the (average) available empirical literature for the last 30 years. These results are fairly robust across models and across different aspects of the meta-analyses, notwithstanding the caveat that available empirical results are based on specifications that are not necessarily estimated using policy rules or expectation formations that follow the same rules of harmonisation as in the controlled simulation exercises conducted with ESCB models. Reconciling theoretical models with empirical evidence reveals that while there is general alignment, discrepancies exist, particularly in the magnitude of inflation effects. The empirical literature (mostly based on backward-looking VAR-type models) suggests a smaller effect of monetary policy shocks on inflation than that found using the ESCB models, especially typical DSGE models (which include anticipation effects that are not available when using empirical models). Meanwhile, estimated semi-structural models are closer to the VAR or local projections type of evidence, especially in the short and medium run, given also their common backward-looking type of dynamics. Importantly, while some

semi-structural models can be simulated under model-consistent expectations, this does not significantly alter the gap with DSGE-based results, suggesting that other channels drive the heterogeneity.

7. There is evidence of heterogeneous effects across countries, sectors and domestic demand components, reflecting differences in structural economic characteristics.

   (a) Among the main euro area countries, the effects of monetary policy shocks on real GDP are somewhat stronger in Germany. A correlation analysis between country-specific effects and various structural characteristics confirms that heterogeneity could be associated with sectoral composition (importance of manufacturing or industry), labour market flexibility, export share, and the importance of bank lending for firms' external financing. Furthermore, some smaller euro area countries tend to be more sensitive than the euro area as a whole to common monetary policy changes.

   (b) In the short run, manufacturing and construction are more sensitive than services to interest rate changes when it comes to activity and prices, with construction being the most sensitive sector over the medium term. Looking at the demand composition of GDP, business investment is significantly more responsive overall to monetary policy than private consumption. A time-varying analysis also shows that this relatively stronger sensitivity diminished after 2012.

8. The average effects of monetary policy shocks found in the empirical literature and in the models should be interpreted in the context of a monetary policy reaction that is time-varying and depends on the underlying shock and state of the economy. Focusing, for instance, on the period 2022-23, the paper finds that:

   (a) The response of inflation over the monetary policy tightening period of 2022-23 might have been stronger than in previous tightening episodes and associated with a broadly unchanged response of economic activity. This effect – also related to stronger transmission via the credit channel relative to previous tightening cycles – has led to a lower so-called "sacrifice ratio", which allowed the authorities to bring inflation down towards their 2% target without pushing the euro area economy into recession.

   (b) Monetary policy reacted less strongly to demand shocks during the 2022-23 tightening episode compared with the 2005-08 episode, but more strongly to aggregate supply and energy shocks, indicating limited "looking through" in the recent tightening episode.

   (c) State-dependency becomes significant during periods of high inflation, with greater endogenous price and wage flexibility. Therefore, monetary policy has a more potent effect on wage and price inflation in high inflation

regimes, leading to a lower sacrifice ratio, such as the one documented during the 2022-23 tightening episode.

(d)   Inflation expectations were found to be more firmly anchored during the post-pandemic inflation outburst, as the prompt and swift monetary policy response prevented any de-anchoring and the wage-price spirals that characterised earlier episodes of significant adverse supply shocks (such as the oil price shocks of the 1970s).

9.   Lastly, these findings, based on the average impulse response functions of several models and the empirical literature, can be used to inform the judgement and complement a model-based analysis undertaken by monetary policy institutions. Judgement based on these "satellite" empirical models is effective as long as the models are well specified, align with the (unconditional) empirical evidence, and thus capture all relevant transmission channels, which are typically included in standard projection models. Missing channels in the satellite models could lead to an over-estimation of the contribution made by the very feature they are designed to highlight.

1 Introduction

This occasional paper offers an analysis of monetary policy transmission to output and prices within the models maintained and routinely used within the European System of Central Banks (ESCB), which are benchmarked against existing empirical frameworks. The main aim of the analysis is to shed light on the sources of heterogeneity across macroeconomic models in terms of the transmission of monetary impulses, and to provide, to the extent possible, a link to empirical benchmarks. The analysis focuses on changes in the interest rate, which is the main monetary policy instrument, and does not systematically consider so-called unconventional monetary policies, such as asset purchases and forward guidance. Although the paper acknowledges that the macroeconomic outcomes of a monetary policy shock depend on several factors, some important aspects of the monetary policy transmission remain out of scope. For instance, the paper does not include the interaction between monetary and fiscal policy, especially their interplay in the latest tightening episode. This aspect was extensively covered in the ECB's 2021 Strategy Review and updated following the recent upsurge in inflation.[1]

This paper is motivated by a renewed interest in understanding the propagation of monetary policy across macroeconomic models, particularly in light of the disruptive events that have taken place in recent years and the ensuing extensive monetary and fiscal interventions, which might have altered the transmission of (conventional) monetary policy to the economy. It is therefore important to (re-)validate the structural and empirical models regularly used for forecasting and monetary policy analysis.

Our analysis covers those models already in use in the ESCB, with the aim of providing a critical assessment of monetary policy transmission within such models, rather than developing new ones. The empirical benchmarks (largely based on structural VAR models) include the results of recent meta-analyses that scan hundreds of papers available in the literature. All these elements characterise the angle of our analysis as being somewhat complementary to that of the Challenges for Monetary Policy Transmission in a Changing World (ChaMP) Research Network, although this has a stronger connection with academic research and a much broader scope, as it includes all segments of monetary policy transmission and focuses on production networks and microanalysis. While selected results of this paper have also been used to support some analysis contained in the ECB's 2025 monetary policy strategy assessment, the general findings reported here are not only entirely consistent with the conclusions reached by those more comprehensive studies, though they do provide a useful reference for forming a clearer understanding of the impacts of standard monetary policy shocks on key macroeconomic variables (mainly output and consumer prices), through several transmission channels.

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[1] For a detailed analysis of fiscal and monetary interactions, see the ECB Occasional Papers: "Monetary-fiscal policy interactions in the euro area", No 273, 2021, as part of the ECB Strategy Review; and "Challenges for monetary and fiscal policy interactions in the postpandemic era", No 337, 2024.

Aside from this introduction, the occasional paper contains three chapters and a concluding section. Chapter 2 reviews the monetary policy impacts through the lens of ESCB models and illustrates the sources of heterogeneity in transmission across models. Chapter 3 contains a qualitative and quantitative discussion of the available empirical literature that provides a benchmark for our models. Chapter 4 focuses on the heterogeneous and non-linear aspects of monetary policy transmission, while looking more in depth at the 2022-23 tightening episode that followed the inflation upsurge.

2 Down the rabbit Hole: monetary policy impact in ESCB models

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This chapter explores sources of heterogeneity across ESCB macroeconomic models in terms of monetary policy transmission. The analysis covers a set of structural and semi-structural models routinely used for forecasting and policy analysis within the ESCB and is essentially a stocktaking exercise based on available models.[2] Our analysis sheds light on the specific model features that affect the transmission channels of monetary policy impulses and therefore lead to heterogeneous responses in nominal and real variables across models.

The existing models routinely used for policy analysis within the ESCB typically belong to two broad categories: structural and semi-structural. Structural models provide a deep theoretical understanding, while semi-structural models prioritise flexibility and alignment with empirical data to ensure timely responses to emerging economic challenges. Both types of models are essential for the ESCB's policy work. Together, they help guide medium-run projections and inform decision-making.

Dynamic stochastic general equilibrium (DSGE) models, which are micro-founded, belong to the class of structural models. Their general equilibrium structure allows for the construction of an economically sound narrative based on structural shocks. Traditionally, DSGE models assume that agents have rational expectations, in the sense that they know the model economy and the distributions of shocks that affect it and can coordinate their expectations so that the subjective ex ante probability distributions of model variables coincide with their true ex post distributions. This chapter also discusses departures from rational expectations in DSGE models.

Semi-structural models tend to be larger than DSGE models and, at most central banks, serve as the main medium-term forecasting tools. Equations are typically specified to ensure a good data fit and semi-structural models typically show less

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[2] Box 6 offers a complementary view by repeating the analysis using other existing estimated euro area models not regularly deployed for forecasting or policy analysis within the ESCB.

internal structure coherence compared with DSGE models. Broadly speaking, semi-structural models can be flexibly adjusted to incorporate additional structures when needed.

A key distinction between DSGE and semi-structural models concerns agents' behaviour in response to a monetary policy shock. In DSGE models, the transmission reflects agents' intertemporal optimisation: changes in interest rates alter consumption and investment decisions, while future inflation and aggregate demand conditions in turn influence current price setting via a Phillips curve. In semi-structural models, behavioural equations are typically estimated, and do not necessarily stem from a full-fledged intertemporal optimisation problem.

Another source of divergence is expectation formation. Amending the rational expectations framework in DSGE models to attenuate anticipation effects reduces the gap in the strength of monetary policy transmission between DSGE and semi-structural models. DSGE models are explicitly build from micro-foundations and are thus internally consistent, while semi-structural models are closer to the data and typically backward-looking. However, semi-structural models can also have model-consistent expectation formation and assign an explicit role to expectations, as in the case of the ECB-BASE model of the ECB, or the FR-BDF model developed at Banque de France. Furthermore, both sets of models may have different degrees of non-linear characteristics.

Besides the distinction between structural and semi-structural models, the strength of monetary policy transmission critically depends on several structural features of the economy. The frequency of price and wage adjustments is a key determinant of the slope of Phillips curves, i.e. how much prices respond to marginal cost conditions (or output gaps). More frequent price adjustments typically lead to a larger price response and a more attenuated response of real variables such as output. The degree of forward-looking behaviour in price-setting, or the amount of inflation persistence introduced in price-setting behaviour also affects the dynamic effects of monetary policy. Real rigidities and financial frictions are other important dimensions influencing monetary policy transmission. Last but not least, the specification of the monetary policy rule also plays a key role in terms of how forceful and persistent the endogenous reaction of monetary policy is to deviations of inflation from target. In this chapter we will shed light on some of these key drivers by reporting the results of harmonised simulation exercises where specific drivers are harmonised across models.

Table 1 below provides a summary of the models used in the analysis, reporting, for each institution, which model(s) are used and whether they are semi-structural or DSGE and providing the relevant references for each model.

Table 1

Models used in the analysis

	Semi-structural	Structural	References
ECB	ECB-BASE	NAWMII	Angelini et al. (2019), Coenen et al. (2018)
Oesterreichische Nationalbank		DSGE	Grimaud (in progress)
Nationale Bank van België/Banque Nationale de Belgique		DSGE	Rannenberg (2024)
Banca d'Italia		DSGE	Bartocci et al. (2017)
Deutsche Bundesbank		FTANK, Bundesbank EAGLE (with 6 regions)	Gerke et al. (2022), Dengler et al. (2024) Gomes et al. (2012)
Banco de España		DSGE	Bandeira et al. (2018)
Banque de France	BDF_EABDF		Lemoine et al. (2019)
Central Bank of Ireland		EAGLE version with search frictions	Gomes, Jacquinot, Lozej (2023)
Latvijas Banka		DSGE	Bušs and Grüning (2023)
Česká národní banka	CNBg3+ (euro area bloc)	CNBg3+ (domestic bloc)	Brázdik et al. (2020)
Suomen Pankki		DSGE	Kortelainen (2024)
Sveriges Riksbank		MAJA	Corbo and Strid (2020)

Note: The table lists all the ESCB models that have been used in the analysis and the references to the main documentation for each model.

The remaining sections of this chapter present the results of a set of common exercises performed with these models. We initially focus on the propagation of a one-off, unexpected increase in the monetary policy rate, which also happens to be the metric typically used in empirical models to assess the transmission of monetary impulses (see Chapter 3). Our analysis elaborates on the role of the specification of the monetary policy rule. The chapter then digs deeper into the various transmission mechanisms that exist within the two main categories of structural and semi-structural models and explores the role of the slope of the Phillips curve underlying the models, along with financial factors and real rigidities. The second part of the chapter then considers the case of anticipated increases in the monetary policy rate, allowing the modeller to assess the role of anticipation effects. These effects are particularly relevant in the transmission of announced policy rate paths, as in the case of forward guidance. As these announcements may trigger significant responses in inflation and economic activity due to strong anticipation effects (the so-called "forward guidance puzzle") when monetary policy reaction is constrained, our analysis also documents the role of model-specific modifications introduced by modellers to tame the effects of the puzzle. A subsection is devoted to the treatment of expectations in semi-structural models.[3] Among the transmission channels of a monetary policy impulse, the interaction with fiscal policy is also an important

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[3] The exercises underlying section 2.1 were used, together with additional, ad hoc simulations, for the analysis reported in ECB (2025).

element. This chapter does not address the interactions between fiscal and monetary policy, as this subject has been thoroughly analysed in several recent contributions, largely based on the experience of Eurosystem and ESCB models (Kilponen et al., 2015; ECB, 2021; Bonam et al., 2024). The reader is referred to those studies for an in-depth analysis of the interplay between monetary and fiscal policy.

2.1 Unanticipated monetary policy shock

This subsection presents the results of the first common exercise, which is the simulation of an unexpected, one-off increase of 25 basis points in the monetary policy rate (subsection 2.1.1). While the change in the policy rate in the initial simulation period is common to all models by construction, from the second period onwards the policy rate follows the path dictated by the monetary policy rule and therefore adjusts systematically in response to deviations of inflation and output from their respective target or steady-state values.

As the systematic adjustment of monetary policy can be an important driver of heterogeneous transmission across models, we explore three alternative policy rule specifications (subsection 2.1.2). First, we adopt the model-specific monetary policy rule, i.e. the one included in each model based on its empirical performance and/or other considerations. Second, we replace the model-specific rule with a common harmonised rule, this being the monetary policy rule specified in the EAGLE model (see Gomes et al., 2012). This choice carries no normative implications: the exercise is purely positive, aiming solely to describe the propagation of the shock. Third, we use a modified version of the EAGLE monetary policy rule, in which the parameter values are changed to allow for a stronger response of the policy rate to inflation fluctuations around the target and no response to output dynamics. In addition to this relevant dimension, we explore other important model features that can drive heterogeneity in the transmission. We first study the heterogeneity of results between structural and semi-structural models (subsection 2.1.3). We repeat the simulations under the assumption of a common harmonised value for the slope of the price (and wage) Phillips curve in the models (subsection 2.1.4). We then focus on financial factors (subsection 2.1.5) and real rigidities (subsection 2.1.6).

2.1.1 Transmission of an unexpected increase in the monetary policy rate

Chart 1 below shows the results of our first exercise. In the columns, we report the policy rate, the inflation rate (both expressed in annualised percentage point deviations from steady state) and output (in percentage deviations from steady state). For each variable we report the interquartile ranges.

We start by focusing on the first row, which reports results based on model-specific monetary policy rules. Following an interest rate increase, output declines in a hump-shaped manner across all models, as does inflation. The responses display some

heterogeneity, which in turns reflects the role of the different transmission channels at play.

In the case of forward-looking structural models, the behaviour of household consumption is mainly driven by intertemporal substitution effects, as portrayed through a standard Euler equation. A higher nominal interest rate, combined with price rigidities, drives an increase in the real interest rate, which induces optimising (Ricardian) households to postpone consumption and investment decisions and increase their savings. Furthermore, the increase in the real interest rate and the decline in demand also depress the present value of an additional unit of capital, thus lowering investment. The presence of nominal and real rigidities makes the adjustment of aggregate demand components (not reported) a gradual process. In response to the decline in aggregate demand, firms reduce their demand for labour. As a result, both employment and wages fall in equilibrium. This mechanism forms the core of the transmission process and is common to all structural models. In addition, specific elements may introduce further amplification in both classes of models, such as via financial markets, or more persistence, such as through real rigidities in the labour market. In the case of open economy models, demand for domestic goods is further dampened as the domestic currency appreciates, which increases demand for goods produced abroad.

Chart 1

Effects of a monetary policy shock under alternative monetary policy rules

Interquartile ranges across models
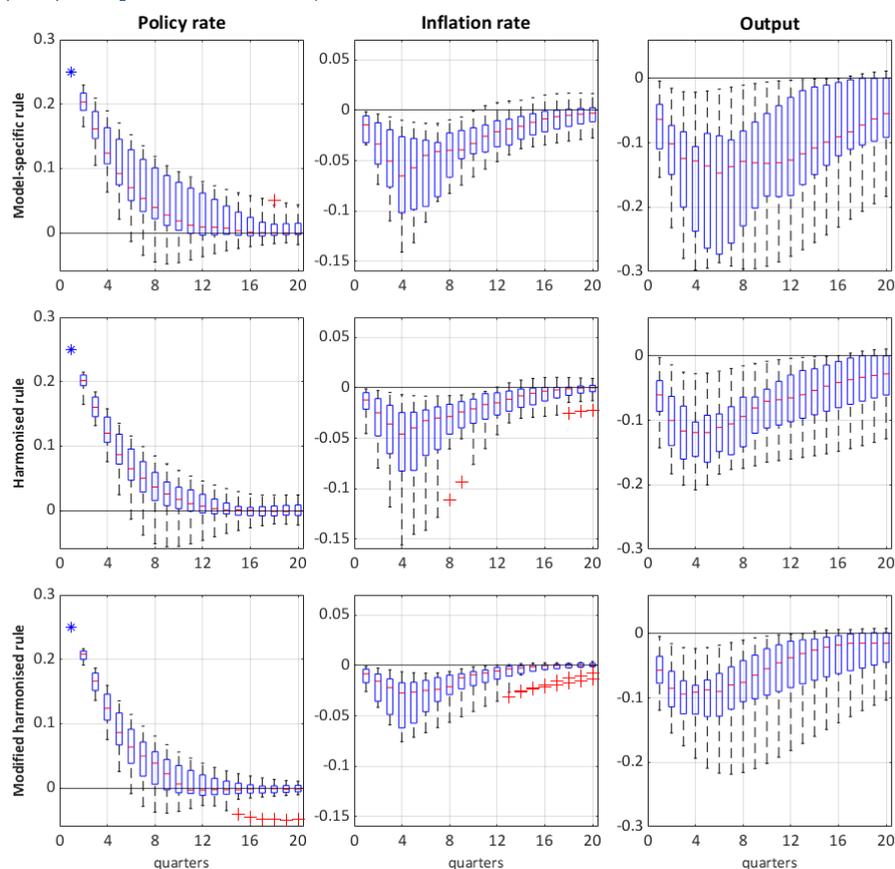
(p.p. and percentage deviations from baseline)

Source: Authors' calculations.
Notes: The chart shows the responses to a monetary policy shock in the set of models used in the common exercise. For the policy rate and the inflation rate, the vertical axis reports annualised percentage point deviations from the steady state; for output, it shows percentage deviations from steady state; the horizontal axis reports quarters. The blue bars report the interquartile range (IQR); the red line is the median. The whiskers report 2*IQR; all observations outside the whiskers are treated as outliers and reported with red crosses.

In the case of semi-structural models, domestic aggregate demand responds through different channels. Interest rates do affect the cost of borrowing and thus reduce investment and consumption. However, while consumption is still affected by interest rate movements, this impact does not work via the Euler equation as it does in DSGE models. Nonetheless, the balance sheet effects among households and firms may amplify the impact of a change in the policy rate. For instance, in the ECB-BASE model, consumption behaviour is based on a permanent income hypothesis and incorporates a higher discount rate due to risk considerations, leading to a more muted response of consumption to changes in interest rates. Subsection 2.1.3 provides further details of the transmission mechanism under semi-structural models.

The exact specification of the monetary policy rule varies across models. While in all models the interest rate responds to its own lagged values and to deviations of inflation from the target, some variability is observed when looking at other variables. All model-specific rules feature interest rate smoothing and a response to deviations of inflation from the target. However, in some cases the quarter-on-quarter inflation rate is considered, while in other cases it is the year-on-year inflation rate that enters the rule. The latter implies greater persistence in the rule, ceteris paribus, and therefore amplifies the impact of a change in the policy rate. Most models feature a response to output growth, with some variability in the coefficient, which ranges from a value of 0.02 to 0.2. A few models display instead a response to the output gap and, in some cases, to variations in the output gap. In a limited number of cases, the rule also responds to changes in the inflation rate.

When monetary policy is harmonised across models, it is assumed that the short-term nominal interest rate is determined by the Taylor rule used in Gomes et al. (2012), where the policy rate responds to euro area-wide inflation and output growth:

$$R_t = \rho R_{t-1} + (1 - \rho)\left[\overline{R} + \theta_\pi(\pi_t - \overline{\pi})\right] + \theta_Y \Delta Y_t; \; \rho = 0.87, \theta_\pi = 1.7, \theta_Y = 0.1$$

In the common monetary policy rule, in line with most of the models in the sample, the policy rate R_t responds to its lagged value (R_{t-1}), inflation deviations from the target $(\pi_t - \overline{\pi})$, and output growth (ΔY_t).[4] In terms of parameter calibration, the harmonised value of the smoothing parameter ρ (0.87) is very close to the average and median across models. The same holds true for the response to inflation θ_π (1.7), where, however, model-specific parameters display some variability. The response to output growth θ_Y (0.1) is also in line with the average and median values, although, as noted above, variability is quite large across models.

Comparing the first and second rows of Chart 1 provides useful insights on the role of the specification of the monetary policy rule. Consistent with the alignment of the harmonised rule and the average rule specification and parameterisation across models, the average responses of the policy rate, inflation and output are substantially similar. Unsurprisingly, the harmonisation largely reduces the dispersion in the responses across models. This is particularly evident for the policy rate and, to a lesser extent, for inflation. The response of output still displays some dispersion, although significantly less than in the benchmark case of model-specific rules, possibly reflecting model heterogeneity related to the modelling of nominal and real frictions as well as differences in the scope of the models, some of which are closed-economy while others are open-economy.[5]

The third row of Chart 1 shows the results obtained when the calibration of the harmonised monetary policy rule is modified as follows: the response of inflation is

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[4]   The same specification for the monetary policy rule was adopted in the harmonised simulations reported in Kilponen et al. (2015) and Bonam et al. (2024).

[5]   Box 8 provides a complementary analysis, showing how changes in structural parameters affect the transmission of the shock in one single model, while keeping the specification of the monetary policy rule unchanged.

twice as large (3.4 as opposed to 1.7), while the response to output growth is now set to zero:

$$R_t = \rho R_{t-1} + (1 - \rho)[\overline{R} + \theta_\pi(\pi_t - \overline{\pi})] + \theta_Y \Delta Y_t; \; \rho = 0.87, \theta_\pi = 3.4, \theta_Y = 0.$$

A few results stand out. First, the response of inflation is now more muted, reflecting the larger coefficient, which implies significantly lower tolerance by the central bank of fluctuations around the target. Dispersion across models is also considerably smaller. As a result of a stronger anti-inflationary stance captured by the larger coefficient in the rule, economic activity is depressed and dispersion across models is somewhat lower.

In summary, the exercise shows that the specification of the monetary policy rule plays a key role in the transmission of a monetary policy shock. Consequently, much of the heterogeneity in the responses of inflation and output can be explained by differences in the specification of the rule across models. Two remarks are in order. First, it should be noted that the exercise has no normative purpose: the chosen specification for the harmonised rule does not rely on any welfare criterion, nor does it aim to approximate an optimal policy. Rather, it provides a common benchmark in analysing the transmission of an unexpected monetary policy shock. Second, while harmonising the monetary policy rule helps clarify an important transmission channel, the specification of the rule remains very much model specific. The calibration or estimation of the parameters in the rule cannot be separated from that of the other structural parameters of the model. Modifying a model-specific monetary policy rule alters the properties of the model in response to monetary policy and other types of shocks and therefore requires special attention.

2.1.3   Deciphering heterogeneity: model categories

Chart 2 below shows the same set of results as Chart 1 but distinguishes between DSGE models (blue area) and semi-structural models (grey area). It should be noted DSGE models far outnumber semi-structural models, which comprise ECB-BASE, EA-BDF and the CNBg3+. While the latter is classified as semi-structural for the purposes of this exercise, the domestic (Czech) economy bloc follows a micro-founded DSGE structure, while the foreign bloc, representing the euro area, adopts a semi-structural form. This section explores the key factors contributing to differences in monetary policy transmission across these two categories of models.

Two main results stand out. First, the transmission of a monetary policy shock to inflation and output is more frontloaded in DSGE models, while it is more gradual and persistent in semi-structural models. Second, harmonising on the monetary policy rule specification still help to shrink the range of responses of inflation and output, even though differences are relatively more pronounced within DSGE than within semi-structural models. Despite these differences, while peak effects differ in size and timing, when considering the whole area underlying each variable of interest (thus providing a more general metric of the effects of the shock), the total effects of the monetary policy impulse are more similar across model categories.

Semi-structural and DSGE models are grounded in distinct theoretical frameworks, designed to serve different analytical purposes, and rely on diverse estimation methodologies (see Box 7 for details). These differences make the two types of model complementary tools for policymakers seeking to understand macroeconomic dynamics.

Chart 2

Effects of a monetary policy shock under alternative monetary policy rules: model categories

Interquartile ranges across models
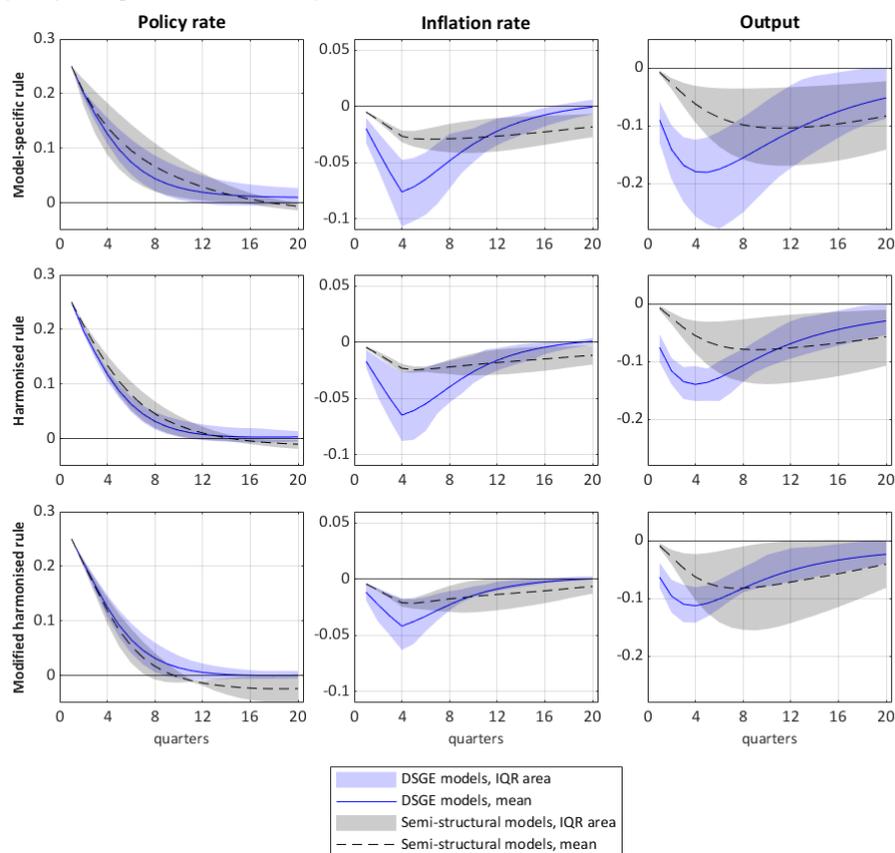
(p.p. and percentage deviations from baseline)

Source: Authors' calculations.
Notes: The chart shows the responses to a monetary policy shock among the set of models used in the common exercise. For the policy rate and the inflation rate, the vertical axis reports annualised percentage point deviations from the steady state; for output, it shows percentage deviations from steady state; the horizontal axis reports quarters. The blue and grey areas report the interquartile range (IQR) for DSGE and semi-structural models, respectively. The solid blue and black-dashed lines represent the mean response across models.

One of the main differences explaining the gap in monetary policy impact between these two types of models lies in the consumption equation. Representative agent DSGE models typically reflect the role of intertemporal substitution, as portrayed by the Euler equation, which describes households' intertemporal choices, i.e. how they allocate current income between consumption and saving for the future. This equation emphasises the strong real interest rate channel driving the response in

DSGE models.[6] Conversely, semi-structural models do not incorporate the Euler equation but typically link the current consumption decision to expected permanent income (discounted sum of future income terms). The following paragraphs briefly describe the mechanics underlying both ECB-BASE and EA-BDF, which belong to the FRB-US type of structural models.[7] For Banque de France models (FR-BDF and EA-BDF), the spread of the real household bank lending rate over the trend in the real short rate influences consumption as follows:[8]

$$c_t^* = \alpha + y_{H,t} + \gamma(r_{LH,t} - \bar{r}_t)$$

Where c_t^* is the consumption target, $y_{H,t}$ is expected real permanent income, and $r_{LH,t}$ is the real long-term bank lending rate. In FR-BDF, a semi-structural model in the style of FRB/US[9], the discount parameter γ is estimated to be relatively small, at -0.95, indicating a low elasticity of intertemporal substitution (σ) of around 0.06.[10] This low elasticity arises because γ is a function of σ and the discount factor β.[11] In FR-BDF, β is calibrated to $0.8^{0.25}$, which is lower than the value typically used in other blocs of the model. This adjustment reflects the need to discount expected (uncertain) income not only by the real interest rate, as would be the case under perfect foresight, but also by a risk adjustment factor.[12]

By comparison, DSGE models often calibrate the elasticity to 1, which corresponds to log utility in the household optimisation framework and leads to a well-known simplification with respect to the balanced growth path.[13] In what follows, we conduct an experiment with the FR-BDF model, where we recalibrate γ to be consistent with $\sigma = 1$, yielding a value of 17. This adjustment allows us to assess how a higher elasticity of intertemporal substitution affects the model's response to monetary policy shocks. Chart 3 reports the responses under the two parameterisations of σ and compares them with the mean response among DSGE models shown in Chart 2.

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[6]   It should be noted, however, that intertemporal substitution plays less of a role in DSGE models that feature some degree of heterogeneity. In Two-Agent New Keynesian (TANK) models, as well as in full-fledged Heterogeneous Agent New Keynesian (HANK) models, the role of intertemporal substitution is de-emphasised (see Box 1).

[7]   In this respect, the CNBg3+ model is quite exceptional. Its core structure describes the Czech economy via a DSGE model, while the euro area is represented via a semi-structural bloc, which does not belong to the FRB-US tradition.

[8]   While ECB-BASE does not explicitly include an interest rate spread, it does include financial and housing wealth, which creates an indirect channel for the transmission of interest rate shocks.

[9]   The model is used for forecasting and policy analysis at the Banque de France; see Lemoine et al. (2019).

[10]   In ECB-BASE, the spread on the lending rate also enters the short-run consumption equation with a small negative coefficient, pointing to a significant, albeit relatively low, direct effect of interest rates on consumption. By contrast, the income channel primarily drives consumption dynamics.

[11]   The exact formula obtained by log-linearising an Euler equation combined with the household budget constraint, as in Campbell and Mankiw (1989), is $\gamma = \frac{\beta\sigma}{1-\beta}$.

[12]   It is also the case for FRB/US; see Brayton et al. (1996).

[13]   There are, however, several studies that use more empirically relevant values: House & Shapiro (AER, 2006), Piazzesi et al. (JFE, 2007), and Albanesi et al. (RES, 2003).

Chart 3

Impulse response functions to a 25 p.p. shock on the annualised interest rate; calculations based on FR-BDF

Interquartile ranges across models

a) Inflation

(year-on-year changes; annualised percentage point deviations from baseline)

IES = 1
IES = 0,06
DSGE average response (model specified rule)

b) GDP

(percent deviation from baseline)

IES = 1
IES = 0,06
DSGE average response (model specified rule)
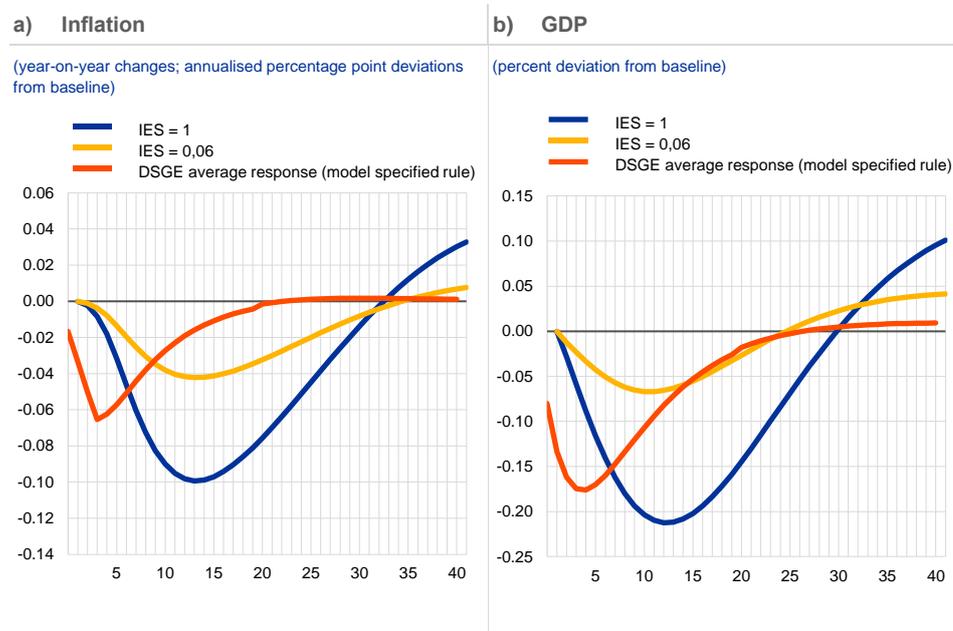
Source: Authors' calculations.
Note: The horizontal axis reports quarters after the shock.

Another important distinction between semi-structural and DSGE models lies in their approach to expectation formation, a crucial factor influencing their response to monetary policy shocks. This dimension is explored in Sections 2.2.1 and 2.2.2.

2.1.4 Inspecting the mechanism: the slope of the Phillips curve and related short-term trade-offs

All DSGE models used in the harmonised exercise feature New Keynesian price Phillips curves, and most also include New Keynesian wage Phillips curves.[14] In this subsection, we examine the effect of harmonising the slopes of the price and wage Phillips curve. Such harmonisation yields a common implicit trade-off between inflation and output stabilisation across models. The exercise considers a monetary policy shock, which acts as a demand shock and thus does not induce movements of opposite direction in prices and quantities. Nonetheless, fixing a common slope of the Phillips curve across models is instructive, as it allows us to isolate the role of nominal rigidities in determining the transmission of monetary policy.

In the linearised version of the price Phillips curve, "slope" refers to the coefficient attached to the deviation of marginal costs from their steady-state value. For

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[14] Box 4 provides a self-contained analysis within a medium-sized DSGE model framework that includes labour market frictions.

instance, the linearised price Phillips curve in the model of Smets and Wouters (2007) is given by:

$$\widehat{\Pi}_t = \frac{1}{1+\beta\chi_p}\left(\beta E_t \widehat{\Pi}_{t+1} + \chi_p \widehat{\Pi}_{t-1} + \frac{(1-\xi_p)(1-\xi_p\beta)}{\xi_p}\frac{1}{(\mu_p-1)\epsilon_{p,kim}+1}\widehat{mc}_t\right) + \varepsilon_{p,t}$$

where $\widehat{\Pi}_t$ and $\widehat{mc}_t$ denote the percentage deviation of inflation and marginal costs from their respective steady-state values, $\varepsilon_{p,t}$ is a cost-push shock, while $\beta, \xi_p, \chi_p, \mu_p$ and $\epsilon_{p,kim}$ denote the household discount factor, the probability that a firm cannot change its price ("Calvo" parameter), the degree of indexation, the price markup, and the Kimball (1995) super elasticity, respectively. The slope is thus given by:

$$\kappa_p = \frac{1}{1+\beta\chi_p}\frac{(1-\xi_p)(1-\xi_p\beta)}{\xi_p}\frac{1}{(\mu_p-1)\epsilon_{p,kim}+1}$$

To make the dynamics of inflation in the models more comparable, it is important to harmonise the κ_p coefficient, rather than merely the degree of nominal rigidity in the form of the Calvo parameter ξ_p. In particular, the final fraction $\frac{1}{(\mu_p-1)\epsilon_{p,kim}+1}$ measures a form of "real rigidity" that is smaller than 1 in models with strategic complementarity in price setting and equal to 1 in those models without strategic complementarity. In the exercise with a harmonised κ_p, we choose the parameter ξ_p in each model in order to set κ_p equal to 0.0072, the value estimated for the NAWM II model.[15]

The linearised wage inflation Phillips curve in Smets and Wouters is given by

$$\widehat{\Pi}_{w,t} = \frac{(1-\xi_w)(1-\xi_w\beta)}{\xi_w}\frac{1}{(\mu_w-1)\epsilon_{w,kim}+1}(\widehat{mrs}_t - \widehat{w}_t)\beta E_t \widehat{\Pi}_{w,t+1} + \chi_w \widehat{\Pi}_{w,t-1}$$
$$- \beta\chi_w\widehat{\Pi}_t + \varepsilon_{p,t}$$

Where $\widehat{\Pi}_{W,tt}$ and $\widehat{mrs}_t - \widehat{w}_t$ denote the percentage deviation of inflation and the inverse wage markup from their respective steady-state value, while ξ_w, χ_w, μ_w and $\epsilon_{w,kim}$ correspond to their counterparts in the price Phillips curve. The slope is accordingly given by

$$\kappa_w = \frac{(1-\xi_w)(1-\xi_w\beta)}{\xi_w}\frac{1}{(\mu_w-1)\epsilon_{w,kim}+1}$$

In the exercise with a harmonised κ_w, we set κ_w to 0.0065, also taken from the estimation of the NAWM.[16]

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[15] See Coenen et al. (2018).

[16] If wage setting follows the setup developed in Erceg et al. (2000), the real rigidity term is given by $\frac{1}{1+\zeta\epsilon_w}$, where ζ and ϵ_w denote the labor disutility curvature and the elasticity of substitution between labour varieties, respectively.

Chart 4

Responses to an unexpected increase in the policy rate with model-specific and harmonised wage inflation Phillips curve slopes
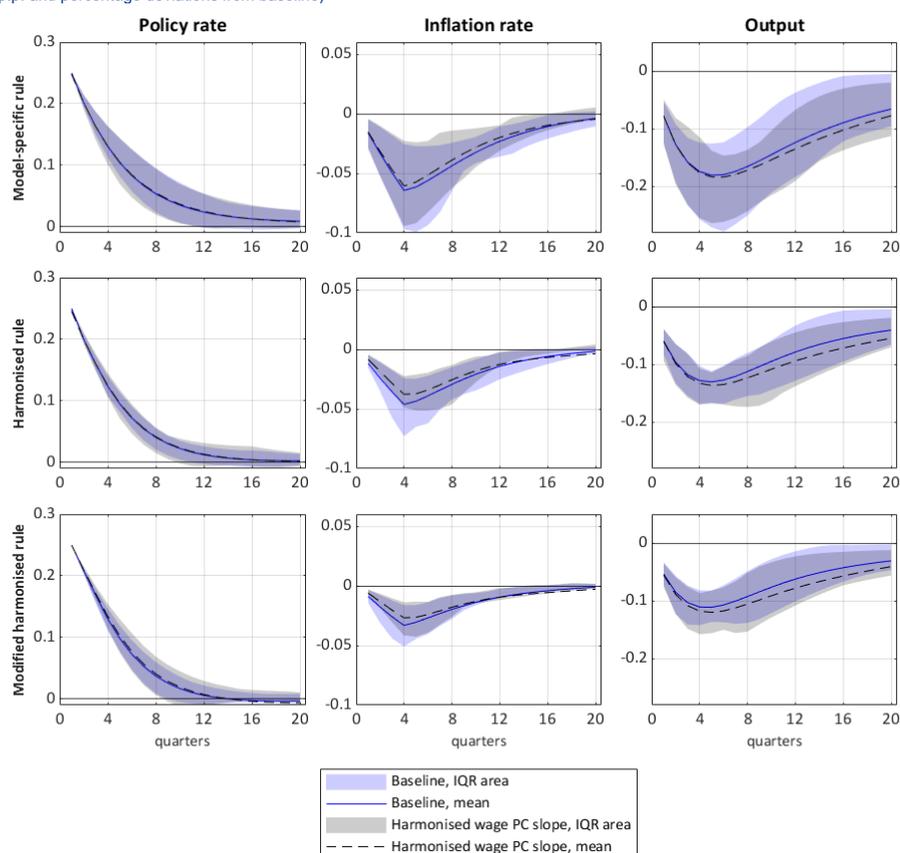
(p.p. and percentage deviations from baseline)

Source: Authors' calculations.
Notes: The shaded areas display the 25th to 75th percentile impulse response ranges. The light and dark violet light areas show the range for the simulation with model-specific values of κ_w. The grey and dark violet areas show the range for the simulations with κ_w= 0.0065. The solid blue and the black dashed lines report the mean response across models. For the policy rate and the inflation rate, the vertical axis reports annualised percentage point deviations from the steady state; for output, it shows percentage deviations from the steady state; the horizontal axis reports quarters.

Chart 4 shows that harmonising κ_w across models narrows the range of results obtained for inflation under the two harmonised monetary policy rules, and does so slightly under the model specific rules. Furthermore, the range of output results becomes narrower under the model-specific rules. Harmonising κ_p also (Chart 5) further narrows the range of inflation responses for all policy rules. The range of output responses narrows further under the model-specific rule, while it becomes slightly wider under the other two rules. All in all, we can conclude that differences in wage and price Phillips curve slopes, when combined with differences in monetary

policy rules, are an important driver of the differences we observed in the inflation response to an unanticipated monetary policy shock across models.

Chart 5

Responses to an unexpected increase in the policy rate with model-specific and harmonised wage and price inflation Phillips curve slopes

(p.p. and percentage deviations from baseline)

2.1.5   Inspecting the mechanism: the role of financial factors

Many of the models used in the harmonised simulations feature financial factors in some form. The inclusion of such elements dates back at least to the aftermath of the global financial crisis, when their role (re)gained centre stage. The specific forms of financial market frictions considered in each model include, in the simplest case, two types of agents in the household sector (Ricardian and hand-to-mouth consumers), and, in more sophisticated setups, features such as assets in the utility function, a banking sector with agency costs, or financial market segmentation. Gauging the role of such factors in the transmission of a monetary policy shock is not a straightforward task. These frictions are incorporated into the model to account for

a meaningful financial sector, both as a source of shocks and as an amplifier of other disturbances. In some cases, such as with hand-to-mouth consumers, their role typically relates to fiscal policy and its interactions with monetary policy. In other setups, the specific frictions introduced into the model were originally linked to non-standard monetary policy measures, with financial market segmentation being one such friction allowing central bank asset purchases to have nontrivial real effects. As a result, the extent to which the transmission of a standard monetary policy shock is affected by the presence of financial frictions is very much model-specific. This notwithstanding, a harmonised exercise was performed, in which the most relevant parameters related to the model-specific financial frictions were modified to dampen the role of the financial factors to the extent possible. A few caveats are in order. First, the experiment does not include all the models used in the benchmark simulations, as in some cases no meaningful financial channel is present in the model. Second, the subgroup includes DSGE models and two semi-structural models (ECB-BASE and CNBg3+), which therefore changes and somewhat narrows the scope of the analysis compared with the analysis reported in the previous subsections. Third, it should be stressed that, as in the case of harmonising the monetary policy rule specification, changing only the parameters most deeply related to financial market factors clearly alters the models' properties, since each model and the related financial factors have been calibrated or estimated including all parameters and all transmission channels. Therefore, the exercise should be interpreted solely as an approximation to a limiting case in which financial channels are de-emphasised. Chart 6 below shows the results by comparing the responses to an unanticipated 25-basis point increase in the monetary policy rate under the benchmark parameterisation and under a quasi-financial-sector-free calibration. While the impact of harmonising the monetary policy rule is still visible, in all cases the results remain largely unchanged when comparing the two sets of simulations. One possible explanation for this relates to the nature of the exercise. As explained above, in some models the only "financial" imperfection included in the model is the presence of a share of hand-to-mouth consumers, which in some cases is already calibrated or estimated to a relatively low value (typically not much beyond 20%). While their presence can have major implications depending on the fiscal sector setup, if the latter is kept fixed while changing the share of (non-)Ricardian consumers, only minor modifications appear in the transmission of a monetary policy shock. In other cases, the specific frictions introduced relate more to non-standard monetary policy measures (such as asset purchases) than to standard ones. In such cases, altering the financial sector specification has little effect on the transmission. All in all, in each model setup the financial sector plays a key role, both as a source of shocks and as an amplifier of other (non-monetary) shocks. As the frictions are highly model-specific, it is hard to obtain a common message from harmonised simulations.[17]

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[17] For the NAWM II model, Figure 6 in Coenen et al. (2019) shows the results of a similar exercise. Consistently with the results of Chart 6, differences in the responses of inflation, output and the policy rate are quantitatively not large. Larger differences are observed in the reported financial variables. For the EAGLE-FLI model, Bokan et al. (2016) show that a higher loan-to-value ratio, or stricter bank capital requirements, may elicit a stronger output response to a monetary policy shock.

Chart 6

Responses to an unexpected increase in the policy rate: the role of financial factors

(p.p. and percentage deviations from baseline)
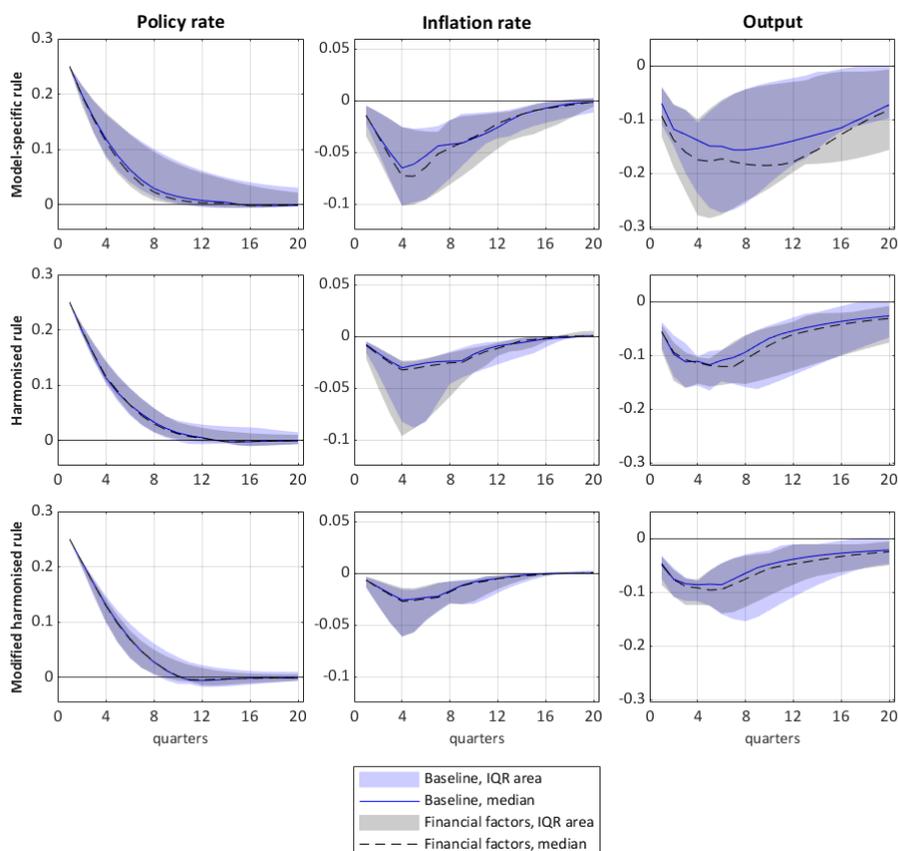
Source: Authors' calculations.
Notes: The shaded areas display the 25th to 75th percentile impulse response ranges. The solid blue and black dashed lines report the median response across models. For the policy rate and the inflation rate, the vertical axis depicts annualised percentage point deviations from the steady state; for output, it shows percentage deviations from the steady state; the horizontal axis reports quarters. In the legend, "Financial factors" refers to the scenario *without* financial factors.

2.1.6   Inspecting the mechanism: the role of real rigidities

Among the various factors influencing the transmission of an unanticipated monetary policy shock, real rigidities play an important role. In DSGE models, these rigidities include habit persistence in household consumption and adjustment costs incurred by firms when changing their investment decisions. In semi-structural models, the dynamics of consumption and investment typically include some polynomial adjustment costs. In both cases, the purpose of introducing some degree of real rigidities into the models is to replicate the sluggish response of real variables observed in the data following a monetary policy shock. In order to explore the role of real rigidities in the transmission, a harmonised simulation exercise was performed, in which the parameters related to real rigidities were lowered as much as possible. It bears repeating that changing only those parameters most deeply related to real rigidities clearly alters the models' properties, since each model and the related real rigidities parameters have been calibrated or estimated including all

parameters and all transmission channels. Therefore, the exercise should be interpreted as being merely an approximation to a limiting case in which real rigidities are de-emphasised. Chart 7 presents the results by comparing the responses to an unanticipated 25-basis-point increase in the monetary policy rate under the benchmark parameterisation and in the case of almost no real rigidities.

Chart 7

Responses to an unexpected increase in the policy rate: the role of real rigidities

(p.p. and percentage deviations from baseline)
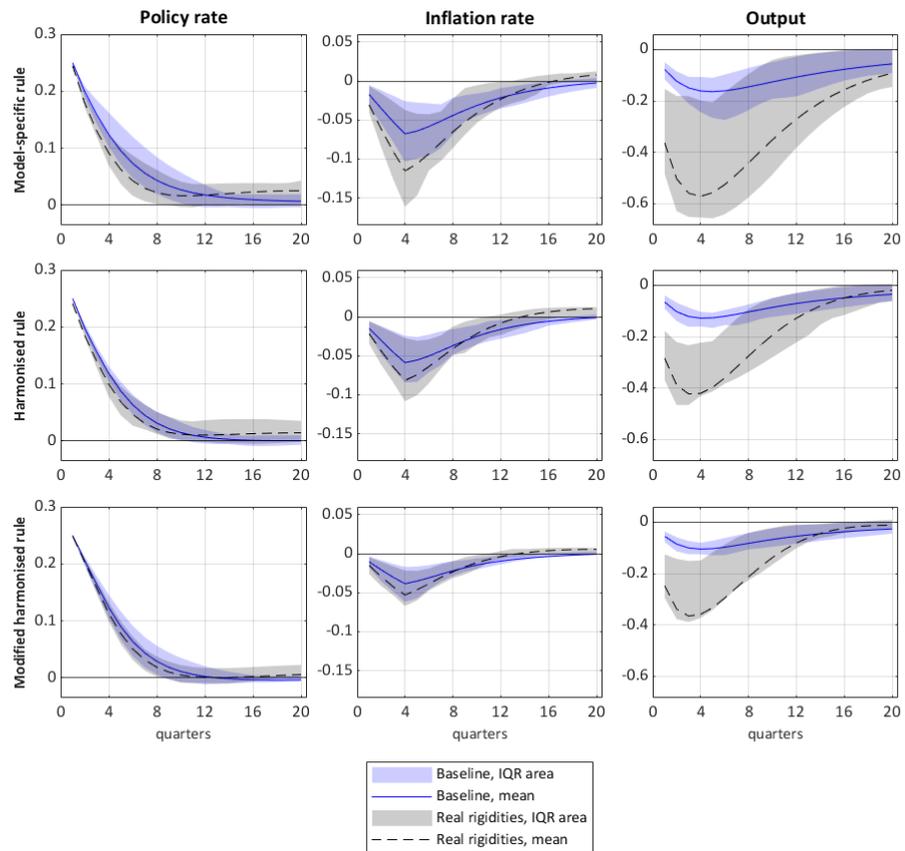
Source: Authors' calculations.
Notes: The shaded areas display the 25th to 75th percentile impulse response ranges. The solid blue and black dashed lines report the median effects across models. For the policy rate and the inflation rate, the vertical axis reports annualised percentage point deviations from the steady state; for output, it shows percentage deviations from the steady state; the horizontal axis reports quarters.

Reducing the real rigidities parameters is akin to removing the sluggishness in the response of output. As a result, the fall in output is larger (about three times that of the benchmark case). The response of inflation is not significantly altered. As output components adjust more rapidly to the shock, current inflation also reflects the reduction in future aggregate demand, doing so via the Phillips curve. Current inflation therefore falls by more, although the difference with respect to the benchmark case is moderated by the presence of nominal rigidities. Importantly, when moving from model-specific to harmonised monetary policy rules, the dispersion in output responses across models shrinks, as observed in the previous simulations.

2.2 Anticipated monetary policy shock

The common exercise presented in Section 2.1 provided evidence on the transmission channels at play in the set of models considered here, in response to a standard unanticipated increase in the monetary policy rate. This section now explores the role of anticipation effects in determining the effectiveness of a central bank's announcement regarding the future path of the policy rate. The analysis inherently concerns models in which at least some agents are forward-looking.

To shed light on how an announced peg of the policy rate to a specified (credible) future path transmits to the macro economy across models, this section illustrates results from two sets of simulation exercises.

First, we consider a four-quarter anticipated increase in the policy rate. Here, the central bank announces an increase in the policy rate in the current quarter (which comes as a surprise to the public, as in the analysis presented in Section 2.1) and credibly commits to keeping the rate subsequently unchanged at its new level for the next three quarters. The simulation is performed, once again, both with model-specific monetary policy rules and with the harmonised rule being active from the fourth quarter onward. It should be emphasised that this increase in the monetary policy rate does not reflect a change expected by agents under current macroeconomic conditions, as per the systematic component of the monetary policy rule. In contrast, the simulations are intended to capture the impact of a shock to future interest rates that is anticipated by agents. Chart 8 reports the results. As in Section 2.1, the results shown in the three panels in the first row were obtained under model-specific monetary policy rules, while those in the second row and third row use the harmonised and modified harmonised rule, respectively. Two main results stand out. First, compared with an unanticipated increase in the policy rate, the effects on inflation and output are quantitatively larger, reflecting anticipation effects and the fact that the interest rate remains higher for a longer time. Second, the dispersion of real effects shrinks as we move from model-specific to harmonised monetary policy rules. This shrinkage is qualitatively similar to that observed under an unanticipated monetary policy shock.

We then repeat the exercise under the assumption that the central bank credibly commits to keeping the policy rate unchanged at its new, higher level for eight quarters instead of four (with monetary policy rule being active again thereafter). The purpose of the exercise is to show whether, and to what extent, anticipation effects are strong enough to generate a "forward guidance puzzle", namely unrealistically strong economic responses to anticipated policy rate paths, which may affect transmission across models.[18] Chart 9 further below presents the results. Compared with a four-quarter peg, the results are quantitatively stronger, but qualitatively similar. Quantitatively stronger responses reflect both the fact that the monetary policy shock is longer lasting, as well as the stronger anticipation effect, given the announced path of the monetary policy rate. The longer the anticipation horizon, the

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[18] For an extensive discussion of the impact of forward guidance in structural models, see ECB (2022).

lower the trough of inflation and output in response to the policy announcement. As before, harmonising the monetary policy rule reduces the dispersion across models.

Last but not least, to provide a synthetic indicator that summarises the models' properties under anticipated monetary policy shocks, Chart 10 reports the peak effects on inflation and output as we move from an unanticipated increase in the policy rate to a 4-quarter and an 8-quarter anticipated increase. The increase in the peak effect is clearly larger in absolute value as we move from a 4- to an 8-quarter peg compared with the increase observed when comparing a 4- with a 1-quarter increase. This holds true even under the harmonised rule, although this dampens the peak effects somewhat. The strong increase observed when moving from a 4- to 8-quarter anticipation horizon reflects both the size of the shock and the presence of the forward guidance puzzle. In other words, the prolonged suspension of the Taylor rule drives the results. This point is discussed further in Section 2.2.[19]

Chart 8

Effects of an anticipated 4-quarter increase in the monetary policy rate under alternative monetary policy rules

(p.p. and percentage deviations from baseline)
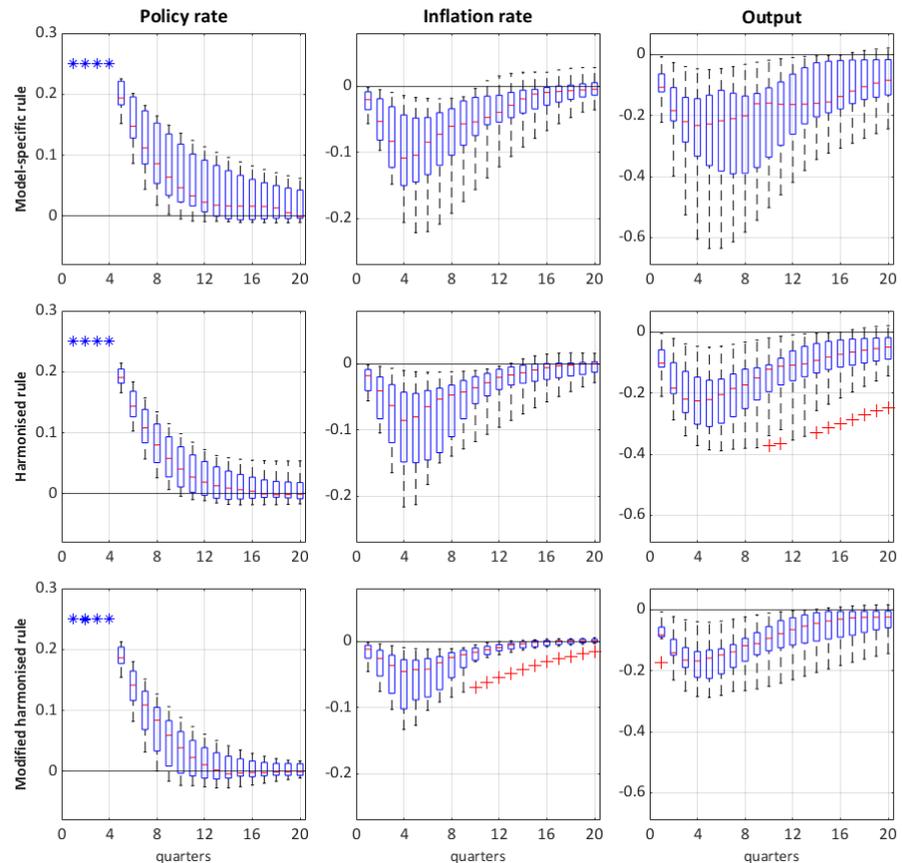
Source: Authors' calculations.

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[19] Eggertsson and Schüle (2024) explore under which condition the standard 3-equation New Keynesian model produces a forward guidance "puzzle". This emerges when monetary policy is somewhat constrained either by its promise to depart from the Taylor rule, or by the effective lower bound.

Chart 9

Effects of an anticipated 8-quarter increase in the monetary policy rate under alternative monetary policy rules

(p.p. and percentage deviations from baseline)

Source: Authors' calculations.
Notes: The chart shows the responses to a monetary policy shock in the set of models used in the common exercise. For the policy rate and the inflation rate, the vertical axis reports annualised percentage point deviations from the steady state; for output, it shows percentage deviations from the steady state; the horizontal axis reports quarters. The blue bars report the interquartile range (IQR); the red line is the median. The whiskers report 2*IQR; all observations outside the whiskers are treated as outliers and reported with red crosses.

Chart 10

Chart 10
Peak effects of anticipated increases in the monetary policy rate under alternative monetary policy rules and different anticipation horizons

(p.p. and percentage deviations from baseline)
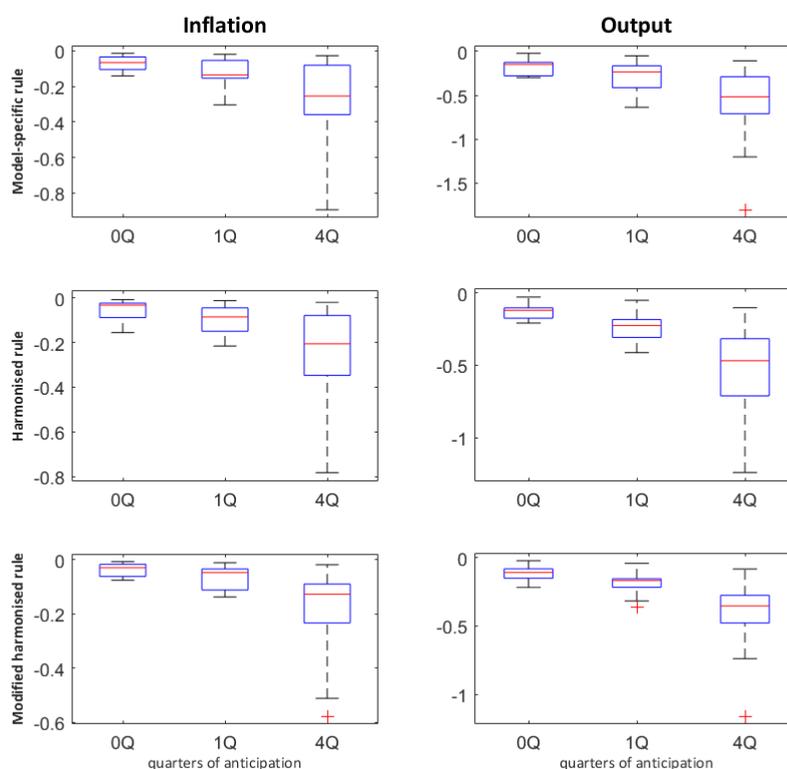
Source: Authors' calculations.
Notes: The chart shows the responses to a monetary policy shock in the set of models used in the common exercise. For each variable, the blue bars report the interquartile range (IQR); the red line is the median. The whiskers report 2*IQR; all observations outside the whiskers are treated as outliers and reported with red crosses. For the inflation rate, the vertical axis reports annualised percentage point deviations from the steady state; for output, it shows percentage deviations from the steady state; the horizontal axis reports the numbers of quarters of anticipation.

2.2.1 Anticipation effects and the forward guidance puzzle in DSGE models

It is by now well known that DSGE models featuring rational expectations often produce unrealistically strong macroeconomic responses to anticipated future interest rate movements. For instance, Del Negro et al. (2023) show that a promise made by the central bank to keep interest rates fixed for several quarters at a lower level than what its usual reaction function would imply leads to effects on current inflation and output that are "unrealistically large" and become larger the longer it promises to keep interest rates fixed. This is known as the "forward guidance puzzle" and it is due to several properties intrinsic to DSGE models. First, the high sensitivity of consumption to interest rates through the Euler equation (see also Section 2.1.1), particularly to interest rates in the far future. Second, the New Keynesian Phillips curve, which links contemporaneous inflation to all future deviations of the output

gap from zero. Third, the key condition for the "puzzle" is that the central bank's promise entails a departure from the Taylor rule during a certain period, or that the policy rate is constrained, perhaps by the effective lower bound (Eggertsson and Schüle, 2024). Since these features and conditions are not exclusive to DSGE models, the "forward guidance puzzle" may also occur in other (non-DSGE) models that share these properties (see Section 2.2.2).

Nearly all the DSGE models used in this chapter depart in some way from fully rational expectations in order to alleviate the forward guidance puzzle. This makes them suitable for certain specific policy analyses, such as evaluating the macroeconomic implications of a specified interest rate path (not just a one-off monetary policy shock) or of anticipated monetary policy shocks.

The precise method used to alleviate the forward guidance puzzle differs across the models used in this chapter. One approach, following Gabaix (2020), is to introduce behavioural discounting, whereby agents in the model discount future deviations of variables from their respective steady state values by a constant factor.[20] Another way is to add preferences over safe assets to the household's utility function (Rannenberg, 2024). This assumption reduces the responsiveness of consumption to future interest rates by adding extra discounting to the Euler equation and a wealth effect from outstanding government bonds. Yet another approach is to make the anticipated policy subject to an informational friction: a certain percentage of agents do not account for the pre-announced policy path, instead forming their expectations in line with the policy rule (ECB, 2022).[21] In effect, a chosen fraction of households in this case believes that the central bank will continue to follow its usual reaction function (i.e. the Taylor rule), disregarding forward guidance on the future interest rate path. While more ways to attenuate the forward guidance puzzle exist (ECB, 2022), these three approaches are the ones chosen in the models considered here. Boxes 2 and 3 at the end of this chapter provide model-specific ways to address related issues. Box 9 describes the amendments to rational expectations introduced in the CNBg3+ model, which features both a DSGE-type core bloc and a semi-structural foreign economy bloc.

Charts 11 and 12 illustrate the need to alleviate the forward guidance puzzle and at the same time show the models' success in doing so. In these two charts, the simulation from Section 2.2 (i.e. of anticipated monetary policy shocks) is repeated, once with the devices in the DSGE models to tame the forward guidance puzzle activated, and once with these same devices deactivated. Chart 11 shows the results for an anticipated interest rate peg of four quarters.[22] The grey area presents the impulse response functions (IRFs) of the models when the devices to tame the forward guidance puzzle are activated, while the blue area shows the devices when they are deactivated. Clearly, deactivating the respective devices in the models

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[20] Some of the models used apply the discounting only to the expected interest rate deviations, while others apply the discounting to expectations about all variables, as in Gabaix (2020).

[21] This may occur where the central bank loses some of its credibility in the eyes of agents.

[22] The chart reports results for DSGE models only in the two cases, without looking at semi-structural models.

leads to a significant amplification of the interest rate peg's impact on inflation and output.

Chart 11

**Effects of an anticipated 4-quarter increase in the monetary policy rate under alternative monetary policy rules, switching devices on and off to alleviate the forward guidance puzzle**

(p.p. and percentage deviations from baseline)

Source: Authors' calculations.
Notes: The shaded areas display the full impulse response ranges, while the lines show the means. The grey area corresponds to the models when the mechanisms to dampen anticipation effects are activated, while the blue area shows the results when these mechanisms are deactivated. For the policy rate and the inflation rate, the vertical axis reports annualised percentage point deviations from the steady state; for output, it shows percentage deviations from the steady state; the horizontal axis reports quarters.

Even more starkly, Chart 12 shows the same results, but now for an interest rate peg of eight quarters. Here, the explosive behaviour of "unadjusted" DSGE models under an interest rate peg becomes quite striking. While in most models the negative effects of the contractionary monetary policy shock on inflation and output become even more amplified, in some models the opposite occurs: the IRFs of inflation and output flip signs. This is a manifestation of the "reversal puzzle", a phenomenon closely related to the forward guidance puzzle (see, for instance, Carlstrom et al. 2015, or Gerke et al., 2020).

In short, many of the DSGE models used in this chapter depart in some way from the assumption of perfect rationality of agents when it comes to anticipating future

monetary policy. This helps the models to obtain empirically plausible and less heterogeneous reactions to forward guidance monetary policy shocks.

Chart 12

Effects of an anticipated 8-quarter increase in the monetary policy rate under alternative monetary policy rules, switching devices on and off to alleviate the forward guidance puzzle

(p.p. and percentage deviations from baseline)


Source: Authors' calculations.
Notes: The shaded areas display the full impulse response ranges, while the lines show the means. The grey area corresponds to the models when the mechanisms to dampen anticipation effects are activated, while the blue area shows the results when these mechanisms are deactivated. For the policy rate and the inflation rate, the vertical axis reports annualised percentage point deviations from the steady state; for output, it shows percentage deviations from steady state; the horizontal axis reports quarters.

2.2.2 Treatment of expectations in semi-structural models

Semi-structural models offer a flexible approach to expectation formation, allowing for backward-looking, model-consistent, and hybrid setups. The model-consistent expectations (MCE) version is similar to DSGE models in its forward-looking nature. Under MCE, agents fully understand the consequences of news about future policy changes according to the model economy. A sequence of policy changes or permanent shifts can thus be interpreted as fully committed guidance on future policy decisions. Economic agents adjust their behaviour immediately to anticipated news shocks, causing an immediate impact on all components of aggregate demand and prices. This is not what happens in the case of backward-looking expectations,

where the economy does not respond at the time of the policy announcement, but only when the policy change is actually set in place. The backward-looking version, often used in forecasting, relies on agents forming their expectations based on simplified VAR models, which capture a reduced-form view of the economy. For this reason, we refer to it as the VAR-based case. In hybrid setups, financial agents are forward-looking, while other agents, like households and firms, are backward-looking.[23] This versatility allows semi-structural models to adapt their responses based on the nature and timing of policy shocks, making them particularly effective when the economic environment or the timing of policy changes is uncertain.

Unlike DSGE models, FRB/US-style semi-structural models are immune to the forward guidance puzzle because they do not rely on an explicit and overly influential real interest rate channel (see Box 7). For the same reason, anticipated shocks do not elicit dramatically different responses across expectation settings, as is sometimes the case in DSGE models (see Charts 11 and 12). However, the choice of expectation formation does affect the speed and magnitude of monetary policy transmission. In the EA-BdF model, for instance, inflation, consumption and investment respond sharply when agents are forward-looking (MCE), whereas under backward-looking expectations (VAR-based), the shock transmits more gradually, with domestic demand components adjusting over time. The transmission is therefore faster under MCE than under VAR-based expectations (see Chart 13).

When agents are forward-looking, the exchange rate appreciates more strongly in response to a monetary policy shock, whereas in the backward-looking case, the adjustment is more gradual (see Hybrid case versus VAR-based). The responses of short-term and long-term interest rates are fairly similar under all three cases, with the persistence of the shock largely driven by the inertia embedded in the Taylor rule, which is identical in the EA-BDF model and in the satellite VAR model used for backward-looking expectations. As expectations regarding the short-term interest rate are similar in both cases, differences regarding the response of the real exchange rate are largely driven by differences in inflation expectations. Given the stickiness of prices, we also get a stronger appreciation of the nominal effective exchange rate in the short run, which in turn explains the larger drop in net real exports and, through second-round effects, in other demand components. [24]

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[23] See, for example, Bernanke, Kiley, and Roberts (2019).

[24] However, not all semi-structural models respond in the same manner. For example, in FR-BDF – a semi-structural model used for projection exercises at the Banque de France and corresponding to one of the two blocks of the EA-BDF – there is a notable dampening effect on both consumption and investment under model-consistent expectations (MCE). This is due to forward-looking agents smoothing their perceptions of permanent income, which reduces the volatility of their consumption responses. In the backward-looking case, the model generates a strong medium-term response in consumption, creating an overshooting effect. However, when agents are forward-looking this overshooting is mitigated, resulting in a smaller initial drop in consumption, followed by a gradual convergence back to normal, as expectations are tied to the discounted present value of future income. In contrast, the rest of the euro area block within the EA-BDF model exhibits a stronger income reaction without the overshooting seen in FR-BDF, meaning that while the peak impact is similar across both expectation formations, the timing differs. Investment, which primarily responds to activity levels, also shows a more muted decline under MCE in FR-BDF due to the more moderate response of demand.

Chart 13

Impulse response functions to a 25-pp shock on the annualised interest rate; calculations based on EA-BDF

(p.p. and percentage deviations from baseline)
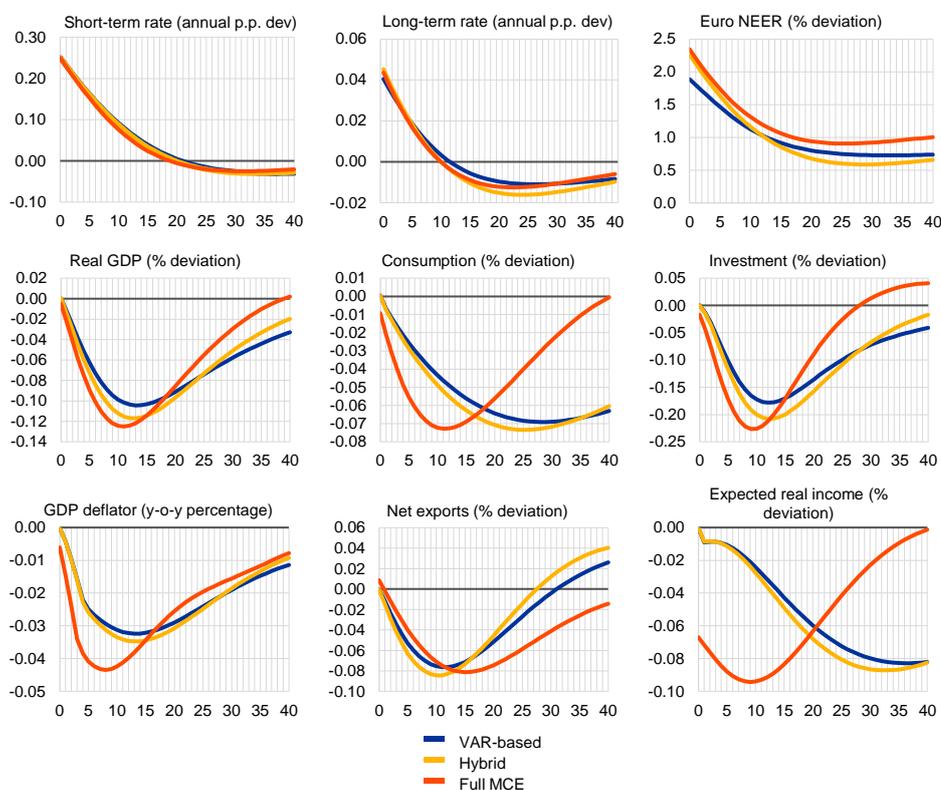
Source: Authors' calculations.
Notes: the IRFs are calculated as a percentage or as absolute deviations, depending on the type of variable between the alternative and baseline scenarios. VAR-based corresponds to backward-looking expectations; Hybrid corresponds to the case when financial agents are forward-looking, while the rest are backward-looking. Full MCE stands for model-consistent expectations.

Similarly to FR-BDF, in ECB-BASE, MCE leads to more gradual transitions in response to unanticipated monetary policy shocks. The reasons for this are twofold. First, the empirical dynamics implied by VAR-expectations trigger a much stronger and more hump-shaped reaction of the long-term interest rate compared with MCE. In contrast, the MCE setup discounts future term premium volatility and leads to a smoothing through financial repricing, (see Chart 14, panel a). Second, permanent labour income, i.e. households' perception of the discounted flow of income, is much more dampened under MCE, with a gradual revision back to zero, producing smoother consumption over the cycle when compared with backward-looking expectation cases (see Chart 14, panel b). In the semi-structural model, consumption is determined on the basis of a tight empirical relationship with permanent income. This channel is dominant over the real interest rate channel that typically drives consumption-savings decisions in DSGE models.

Chart 14

Impulse response functions to a 25-pp shock on the annualised interest rate

Long-term interest rate	Labor income (permanent)
(p.p. and percentage deviations from baseline)	(p.p. and percentage deviations from baseline)
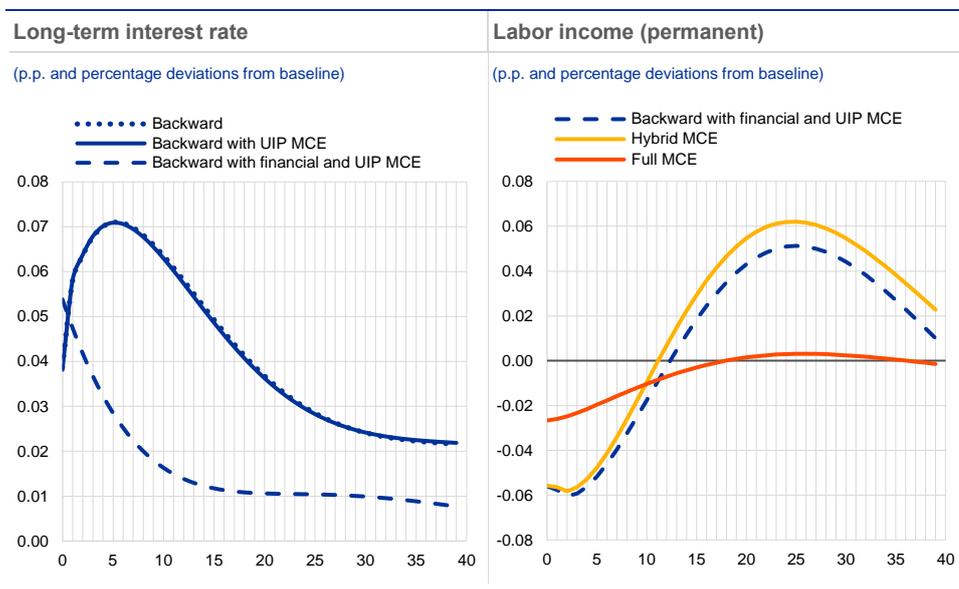
Source: Authors' calculations.
Notes: Calculations based on ECB-BASE.

Overall, in the MCE case, semi-structural models often generate faster (more front-loaded) and, in some instances, stronger responses. However, fully forward-looking expectations in semi-structural models do not typically replicate the average DSGE response, as these models prioritise the expected income channel while placing less emphasis on interest rate changes, which are a key driver in DSGE models. Conversely, when rational expectations are constrained in a DSGE model, the heterogeneity between these two modelling families diminishes significantly (see Section 2.1.3).

2.3   Conclusions

This chapter has provided an in-depth analysis of the transmission of monetary policy impulses in models routinely used for forecasting and policy analysis within the ESCB. A few results emerge. First, the transmission differs across the two main broad model categories, namely structural (DSGE) and semi-structural models, with the former displaying stronger impact effects which reflect the typical forward-looking behaviour of expectations. Second, the specification of the monetary policy rule also matters: once the same rule – both in terms of variables and parameter values – is adopted across all models, the variability in the responses of inflation and output largely shrinks. Third, the underlying supply-side dynamics captured by the Phillips curve are also crucial in determining the transmission. The role of financial frictions, while important in specific models to capture the role of the financial sector both as a source of disturbances and as an amplification mechanism, appear less clear when comparing the transmission of monetary policy across models when the financial channel is active or, where possible, deactivated. Real rigidities are also an important factor in the transmission. Lastly, the expectation formation mechanism

plays a key role in determining the timing and strength of macroeconomic response to the monetary policy impulse.

Box 1
Heterogeneous effects of monetary tightening in response to energy price shocks

Prepared by Alina Bobasu (European Central Bank), Michael Dobrew (European Central Bank) and Amalia Repele (Bocconi University)

Starting in mid-2021, energy prices soared to unprecedented heights. Initially driven by the global post-pandemic rebound, this was exacerbated by Russia's invasion of Ukraine. The euro area economy – heavily dependent on energy imports – endured significant disruptions. The paper by Bobasu, Dobrew and Repele (2024) uses a small open-economy Heterogenous Agent New Keynesian (HANK) model for the euro area to analyse shock transmission and the monetary policy response. Their analysis is based on observed differences in households' exposure to energy costs and their wealth. The authors assess the implications of two types of monetary policy responses: a "passive" response that keeps the real interest rate constant and "active" policies that raise the real rate substantially by responding to inflation measures, such as headline, core or energy inflation. The results show that an increase in foreign energy prices has adverse economic consequences regardless of the monetary policy response. However, a passive policy response can be effective in mitigating the economic consequences, whereas active policy responses exacerbate them by producing adverse effects on aggregate demand.

Under the baseline policy, which keeps the real rate constant, an energy price shock initially causes inflation to spike, although it quickly reverses and falls (Chart A).

Although the nominal interest rate rises due to the Fisher equation, this scenario results in the smallest decline in consumption and output because real rates do not change and because the price effects, combined with lower labour income, do not incentivise households to save more, while domestic demand is supported by stable foreign demand. In contrast, active policy responses, such as those reacting to contemporaneous inflation, significantly raise the real interest rate, leading to a much larger contraction in consumption and output. All policy rules reacting to contemporaneous measures of inflation would actively respond to an energy price shock by raising the real rate. The differences between a headline and a core inflation rule in terms of real rates and inflation outcomes are barely noticeable, although a rule targeting core inflation produces a slightly higher inflation rate. The higher real rate causes households to reduce their spending on domestic goods, exacerbating the negative effects on labour demand and leading to a fourfold decline in consumption compared with the baseline. Additionally, the real exchange rate appreciates, reducing the pass-through of foreign energy prices but further weakening foreign demand.

Not all households are affected equally by rising energy prices.

Notably, households with little wealth are the hardest hit. Not only do they spend a larger share of their income on energy-related goods and services, but they also have little or no savings to smooth their consumption in response to shocks. Additionally, they rely on wages as their main source of income and rarely benefit from either higher interest rates on savings or higher asset prices. Indeed, in our model these low-wealth households are affected the most by an energy price shock. Active policy rules in particular heavily amplify the consumption response through high real rates that reduce aggregate demand and therefore labour income for these households, while also benefiting wealthy households through higher returns on savings. The implications for the real

economy are therefore amplified as fewer wealthy households, with a higher marginal propensity to consume, are mostly affected.[a]

Chart A
Effects of an energy price shock under contemporaneous policy rules

(pp and percentage deviation from baseline)
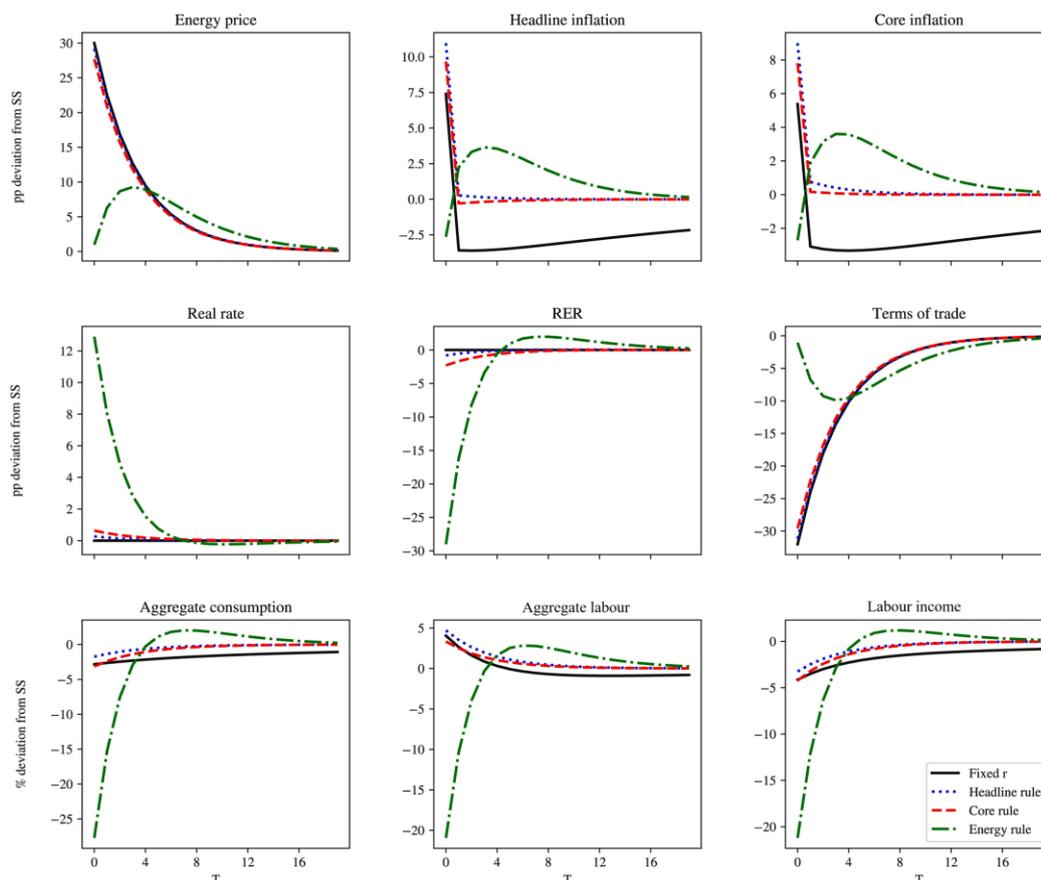
Source: Authors' calculations.
Notes: The chart shows the aggregate responses to an energy price shock, contrasting a rule that keeps rates fixed with policy rules that react to contemporaneous measures of inflation, as described in Appendix B in Bobasu, Dobrew and Repele (2024). RER refers to real effective exchange rate; The Y axis denotes percentage deviations from the steady state; the X axis refers to quarters following the shock; T refers to quarters.

A comparison with the consistent RANK model shows that household heterogeneity matters for monetary policy transmission.

To better gauge the implications of households' heterogenous balance sheets and energy exposures and the implications of this heterogeneity for monetary policy transmission, we next solve a representative-agent new Keynesian (RANK) model, which we calibrate to be as close as possible to our baseline HANK model with a fixed interest rate rule for monetary policy. In the HANK model, GDP drops significantly more than in the RANK model, due to the strong consumption expenditure channel, especially among low-wealth households (see Chart B). These households face larger expenditure increases and are unable to buffer the shock because they hold little or no assets. The aggregate effect of these low-wealth households is substantial, as shown in the middle and right panels. These partial equilibrium forces are important drivers of general equilibrium responses. Therefore, the general equilibrium effects are also more pronounced in the HANK model, with labour income and energy production experiencing larger declines. In contrast, inflation

reacts more sharply in the RANK model, although the shock is short-lived. A key difference is that in the RANK model, the economy returns to its steady state relatively quickly, whereas under the HANK model it shows much greater persistence due to the role of endogenous asset distribution.

Chart B

Comparison of the HANK and RANK models

(pp and percentage deviation from baseline)
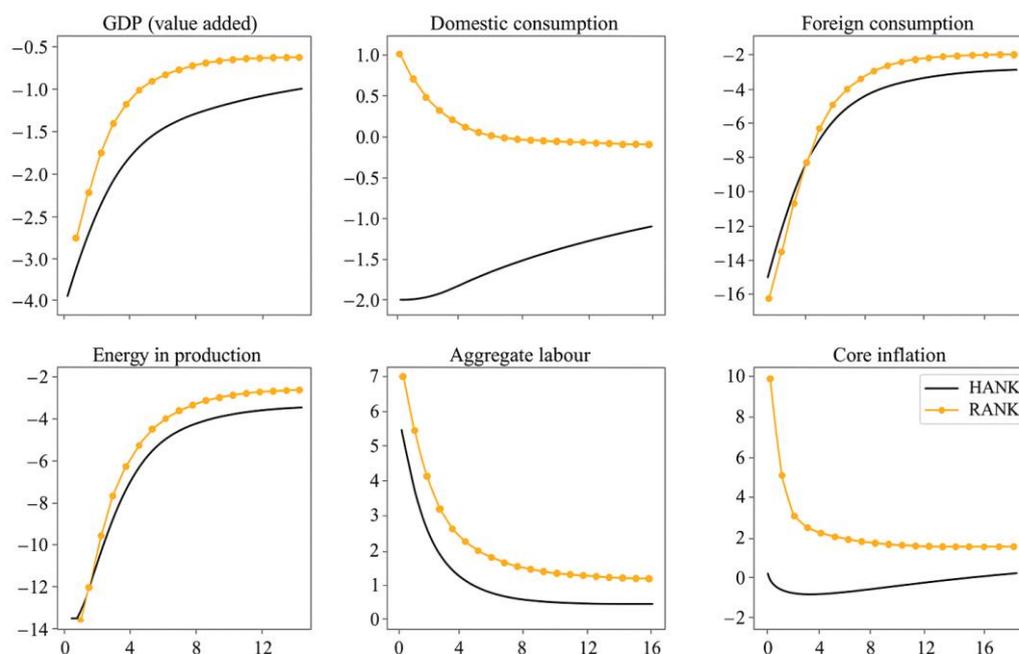
Source: Authors' calculations.
Notes: The chart shows the decomposition of the aggregate consumption response to an energy price shock, calibrated as a 30% increase in the foreign energy price. Monetary policy is implemented under a fixed interest rate rule.

Box footnotes

[a] For a detailed analysis of the distributional effects of a foreign energy shock for different monetary policy rule specifications, see Bobasu, Dobrew and Repele (2024).

Box 2

Dampening inflation expectations without dampening interest rate expectations

Prepared by Stéphane Dupraz (Banque de France)

Standard DSGE models under full-information rational expectations tend to greatly overstate the effect of future policy rates on inflation and output today (see Section 2.2.1). While this so-called forward guidance puzzle has been widely discussed when applied to forward guidance policies at the effective lower bound (ELB) (see Del Negro et al., 2023), it also has implications for policy evaluation away from the ELB. For instance, in a tightening cycle it is likely to exaggerate the effect of a "length strategy", which tightens policy stance by playing on expectations of higher future rates, instead of going for a "level strategy" that raises the peak level of interest rates.

Leading solutions to the forward guidance puzzle involve dampening the effect of future policy rates by weakening the expectation channel. Assumptions of bounded rationality, such as cognitive

discounting (Gabaix 2020) or finite planning horizons (Woodford 2019), make expectations less forward-looking and therefore less responsive to policy announcements about the future. Beyond solving the forward guidance puzzle, these assumptions are also consistent with the weak response of households' expectations regarding inflation and activity as contained in surveys (see Coibion et al., 2023).

Yet asset prices react strongly to announcements about future rates (see Gürkaynak et al. 2005; Swanson 2021), making it important to distinguish between two components of the expectation channel. Since the strong reaction of forward rates and long-term rates likely reflects a change in expectations of future policy rates, this suggests that monetary policy announcements can strongly influence expectations of interest rates – at least among financial market participants – even if they have little effect on households' expectations of inflation and output.

By assuming that households and firms have boundedly rational expectations but that financial market participants have rational expectations, we can reconcile the muted reaction of inflation and output expectations and the strong response of asset prices (Dupraz et al., 2024).

Muted expectations of inflation and output among firms and households are sufficient to avoid the forward guidance puzzle. However, since these households and firms face long-term rates that reflect financial intermediaries' expectations of future policy rates, announcements about future rates have more effect than in models where all expectations are boundedly rational.

Under this dual assumption on expectations, length strategies appear less favourable than under rational expectations. The left panels of Chart A show that under rational expectations, a length strategy that relies strongly on expectations as to future rates is very appealing relative to a level strategy, as it brings inflation down at a much lower cost on output today and at an only slightly higher output cost tomorrow. Meanwhile, when households and firms have less forward-looking expectations, as shown in the right panels, the output gain today is smaller and the output cost tomorrow much larger.

This holds true even when the announcement on future rates is assumed to be fully reflected in long-term interest rates today. If expectations of future policy rates are also dampened – perhaps because the central bank's announcements are not deemed credible – a length strategy becomes even less appealing. The dashed lines in Chart A plot the difference between a length strategy and a level strategy in this case. The non-credible length strategy makes the output cost larger tomorrow without bringing down inflation today.

Chart A

Length strategy versus level strategy depending on expectations formation

a) Rational expectations	b) Boundedly rational firms and households
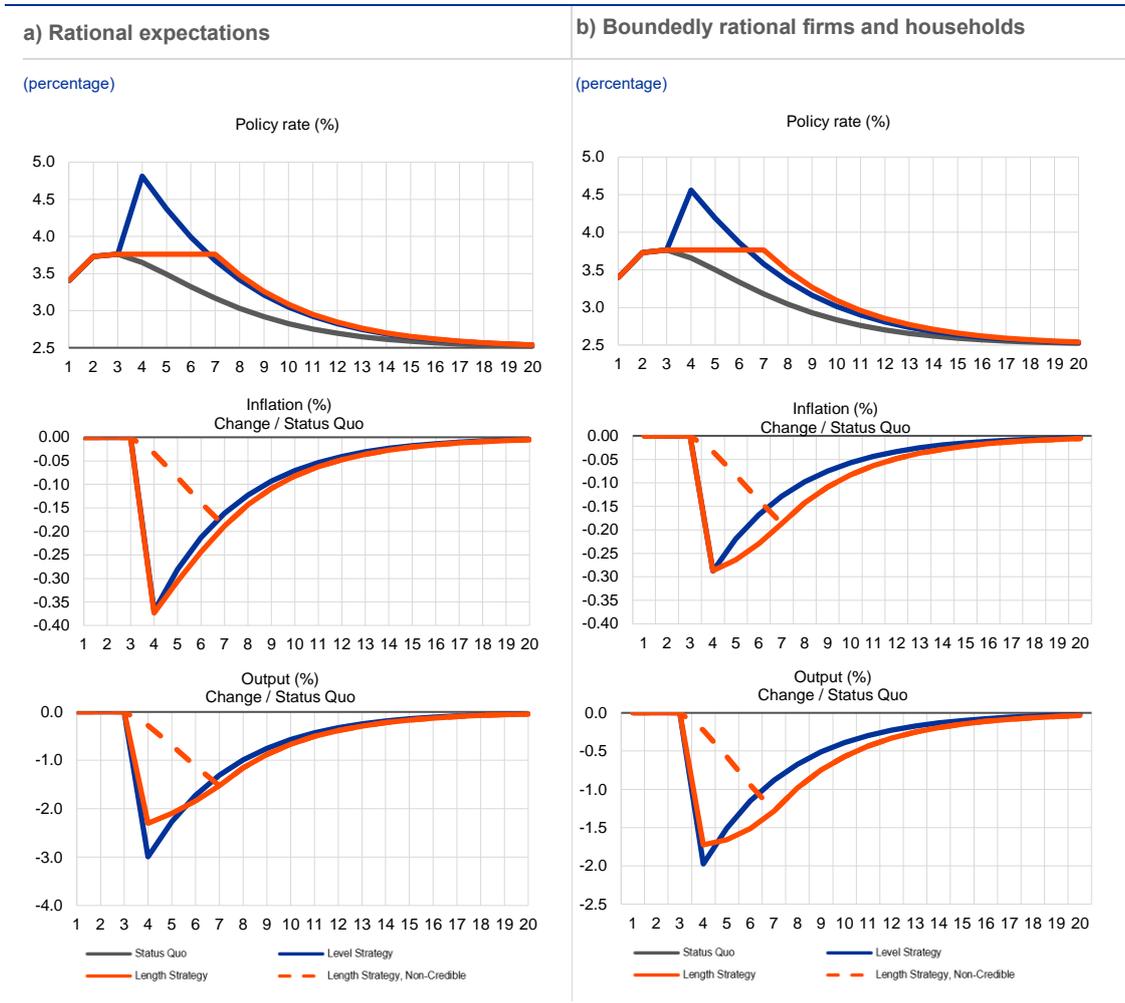
Source: Authors' calculations.
Notes: The panels compare the effect of a length strategy and a level strategy on inflation and output, under rational expectations (left) and a model of bounded rationality where firms and households have finite planning horizons, but financial market participants have rational expectations, based on Dupraz et al. (2024). In both cases, the economy is hit by a supply shock and the central bank initially reacts according to its standard Taylor rule (status quo policy). In the length strategy, the central bank deviates from the status quo policy when it reaches the peak level of interest rates by announcing that rates will remain at this level for four more quarters (then resuming its Taylor rule). In the level strategy, the central bank deviates from the status quo policy by raising rates to a higher peak level (then resuming its Taylor rule). The level of the new peak is such that the impact on inflation is the same as in the length strategy.

Box 3
Sacrifice ratios from policy announcements in the New Keynesian Model

Prepared by Gene Ambrocio, Markus Haavio and Nigel McClung (Bank of Finland)

When evaluating the merits of alternative policy rate paths over a given horizon with the aim of disinflating the economy, sacrifice ratios (the ratio of cumulative changes in output relative to cumulative changes in inflation) tend to be quite useful as a summary statistic. In these situations, and particularly when inflation pressures are expected to arise from the supply side, the central bank will typically look to disinflate the economy without generating additional downward pressure on economic activity and output. Hence, a policy rate path which generates a low sacrifice ratio would be preferable.

Two approaches to crafting policy rate paths may be considered: a level approach favouring immediate and forceful action, or a length approach entailing a more gradual but prolonged tightening. Both approaches could feasibly generate the required disinflation but could also have different effects on output. The key difference is the timing as to when monetary tightening is relatively strongest.

Length strategies deliver lower sacrifice ratios

In Ambrocio, Haavio and McClung (2024), we find that when these policy alternatives are evaluated through the lens of the basic New Keynesian model, length strategies tend to deliver lower sacrifice ratios. However, standard approaches to mitigating the forward guidance puzzle by adding cognitive discounting to expectations à la Gabaix (2020) attenuate the rate at which sacrifice ratios decline with the policy implementation horizon, thus tilting the balance in favour of level strategies.

This result is due to an inherent feature of the New Keynesian model, whereby inflation is more "forward-looking" than output and can be analytically derived in the basic three-equation textbook version of the log-linearised model. In linear models, the effects of a policy rate path can be decomposed into the sum of the effects of a sequence of news shocks about the policy rate in the future. In turn, the effect of each news shock component can be obtained in a setting where the policy rate is treated as exogenous over the evaluation period while following the Taylor rule thereafter (see, for example, Laseen and Svensson, 2011). This allows us to focus our attention on simple examples of policy paths: an announcement today that the interest rate will be raised in H periods, where a low H (potentially zero or one) is representative of the level approach, and a large H is representative of the length approach. A full policy-rate path scenario can then be constructed from weighted combinations of these simple policy paths.

Using these simple policy examples, the sacrifice ratio associated with a policy announcement that the interest rate will be raised H periods ahead decreases in H or, alternatively, in the lead time between announcement and implementation. The bottom panel of Chart A below illustrates the associated sacrifice ratios for these simple policy announcements made H periods in advance (period T-H) up to an unannounced policy rate increase (period T). The associated sacrifice ratios for level and length strategies are weighted combinations of these sacrifice ratios, with level strategies placing more weight on the (larger) ratios close to the date of implementation and length strategies placing more weight at longer horizons.

Chart A

Length strategy versus level strategy depending on expectations formation

a) Output	b) Inflation	c) Sacrifice ratios

Much of the gains are achieved at low implementation horizons

Another important feature of our results is that sacrifice ratios are convex over the horizon H, meaning that most of the reduction in sacrifice ratios is achieved when increasing the horizon at low initial levels, such as where at least one third to one half of the gains are achieved from one to two-period ahead announcements. Finally, our results largely carry over to a model with additional real and nominal rigidities (based on Afsar et al., 2024).

Box 4

Monetary policy shocks and the response of monetary policy to unemployment fluctuations

Prepared by Sandra Gomes (Banco de Portugal), Pascal Jacquinot (ECB), and Matija Lozej (Central Bank of Ireland)

Monetary policy that focuses more strictly on inflation, with no regard to labour market developments, tends to generate greater fluctuations among the member countries of the monetary union. This also implies greater cross-country heterogeneity within the monetary union, and greater heterogeneity between constrained and unconstrained households within countries, both in terms of consumption and employment.

Monetary policy shocks and the response of monetary policy to unemployment fluctuations

Monetary policy and the labour market are linked through many channels and can have significant effects on each other. These linkages run both ways, in the sense that monetary policy transmission

may be affected by labour market institutions and prevailing conditions, while labour market conditions may be influenced by monetary policy. Recent research has shown that household heterogeneity, in the presence of market incompleteness and therefore uninsurable income risk, can affect the transmission mechanism of monetary policy (see den Haan et al, 2017; Ravn and Sterk, 2017; Ravn and Sterk, 2021). Since labour income is the main source of income for most households, the fact that it cannot be insured affects a household's marginal propensity to consume and therefore aggregate consumption. These linkages have been shown exist in the United States (see, for example, Patterson, 2023) and more recently in cyclical sectors (see Herman, 2023). Some of these issues were explored in the ECB's 2021 Strategy Review (see Brand et al., 2021), with subsequent work having explored these issues further, including in the context of cross-country differences within the monetary union.

In a monetary union of countries with different labour market institutions, one can expect (un)employment to react differently to shocks, including monetary policy shocks, both across the countries and across the segments of the labour market within each country. This has been documented for the euro area in Herman and Lozej (2023), who show that unemployment volatility can differ significantly across the member countries of the monetary union, with the bulk of unemployment fluctuations being due to fluctuations in the job-finding rate of households with low educational attainment. Using a simple HANK model with search frictions, the authors show how such differences in the institutional features of the labour market, such as the degree of wage rigidity and the share of surplus obtained by workers during wage negotiations, can affect the strength of monetary policy transmission.

Gomes et al. (2023) explore these same issues under a significantly richer TANK model of a monetary union embedded in a global economy (building on the structure of the EAGLE model), but in a framework with nominal price and wage rigidity and search frictions. The main feature of this model is that the labour market for hand-to-mouth (HtM) households is more volatile than the labour market for Ricardian consumers, in line with the empirical evidence. This framework allows us to analyse both within-country and across-country heterogeneity in a monetary union within a single framework that is close to policy models. While Gomes et al. (2023) focus on monetary policy responses to demand and supply shocks, in this box we use their framework to focus on the effects of monetary policy shocks. Here we explore the effects of various targeting rules for monetary policy, where the central bank pays varying degrees of attention to labour market conditions. For our calibration, we chose a typical euro area core country, namely Germany (as in Gomes et al., 2023), as it allows us to illustrate the implications of lower unemployment benefits following the Hartz IV reform on HtM households. The calibration of the model also reflects other differences between monetary union blocs, the United States, and the rest of the world, including differences in trade openness and in nominal and real rigidities (see Gomes et al., 2023 for further details).

Our analysis exposes several issues. First, the responses to a monetary policy shock across countries in the monetary union are not uniform, which is to be expected since the countries are not identical. Second, and more importantly, monetary policy rules conducive to stricter inflation targeting tend to exacerbate differences in responses across countries. Third, monetary policy shocks cause different responses in terms of income, employment and consumption among the two types of households within each country, and these differences increase if the central bank follows stricter inflation targeting. Lastly, even when responses to a monetary policy shock are similar, this can happen for quite different reasons.

Chart A shows the responses of a set of aggregate variables to a standard one-quarter increase in the interest rate by 25 basis points, with an active Taylor rule. The results are shown for the euro area, for Germany, and for the rest of the euro area. Each line represents a monetary rule, which attempts to capture the degree of "hawkishness" of the central bank in conducting monetary policy. The rules considered are inflation targeting with a response to the output gap and a response to unemployment gap, strict inflation targeting, strict average inflation targeting, and average inflation targeting with a response to the unemployment gap. To align the model with the benchmark, which is based on a response to the output gap, the coefficient on the response to the unemployment gap has been calibrated to mimic the response of the rule with the output gap.

A few observations stand out. First, rules that follow stricter inflation targeting (either in the form of inflation or average inflation) imply a stronger response of variables to a monetary policy shock. This is because, in equilibrium, agents are aware that the central bank is a strict inflation targeter, causing forward-looking firms to reduce prices by more. This implies higher real interest rates, leading to a sharper reduction in consumption and demand. In the case of strict average inflation targeting, inflation tends to overshoot once the shock is over, and the Taylor rule dictates that interest rates should remain higher for somewhat longer than under other rules.

Second, stricter inflation targeting amplifies differences across countries in the euro area. This can clearly be seen when comparing the middle and rightmost columns in Chart A (subplots are drawn so that the axes are the same). These differences reflect country heterogeneity in many dimensions, most notably export orientation, and therefore their different exposure to the euro area exchange rate, along with structural differences in the domestic economy, including the labour market (as discussed below).

Chart A

Responses to a standard monetary policy shock – aggregate variables

(percent and percentage-point deviation from steady state)
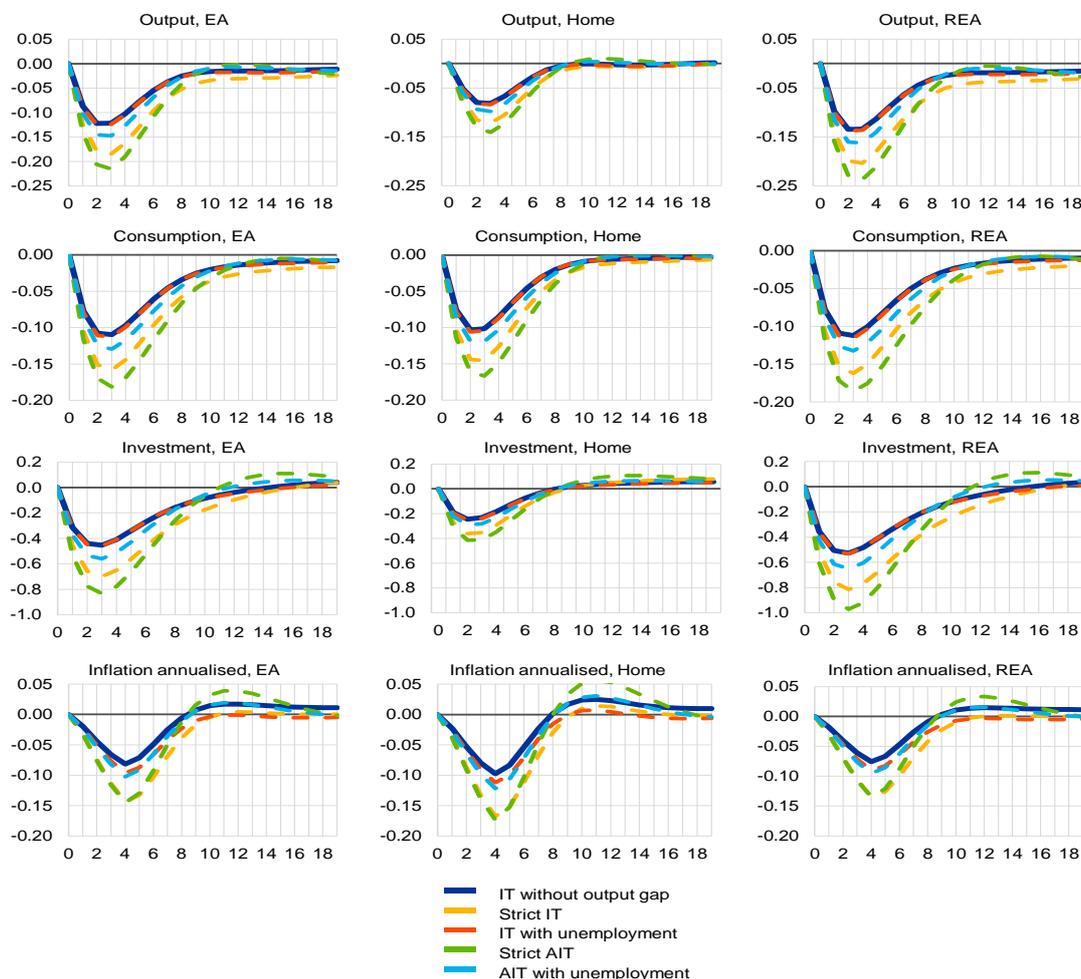
Source: Authors' calculations.
Notes: All variables are expressed as a percentage deviation from the steady state, except inflation, which is expressed as a percentage-point deviation, annualised. The units on the x-axis are quarters.

Chart B shows the effects of a monetary policy shock within each bloc of the euro area. As explained, the model is calibrated so that it reflects the empirical fact that employment fluctuations for households that tend to be poorer (proxied here by HtM households) are more pronounced. We focus on consumption and unemployment rate. The first point to note is that consumption falls by less among Ricardian households than in the case of HtM households, as Ricardian households are more able to smooth their consumption. Moreover, the decline in their consumption is relatively short-lived, as it depends almost entirely on fluctuations in the real interest rate and these fluctuations happen to be relatively short-lived as well. The heterogeneity of Ricardian households' responses to a monetary policy shock across both blocs of the euro area is also relatively limited, for the same reasons, as differences in price rigidities between the blocs and, therefore, in real interest rates are not very large.

Second, the consumption response of HtM households is markedly different from that of Ricardian households. Consumption among HtM households falls by more, and more persistently than that of Ricardian consumers (and more so when the central bank is a stricter inflation targeter). This is because consumption among HtM households is tied to their labour income, which is in turn tied to (sticky) wages and to a labour market that is more responsive for HtM households than it is for Ricardian households. There is also considerable labour market heterogeneity across the monetary union, with unemployment among HtM households in the rest of the euro area rising to nearly twice the level seen in Germany.

Chart B

Monetary policy shock and within-country heterogeneity

(percent and percentage-point deviation from steady state)
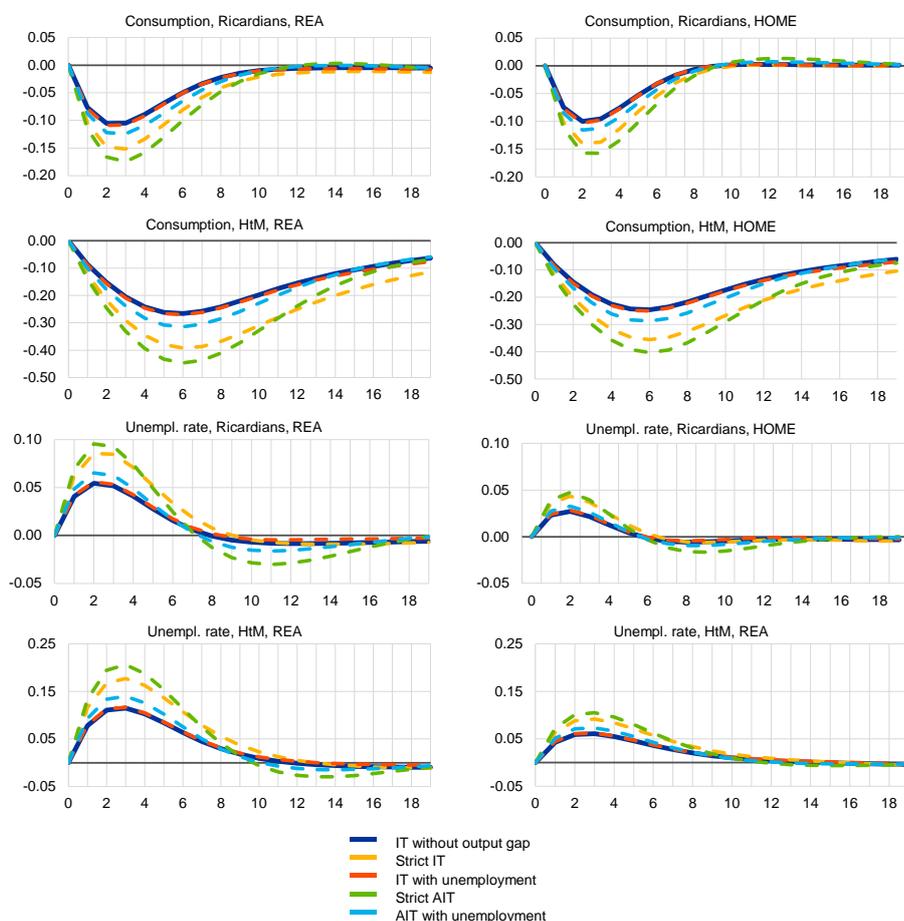
Source: Authors' calculations.
Notes: Consumption is expressed as a percentage deviation from the steady state, while the unemployment rate is expressed as a percentage-point deviation from the steady state. The units on the x-axis are quarters.

This raises the question of why then the consumption response among HtM households is very similar in both blocs of the euro area. This has to do with the level of unemployment benefits and illustrates how labour-market institutions can affect the transmission of monetary policy. Notably, following the Hartz IV reform in Germany, unemployment benefits are lower than in the rest of the euro area (the exact difference depends on the unemployment duration and family circumstances). This difference is the main reason why consumption among HtM households in Germany declines by about as much as in the rest of the euro area despite a smaller rise in unemployment among

such households, as they lose more income upon becoming unemployed (average wages – not shown –move little and do so similarly across blocs). This illustrates how the same consumption outcome can arise from very different economic mechanisms, depending on the institutional set-up in a particular country.

Box 5

Simulating monetary policy shocks

Prepared by Ansgar Rannenberg (Nationale Bank van België/Banque Nationale de Belgique)

Evaluating the effect of changes in monetary policy using rational expectations macroeconomic models is a staple in the work of central bank macro modellers and other researchers. However, how to go about this task is not always obvious. Following Rannenberg (2025), this box shows that monetary policy tightening (or loosening) can be simulated using contemporaneous and anticipated monetary policy shocks calibrated purely on the information embedded in Overnight Index Swap (OIS) rates, conditional on a given quasi-linear model, i.e. where the only potential non-linearity is the effective lower bound. If the information available from the OIS rates is used correctly, the result is identical to what would be obtained if the modeller knew the magnitudes of the shocks and thus could use them to simulate the non-tightening counterfactual scenario of interest.

This box illustrates the result using simulations of a simple, purely forward-looking New Keynesian model, although the key results presented below could be generated using any linearised DSGE model:

$$\widehat{\Pi}_t = \kappa \widehat{Y}_t + E_t \widehat{\Pi}_{t+1} + u_{\Pi,t}$$

$$\widehat{Y}_t = E_t \widehat{Y}_{t+1} - \left(\widehat{R}_t - E_t \widehat{\Pi}_{t+1} \right) + u_{Y,t}$$

$$\widehat{R}_t = \phi_\Pi \widehat{\Pi}_t + \phi_y \widehat{Y}_t$$

$$u_{\Pi,t} = \rho_{u\Pi} u_{\Pi,t-1} + \eta_{\Pi,t}$$

$$u_{Y,t} = \rho_{uY} u_{Y,t-1} + \eta_{Y,t}$$

where $\widehat{\Pi}_t, \widehat{Y}_t, \widehat{R}_t, u_{\Pi,t}$ and $u_{Y,t}$ denote inflation, output, the nominal interest rate, and exogenous cost-push and demand shocks with innovations $\eta_{\Pi,t}$ and $\eta_{Y,t}$, respectively. The calibration is given by $\kappa = 0.05$, $\phi_\Pi = 1.5$, $\phi_y = 0.5/4$ and $\rho_{u\Pi} = \rho_{uY} = 0.950$. The first step simulates the response of the model to inflationary cost-push and demand shocks. It is assumed that over the course of five quarters, a new unexpected shock innovation arrives each quarter. I refer to the quarter just before the first shock arrives as quarter zero. As shown in Chart A (solid line labelled "Baseline"), the shocks have the effect of increasing inflation, which causes the policy interest rate to rise sharply and GDP to fall heavily. This tightening is reflected both in the increase in the policy interest rate and, importantly, in the successive upward shifts of the forward curves (see the lower right panel).

The goal is to compute the effect of the monetary tightening compared with a counterfactual where monetary policy does not immediately respond to the paths of output and inflation triggered by the supply and demand shocks. Instead, during quarters 1 to 3, it pegs the interest rate to the path expected in quarter 0, before the arrival of the shocks in response to which monetary policy tightens. This path is denoted as $\widehat{R}_t^{acc}$. Agents fully anticipate the length of the interest rate peg under monetary accomodation. For simplicity, I assume that in period 0, the economy is in steady

state, implying that $\hat{R}_t^{acc}$ = 0. As shown in Rannenberg (2025), this simplifying assumption is in fact not necessary. Formally, the accommodative policy is described by

$$\hat{R}_t \begin{cases} 0 \ for \ t = 1,2,3 \\ \phi_\Pi \hat{\Pi}_t + \phi_y \hat{Y}_t \ for \ t > 3 \end{cases}$$

As shown in Chart A (black dotted line), over its duration the interest rate peg implies higher output and inflation than under the baseline policy. From period 4 onward, the paths of output and inflation are identical in both scenarios, due to the fact that the model is purely forward-looking, i.e. with no lags of endogenous variables. However, the results also hold also under less restrictive assumptions.

Chart A

Effects of cost-push shocks under the baseline and with monetary policy accommodation over the three quarters

(percent and percentage-point deviation from steady state)
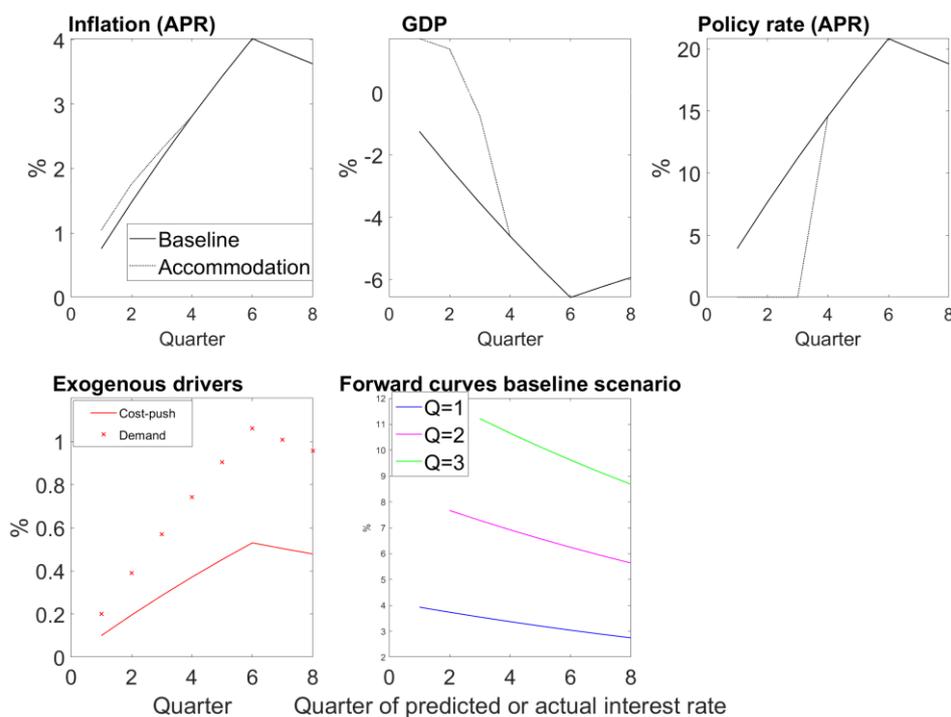
Source: Authors' calculations.
Notes: All variables are expressed as percentage deviations from the steady state, except inflation and the policy rate, which are expressed as percentage-point deviations, annualised. The units on the x-axis are quarters.

I define the effect of the tightening as the difference between the value of a variable without monetary accommodation X_t^{base} and its value under monetary accomodation as $\Delta X_t = X_t^{base} - X_t^{acc}$. ΔX_t is displayed in Chart B as the black solid line labelled "True effect". The lower-right panel of Chart B displays the result of this computation for the forward curves observed during the first three quarters. Formally, these are the $E_k \Delta \hat{R}_j$ for each period j for which $k \leq j \leq 3$ and each $k = 1,2,3$. I refer to the $E_k \Delta \hat{R}_k, E_k \Delta \hat{R}_{k+1}$ ... sequence as the normalised forward curve of quarter k.

I then conduct two additional simulations featuring only monetary policy shocks and therefore no non-policy shocks. In the first simulation, which I call "Staggered foresight", I peg the interest rate such that in the first three quarters, the simulation replicates the respective normalised forward curve. Formally, in each quarter $k = 1 - 3$, I peg $E_k \hat{R}_j = E_k \Delta \hat{R}_j$, for each period j for which $k \leq j \leq 3$. For each quarter, the solid lines shown in the lower-right panel of Chart B depict the respective expected interest rate trajectory induced by this peg. More precisely, the blue solid line displays $E_1 \hat{R}_1$, $E_1 \Delta \hat{R}_2$ and $E_1 \Delta \hat{R}_3$. For $j > 3$, monetary policy follows the model's interest feedback rule $\hat{R}_t = \phi_\Pi \hat{\Pi}_t + \phi_y \hat{Y}_t$, which is fully anticipated. The results of this simulation, shown by the red dotted diamond line, exactly replicate the effect of the tightening computed from the results of the two simulations of the adverse supply shocks (the black solid line).

Chart B

Effects of monetary tightening

(percent and percentage-point deviation from steady state)
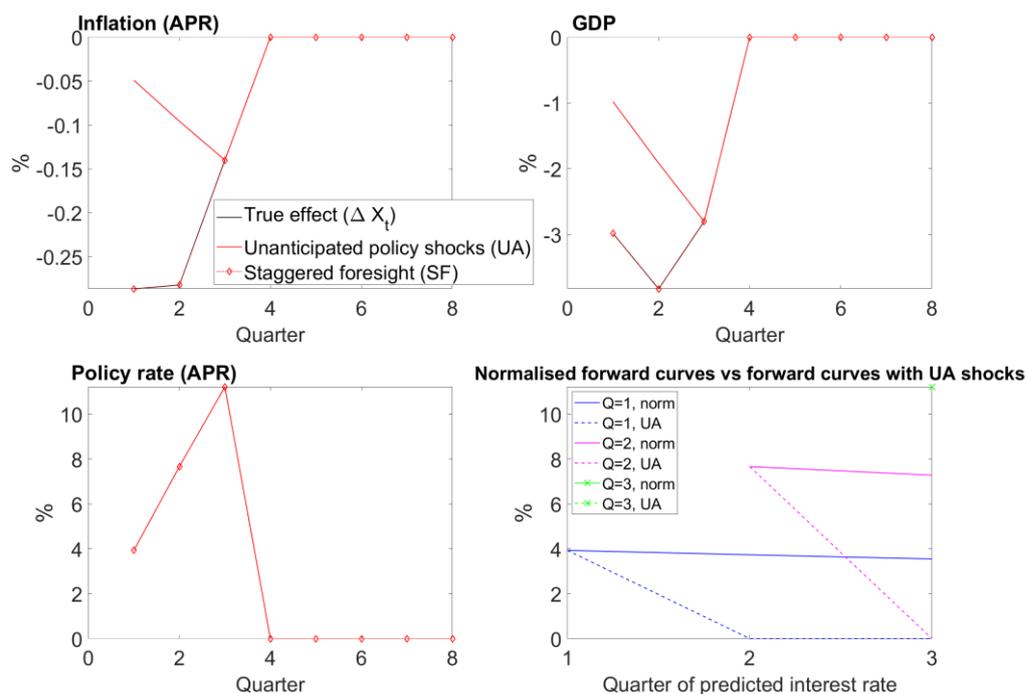

Source: Authors' calculations.
Notes: All variables are expressed as percentage deviations from the steady state, except inflation and the policy rate, which are expressed as percentage point deviations, annualised. The units on the x-axis are quarters.

In the second simulation, labelled "Simulation as unanticipated monetary policy shocks", I also replicate the path of $\Delta \hat{R}_k$ for $= 1 - 3$, but not the normalised forward curve observed at each point in time. Specifically, in each quarter k agents assume that beginning in $k + 1$, the interest rate will follow the model's interest feedback rule. As the model lacks interest rate smoothing, the rate returns to its steady state. As shown in Chart B, this simulation strongly understates the true effect of the tightening. The lower right panel of the chart suggests how this result arises: while the simulation replicates the respective contemporaneous $\Delta \hat{R}_k$ in each quarter k, the respective expected interest rate trajectory for the following quarters is systematically below the normalised forward curve.

Hence, without knowing the shocks that caused the tightening, the effect of the monetary tightening compared with a monetary accommodation counterfactual where the interest rate remains constant for three quarters can be computed by feeding into the model, in each quarter, the respective deviation of the forward curve from the non-tightening counterfactual. Recall that under the non-tightening counterfactual the forward curve is the interest rate trajectory expected in quarter 0 (just before the tightening starts) for the subsequent three quarters. Therefore, the elements of the normalised forward curves $E_k \Delta \hat{R}_j$ can be easily estimated from financial market data as $E_k \tilde{R}_j - E_0 \tilde{R}_j$ for each j for which $k \leq j \leq 3$, and for each quarter $k = 1,2,3$. The $E_0 \tilde{R}_j$ sequence denotes the quarter 0 forward curve derived from quarter 0 OIS rates, which also equals the interest rate trajectory in the non-tightening counterfactual scenario. The $E_k \tilde{R}_j$ sequences denote the forward curves observed in each quarter k=1,2.,3.

Box 6
A comparative model approach to monetary policy transmission in the euro area

Prepared by Nuno Vilarinho Gonçalves (Banco de Portugal)

The formulation of effective and robust monetary policy relies critically on a thorough understanding of the mechanisms whereby policy instruments are transmitted to the broader economy. Comparative analyses of structural macroeconomic models have proven to be invaluable in evaluating the strengths and limitations of these frameworks, particularly as regards their ability to guide quantitative policy decisions. The contributions by Taylor and Wieland (2012) and Wieland et al. (2012, 2016) provide a systematic framework for the comparative assessment of such models. This Box draws on the public archive of structural macroeconomic models developed by these authors (www.macromodelbase.com) to evaluate the effects of monetary policy shocks as part of the harmonised common exercise described in Section 2.2.

The purpose is to use euro area estimated structural models readily available to the public to run the harmonised common exercise and assess the impact of monetary policy shocks and their robustness across models, while also highlighting the uncertainties that can arise from differences in modelling approaches.

Euro area estimated structural models: selection and characteristics

The selected models are consistent with estimated medium-size New Keynesian DSGE models, widely used in monetary policy analysis. These models incorporate microfounded dynamics with added frictions such as nominal rigidities, adjustment costs, and behavioural features like habit formation. The selection criteria focused on estimated euro area models that could be solved in all harmonised exercises proposed.

These models feature a mix of closed- and open-economy frameworks. Among the latter are the EA_SR07 model of Adolfson et al. (2007), EA_QUEST3 developed by Ratto et al. (2009), EA_PV17 from Priftis and Vogel (2017), and the two-country EA_PV15 model produced by Poutineau and Vermandel (2015). EA_QUEST3 and EA_PV17 include liquidity constrained households, whereas the other models consider only forward-looking, permanent-income households. Several models include financial frictions, which play a central role in the transmission of monetary policy. The financial accelerator mechanism of Bernanke et al. (1999) is incorporated in EA_GE10 (Gelain, 2010) and EA_VI16 (Villa, 2016), while a detailed banking sector is present in EA_PV15. Regarding the labour market, most of the models account for monopolistic competition in labour supply and

Calvo-style rigidity in nominal wages. EA_CKL09 (Christoffel et al., 2009) additionally introduces Mortensen and Pissarides (1994) matching frictions in the labour market, while EA_SWW14 (Smets et al., 2014) incorporates labour decisions on the extensive margin. All models are estimated using Bayesian techniques, albeit differing in observed variables and estimation samples. Model-specific monetary policy rules feature interest rate smoothing and reactions to inflation and to a real variable (the output gap or output growth) in all models. In EA_SR07, the policy rule also includes a reaction to the real exchange rate.

Implications of monetary tightening: a comparative analysis

To assess uncertainty over policy effectiveness, a 25 basis-point contractionary monetary policy shock is simulated in each model under three alternative rules: the model-specific rules estimated alongside the structural parameters; a harmonised rule based on the EAGLE model (Gomes et al., 2012) so as to make a clean comparison of the implications of different model structures, this rule being a function of lagged interest rate, inflation rate and output growth; and a modified harmonised rule that mutes the response of interest rates to output.[a]

Chart A

Impulse responses to a 25-bp temporary unanticipated rise in the nominal interest rate

Deviations from steady state: Output in percentage; policy rate and inflation expressed in annualised percentage points
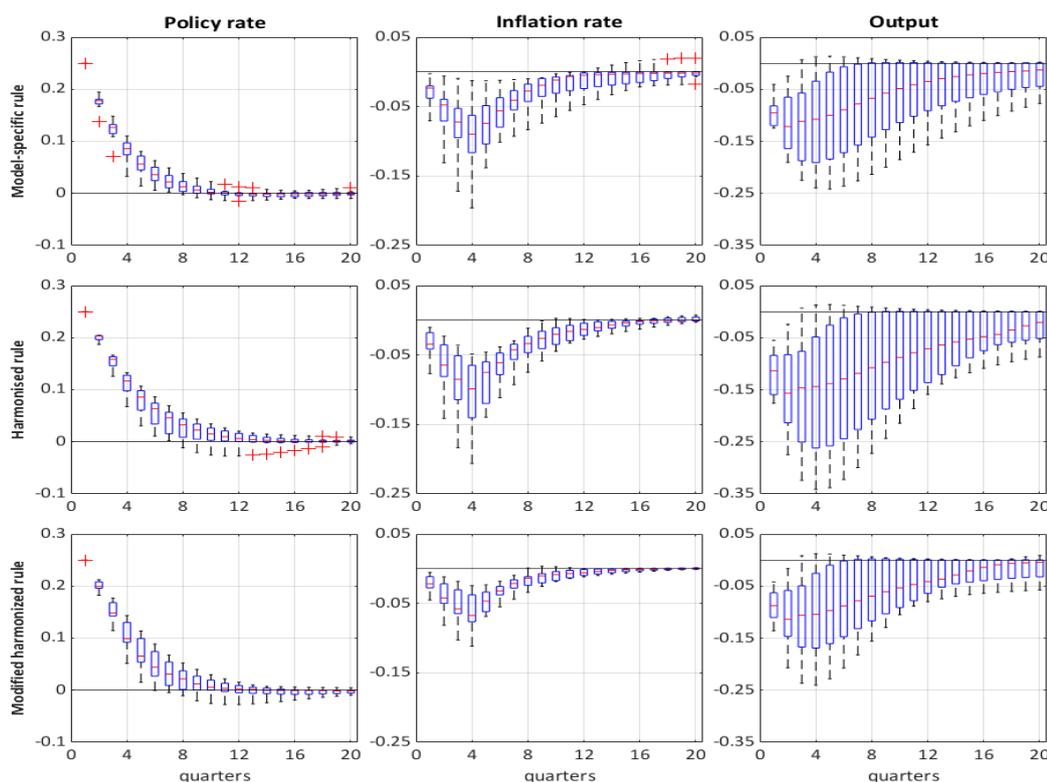
Source: Author's calculations.
Notes: The first row shows impulse responses when monetary policy in each selected model follows a model-specific estimated rule. The second and third rows show responses when, in all selected models, monetary policy follows the harmonised rule and the modified harmonised rule, respectively. The selected models and the Macroeconomic Model Data Base (MMB) 2.3 platform were adapted to perform deterministic simulations. The MMB software and a brief description of each model can be downloaded from the MMB website. The horizontal axis reports quarters. The blue bars show the interquartile range (IQR); the red line is the median. The whiskers report 2*IQR; all observations outside the whiskers are treated as outliers and reported with red crosses.

The simulations based on the model-specific rule represent the most likely data-driven reaction of the economy to the monetary policy shock in these models. Assessing the range of predicted effects across models provides a measure of the degree of model uncertainty about monetary policy transmission (Wieland et al., 2016).

The results shown in Chart A reveal some heterogeneity in the predicted macroeconomic outcomes, reflecting both model uncertainty and structural differences. Under model-specific rules, the responses of key variables, particularly output, show substantial dispersion to monetary policy shock. This variability illustrates the high degree of model uncertainty and the sensitivity of policy implications to the specific assumptions embedded within each framework. Differences in the models' estimation sample period may also add to this volatility. When the harmonised rule is applied, the dispersion in responses to inflation and output becomes more pronounced. This increase in variation highlights the structural differences across models, as the uniform policy rule eliminates discrepancies arising from idiosyncratic rule specifications. The use of the modified harmonised rule mitigates the dispersion to some extent, yielding lower magnitudes of responses and reduced persistence in output and inflation dynamics. This finding suggests that monetary policy rules with muted feedback on output may offer more robust predictions across a wide range of structural frameworks.

The role of financial frictions

Following the global financial crisis, New Keynesian DSGE models have been fitted out to include more detailed financial sectors and financial frictions that serve to amplify financial and economic shocks. To isolate the impact of financial frictions, the following analysis compares the responses of all selected models with those without detailed financial sectors or frictions.

Chart B shows the impulse responses to a temporary unanticipated shock using the selected models. The results indicate that in the selected sample of models, those that include financial frictions (EA_GE10, EA_PV15 and EA_VI16) show larger impacts of monetary policy, particularly under the harmonised rule. Differences emerge in the mean responses given by the two subsets of models, with models lacking detailed financial sectors exhibiting a less negative impact on inflation until the tenth quarter and showing a milder output response throughout all time spans. The analysis also shows that, when considering the modified version of the harmonised rule, inflation and output volatility are initially less sensitive to the effects of financial frictions.

The results described in this Box go to show the considerable degree of model uncertainty inherent in monetary policy analysis when we use a diverse pool of models. This uncertainty is particularly evident in the transmission of policy to output, where structural differences between models play a critical role. While the comparative exercise provides valuable insights, it is important to acknowledge its limitations. Most of the selected models are estimated on data predating the global financial crisis, raising questions about their relevance in the current economic environment. Moreover, ongoing advances in macroeconomic theory and estimation techniques may lead to different estimations of key parameters, thus changing policy implications over time as new models grow old and become obsolete. Even so, these considerations underscore the importance of accounting for model uncertainty and structural changes when assessing monetary policy transmission.

Chart B

Impulse responses to a contractionary monetary policy shock under the modified harmonised rule

Deviations from s.s.: output expressed as a percentage; policy rate and ìnflation expressed in annualised percentage points

Box footnotes

[a] For more details see the description of the harmonized rule and the modified harmonized rule in Section 2.1.

Box 7
General differences between semi-structural (FRB/US-type) and DSGE models

Prepared by Anastasia Zhutova (Banque de France), Georg Muller (ECB) and Srečko Zimic (ECB)

Semi-structural and DSGE models differ fundamentally in their purpose, theoretical foundations, and estimation techniques. These differences influence how they are used by policymakers and explain why both types of models are necessary to capture the full spectrum of macroeconomic dynamics.

Theoretical underpinnings

DSGE models prioritise internal consistency by adhering to micro-founded theoretical principles, with structural parameters influencing multiple parts of the system. This ensures coherence and

allows for consistent simulations of structural changes. For instance, in DSGE models, consumption dynamics are derived using a representative agent framework, where the agent is both a consumer and an owner of the means of production. Consumption is driven primarily by expected future interest rates through the Euler equation, tightly linked to equilibrium conditions and influenced by parameters such as the consumer's discount factor.

In contrast, semi-structural models prioritise empirical fit, offering richer specifications of individual components while relaxing the cross-equation restrictions that ensure consistency in DSGE models. For example, models such as ECB-BASE account for individual income risks and varying propensities to consume from different income sources, thus emphasising the expected income channel over the interest rate channel in driving consumption. However, this flexibility comes at the cost of system-wide coherence, as relationships such as interest rate effects on consumption may not align seamlessly with other optimisation problems, such as those faced by firms.

Semi-structural models rely on a theoretical anchor for long-term relationships, while reduced-form, short-run equations represent the economy's behaviour in a more flexible, data-driven way. In models in the vein of FRB/US (a model of the Federal Reserve Board), this flexibility is made possible through the Polynomial Adjustment Costs (PAC) framework, which allows for the gradual adjustment of variables towards their micro-founded long-run targets. Semi-structural models thus strike a balance between theory and empirical data, offering flexibility by being able to include a wider range of factors that may not be easily captured within the more rigid micro-founded framework of DSGE models.

Structure

Semi-structural models focus on capturing inertia in economic variables through error correction mechanisms (ECM) and lagged dynamics, aiming for white noise residuals. In contrast, DSGE models capture inertia by specifying shocks as autoregressive processes. As a result, these models tend to be more responsive to shocks, such as interest rate changes, while semi-structural models exhibit slower, stickier adjustments because they tend to focus on gradual changes in economic relationships. This difference also implies that each separate component of a semi-structural model can perform well in forecasting individually, while in DSGE models, the forecasting capabilities of individual equations may be poor, requiring the full system to produce meaningful forecasts.

Estimation techniques

The piecewise versus system orientation also transmits to different estimation approaches. DSGE models are typically estimated using system-wide estimation techniques such as Bayesian methods, which ensure consistency with cross-restrictions between parameters of all equations implied by micro-foundations. Meanwhile, semi-structural models are estimated equation-by-equation utilising a mix of different estimation techniques.

This simultaneous estimation approach in DSGE models reduces the risk of reverse causality and ensures that the relationships between variables are coherent throughout the system. By contrast, the estimation residuals in equations of semi-structural models are not structural shocks, although these models do offer certain advantages: they can be updated with new data or additional blocs can be added without having to re-estimate the entire system; a misspecification of one model equation does not propagate to the other parts of the model as strongly as in system-wide estimated DSGE models; the separate determinacy of equations means that the model can be

solved more easily when running it conditional on fixed exogenous paths in other parts of the model economy.

The above-mentioned characteristics of semi-structural models offer significant flexibility, particularly in addressing short-term policy concerns and incorporating new data or shocks. This flexibility makes them particularly useful for central banks, which need to quickly adapt their models to emerging policy questions. However, this flexibility may come at the cost of weaker theoretical consistency, as the empirical focus may obscure some of the structural mechanisms underlying the economy. DSGE models, while more rigid in structure, provide a systematic framework for a deeper understanding of the economy's dynamics. They are particularly well-suited to exploring how economies react to structural changes, such as reforms or technological advancements.

Box 8
The role of nominal and real rigidities in monetary policy transmission

Prepared by Igor Vetlov (Deutsche Bundesbank)

Using the Euro Area and Global Economy (EAGLE) model[a], we explore how price and wage stickiness, investment adjustment costs, and habit formation in consumption can affect monetary policy transmission in the euro area. In the illustrative simulations provided below, the alternative parameters, associated with nominal and real rigidities, broadly reflect the parameter ranges of the structural models used in the common exercises set out in this paper.

Nominal rigidities tend to limit the disinflationary impact and raise the output losses of monetary tightening. Price stickiness refers to the slow adjustment of prices in response to changes in supply and demand, often due to menu costs, long-term contracts, or other market frictions. Higher price stickiness (a Calvo parameter of 0.9 versus 0.75) causes a more delayed reduction in inflation, thus prolonging the adjustment period and pushing up the output costs of disinflation. Nominal wage stickiness occurs when wages adjust slowly to changes in economic conditions due to long-term contracts, labour market regulations, or institutional factors. Similar to price stickiness, wage rigidities also tend to reduce monetary policy effects on inflation and induce a larger drop in output. Moreover, stickier wages (a Calvo parameter of 0.9 versus 0.75) lead to slower changes in labour costs and delay the recovery of employment and production (see Chart A, upper panel).

Chart A

Monetary policy impact under alternative parametrisation in the EAGLE model

a) Price rigidities

(p.p. and percentage deviation from baseline)

- ■ High price rigidity
- ■ Low price rigidity

b) Wage rigidities
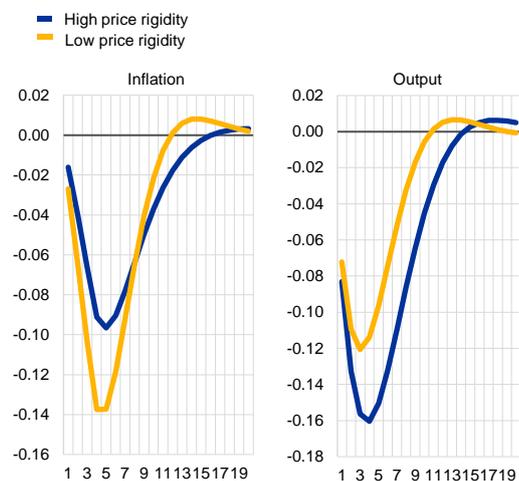
(p.p. and percentage deviation from baseline)

- ■ High wage rigidity
- ▪▪ Low wage rigidity
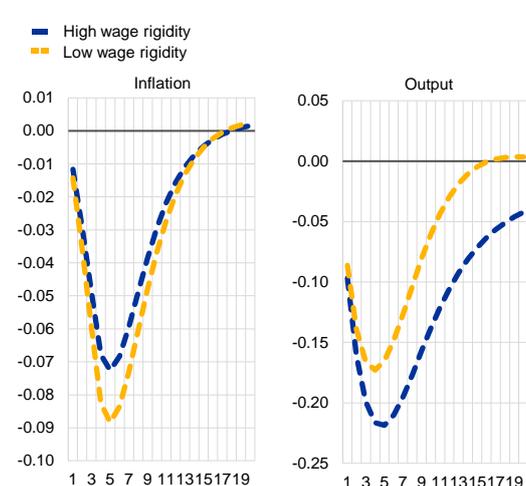
c) Real rigidities in consumption

(p.p. and percentage deviation from baseline)

- ■ High cons. rigidity
- ■ Low cons. rigidity
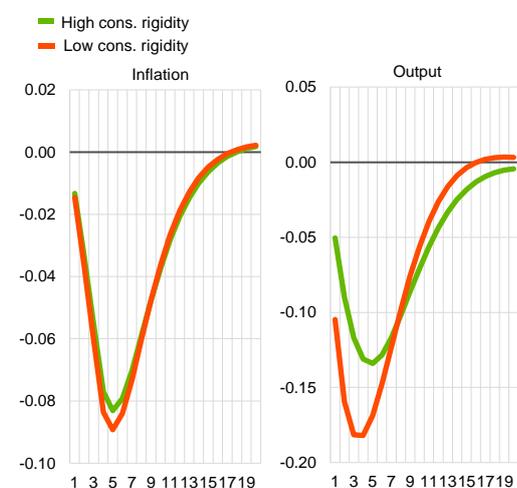
d) Real rigidities in investments

(p.p. and percentage deviation from baseline)

- ▪▪ High invest. rigidity
- ▪▪ Low invest. rigidity
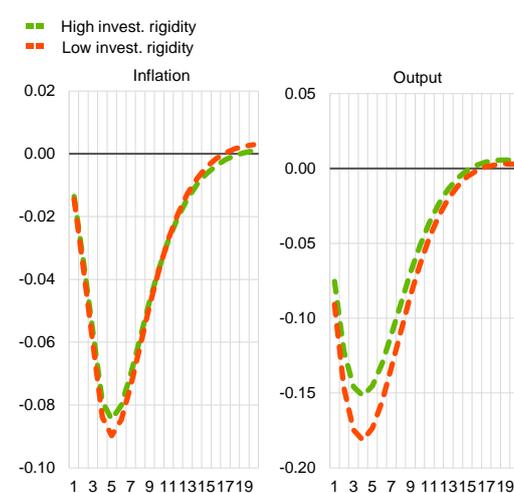
Source: Authors' calculations.
Notes: The chart shows the deviation of the inflation rate (in pp) and output (in percent) from the baseline (steady state) in response to a monetary policy shock over a horizon of 20 quarters. The policy shock is calibrated to a 25-basis-point increase in the short-term interest rate in the first quarter; thereafter, the interest rate follows the model's monetary policy rule.

Higher real rigidities in consumption and investment tend to delay and dampen a broader reduction in output following a monetary policy tightening process. Habit formation in consumption implies that consumers' current consumption preferences are influenced by their past consumption levels. Because consumers' consumption patterns adjust more gradually (0.9 versus 0.6 in terms of habit parameter), the immediate impact of monetary policy on aggregate demand will be smaller. Investment adjustment costs mean the expenses incurred by firms when they alter their investment levels and can often arise when changing production processes, installing new equipment, or

retraining employees. Due to higher adjustment costs (11 versus 5 in terms of adjustment parameter costs), firms may not immediately revise their investment, thus dampening the immediate effect of monetary policy on economic activity. In both cases, parameter variation implies only a limited quantitative impact on inflation adjustment dynamics (see Chart A, lower panel).

The differences in modelling assumptions regarding the strength of nominal and real rigidities may therefore account for a significant part of the observed model heterogeneity in terms of monetary policy impact evaluations. Ceteris paribus, a monetary policy tightening in models featuring stronger nominal rigidities combined with weaker real rigidities would imply a smaller reduction in inflation and a larger drop in output when compared with models that assume more flexible price and wage setting and a stronger presence of frictions in consumption and investment decision-making.

Box footnotes

[a] EAGLE is a large-scale calibrated multi-country micro-founded general equilibrium model. See Gomes et al. (2012) for documentation on the basic version of the model. All simulations are run with the EAGLE model-specific monetary policy rule.

Box 9

## The Limited-Information Rational Expectations approach and anticipation schemes in the CNBg3+ model

Prepared by František Brázdik (Česká národní banka)

The Limited Information Rational Expectations (LIRE) approach refines the Full Information Rational Expectations (FIRE) framework originally used in the Czech National Bank's (CNB) core macroeconomic forecasting model. It was introduced to address the excessive influence of long-term anticipated shocks on current economic decisions. Unlike FIRE, which assumes agents have perfect knowledge of all future shocks, LIRE incorporates information gradually. In this framework, only near-term future events are fully anticipated, while more distant ones enter expectations progressively (Brázdik et al., 2020).

A key advantage of LIRE is its ability to reduce the "forward guidance puzzle". By assuming a finite visibility horizon, LIRE ensures that economic agents do not overreact to distant future shocks, treating them instead as unanticipated until they come closer to realisation. This approach also enhances forecast stability and consistency, preventing large discrepancies between consecutive forecasts that often arise in traditional rational expectations models. Under FIRE, shifting forecast horizons can lead to significant variations in expected economic outcomes, whereas LIRE smooths these transitions, making forecasts more stable and reducing inconsistencies (Musil, Tvrz & Vlček, 2021).

Another important feature of LIRE is its flexibility in expectation formation. Unlike traditional models that treat all shocks similarly, LIRE allows different types of economic disturbances, such as foreign and domestic shocks, to have different expectation horizons. This adaptability makes LIRE particularly useful for central banks and policymakers. By integrating a moving-horizon expectation scheme and gradual information assimilation, LIRE offers a more realistic and robust forecasting framework for monetary policy and macroeconomic analysis (see Brázdik et al., 2020; Musil, Tvrz & Vlček, 2021).

Chart A

Impulse responses to a monetary policy shock

a) Output	b) Y-o-y Inflation	c) Policy rate
(p.p. and percentage deviation from baseline)	(p.p. and percentage deviation from baseline)	(p.p. and percentage deviation from baseline)

Legend (each panel):
- 4 periods ant.
- 8 periods ant.
- 8 periods unant.
- 8 periods LIRE
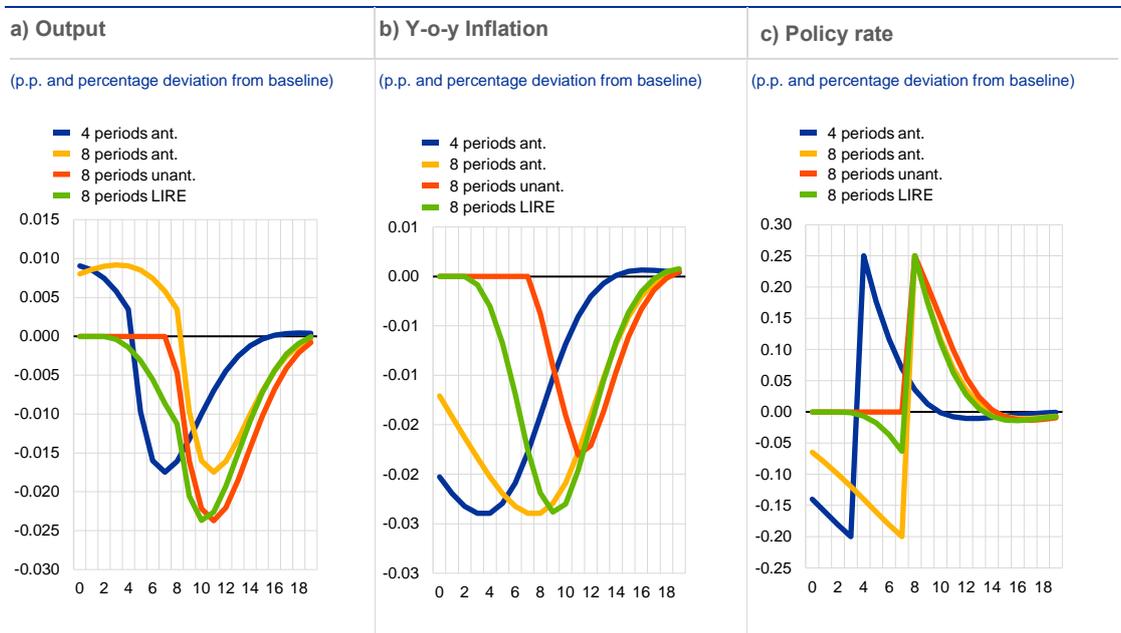
Sources: Author's/CNB calculations.
Notes: The chart shows deviations of output (in %), YoY inflation rate (in p.p.), and policy rate (in p.p.) from steady state in response to a 25 basis-point shock to the policy rate at different horizons (4 and 8 periods) and under varying anticipation schemes for the shock (anticipated, unanticipated, LIRE anticipation scheme). Simulations are performed using the harmonised (EAGLE) monetary policy rule described in Section 2.1.

Chart A compares the impulse response functions for four different simulations of a policy shock: a fully anticipated shock occurring in four periods (blue line), a fully anticipated shock occurring in eight periods (yellow line), an unanticipated shock occurring in eight periods (red line), and a shock under the LIRE scheme occurring in eight periods (green line). This illustrates the LIRE decay scheme of weights [1, 0.8, 0.6, 0.4, 0.2], meaning that a shock occurring within one period is fully anticipated, whereas a shock five periods away is foreseen with only 20% certainty. This mechanism helps smooth the transition between expected and unexpected events, preventing extreme policy reactions while still allowing for forward-looking behaviour in monetary policy modelling.

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3 The pool of tears: empirical benchmarks

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This chapter aims to benchmark the model-based results discussed in Chapter 2 with an empirical counterpart through a quantitative and qualitative meta-analysis on the effects of conventional monetary policy (MP) decisions on the economy, notably on output and prices. There is an important caveat to bear in mind when comparing the empirical literature with the model-based results. Models, especially structural ones, are by design micro-founded and internally consistent, and some of their key elements and features cannot be harmonised or made consistent with the models used in the empirical literature. For instance, this is the case for policy rules, which are indeed implicitly embedded in a VAR model (in the endogenous responses of interest rates and macro variables to any shocks) but cannot be explicitly modelled as in a DSGE. Nonetheless, the comparison is important as it provides a data-based reference point for models and helps to shed more light on their characteristics or to recalibrate them if needed.

That said, this chapter focuses on quantifying MP effects averaged across several papers in the literature and on reporting the main transmission mechanisms that the literature has scrutinised. Both are crucial aspects for policymakers in designing and implementing appropriate MP measures when needed.

This survey starts by reviewing important aspects related to the identification of MP shocks and the model specifications. We then discuss the quantitative results, based on ESCB analysis and available meta-analyses, together with the key transmission channels in advanced economies (mostly euro area and the United States). The section concludes with a "reconciliation" of the empirical benchmarks with the model-based results.

3.1 Preparatory "qualitative" considerations

Before providing a quantitative summary of the literature, we should first recap certain qualitative aspects related to identification, model specification and data

choices that make the results heterogeneous and difficult to aggregate across the numerous papers that exist on the transmission of conventional MP shocks. Surveying these aspects, therefore, allows us to understand the main caveats to be wary of when "averaging" results across studies and comparing them with those of ESCB models.

Identification strategies

The identification of shocks is the first crucial element determining the accuracy and reliability of estimates as to the causal effects of MP on key macroeconomic variables.

In earlier studies, conventional MP shocks were captured by contemporaneous restrictions on the effect of changes in the short-term interest rate on macroeconomic variables. Nonetheless, important shortcomings of this MP measure are its endogeneity to economic variables and the fact that it can contain anticipatory movements of output and inflation (Romer and Romer, 2004).[25] Bauer and Swanson (2022) reproduce estimates made by other papers, such as Gertler and Karadi (2015), Ramey (2016), Miranda-Agrippino and Ricco (2021) and Plagborg-Møller and Wolf (2021), using orthogonal MP surprises with respect to macroeconomic data that pre-date the MP announcement. They find estimates up to four times larger compared with unadjusted MP surprises.

While empirical approaches to identifying MP shocks vary, most studies employ some form of Structural Vector Autoregressions (SVARs) or, more recently, Local Projections (LP) (see, for example, Jordá, 2005, or Jordá, 2023). In both cases, the econometrician must rely on identified shocks, which can be done internally, as in the VAR literature, or using external shocks. Beyond traditional SVAR identification methods, recent developments in the literature focus on narrative-based methods and the use of external instruments. SVAR models are widely used due to their flexibility and ability to model dynamic relationships among variables. Overall, the approaches used aim to isolate the unexpected components of MP changes from systematic policy responses to economic conditions.

More precisely, the following SVAR methodologies are commonly used to identify MP shocks:

- **Recursive identification (Cholesky decomposition):** this approach involves ordering variables in a specific sequence, typically placing MP instruments (such as interest rates) last, or at least after output and price-related variables. It assumes that MP responds to contemporaneous movements in other variables that are ordered before the policy instrument, while not influencing them within the same period (see Bagliano and Favero,1998; Bernanke et al., 2005; for a non-standard ordering, see also Ciccarelli et al., 2013).

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[25] For instance, the typically positive correlations in the data among GDP, prices and interest rates make it difficult for this identification approach to eliminate the so-called "price puzzle", meaning the failure to find a negative causal relationship going from increases in the MP 'shock' to prices.

- **Identification via sign restrictions:** this approach identifies MP shocks by imposing sign restrictions on the responses of key macroeconomic variables, such as output and prices, following a policy intervention (see Ulhig, 2005; Arias et al., 2019; Brandt et al., 2021; Burriel and Galesi, 2018; Mandler et al., 2022). For instance, a contractionary shock is generally expected to raise interest rates, reduce output and decrease inflation.

- **External instruments:** several studies (e.g. Gertler and Karadi, 2015; Bauer and Swanson, 2022; Odendahl et al., 2024) use external instruments or externally identified shocks to quantify the causal effect of MP on output and inflation. This approach relies on external series available or developed "outside" the VAR, which function as noisy measures of the true shock (e.g. series based on narrative evidence, shocks from estimated DSGE models, or high-frequency information). If the external instrument is contemporaneously correlated with the structural policy shock (relevance condition) and contemporaneously uncorrelated with the other structural shocks (instrument exogeneity condition), it can be used to identify the shock (see, for example, Ramey, 2023).

- **Narrative-based approach:** this approach involves using historical records, minutes of central bank meetings, or other qualitative information to identify dates and reasons for MP changes (see Romer and Romer, 2004; Aruoba and Drechsel, 2024). By examining the stated rationale for policy actions, researchers can distinguish between endogenous responses to economic conditions and exogenous policy shifts intended to manage inflation or output gaps independently of current economic data.

- **Narrative-sign restrictions approach:** this particular approach allows us to impose the sign or the size/relevance of the shock at a specific time, such as when the central bank makes a surprise interest rate move, instead of restricting the Impulse Response Function (IRF) itself. For instance, Antolín-Díaz and Rubio-Ramírez (2018) use this approach to refine traditional SVAR identification methods. The authors find that the narrative sign restrictions approach sharpens and even changes the inference of SVARs originally identified via traditional sign restrictions.

- **High-frequency identification (HFI):** recent advances in the literature employ HFI to identify unanticipated MP shocks. This approach involves the use of high-frequency financial data to measure interest rate (or stock market) movements around central bank policy announcement dates to identify the unexpected component of MP actions (see, among others, Gertler and Karadi, 2015; Miranda-Agrippino and Ricco, 2021; Bauer and Swanson, 2022). It assumes that financial markets are quick to capture new information, allowing researchers to distinguish the exogenous component of policy changes from anticipated moves (Kuttner, 2001; Gürkaynak et al., 2005). Some studies (e.g. Jarociński and Karadi, 2020) combine the HFI approach with sign restrictions on the co-movement of interest rates and other asset prices to further disentangle MP and central bank information shocks.

Lastly, it should be noted that between the years of the Great Financial Crisis and the more recent surge in inflation, several studies have analysed the impact of so-called unconventional monetary policy (UMP) shocks. These "unconventional" tools have by now become standard. This paper, however, abstracts from scanning the effects of these measures and reports only a few references where necessary. For the sake of completeness, suffice to say that when attempting to identify UMP shocks, the literature has broadly followed similar approaches to those used for conventional shocks. Examples here include Gambetti and Musso (2020), who employ Cholesky identification for an APP announcement shock, constructed as deviations of APP sizes from Bloomberg survey expectations; Brandt et al. (2021) and Burriel and Galesi (2018), who use sign restrictions to identify MP shocks; Grüning and Zlobins (2023), who use external instruments to identify QE/QT shocks. Meanwhile, Lhuissier and Nguyen (2021) use external instruments for announcement shocks; Motto and Ozen (2022) use external instruments for market-stabilization QE at a daily frequency; and Bernardini and Conti (2023) use external instruments and a combination of zero, sign and narrative restrictions with daily data and identify announcement and implementation shocks to evaluate the effects of the ECB Asset Purchase Programme (APP) and the Pandemic Emergency Purchase Programme (PEPP).

Model specifications

The bulk of the empirical literature on MP transmission is based on linear models. For instance, MP shocks are either used as instruments in proxy SVARs (e.g. Kerssenfischer, 2022; Gertler and Karadi, 2015), or as regressors in Global VARXs (e.g. Burriel and Galesi, 2018), BVARs (e.g. Mandler et al., 2022; Altavilla et al., 2016; Antolín-Díaz and Rubio-Ramírez, 2018), FAVARs (e.g. Barrett and Platzer, 2024) and SVARs (e.g. Bauer and Swansson, 2022).

More recent contributions have employed non-linear empirical frameworks to identify the effects of both conventional (Zlobins, 2022; Baller and Noeller, 2023) and unconventional (Gambetti and Musso, 2020; Grüning and Zlobins, 2023; Zlobins, 2022) MP structural shocks. Such non-linear effects are captured via time-varying parameter (TVP) models (e.g. Gambetti and Musso, 2020; Koop et al., 2009; Mateju, 2019), smooth-transition SVARs (e.g. Zlobins, 2022), or local projections with interaction terms (Bachmann et al., 2022). Interestingly, in some studies (e.g. Baller and Noeller, 2023), the effect of MP is state-dependent because of constraints in the supply of inputs and the capacity utilisation of firms. Tenreyro and Thwaites (2016) employ state-dependent local projections where the state is a moving average of GDP growth, to determine whether MP is more powerful during recessions.

Data transformation and controls

It is also important to remark that in all modelling frameworks, the transformation of macroeconomic variables matters when interpreting empirical results. For instance, most studies employ monthly data, with the variables commonly entering the models

in log levels. A few studies employ quarterly data (e.g. Koop et al., 2009; Mojon and Peersman, 2001; Barigozzi et al., 2014), while the use of year-on-year growth rates remains limited (Odendahl et al., 2024; Boivin et al., 2009; Ciccarelli et al., 2015). Interestingly, according to a meta-analysis conducted by Havranek and Rusnak (2013), researchers who use monthly instead of quarterly data systematically report a faster MP transmission.

Lastly, empirical specifications, while focusing mainly on key macroeconomic variables, are typically completed with additional variables that either account for the relevant transmission channels – such as credit (e.g. Ciccarelli et al., 2015; Andrade and Ferroni, 2021) – or control for global factors – such as shifts in the exchange rate (e.g. Barigozzi et al, 2014), oil price, world commodity prices and foreign output dynamics (e.g. Georgiadis, 2015; Mojon and Peersman, 2001).

Relevant empirical transmission channels

Before discussing the numerical impacts, a key question is how MP transmits to the economy. The literature has discussed and tested several transmission channels. Changes in the short-term policy rate, i.e. the interest rate channel, propagate to real borrowing costs, savings, and investment decisions, subsequently affecting aggregate demand and prices (see, for example, Boivin et al., 2009).[26]

Furthermore, the cash-flow channel suggests that MP directly influences household spending through cash flows and disposable income. When the central bank raises its policy interest rate, the interest rate expenses of households with debt linked to short-term rates (e.g. adjustable-rate mortgages) rise, thus reducing households' disposable income and spending (by around 23-30%). See, for example, Flodén et al. (2020) for Sweden; Ahn et al. (2024) for Norway; DiMaggio et al. (2017) for the United States. Heterogeneous household balance sheets, which imply different marginal propensities to consume (i.e. higher for mortgage holders and renters during MP tightening), also play a role in MP transmission (see Cloyne et al., 2020).

The credit channel happens to be another MP transmission channel, encompassing both bank lending and the balance sheet channel. MP responses produce modest movements in short-term interest rates but can lead to significant shifts in credit costs due to the reaction of term premia and credit spreads (Gertler and Karadi, 2015). The proxy commonly used in the literature to capture the credit channel is the excess bond premium (see, for example, Gilchrist and Zakrajsek, 2012 for the United States; Gilchrist and Mojon 2018 for the euro area economy; Andrade and Ferroni, 2021; Kerssenfischer, 2022). Caldara and Herbst (2019) find that credit spreads matter for underpinning a statistically significant effect of MP on output and unemployment.

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[26] For the sake of completeness, note that for UMPs (which have not been surveyed here) there can be a direct influence on agents' expectations and the term structure of interest rates, while also affecting asset prices and/or lending activity in the banking sector. Such policies are also likely to shape the conditions in the (bond) market for non-bank credit.

Meta-analysis findings suggest that the cross-country variation in MP transmission is robustly associated with differences in financial development: countries with higher financial development exhibit slower MP transmission (Havranek and Rusnak, 2013).[27] Heterogeneous bank balance sheet characteristics (capital ratio, percentage of non-performing loans, etc.) may lead to varied transmission of MP to household deposit rates and lending rates for NFCs. Altavilla et al. (2020) find that a deterioration in bank balance sheets generally leads to a lower pass-through of interest rate changes to household deposit rates. Non-conventional MP can help to mitigate these effects. Altavilla et al. (2021) show that UMP acts by reducing risk premia components in sovereign bonds.

Interestingly, the structural shift of economies from manufacturing to services, whereby services account for an increasing share of intermediate inputs ("services deepening"), may influence MP transmission due to differences in price stickiness across sectors. Galesi and Rachedi (2019) find that service deepening slows the transmission of MP to inflation because prices in services are stickier than in non-service sectors.

Moreover, MP affects the economy through changes in asset prices. MP tightening typically reduces asset prices, which adversely affects household wealth, the value of collateral and, consequently, spending. Cross-border spillovers can also materialise owing to financial linkages. Degasperi et al. (2023) find that following a US MP tightening process, global risk appetite falls, as do equity holdings, suggesting worldwide portfolio rebalancing towards safe assets, affecting capital flows.

Changes in MP can also influence exchange rates, which in turn affect net exports.[28] Mojon and Peersman (2001) make the underlying assumption that MP shocks in euro area countries have no contemporaneous impact on output and prices, but do affect the exchange rate. They show that a contractionary MP shock leads to a temporary fall in GDP that peaks at around four quarters, while the price level declines only gradually. Georgiadis (2015) finds that external factors, including the exchange rate, provoke an asymmetric response of output and inflation to an MP shock. Moreover, countries with fixed exchange rates have been found to experience weaker MP transmission (Deb et al., 2023). Inoue and Rossi (2019) corroborate that both conventional and unconventional MP shocks affect the exchange rate, with varying effects depending on how MP influences agents' expectations, as well as its perceived effects on the riskiness/uncertainty present in the economy.

The expectations channel refers to the effect that MP has on household and firm expectations and the anchoring of inflation expectations, although evidence on this propagation mechanism remains scarce. Based on cross-country evidence, Deb et al. (2023) find that MP tightening leads to an immediate and significant reduction in

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[27] However, the meta-analysis conducted by Grauwe and Costa Storti (2004) shows that macroeconomic factors, such as openness, country size and the banking sector, do not significantly affect output response to MP shocks. The effectiveness of MP could be state-dependent, i.e. hampered in high-inflation environments.

[28] Although this channel has not been analysed in Chapter 2, we cite some empirical literature here for the sake of completeness.

economic activity, while its effects on inflation and inflation expectations manifest more slowly.

Additional channels of MP can become relevant and visible through their interaction with other policies, notably fiscal policy. For instance, US fiscal policy shocks seem to have a larger impact if the Federal Open Market Committee (FOMC) is composed of more dovish-leaning members, as MP reacts more slowly to the fiscal stimulus shock (Hack et al., 2024). Structural factors, such as credible MP frameworks, have been found to enhance the effectiveness of MP (Deb et al., 2023).[29]

Differences in MP transmission across jurisdictions

Empirical studies have also pointed certain differences in MP transmission across different economic areas, especially between the United States and the euro area, although the results are not yet conclusive. In the following sub-section, we quantify the existing evidence based on recent meta-analyses related to this comparison.

In the euro area, shocks tend to have more heterogeneous effects due to structural and economic diversity among Member States. For instance, contractionary MP shocks generally lead to reduced investment and consumption, but with significant variations across countries (Barigozzi et al., 2014; Mojon and Peersman, 2001; Baller and Noeller, 2023; Corsetti et al., 2022). Ciccarelli et al. (2015) find that bank lending, credit demand, and non-borrower balance sheets can all be important, depending on the time period analysed.

In the United States, MP shocks typically produce clear and consistent effects on macroeconomic variables. A contractionary shock usually leads to a decline in consumption and investment due to higher borrowing costs and lower household wealth through lower asset prices. Miranda-Agrippino and Ricco (2021) find that the credit channel magnifies the size of the economic contraction through the responses of both credit and financial markets. However, in a meta-analysis study, De Grauwe and Storti (2004) could not find any significant differences in the output and price effects of monetary policies between the United States and euro area countries.

3.2   A harmonised quantitative assessment

As outlined in the previous section, deriving a homogeneous estimate of the impact of MP across studies can be challenging due to differences in identification strategies, estimation samples, model specifications, variable transformations, transmission channels and across jurisdictions.[30] Nonetheless, empirical findings

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[29]   The interaction between monetary and fiscal policy has been analysed at length by Bonam et al. (2024) and Debrun et al. (2021).

[30]   Note also that each paper measures the MP shock differently (e.g. shock normalised to induce an increase – varying across papers – in a given MP indicator (e.g. 1y/2y/10y government bond yield, forward interest rates, or the EA OIS10Y). The outcome variables are not defined in the same way, with studies using, for example, quarter-on-quarter growth, log levels or year-on-year growth rates, or relying on interpolated data (e.g. GDP) from other monthly economic indicators.

point to comparable effects on both output and prices. In this section, we report the results based on available meta-analyses conducted by independent scholars.

3.2.1 Recent meta-analyses[31]

Meta-analysis is a systematic approach that relies on statistical techniques to combine results from different studies and obtain a quantitative estimate of the overall effect of a particular shock or "intervention" on a defined outcome. The existing literature cites a few examples that have been used to provide a harmonised estimate of the impact of MP shocks on output and inflation, in some cases also accounting for potential publication bias or modelling misspecification. In this subsection, we summarise the results of a very recent analysis carried out by Enzinger et al. (forthcoming).

The authors build and analyse a novel dataset comprising 409 relevant primary studies (published in peer-reviewed journals (75%), working papers (22%), and books and reports (3%)) covering the past 40 years. The literature search ended in February 2023, with the most recent sample dated July 2021). The studies contain 4,871 impulse-response graphs, from which the authors extract 81,697 point estimates and confidence bounds for a wide range of countries (not just the euro area), along with time periods, regimes, estimation and identification methods, and further study characteristics.

Confidence intervals (or credible sets) are calculated as averages of the intervals of the primary studies. These intervals are standardised to derive the implied confidence intervals (CIs) for each estimate. The mean or median of these CIs are then taken at the respective level.

This approach, which is complementary to the ESCB analysis, retains the sampling uncertainty contained in the primary study impulse response functions (IRFs).

Average (mean and median) baseline IRFs for output and prices

Chart 1 shows the average IRFs of output, prices and interest rates following a 25-basis-point conventional monetary policy shock, based on our full sample. The point estimates (solid lines) are calculated as averages (mean and median) of all primary study point estimates per quarter. The confidence bounds (shaded areas) are the standardised averages (mean and median) of the respective upper and lower confidence intervals from the primary studies. Notably, the collected estimates and their standard errors have been winsorised at the 2nd and 98th percentile to reduce the impact of potentially spurious outliers, which is standard practice in the literature (e.g. Zigraiova et al., 2021; Gechert and Heimberger, 2022). Note also that original

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[31] This subsection has been co-authored with Alessandro Giammaria (ECB) and with Sebastian Gechert (TU Chemnitz), Philipp Heimberger (WIIW) and Franz Prante (TU Chemnitz), who served as external consultants for this chapter.

results are usually reported for a 1% increase in the interest rate, although we show here standardised results.[32]

The mean response of output is negative on impact but initially small, suggesting there is no "activity puzzle". The average response builds up and peaks at around -0.25% about two years after the shock. However, the confidence bounds (blue shaded areas) are wide. While for the 95% confidence interval (not reported), we cannot reject a zero effect across all response horizons, the 68% confidence interval does not include zero for the response horizons between three and 14 quarters.

The average price level response (blue solid line) to a contractionary monetary policy shock is also negative on impact, i.e. there is no "price puzzle". However, the response builds up more slowly than the output response, with the peak price level response being -0.18% after about four years. Note that, according to standard theory, the price level response is not expected to return to zero. The 68% confidence takes around 12 quarters to no longer contain a zero response. The corresponding annual inflation response peaks at -0.05 percentage points after about three years.

The median responses of output and prices (yellow solid line and shaded areas) point to smaller dampening effects of contractionary monetary policy shocks across all response horizons. The peak output response is -0.15% about two years after the shock, while the peak price level response is -0.11% after about four years, with the corresponding annual inflation response peaking at -0.03 percentage points after about three years. This indicates that the distribution is left-skewed. Notably, the mean and median responses of the interest rate variable are virtually the same, pointing to a symmetrical distribution.

Simple averages of all reported estimates are useful when it comes to eliminating sampling error and random misspecification bias. The central limit theorem ensures that the average of many estimates provides adequate estimates of "true" effects, but only as long as sampling error and misspecification bias are random (Ioannidis et al., 2017). The desirable statistical properties of meta-averages no longer exist if there is systematic reporting bias, as this will distort any average estimate. The left-skewness of the distribution of the output and prices responses may be (partly) explained by systematic reporting bias, as recent literature on publication bias in economics highlights that researchers should test and correct for selective reporting (e.g. Havránek, 2015; Andrews and Kasy, 2019; Brodeur, Cook, and Heyes, 2020). The skewness can also be due to the normalisation of shock size, which is a non-linear transformation. Normalising the part of the shock distribution that is close to zero and the part that has larger values for the size of shock creates an asymmetric distribution skewed towards absolutely larger values. Chart 1 clearly shows this phenomenon as the small deviation of median and mean in the IRF of the MP

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[32] The fact that uncertainty over the first value of the interest rate IRF exists at the first horizon reflects the estimation uncertainty inherent in the models from the empirical literature. Many papers rely on Bayesian methods and/or on external instruments to identify monetary policy shocks. Normalisation has been applied in order to align the central estimate across studies (yellow line). Note also that the absence of skewness (difference between mean and median) in the interest rate IRF is not an artefact, but reflects symmetry as observed in the primary studies.

instrument (an IRF that is not normalised) vs those that are normalised (GDP and prices).

Chart 1

Impact of a 25-basis-point monetary policy shock on output, prices (level and inflation) and interest rates

a) Output

(percent and percentage-point deviations)
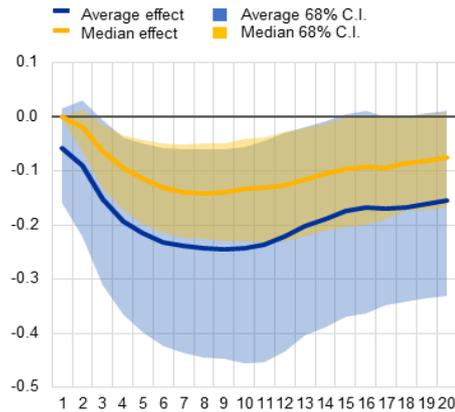
b) Price level
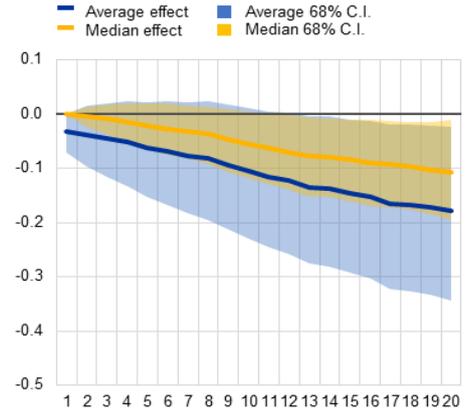
c) Annual inflation
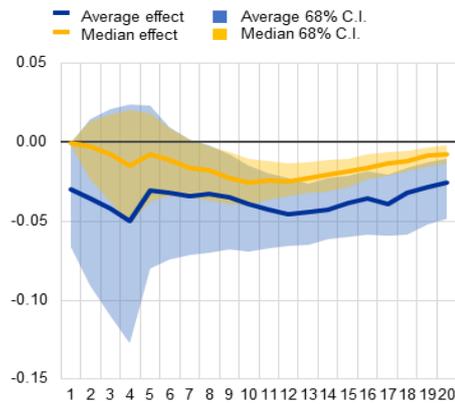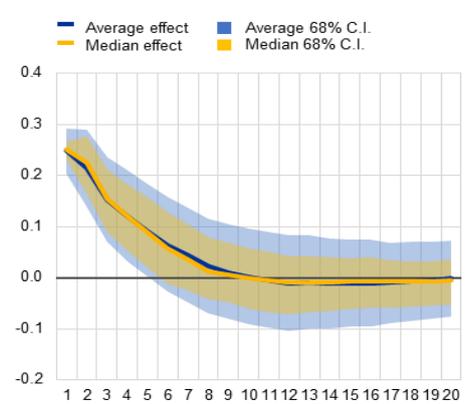
d) Interest rates

Source: M. Enzinger, S. Gechert, P. Heimberger, F. Prante and D. Romero, "The overstated effects of conventional monetary policy on output and prices" (forthcoming).
Notes: IRFs have been harmonised to reflect the effects of a 25-basis-point conventional monetary policy shock. Simulation horizon in quarters. Confidence intervals are calculated as means or medians from the 68% confidence intervals of the primary studies. For the inflation transformation, we define $\bar{x}_t$ as a baseline and x_t as a counterfactual. Then, the percentage deviation between the counterfactual and baseline at time t can be approximated by:

$$\hat{x}_t = \log(x_t) - \log(\bar{x}_t)$$

Then,

$$\hat{x}_{t+4} - \hat{x}_t = [\log(x_{t+4}) - \log(\bar{x}_{t+4})] - [\log(x_t) - \log(\bar{x}_t)]$$
$$\Leftrightarrow \hat{x}_{t+4} - \hat{x}_t = [\log(x_{t+4}) - \log(x_t)] - [\log(\bar{x}_{t+4}) - \log(\bar{x}_t)]$$
$$\Leftrightarrow \hat{x}_{t+4} - \hat{x}_t \approx \frac{x_{t+4} - x_t}{x_t} - \frac{\bar{x}_{t+4} - \bar{x}_t}{\bar{x}_t}$$

which is effectively the difference in the respective annual growth rates.

Publication bias-corrected estimates

P-hacking, meaning the preference among researchers, referees and editors for statistically significant results, is widely viewed as a major concern in economics (Brodeur, Lé et al., 2016; Brodeur, Cook and Heyes, 2020; Brodeur, Carrell et al., 2023; Chopra et al., 2024). More broadly, publication bias, which includes p-hacking

but also a tendency to conform with theoretical expectations or seminal publications, can distort the conclusions of qualitative or simple quantitative reviews of the empirical evidence (Stanley, 2005; Havránek, 2015; Ioannidis et al., 2017; Andrews and Kasy, 2019; Gechert, Mey et al., forthcoming).

Chart 2

Publication bias-corrected estimates
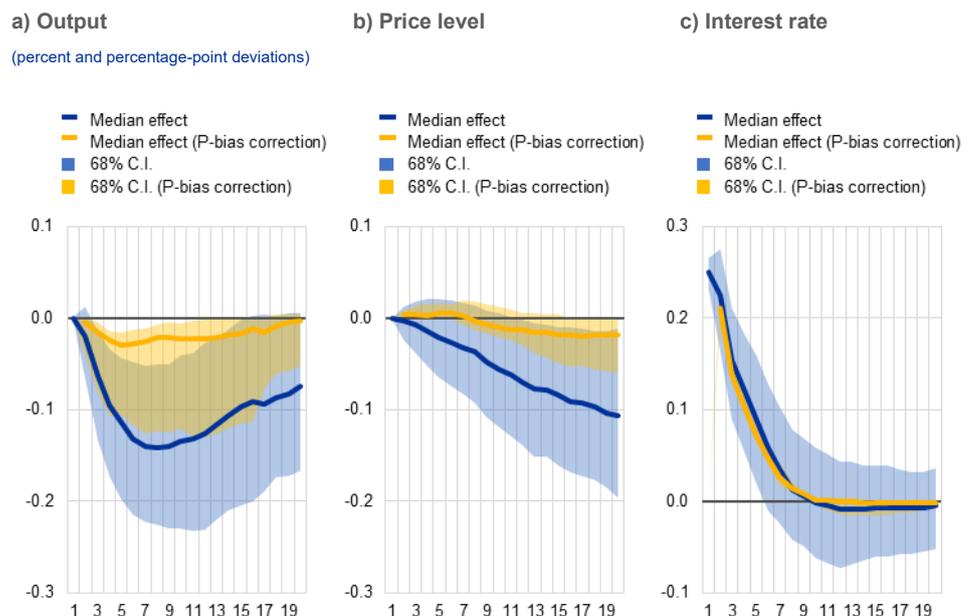
a) Output

(percent and percentage-point deviations)

b) Price level

c) Interest rate

Source: M. Enzinger, S. Gechert, P. Heimberger, F. Prante and D. Romero, "The overstated effects of conventional monetary policy on output and prices", (forthcoming).
Notes: IRFs have been harmonised to reflect the effects of a 25-basis-point conventional monetary policy shock. Simulation horizon in quarters. Confidence intervals are calculated as means or medians from the 68% confidence intervals of the primary studies.

Using the meta-analysis toolbox allows us to generate a quantitative synthesis of the existing literature, including the identification of, and correction for, p-hacking and publication bias. By running a battery of established tests to estimate a range of bias-corrected effect sizes, one can document a robust pattern of selectively reported statistically significant negative output and price level responses to contractionary MP shocks, particularly at the most relevant response horizons.

Chart 2 appears to show that these average responses are likely plagued by p-hacking and publication bias leading to inflated effect sizes. Corrected estimates are smaller, ranging from 0 to -0.03% at the peak for output and from 0 to -0.02% for the price level.

Relevant heterogeneous aspects

Heterogeneity has been checked along several dimensions.

Top journals versus the rest

Askarov et al. (2024) analyse more than 20,000 empirical results published in 31 leading general interest economics journals. They selected 25% of all the estimates to check for statistical significance and found that more than 50% of the results of this selection were significant. Among the top five journals, this selection bias is even stronger, as two-thirds of all estimates published in these journals were found to be significant. Other studies from the meta-research literature also find that publication bias in leading journals is substantial and at least as significant as in lower-ranked publication outlets (e.g. Brodeur, Cook and Heyes, 2020; Heimberger, 2022).

We define estimates in leading journals as those published in an A+ or A journal of the economics profession, as measured by the Handelsblatt ranking. Estimates from these leading journals account for around 15% of all our estimates.

Notably, the results shown in Chart 3 suggest that the responses of output and prices published in leading journals display stronger dampening effects of contractionary MP than those published elsewhere. The larger difference between the median and mean responses –particularly at the relevant response horizons – indicates that the distribution is left-skewed.

Chart 3

Top journals vs other publications

a) Output

(percentage deviations)
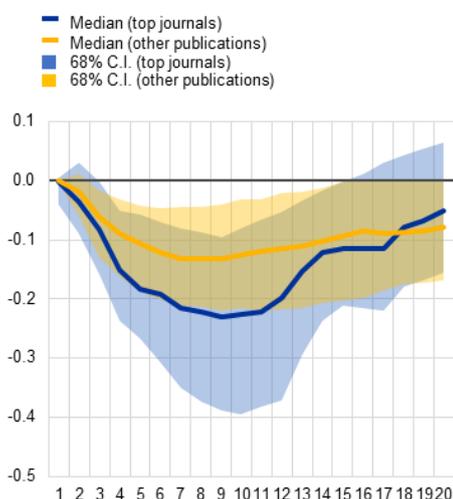
b) Price level
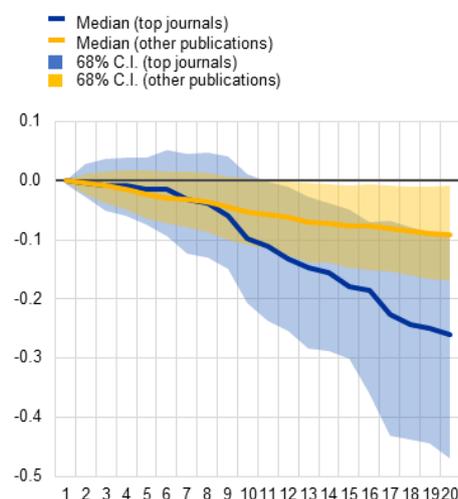
Legend:
- Median (top journals)
- Median (other publications)
- 68% C.I. (top journals)
- 68% C.I. (other publications)

Source: M. Enzinger, S. Gechert, P. Heimberger, F. Prante and D. Romero, "The overstated effects of conventional monetary policy on output and prices", (forthcoming).
Notes: IRFs have been harmonised to reflect the effects of a 25-basis-point conventional monetary policy shock. Simulation horizon in quarters. Confidence intervals are calculated as means or medians from the 68% confidence intervals of the primary studies.

Central banker vs non-central banker co-authors

Fabo et al. (2021) find that reported results on the macroeconomic effects of quantitative easing differ significantly between central bank researchers and academic economists. Central bank affiliations account for 53% of our estimates.

When using their approach, however, Chart 4 shows that there is no marked difference between papers penned by central-bank-affiliated researchers and those produced by authors with no central bank affiliations when it comes to the average and median responses of output and prices to conventional MP shocks. On average, central bank researchers appear to report a slightly smaller output response in the first year and a half after the shock.

Chart 4

Central bank vs non-central bank as co-authors

(percentage and percentage-point deviations)
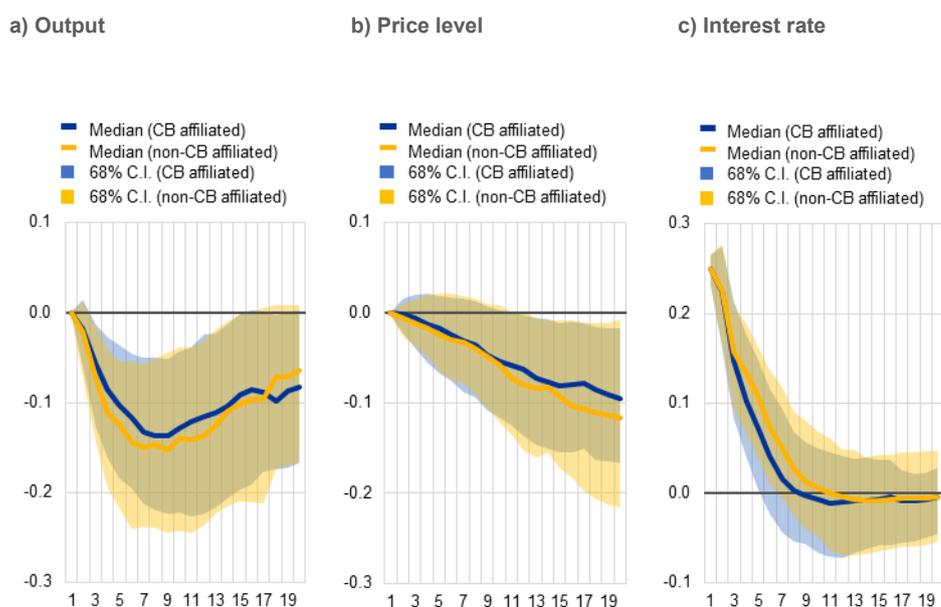
a) Output   b) Price level   c) Interest rate

Source: M. Enzinger, S. Gechert, P. Heimberger, F. Prante and D. Romero, "The overstated effects of conventional monetary policy on output and prices" (forthcoming).
Notes: IRFs have been harmonised to reflect the effects of a 25-basis-point conventional monetary policy shock. Simulation horizon in quarters. Confidence intervals are calculated as medians from the 68% confidence intervals of the primary studies.

Identification approaches

The literature shows that different strategies for identifying MP shocks may systematically affect the results obtained (e.g. Coibion, 2012; Ramey, 2016; Nakamura and Steinsson, 2018). Therefore, we study the macroeconomic effects of MP shocks across different sub-samples of shock identification methods.

Chart 5 points to different sub-sample medians, indicating that the reported effects vary by identification approach. The use of high frequency identification is associated with particularly large dampening effects of contractionary MP shocks on output. This result may be due to the publication bias discussed above, or to the fact that high

frequency data can lead to estimation biases, given that innovations in some of the macroeconomic variables are typically correlated with the MP shock. The use of sign restrictions and narrative identification is associated with stronger price level effects, particularly at longer response horizons. The use of narrative identification relates to moderate output effects and appears to be less skewed. This could simply be because most papers adding narrative restrictions to simple sign restrictions leave the response of the "outcome" variable unconstrained. The price puzzle appears mainly in estimates that rely on Cholesky decomposition and narrative identification. Cholesky decomposition is also associated with the lowest effects, especially on prices.

Chart 5

Identification approaches (median effects)

(percentage and percentage-point deviations)
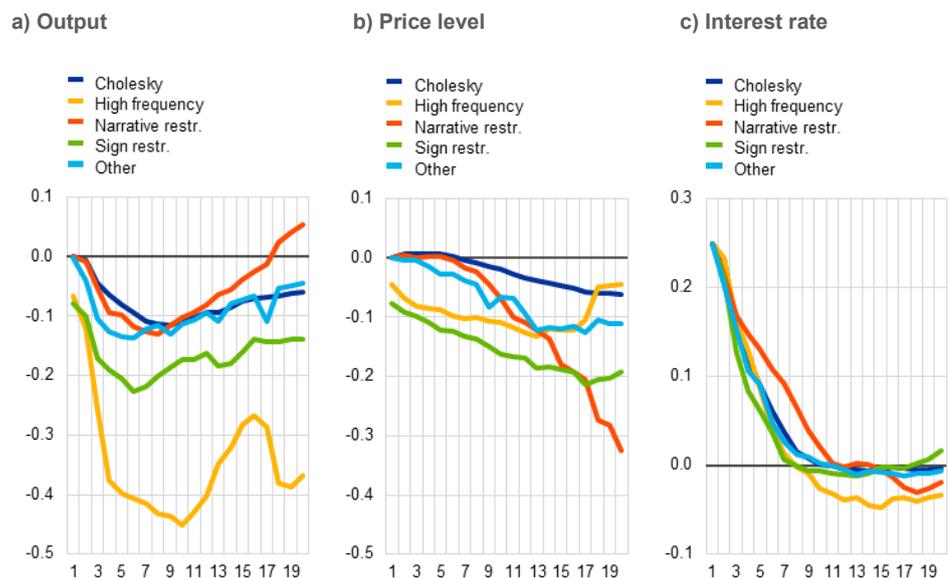
Source: M. Enzinger, S. Gechert, P. Heimberger, F. Prante and D. Romero, "The overstated effects of conventional monetary policy on output and prices" (forthcoming).
Notes: IRFs have been harmonised to reflect the effects of a 25-basis-point conventional monetary policy shock. Simulation horizon in quarters. Solid lines represent median effects for each different identification approach. The identification shares – based on quarterly values from IRF estimates within response horizons up to five years (81,697 estimates) – are as follows: Cholesky: 48%; Sign restrictions: 19%; High-frequency:13%; Narrative: 12%; Other: 8%.

Country groups/MP areas

As with the ESCB internal meta-analysis, this also shows a predominance of studies for the United States. Notably, about 45% of the sample contains estimates for the United States, while 20% refers to euro area Member States, 15% to other advanced economies (e.g. Japan), and the remainder to emerging market economies. Only a handful of papers cover the sample up to the COVID sample, and none of them go beyond 2021.

Chart 6 shows that responses of output and prices to conventional MP shocks in the United States do not differ markedly from those in the euro area, with both showing a relatively stronger impact than in other advanced economies and developing

countries. This suggests that, on average, structural differences across different advanced economies may not play a prominent role in determining how large the impact of MP on the economy is. However, the dampening effects of contractionary MP on output and prices are markedly smaller in emerging market economies than in advanced economies.

These results for country (group)-specific macroeconomic effects of MP hold in a multivariate meta-regression framework, where the standardised effect sizes are regressed on country (group) dummies while controlling for publication bias.

Chart 6
Identification approaches (median effects); country groups (median effects)

(percentage and percentage-point deviations)
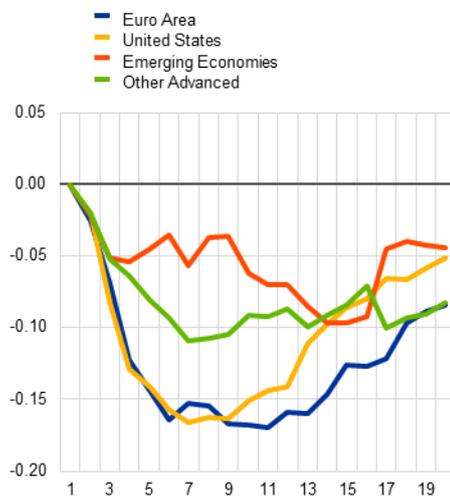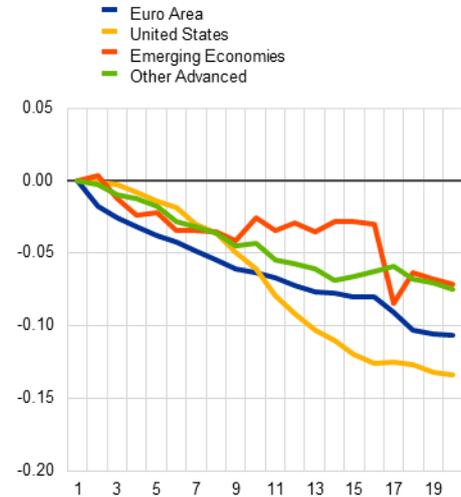
Source: M. Enzinger, S. Gechert, P. Heimberger, F. Prante and D. Romero, "The overstated effects of conventional monetary policy on output and prices" (forthcoming).
Notes: IRFs have been harmonised to reflect the effects of a 25-basis-point conventional monetary policy shock. Simulation horizon in quarters. Solid lines represent median effects for each different economic area.

3.3 Reconciling theoretical models and empirical evidence

This final section connects the dots between the model-based results presented in Chapter 2 and those just reviewed in Chapter 3. Clearly, we can only compare the two set of results based on the selected dimensions, with no possibility of checking the model-based results against all the exercises we described in Chapter 2. Other empirical heterogeneity dimensions will be explored in the next chapter.

We first compare the results of the meta-analysis of the empirical literature by Enzinger et al. (forthcoming) with the first common exercise across ESCB models described in Section 2.1, with unanticipated shocks and different policy rules across models. These are the most comparable sets of results based on "pure" shocks with possibly different empirical rules, which is the typical situation that occurs across different identification schemes and economic jurisdictions.

Notwithstanding the key caveat that we mentioned at the start of this chapter, i.e. that we cannot harmonise results across chapters in crucial dimensions such as shock persistence or the policy rule, the results are somewhat "reassuring" and largely consistent with what one would expect. Notably, Chart 7 (which uses the results of Chart 1 of this chapter for the meta-analysis) shows that the median response of output is similar across theoretical and empirical models, peaking at around -0.15% after about two years in both cases, although theoretical models suggest a somewhat faster pass-through in the short term. This is clearly reassuring and may be linked to the practice of IRF matching, which is used to calibrate DSGE parameters with SVARs (see, for example, Christiano et al., 2005).

The interpercentile range of the ESCB models (blue shaded area in Chart 7) suggests a potentially more dampening effect on output during the first two years after the shock, compared with the average 68% confidence interval in the empirical literature (yellow shaded area).

The median price-level response is predicted to be stronger in the surveyed theoretical models than in the empirical literature, with a peak of -0.15% versus -0.11% after four years. In particular, during the first two years after the shock, the median price level response in the models falls outside the average 68% confidence interval from the literature, although it moves back inside the interval from quarter 9 onwards. Note also that the dynamics and persistence of the shock are on average very similar across the two sets of results.

Chart 7

Reconciling theoretical models and empirical evidence

(percentage and percentage-point deviations)
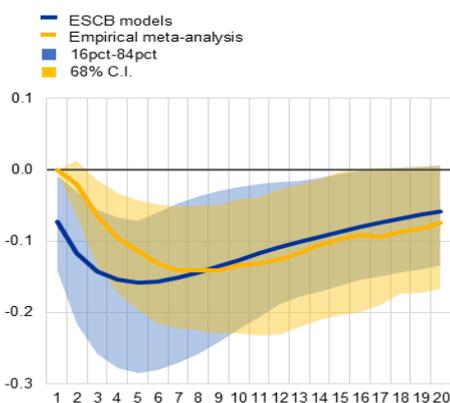
a) Output   b) Price level
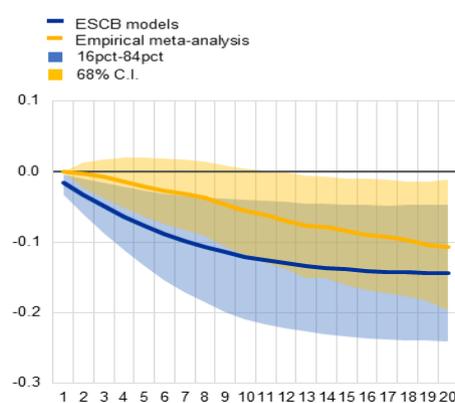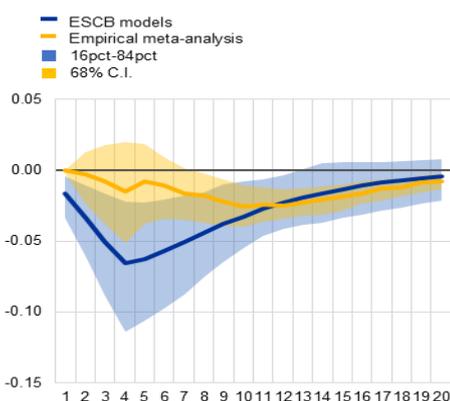
c) Annual inflation   d) Interest rates
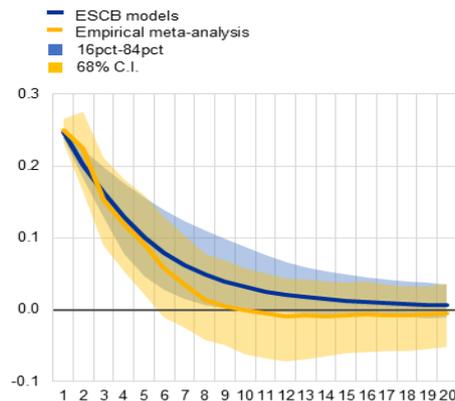
Sources: ESCB staff calculations, and M. Enzinger, S. Gechert, P. Heimberger, F. Prante and D. Romero, "The overstated effects of conventional monetary policy on output and prices" (forthcoming).
Notes: IRFs have been harmonised to reflect the effects of a 25-basis-point conventional monetary policy shock. Simulation horizon in quarters. The yellow shaded area represents the median from the 68% confidence intervals of the primary studies of the meta-analysis, as shown in Chart 1 of this chapter). The blue shaded area represents the 84th-16th percentile range of collected ESCB macroeconomic model impulse response functions to an unanticipated monetary policy shock, with model-specific rules (see Chart 1 of Chapter 2).

Overall, the two sets of results are broadly in line with expectations, although they also deliver a rather firm message that the empirical evidence supports a less effective MP (on inflation) at the peak than that found by the models, especially typical DSGE models, even when these are estimated. This gap between model and empirical evidence would be even greater (including for GDP) if publication bias were seriously considered. Conversely, estimated semi-structural models are closer to the average empirical evidence, especially over the short and medium term (see Chart 8).[33] As explained in Section 2.1.2, semi-structural models yield smaller peak effects than DSGE models because, by design, they do not have a strong interest rate channel. At the same time, these models, by abstracting from some of the cross-equation restrictions required for full structural identification, allow for a richer

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[33] See Box 7 of Chapter 1 on major divergences between semi-structural models (style FRB/US) and DSGE models.

modelling of consumption – incorporating individual income risk and varying propensities to consume from different income sources. As a result, their consumption dynamics better reflect the observed persistence in consumption, bringing their results closer to empirical patterns.

There appear to be significant discrepancies between euro area semi-structural models (typically used for projections) and structural models (more commonly used in policy simulations), mainly as regards the more front-loaded responses, and would deserve further attention in the estimation of models.

Chart 8

Reconciling theoretical models and empirical evidence: comparison across sets of models

(percentage and percentage-point deviations)
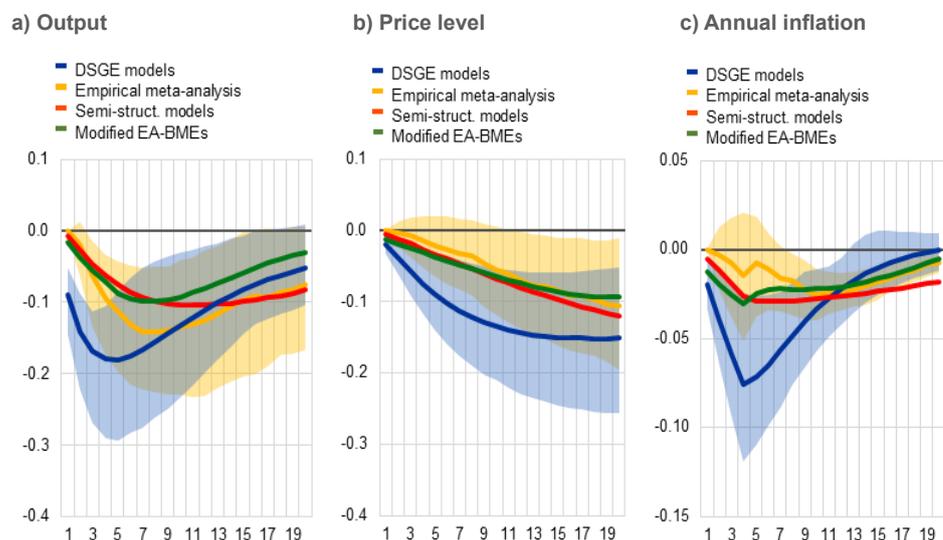
Sources: ESCB staff calculations. Meta-analysis based on M. Enzinger, S. Gechert, P. Heimberger, F. Prante and D. Romero, "The overstated effects of conventional monetary policy on output and prices" (forthcoming).
Notes: Modified EA-BMEs model builds on the Eurosystem's BMEs (see, e.g.,   ECB, 2016) while incorporating a forward-looking financial block à la Dornbusch. This extension endogenises monetary policy, long-term interest rates and the exchange rate. It uses forward-looking expectations for the latter two variables and assumes the same Taylor rule as ECB-BASE for the policy rate. The model equations link other endogenous variables to exogenous shocks using the official BMEs, which are updated annually. IRFs have been harmonised to reflect the effects of a 25-basis-point conventional monetary policy shock. Simulation horizon in quarters. The yellow shaded area represents the median from the 68% confidence intervals of the primary studies in the meta-analysis. The blue shaded area represents the 84th-16th percentile range of collected ESCB DSGE models' impulse response functions (common exercise 1, with model-specific policy rate rules). The average IRF of three ESCB semi-structural models is shown in red.

Basic Model Elasticities (BMEs) provide another useful comparative reference , although a direct comparison with this tool is not feasible, as BMEs operate within a partial equilibrium framework.[34] Instead, we use an EA-BMEs model, which builds on the Eurosystem's BMEs while incorporating a forward-looking financial block à la

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[34]   BMEs are a tool designed to assess the impact of changes in assumptions on projections in a mechanical manner. Essentially, BMEs function as a simplified, linearised version of a multi-country model centred around a specific baseline. National central banks (NCBs) provide impulse responses to exogenous shocks (e.g. a 10% increase in oil prices), and ECB staff compile these elasticities to construct a euro area-wide BME model. For more details, see ECB (2016), "A guide to the Eurosystem/ECB staff macroeconomic projection exercises".

Dornbusch.[35] This framework maintains the real-side propagation mechanisms of the Eurosystem projections, ensuring internal consistency. The response to monetary policy shocks in EA-BMEs is similar to those observed in the semi-structural models and in the empirical meta-analysis, especially to the IRFs of the empirical literature that identified monetary policy shocks using a more agnostic or Cholesky-type decomposition (see Chart 5). This is because most ESCB central banks rely on large-scale semi-structural models for projections, where GDP elasticity to interest rates is low and the Phillips curve does not exhibit excessive amplification.

Lastly, it is worth noting that the relative differences across models are maintained even if we compute the cumulative total impacts, namely the areas under each average IRF shown in Chart 8, notwithstanding the different persistence across the various sets of models (Chart 9).

Chart 9

Reconciling theoretical models and empirical evidence: total effects

(percentage and percentage-point deviations)
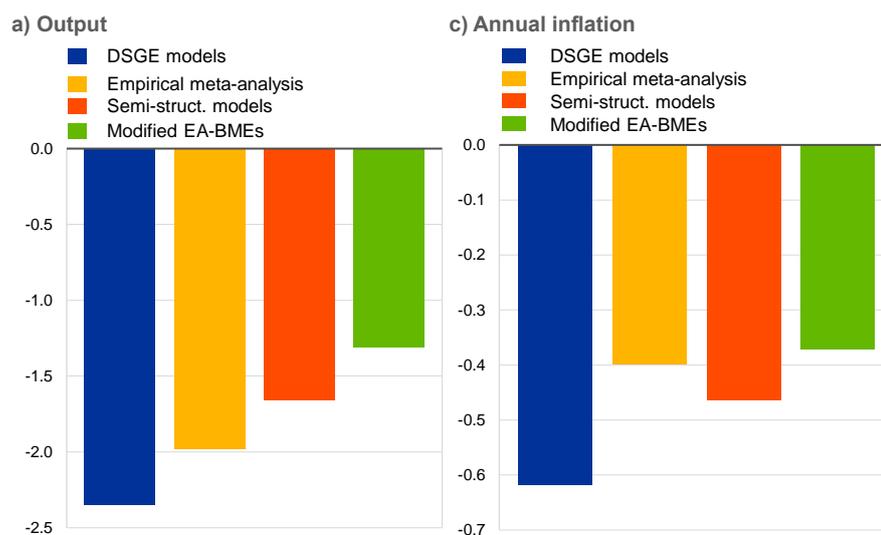
Sources: ESCB staff calculations. Meta-analysis based on M. Enzinger, S. Gechert, P. Heimberger, F. Prante and D. Romero, "The overstated effects of conventional monetary policy on output and prices" (forthcoming).
Notes: The bars represent the (average) total effect over 20 quarters of a 25-basis-point conventional monetary policy shock across sets of models. Total effects are computed as the area under the curves in Chart 8.

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[35] EA-BMEs has been developed in unpublished internal work at Banque de France by Y. Kalantzis, M. Mogliani and P.-A. Robert in the context of the Working Group on Forecasting. For a definition of BMEs, see for instance "A guide to the Eurosystem/ECB staff macroeconomic projection exercises", ECB, June 201

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4 The Queen's croquet ground: heterogeneity and non-linearity

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This chapter provides an empirical assessment of monetary policy transmission in the euro area, focusing on heterogeneous effects of monetary policy across countries, sectors, domestic demand components, and across time using multi-country, multi-sector and time-varying empirical VAR models. The analysis is augmented by discussion of possible economic explanations for the estimated heterogeneity. The chapter also provides an empirical assessment of the transmission of the unprecedented monetary policy tightening that took place in the euro area in 2022-23 to financial markets and the banking system, and to economic activity and inflation, drawing comparison also with past tightening episodes. The empirical analysis begins with simple linear VAR models, similar to those commonly used in the literature, estimated over different subsamples or for different economies. Potential nonlinearities are then assessed via time-varying and state-dependent models.

4.1 Has monetary transmission changed over time?

4.1.1 Sub-sample analysis

The starting point for our analysis of euro area monetary policy transmission is a simple linear structural Bayesian VAR (BVAR) estimated over different sub-samples. Specifically, we consider a quarterly BVAR in (log)-levels over the period 2002-2024, using real GDP, HICP, the 3-month Euribor, the Euro STOXX and the EUR/USD exchange rate (see Zlobins, 2025). Identification is achieved via a combination of high frequency information with narrative sign restrictions. The results obtained for the full sample (2002Q1 to 2024Q2 are then compared with those for the pre-ELB sample (2002Q1 to 2014Q1) and the pre-COVID-19 sample (2002Q1 to 2019Q4).[36]

The monetary policy shock is normalised to raise the short-term rate by 25 basis points at peak. The shock lowers consumer prices by about 0.4 percentage points and real GDP by almost 1 percentage point at their respective peaks. While the latter response is broadly stable across samples, the full sample response of inflation looks instead to be substantially larger than the pre-COVID estimates. Notably, over

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[36] ELB refers to "effective lower bound".

the same period the response of the 3-month Euribor displays a higher degree of persistence.[37]

Overall, comparing the results across the different estimation periods provides evidence for a somewhat more persistent behaviour of the short-term interest rate and a stronger reaction of inflation, while that of real GDP has remained broadly unchanged in recent years (Chart 1). This result is robust even when using several different identification schemes and monthly data. It suggests an improved "sacrifice ratio" (the ratio of cumulative changes in output relative to cumulative changes in inflation), which could explain the successful disinflation engineered by the ECB without excessively contracting economic activity in the process.

Chart 1

Impulse response functions to a conventional monetary policy shock in the euro area over different samples

(percentage and percentage-point deviations from pre-shock level)
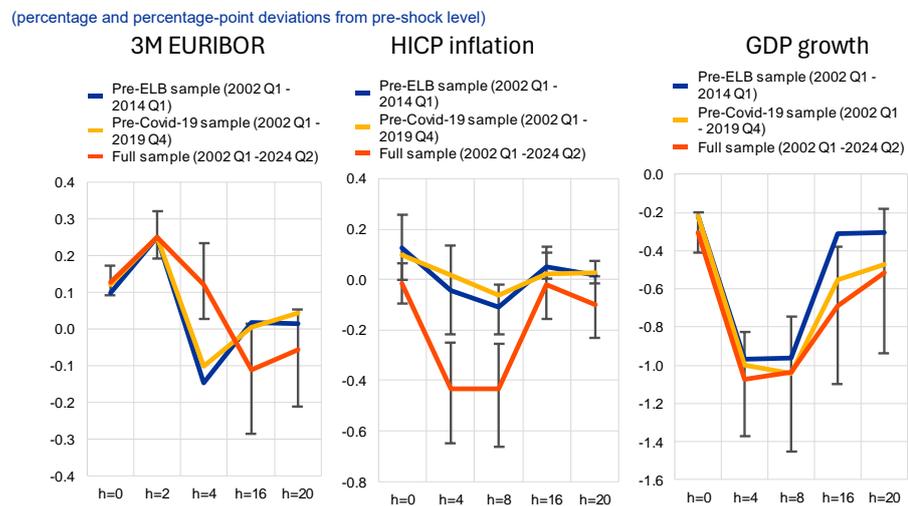
Sources: Zlobins (2025). Notes: Figures show impulse response functions from a Bayesian SVAR to a conventional monetary policy shock, normalized to generate a 25 basis points peak increase in the 3-month EURIBOR. Solid lines show the median responses at selected horizons while whiskers denote the 68% credible sets from estimation using the full sample.

4.1.2   Stronger than expected transmission to lending variables

One possible explanation for the increased effectiveness of monetary policy in bringing down consumer prices in the latest tightening episodes might stem from the concurrence of two factors: (i) a particularly more forceful transmission of monetary policy via bank lending in the euro area, which dampened aggregate demand; and (ii) a prompt and credible response to adverse supply shocks by the ECB, which prevented a de-anchoring of inflation expectations while also avoiding a recession (Villeroy, 2024; see also Section 4.4).[38] Restrictive monetary policy has had a significant effect on bank lending conditions. Despite a slower and weaker increase in deposit rates to the private sector, banks have encountered higher funding costs

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[37]   The findings are subject to variation depending on the sample used and the identification method applied.

[38]   See Lane, P. (2023).

owing to a rapid rise in short- and long-term market rates and bank bond yields, which has in turn led to a substantial rise in lending rates for new loans to firms and households. At the same time, banks have significantly tightened credit standards for loan approvals, reflecting the restrictive policy environment. Unlike during the 2005-08 tightening episode – when banks' supply and ability to lend were constrained –the main driver of the increase in credit standards as measures by the Bank Lending Survey (BLS) during the 2022-23 tightening episode was a heightened risk perception among banks, which rose immediately following the first announcements of policy normalisation at the end of 2021 and then continued to steadily build.[39] As a result, credit volume growth slowed sharply, with nominal credit growth remaining exceptionally subdued from 2022 until 2023Q4.

A simple empirical exercise based on the identification scheme described above shows that the transmission of monetary policy to lending rates and volumes to non-financial corporations was somewhat stronger during the 2022-23 tightening, although the evidence is not entirely conclusive (see Chart 2). It should also be noted that the Structural VAR shows only the reaction to the discretionary component of monetary policy, while it is well known that the bulk of the transmission happens via its systematic component.

Chart 2

Impulse response functions to a conventional monetary policy shock in the euro area over different samples: lending variables

(percentage and percentage-point deviations from pre-shock level)
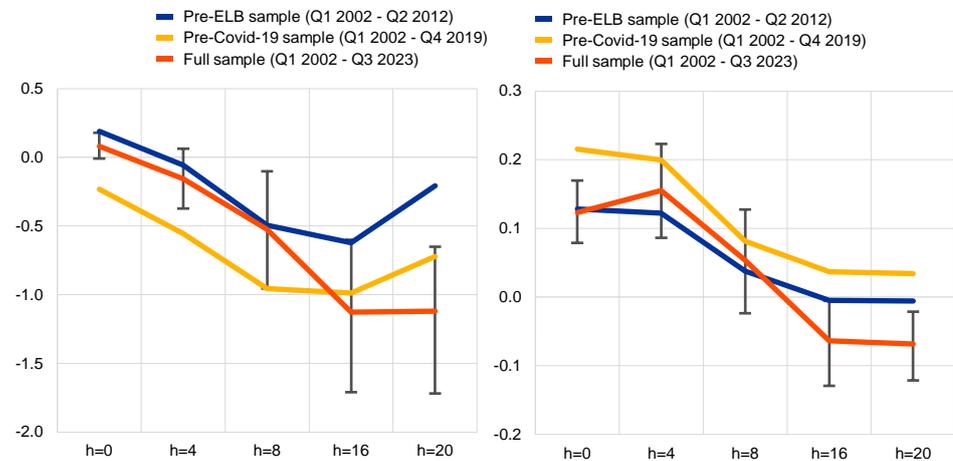
Source: Zlobins (2025). Notes: Figures show impulse response functions from a structural Bayesian SVAR to a conventional monetary policy shock, normalised to generate a 25-bps peak increase in the 3-month EURIBOR. Solid lines show the median responses at selected horizons while whiskers denote the 68% credible sets from estimation using the full sample. IRFs have been harmonised to reflect the effects of a 25 basis-point conventional monetary policy shock. Simulation horizon in quarters.

To shed further light on this issue, we use counterfactual scenarios conducted within a BVAR framework (see Box 1 for more details and results). More precisely, we carry out two counterfactual exercises to assess the transmission of monetary policy to lending rates in 2022-23. In each of them, we first estimate the model over the sample 2003Q1-2021Q4, and then compute forecasts conditional on the actual path of selected variables over the sample 2022Q1-2023Q4. The results shed light on the

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[39] See Bottero, M. and Conti., A.M. (2023).

ability of the conditioning set to explain the dynamics in lending rates. In the first counterfactual, we compute the conditional forecast of the composite cost of borrowing for NFCs based on monetary policy alone (i.e. the actual path of short- and long-term reference rates). In the second, we add risk perception drawn from the euro area BLS to the conditioning set.

The results, as shown in Chart 3, are quite striking. First, the counterfactual path of the composite cost of borrowing for NFCs based on monetary policy alone is significantly lower than the actual path, suggesting that some factor amplified the transmission to the cost of credit compared with historical regularities. Second, there is instead an almost perfect fit between the counterfactual obtained adding risk perception to the conditioning set and the realised path of lending rates.

Chart 3

Model-based counterfactuals for lending rates to non-financial corporations

(percent per annum)
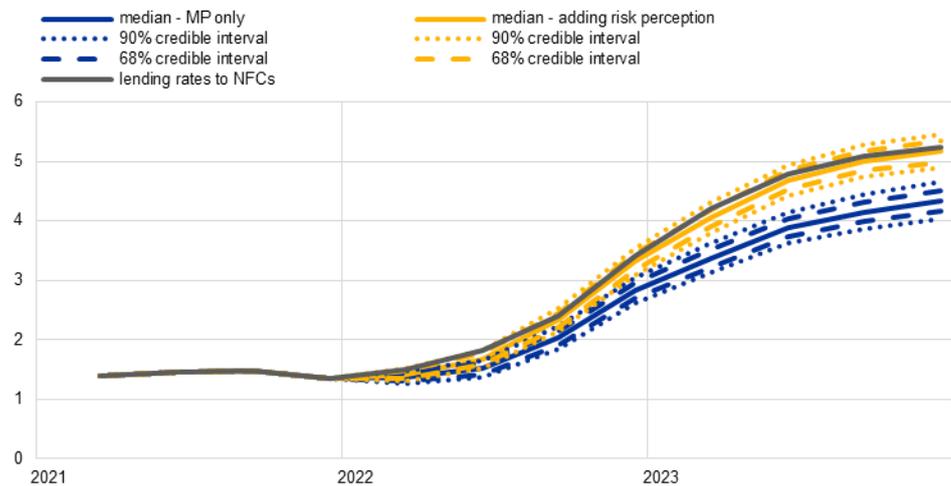
Source: Conti et al. (2024).
Notes: The figure shows the actual evolution of the composite indicator of cost of borrowing for non-financial corporations (black line). The blue line is a counterfactual obtained from a BVAR conditioning on the actual path of 3-month and 10-year nominal interest rates (with 68% and 90% credible intervals). The yellow line is a counterfactual obtained by conditioning also on the actual path of risk perception among banks taken from the Bank Lending Survey. The estimation sample is 2003Q1 – 2021Q4. The counterfactual sample is 2022Q1 – 2023Q4. The latest observations are for 2023Q4.

These findings suggest that banks' risk perception was indeed a major driver of lending rates in 2022-23 and that this channel can rationalise the stronger transmission of monetary policy to the cost of credit to NFCs compared with past historical episodes, which could also indicate potential changes in monetary transmission.

4.2 Heterogeneous transmission across countries and sectors

Effects of monetary policy across euro area countries

The transmission of monetary policy varies significantly across euro area countries owing to structural differences in their economies. Existing literature on the country-specific effects of monetary policy shows that various structural factors play an important role in explaining why the impact of monetary policy differs between economies.

One critical factor is the sectoral composition of economies, as countries with a higher share of capital-intensive sectors or sectors with interest rate-sensitive demand – such as manufacturing, durable goods production, or construction – are typically more affected by monetary policy changes (Carlino and DeFina, 1998, 1999; Owyang and Wall, 2009; Georgiadis, 2015). Labour market characteristics also play an important role, as economies with more rigid real wages typically experience stronger responses in output and employment to nominal demand changes (Abbritti and Weber, 2010). Georgiadis (2015) shows that the strength of monetary policy's impact on real GDP depends on factors determining wage flexibility and employment dynamics, which in turn influence aggregate demand and supply responses. Another important source of variation lies in the degree of trade openness. Countries with larger export sectors tend to experience more pronounced monetary policy effects through the exchange rate channel, as exchange rate movements affect international competitiveness and external demand. Similarly, the strength of the exchange rate channel is positively correlated with an economy's overall openness to international trade.[40] The structure and competitiveness of the banking system may also shape monetary policy transmission. Heightened competition in the banking system can amplify the response of bank interest rates to changes in market interest rates influenced by monetary policy (van Leuvensteijn et al., 2008). Additionally, asset prices channels (through equity and real estate) can differ, depending on the distribution of share ownership and residential property.[41] The relative response of output and inflation to monetary policy impulses is also shaped by the slope of the Phillips curve, which reflects the structural characteristics of the economy.

Empirical analysis using a multi-country Bayesian structural vector autoregression as in Mandler et al. (2022) reveals marked differences between the four largest economies, namely Germany, France, Italy and Spain (BIG-4) when it comes to the effects of a common euro area monetary policy on economic activity and consumer

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[40] Matusche and Wacks (2023) show that the impact of monetary policy in the euro area is affected also by wealth inequality, indebtedness and demographics.

[41] For evidence for the euro area, see, for example, Matusche, A. and Wacks, J. (2023).

prices.[42] The results reported in this section are based on an adapted version of the baseline model in Mandler et al. (2022), which is estimated on quarterly time series for three periods, all starting in 1999, but ending in 2014, 2019 and 2024, respectively, thus allowing to check for changes in monetary policy transmission over time.

The results suggest that the effects of monetary policy on real GDP are somewhat stronger in Germany, although the evidence on cross-country heterogeneity is mixed (see Box 2).[43] Moreover, the relatively stronger output effects in Germany are robust across different estimation periods. When the estimation period ends in 2024, the output response in Italy mildly exceeds that in Spain, although this finding is qualified by a high degree of estimation uncertainty. For consumer prices, the results up to both 2014 and 2019 show stronger effects of monetary policy in Spain and Italy than in Germany and France. Estimating the model up to the most recent period suggests that monetary policy affects prices most strongly in Italy and least strongly in France. The changes observed when adding recent data could be an indication of potential changes in the transmission of monetary policy.

The heterogeneous effects of monetary policy on economic activity across the BIG-4 are likely to reflect cross-country differences in structural economic characteristics.[44] Indeed, a correlation analysis between estimated impulse responses and various structural characteristics shows that the following factors could be relevant: sectoral composition (importance of manufacturing or industry), labour market flexibility, export share, competition in the banking sector, and the importance of bank lending for firms' external financing (see Box 2). The stronger GDP response in Germany to interest rate policy is consistent with the heavier weight of the German manufacturing sector and the production of durable goods, weaker employment protection, the relative importance of exports, and fiercer competition in the banking system than in the other countries under consideration. By contrast, understanding the drivers behind cross-country differences in price responses is a more challenging task. Abbritti and Weber (2010) highlight the role of labour market institutions in shaping these differences. Their analysis shows that countries with low real wage flexibility, but high employment flexibility tend to experience a stronger response in employment – and consequently in output – to a monetary policy impulse. However, this comes at the cost of a weaker response in inflation rates. The findings in Box 1 point to a weaker response of prices in Germany and France, and a stronger reaction in Italy and Spain. Germany's comparatively weaker price reaction and stronger output response may be attributed to its higher labour market flexibility. This flexibility allows quantities, such as employment and output, to adjust more than prices, which is consistent with the findings of Abritti and Weber (2010).

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[42] Mandler et al. (2022) propose a method for comparing impulse response functions across regions that directly evaluates the probability distribution of the differences between impulse responses. This approach leverages the joint distribution of the responses, incorporating the correlation of estimation errors, rather than indirectly comparing their individual distributions. Their analysis is based on a multi-country model that simultaneously includes all examined countries, allowing the model to capture the correlation between the estimation errors of each country's impulse responses. This helps to ensures a robust and comprehensive comparison of impulse responses across regions.

[43] See Corsetti et al. (2022) and Barigozzi et al. (2024).

[44] For a summary and references, see Mandler et al. (2022).

Box 3 presents further results, using a similar setup, on the heterogenous effects of monetary policy in four smaller euro area countries, namely Latvia, Lithuania, Portugal and Slovakia. The results show that real activity in Latvia, Lithuania and Slovakia is more sensitive to monetary policy shocks than in the wider euro area. By contrast, Portugal exhibits no clear evidence of output responding differently compared with the euro area aggregate. In terms of price effects, monetary policy has a stronger impact in all four countries than in the euro area. A correlation analysis shows that differences in sensitivity to monetary policy between these four countries may be linked to structural country characteristics, as discussed for the BIG-4.

Effects of monetary policy across euro area sectors

The sectoral composition of an economy plays a crucial role in the transmission of monetary policy, as highlighted in the previous section. Since the seminal contribution made by Bernanke and Gertler (1995), it is well understood that restrictive monetary policy tends to have a stronger impact on activity in the manufacturing sector than in services. Countries with a larger manufacturing sector tend to experience a stronger effect of monetary policy on real GDP as, a higher share of manufacturing relative to services leads to greater aggregate demand sensitivity to monetary policy and potentially more pronounced output fluctuations.[45] Moreover, the rise of the services sector over the last decade has helped to lower the median frequency of price changes in the economy, likely dampening the short-term inflation response to monetary policy shocks.

Researchers have consistently found that manufacturing is more sensitive to monetary policy adjustments, responding nearly twice as strongly and two quarters earlier than services, as confirmed by a recent ECB study.[46] This heightened sensitivity is largely due to the fact that manufacturing is capital-intensive, making it more vulnerable to interest rate fluctuations. In contrast, the services sector reacts more gradually, with effects becoming apparent about a year after a monetary policy shock and peaking in the second year.

The results of a multi-sector structural BVAR of the euro area corroborate the pronounced differences in the effects of monetary policy on the manufacturing, construction and services sectors (see Box 4).[47] In the short run, manufacturing and construction exhibit greater sensitivity to interest rate changes than services, with construction activity showing the strongest reaction over the medium term. Regarding sectoral deflator responses, the results obtained depend on the identification strategy. In the short run, prices in manufacturing and construction are more sensitive to monetary policy than those in services. Under less restrictive assumptions, however, the price impact in manufacturing becomes comparable to

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[45] Services are, on average, less interest-rate sensitive. Thus, a service-based economy implies a flatter IS curve, which, in principle, reduces the responsiveness to monetary policy.

[46] See box titled "Monetary policy and the recent slowdown in manufacturing and services ", *ECB Economic Bulletin*, Issue 8/2023.

[47] The multi-sector model resembles the multi-country model described in Box 2 by replacing the cross-country dimension with the cross-sectoral dimensions for the euro area.

that in services and weaker than in construction. Over the medium to long term, construction prices remain the most responsive, followed by services, while manufacturing displays relatively lower sensitivity.

As regards the time-varying dimension of these sectoral effects, empirical evidence based on a time-varying-parameter SVAR approach with stochastic volatility (TVP-SVAR-SV) suggests that over time the impact of monetary policy on real sectoral value added has declined to some extent, mainly in the manufacturing sector, whereas for services, the relative changes compared with the past are barely visible (Chart 4). One possible explanation for this is that the post-pandemic liquidity buffers and excess savings amassed by firms and households may have partially mitigated the dampening effects of monetary policy tightening.

Chart 4

Time-varying impact of monetary policy on manufacturing and services
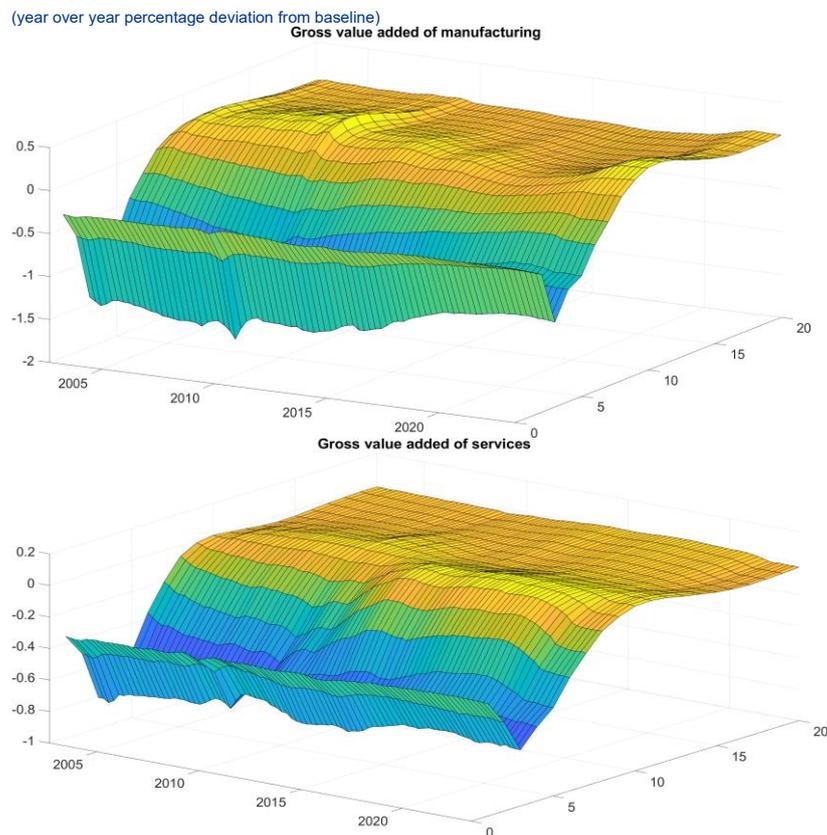
(year over year percentage deviation from baseline)

Sources: Zlobins (2025) and authors' calculation.
Notes: The figures show impulse response functions from the TVP-SVAR-SV, as in Zlobins (2025), to a conventional monetary policy shock over the period running from 2002Q3 to 2023Q3. The shock has been normalised to a 25-bp peak increase in the 3-month EURIBOR in each period, allowing the estimated elasticities to be comparable over time. All variables are expressed as Y-o-Y growth rates, with the exception of the 3-month EURIBOR, which enters the model in levels.

Closely connected to the sectoral dimension of monetary policy transmission are questions regarding its differential impact on the components of domestic demand. Box 6 summarises the evidence on the heterogeneity in the transmission of monetary policy to households and non-financial corporations. Monetary policy tightening affects households primarily through higher borrowing costs and reduced wealth. Rising interest rates increase the cost of servicing variable-rate loans, such

as mortgages, thus reducing disposable income and discouraging new borrowing. Simultaneously, lower prices of assets, such as housing and equities, erode household wealth, thereby weighing on consumption and overall demand. For non-financial corporations, higher rates raise financing costs and restrict credit availability, particularly for smaller or less creditworthy firms. This discourages capital investment and constrains business activity.

Several studies have highlighted the differentiated impact of monetary policy tightening on domestic demand components, such as private consumption, housing investment and business investment. Bernanke and Gertler (1995) showed that tighter monetary policy disproportionately affects interest-sensitive sectors such as housing and durable goods consumption due to increased borrowing costs and reduced access to credit. In the euro area, Angeloni et al. (2003) found that housing investment contracts most sharply and rapidly in response to rate hikes, whereas private consumption and business investment show more gradual adjustments. Iacoviello and Neri (2010) further underscored the housing sector's role in amplifying monetary policy transmission by influencing household wealth and collateral values, thus magnifying the broader economic impact of policy changes.

To update these findings, we adapt the time-varying framework used above to estimate the impact of monetary policy tightening on domestic demand components across time. Our estimates reveal that, during the early part of the estimation period, business investment was more responsive to monetary policy compared with private consumption (Chart 5), which is consistent with the fact that manufacturing output is more sensitive than services to changes in monetary policy. However, this difference has receded after 2012, with the sensitivity of both business investment and private consumption largely converging. The findings for domestic demand components are consistent with the implications of monetary policy effects across sectors. The component of domestic demand that has the higher share of capital goods, namely business investment, reacts more strongly overall to monetary policy shocks. Meanwhile, the domestic demand component with the highest share of services, i.e. private consumption, reacts less strongly, although recently it has been steadily converging with business investment in this regard.

Chart 5

Time-varying impact of monetary policy on private consumption and business investment

(baseline y-o-y percentage deviation from the pre-shock level))
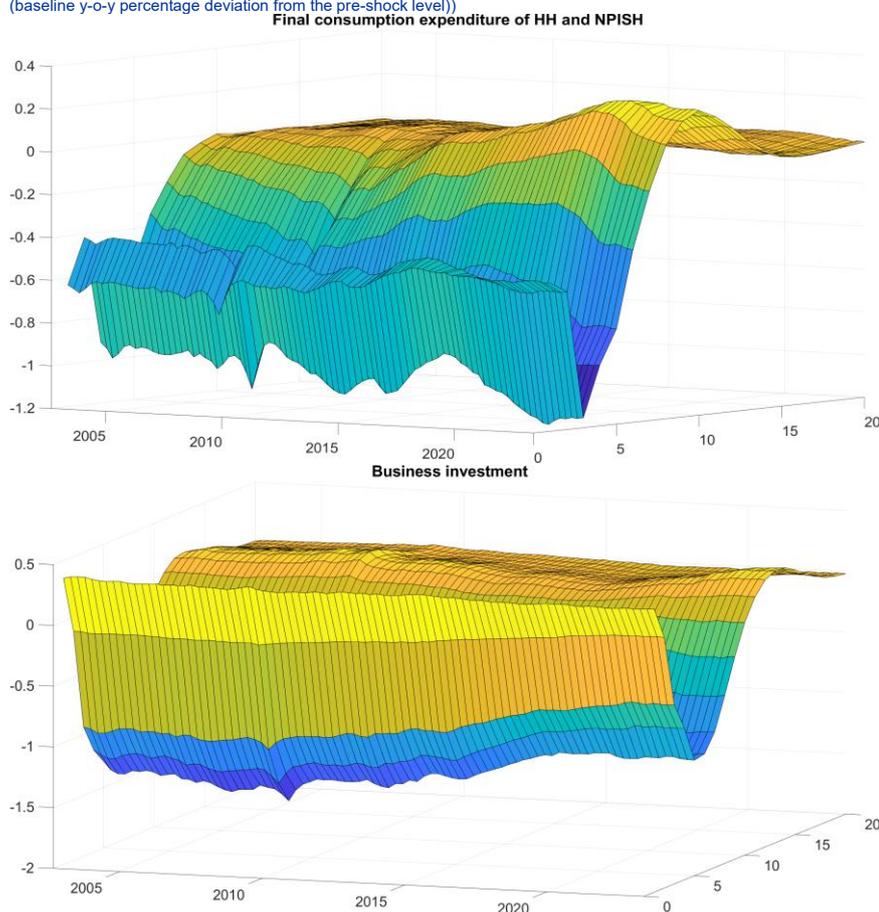
Final consumption expenditure of HH and NPISH

Business investment

Sources: Zlobins (2025) and authors' calculation. Notes: The figures show impulse response functions from the TVP-SVAR-SV, as in Zlobins (2025), to a conventional monetary policy shock over the period running from 2002Q3 to 2023Q3. The shock has been normalised to a 25-bp peak increase in the 3-month EURIBOR in each period, allowing the estimated elasticities to be comparable over time. All variables are expressed as Y-o-Y growth rates, with the exception of the 3-month EURIBOR, which enters the model in levels.

A further perspective on the sector-specific effects of monetary policy focuses on different components of the HICP basket. Monetary policy affects inflation through various channels, the effects of which may differ across consumption items. Higher interest rates encourage households to save and put back discretionary spending, particularly for items often bought on credit. Research consistently shows that spending on durable goods is more cyclical and sensitive to real interest rate changes than spending on non-durables or services, as highlighted by Mankiw (1985) and supported by studies like Forni and Gambetti (2010), Mallick and Mohsin (2016), and Borio et al. (2021). Furthermore, there is a large and growing body of evidence showing that prices in the services sector are considerably "stickier" than in all other sectors in the economy, in the sense that they adjust less frequently. This is broadly consistent with the empirical evidence suggesting that monetary policy has a stronger direct impact on economic activity in interest-sensitive sectors such as construction, capital goods and consumer durables, and a slower, and likely smaller, impact on activity levels in the services sector.

The empirical analysis summarised in Box 5 finds that in the euro area, prices for both goods and services display sensitivity to monetary policy, while in the United States, items with prices sensitive to monetary policy are largely concentrated in services. In both regions, prices in service categories related to recreation, accommodation and food are highly responsive to monetary policy, due to the discretionary nature of spending in these categories. Notably, US housing services, which heavily include owners' equivalent rent, contribute significantly to persistent inflation, a factor absent in the euro area. Meanwhile, goods inflation has declined more rapidly in both regions, and car prices have been identified as particularly sensitive due to their dependence on consumer credit.

4.3 Non-linear monetary policy impact: time-variation

To investigate potential changes in the transmission of monetary policy during the 2022-23 tightening episode, we adopt a flexible SVAR framework with time-varying parameters and covariance matrices. The methodology is aligned with the framework outlined in Zlobins (2025) and used in the previous section for the sectoral analysis.

The benchmark specification is analogous to that reported in the linear fixed-coefficient BVAR. Identification is based on a combination of high-frequency instruments (Altavilla et al., 2019; Jarociński and Karadi, 2020) and narrative sign restrictions (Antolín-Díaz and Rubio-Ramírez, 2018). The analysis based on this more flexible framework confirms the stronger effectiveness of monetary policy in bringing down inflation during the 2022-23 tightening episode, as already hinted at in the simple subsample analysis.

Chart 6 reports the time-varying impulse response functions to a conventional monetary policy tightening over the period 2002Q1 to 2023Q3. First, a higher persistence of the policy rate is observed in the post-pandemic period, as demonstrated by the IRF of the 3-month EURIBOR, reflecting the ECB's forceful response to the inflation surge. The response of output has remained broadly stable over time, with slightly weaker effects towards the end of the sample, whereas the impact on inflation has been much stronger and more persistent in the recent tightening episode, implying a historically low sacrifice ratio. This is also linked to the firm anchoring of inflation, in marked contrast to the 1970s. When inflation began to rise in mid-2021, short-term interest rate expectations initially followed the same path, but as soon as monetary tightening accelerated in mid-2022, inflation expectations plateaued and then fell. The time-varying impulse responses show a much stronger decline in inflation expectations (as measured by the ECB Survey of Professional Forecasters) in the recent tightening episode (Chart 6). Meanwhile, equity prices and the exchange rate do not seem to exhibit any time-varying behaviour.

Chart 6

Time-varying impact of monetary policy

(deviation from pre-shock level)

Real GDP

HICP inflation

3-month EURIBOR

Euro Stoxx 50

EUR/USD

SPF 5-year ahead inflation expectations
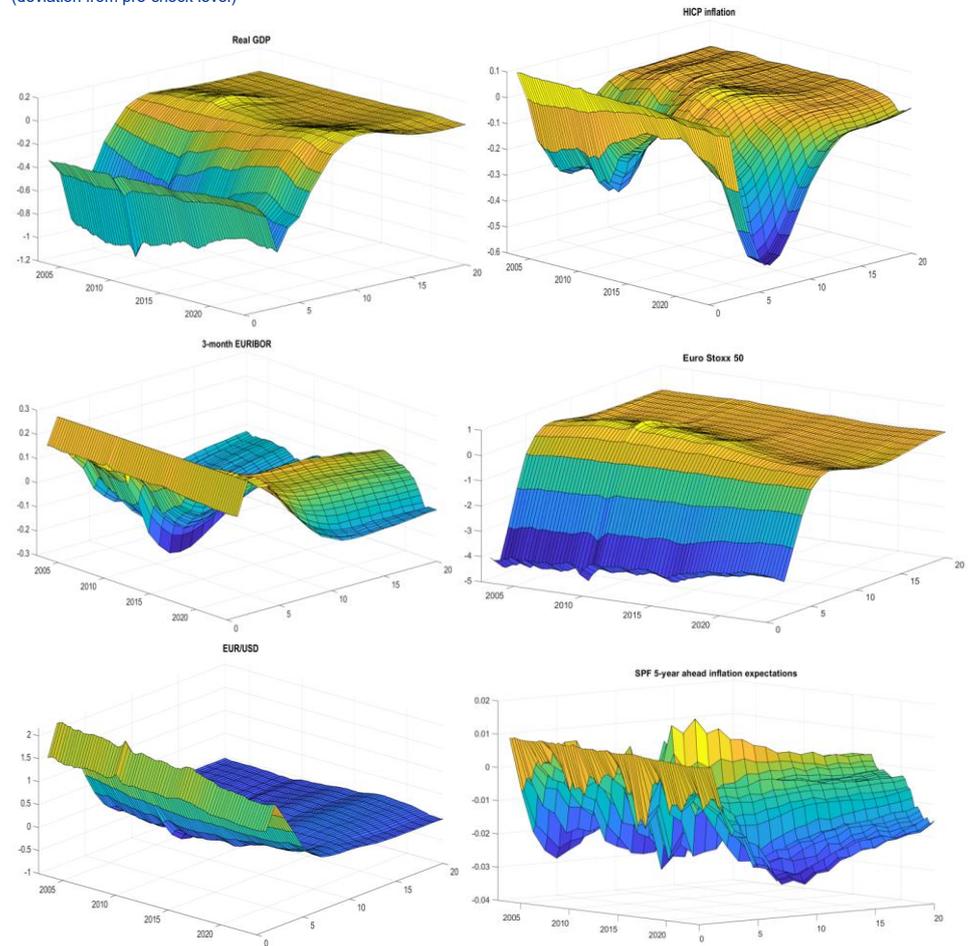
Sources: Zlobins (2025), Eurostat and LSEG data.
Notes: The figures show impulse response functions from the TVP-SVAR-SV to a conventional monetary policy shock over the period running from 2002Q3 to 2023Q3. The shock has been normalised to induce a 25-bp increase in the 3-month EURIBOR in the second period, allowing the estimated elasticities to be comparable over time. All variables are expressed as Y-o-Y growth rates, except for the 3-month EURIBOR, which enters the model in levels.

4.4 Non-linear monetary policy impact: shock and state dependence

The reaction of monetary policy and its impact on economic variables are highly contingent on the underlying source of the shock, such as whether the dynamics are demand- or supply-driven. Studies such as Blanchard and Galí (2007) show that demand shocks, characterised by shifts in consumption or investment, typically elicit countercyclical monetary policy responses aimed at stabilising output and inflation. However, the effectiveness of these responses has diminished over time, particularly in the low-interest rate environment, as highlighted by Summers (2014) and Woodford (2012), when conventional tools faced significant constraints. In contrast, supply-side shocks, such as energy price surges or supply chain disruptions, present a more complex challenge for policymakers. Research by Kilian (2009) and, more

recently, by Coibion et al. (2023) reveals that these supply-driven shocks often create a trade-off between stabilising inflation and supporting economic activity. Recent evidence, particularly from the post-pandemic period, indicates that the pass-through of supply shocks to inflation has strengthened, calling for more aggressive monetary policy action to anchor inflation expectations (Giannone and Primiceri, 2024; Gertler et al., 2022). Overall, on the importance of the origin of the inflationary shocks, the literature provides mixed evidence. Some studies show that supply shocks were three times more important than demand shocks in explaining the deviation of inflation from its mean at the peak impact,[48] while others conclude that demand shocks happened to play a greater role.[49]

This evidence points to a significant shift in the responsiveness of monetary policy in the post-pandemic period, with the ECB displaying a notably stronger reaction to aggregate and oil supply shocks. This marks a clear departure from the more accommodative stance that characterised earlier periods, particularly in the face of supply-driven inflationary pressures. The limited willingness to "look through" these shocks, reflects an adaptive policy shift, consistent with the findings of Coibion et al. (2023), who argue that central banks have become more reactive to inflationary surges triggered by supply-side disruptions in the post-pandemic era. Notably, the ECB's policy response to oil supply shocks has been especially pronounced, with empirical evidence showing a significantly stronger pass-through from energy price increases to headline inflation compared with historical norms. The sharp rise in energy price pass-through – amplified by persistent supply constraints and geopolitical tensions – has called for a more aggressive monetary policy stance to prevent temporary shocks from becoming embedded in inflation expectations. Supporting this, Giannone and Primiceri (2024) emphasise that the ECB's prompt response to inflationary pressures following the initial supply shocks in 2021-2022 played a crucial role in addressing the elevated role of energy prices in inflation dynamics. Overall, the results suggest that the ECB's policy response in 2022-23 was more reactive to supply shocks than during the 2005-2008 period, when the tightening was primarily driven by demand factors (Chart 7, panel a).[50]

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[48] Bańbura, M. et al. (2023).

[49] Giannone, D. and Primiceri, G. (2024).

[50] The results are robust to using alternative measures of the monetary policy rate, such as the Wu-Xia (2016) or the Krippner (2013) shadow rate.

Chart 7
Time-varying impact of aggregate demand, supply and oil supply shocks

(deviation from pre-shock level)

Panel a) Demand shocks
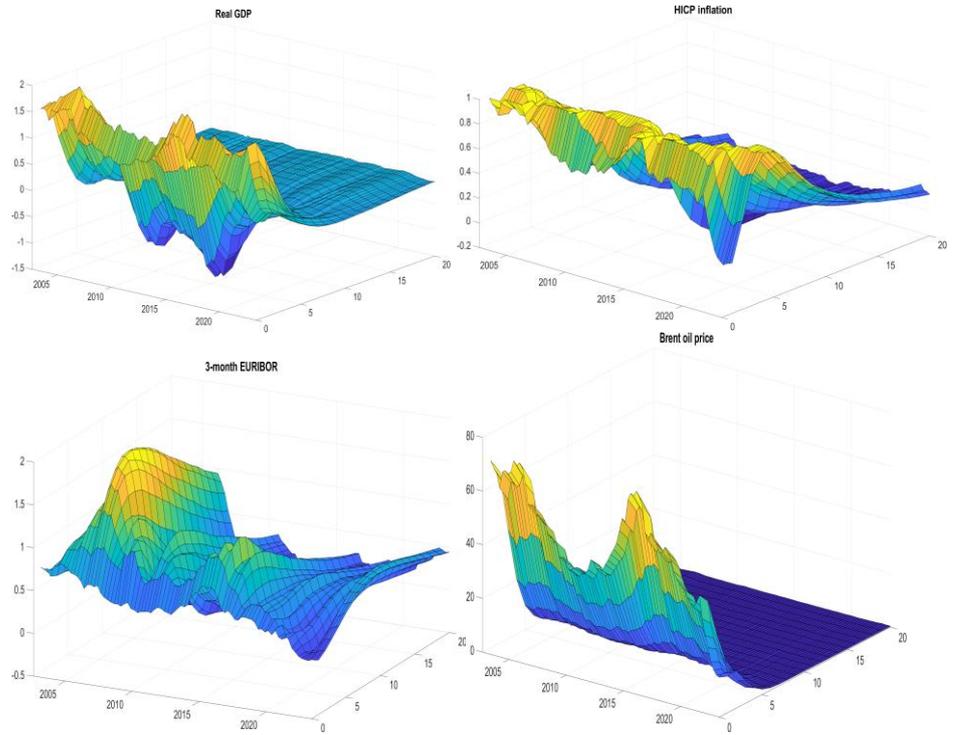
Panel b) Supply shocks
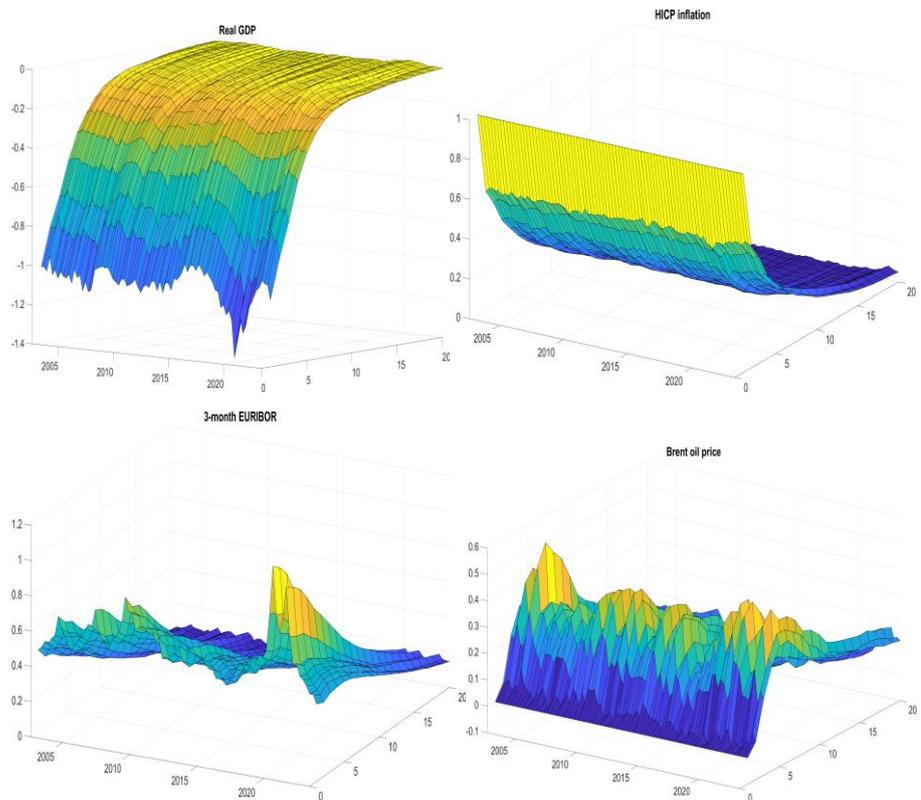
Panel c) Oil supply shocks

Real GDP

HICP inflation

3-month EURIBOR

Brent oil price

The risk of de-anchoring inflation expectations to the upside was effectively contained during this inflationary episode. This outcome was supported by the temporary nature of the initial inflation shocks, as relative price increases stemming from the pandemic and the war-related energy crisis reversed relatively quickly. Model-based counterfactuals underscore that a less vigorous monetary policy response could have led to a persistent upward shift in inflation dynamics.

On the subject of state dependency, the effectiveness of monetary policy, including its impact on inflation expectations, differs depending on the level of inflation. Box 8 below investigates whether and how monetary policy affects inflation expectations non-linearly, using high-frequency event studies of inflation-linked swap (ILS) prices in response to monetary policy announcements from the ECB and the Fed. Three forms of non-linear transmission are examined: time-varying effects, asymmetry in the response to contractionary versus expansionary policies, and state-dependent effects influenced by macroeconomic conditions. The analysis includes data from the COVID-19 period and covers samples up to late 2023. The results show that in the euro area, the effects of contractionary monetary policy on inflation expectations are weaker than expansionary surprises. This was particularly the case during 2014-2019, although this partly reflected the influence of asset purchase announcements.

State-dependent transmission shows stronger pass-through when inflation is high; a result observed in both the euro area and the United States, highlighting the role of inflation levels and uncertainty in shaping policy effectiveness. However, the inclusion of COVID-19 data reduces the statistical significance of these findings due to the high levels of volatility that prevailed during the recovery period. In the United States, the transmission of policy surprises to inflation expectations appears more symmetric, with consistently negative reactions to policy tightening.

Standard New Keynesian (NK) models typically rely on near-linear relationships between economic activity and both wage and price inflation. In these frameworks, large or persistent inflationary episodes are predominantly attributed to exogenous supply shocks, resulting in substantial trade-offs between inflation stabilisation and output stabilisation (see Fratto and Uhlig, 2020). The near-linear nature of the New Keynesian Phillips Curve also implies a muted demand channel for monetary policy, reflected in a high and constant sacrifice ratio, meaning that a significant contraction in output is required to reduce inflation, largely irrespective of the underlying state of the economy.

Recent work by Ascari et al. (in progress) proposes a state-dependent and genuinely convex New Keynesian Phillips Curve (NKPC) designed to capture non-linear inflation dynamics, building on existing evidence of non-linearities in the Phillips curve (Cavallo et al., 2024) and state-dependent price-setting behavior (Gautier et al., in progress). Using the Fair and Taylor (1983) non-linear solution method and a Bayesian-augmented inversion filter (Cuba-Borda et al., 2019), Ascari et al. estimate this model with euro area data from 1999Q1 to 2023Q4 (see Box 7). Their findings suggest that state dependency becomes quantitatively relevant only during the high-inflation period (2021Q1-2023Q4), when endogenous price and wage flexibility is notably larger. Consequently, during such periods of elevated inflation, monetary policy shocks have a more potent effect on wage and price inflation with smaller output losses.[51] The result is a lower sacrifice ratio when inflation is high compared with periods of low inflation.

From a policy perspective, the model suggests that tighter monetary policy under high inflation conditions could be more effective and less costly in terms of lost output than implied by standard NK models. However, caution should be exercised when drawing definitive conclusions, as the model omits key transmission channels, such as financial frictions and investment dynamics. Even so, the analysis underscores the importance of allowing for non-linear and state-dependent behaviour in Phillips curves when evaluating the dynamics of inflation and the efficacy of monetary policy actions.

We use the time-varying estimations discussed above to empirically assess the implications for the sacrifice ratio over time. Mirroring the findings in Box 6, the evidence shows that the euro area has experienced relatively low economic costs

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[51] Consistently, Gargiulo et. al (2024) find using a threshold BVAR approach that, in case of US economy, the effects of monetary policy are larger and longer lasting when inflation exceeds the threshold of 5.5 percent. Canova and Forero (2024) conclude using a similar empirical approach that while the peak response of output growth, unemployment and inflation is smaller, the effects lasts longer when inflation is high.

during the current period of disinflation, with the output loss per percentage point reduction in inflation falling below 2, a level significantly below historical average (Chart 8). Despite rapid and substantial monetary policy tightening, the severe output losses typically associated with disinflationary episodes have been largely avoided. The current disinflation process has been relatively painless compared with past episodes.

Possible explanations for this comparatively lower sacrifice ratio when compared with past tightening episodes could be linked to several cyclical and structural factors that have emerged in the very particular economic context we have witnessed in recent years. Cyclically, the resolution of post-pandemic supply chain disruptions has not only helped to lower inflation but has also supported economic activity. In addition, the post-pandemic cash buffers amassed by firms and households, such as robust profits and excess savings, have also likely mitigated to some extent the costs of disinflation by supporting economic activity. Furthermore, fiscal policy support related to the pandemic and energy crisis has been another factor mitigating the negative impact of monetary policy on economic activity. Structurally, the post-pandemic inflation surge has been marked by a significant increase in the frequency of price changes, implying a steeper Phillips curve that has allowed central banks to achieve the same reduction in inflation but with smaller output losses.[52] At the same time, and once again mirroring the findings set out in Box 7, the sacrifice ratio is low when inflation is high, and vice versa. Notably, in 2022, the sacrifice ratio was nearly 8 times smaller than in 2012, reflecting the greater flexibility of prices and wages in periods of high inflation (Chart 8).

Chart 8
Sacrifice ratio over time

(percentage points)

Moreover, the severity of the output-inflation trade-off depends heavily on inflation expectations. During the recent inflationary episode, there was a real risk that the

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[52] In the basic New Keynesian model, this slope is higher the higher the frequency with which firms adjust their prices to changes in their cost and demand conditions. See also Hernandez de Cos (2024).

sharp and persistent rise in inflation could de-anchor medium- and long-term inflation expectations above target. Indeed, when inflation started rising in mid-2021, short-term inflation expectations initially followed suit. However, once monetary tightening accelerated in mid-2022, inflation expectations levelled off and subsequently declined (Chart 9). This robust anchoring of expectations helped keep the sacrifice ratio relatively low, unlike in earlier episodes – such as the 1970s oil price shocks – when de-anchored expectations led to more aggressive policy tightening and costly disinflation efforts.[53]

Finally, in the most recent tightening episode, monetary policy might have been somewhat less restrictive than assumed, given the potentially higher than assumed natural interest rates. Following decades of decline, there are indications that r-star may have edged up slightly since the 2021 MPSR, although it remains at a relatively low level[54] and therefore cannot be largely accountable for the relatively low sacrifice ratio.[55]

Chart 9

HICP – actual and expected inflation
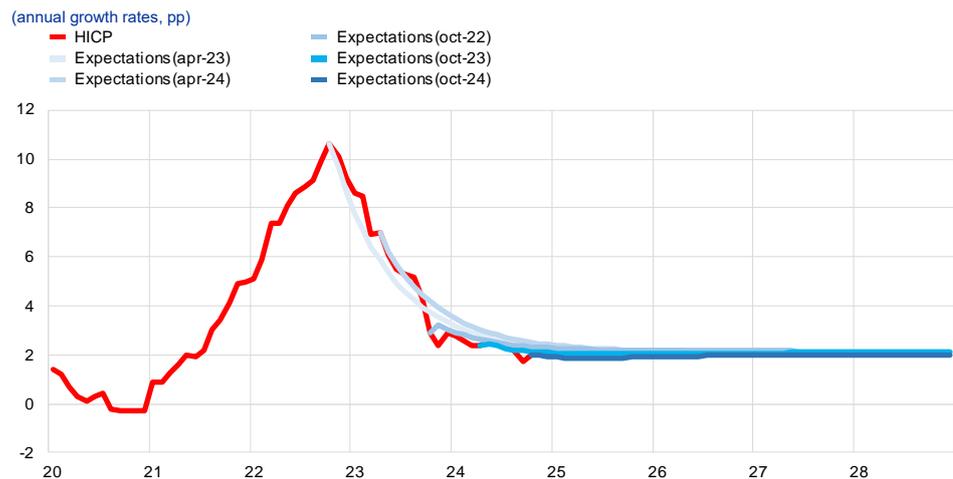
Source: BdE staff calculations.
Notes: Expectations obtained from a mixed frequency dynamic latent-factor inflation model, with data from ILS markets (1y to 30y inflation-linked swaps with fixed duration and 1m to 12m ILS with fixed-date maturities, i.e. fixings), surveys (Survey of Professional Forecasters, Survey of Monetary Analysts and Consensus Forecasts) and the Flash HICP. See Gimeno and Ortega (2024), "Modelling Euro Area Inflation Expectations. The Value of Mixing Sources and Frequencies", *Banco de España Working Paper*, forthcoming.
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[53] See also Villeroy de Galhau, F., "Anatomy of a fall in inflation: from a successful first phase to the conditions for a controlled landing", speech, 28 March 2024.

[54] See also Workstream 1 of the Report for Monetary Policy Strategy Review 2025, entitled "Developments in r* and drivers".

[55] See also Nagel, J. "What can we learn from the recent disinflation episode?", Dinner speech at the CEBRA Annual Conference, August 2024.

This box assesses the behaviour of bank lending to non-financial corporations (NFCs) in the euro area during the unprecedented tightening episodes undertaken by the ECB in 2022-23 as a swift response to the spike in inflation. We find that loans to NFCs were significantly weaker than the level implied by historical regularities in the relationship between credit, monetary policy and the business cycle.

We use counterfactual scenarios conducted within a Bayesian VAR (BVAR) framework to estimate the relationship between lending and its main determinants prior to the start of monetary tightening (in the period 2003-21).[a]

Our BVAR includes macroeconomic, financial and credit variables. More precisely, it incorporates eight endogenous variables: real GDP, HICP short and long-term market rates (the €STR and the 10-year IRS, respectively), NFC lending volumes and lending rates, and indicators of credit demand and supply sourced from the euro area Bank Lending Survey. As for credit supply, we include the sharp increase in risk perception among banks, which was a defining feature of the last tightening cycle and a key driver of the cost of credit.[b] On the demand side, we include demand for loans among firms to finance fixed investment, which experienced a deep and persistent decline over the period.

We design a series of projection exercises starting in 2022Q1, using conditional forecasts. Each exercise consists of three steps. In the first step, we estimate the BVAR coefficients over the sample 2002Q4 to 2021Q4, right before the spike in long-term market interest rates driven by the start of the monetary policy normalisation process and rising expectations of imminent policy rate hikes. In the second step, we assume that only a subset of the variables included in the BVAR model is known for the full sample up to 2023Q4, while the other variables are observed only up to 2021Q4. Third, we compute conditional forecasts for all unobserved variables over the period 2022Q1 to 2023Q4, based on the estimated coefficients (step 1) and the conditioning set (step 2).

The conditional forecasts based on the actual evolution of interest rates and business cycle variables fail to accurately replicate the magnitude and pace of the decline in the annual growth rate of loans to NFCs. The counterfactual NFC lending growth tracks the actual dynamics fairly well until the end of 2022Q2, when firms turned more to bank lending in response to the inflation surge triggered by the adverse energy shock (Chart A, left panel). However, the model is unable to replicate the steep decline in loan dynamics that began in the autumn of 2022, with a gap between the counterfactual and the actual annual growth rates of around 2.5 percentage points on average until 2023Q4.

Business cycle- and monetary policy-based counterfactuals also fail to reproduce risk perception among banks and demand among firms for loans for fixed investment. Both the initial rise in risk perception (Chart A, centre and right panel) and the contraction of demand among firms for loans to finance fixed investment occurred more rapidly than implied by historical regularities, hinting at an amplification of, respectively, the bank lending and interest rate channel.[c] The unprecedented scale and speed of the interest rate hikes may explain this amplification.

(Year-on-year percentage change; net percentages)
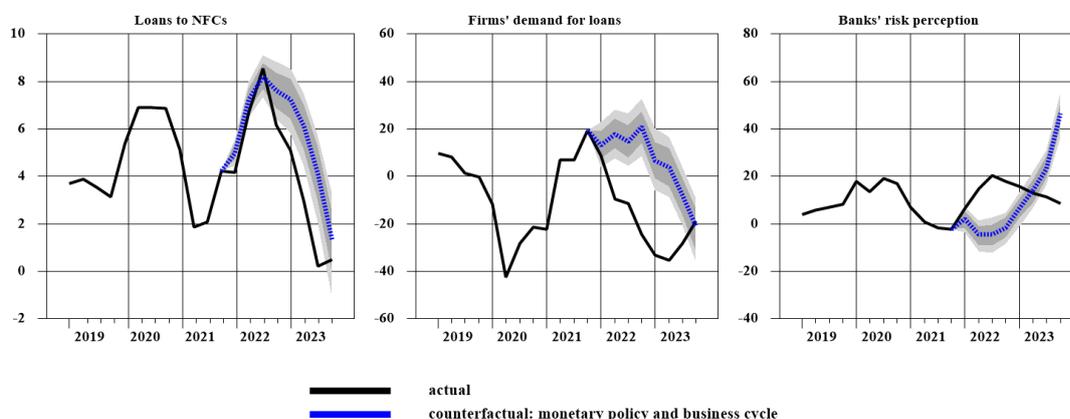
Source: ECB, Eurostat, LSEG and authors' elaborations.
Note: The dark (light) grey shaded area is the 68% (90%) credible interval obtained from the BVAR posterior distribution. The estimation is conducted over 2003Q1-2021Q4, while the projections refer to 2022Q1-2023Q4.

Given the model's inability to replicate the evolution of the BLS demand and supply indicators, we conduct a second counterfactual scenario in which we expand the previous conditioning set by adding the actual path of banks' risk perception and firms' demand for loans to finance fixed investment (observed over the period 2022Q1 to 2023Q4). The counterfactual path of NFC lending growth improves significantly, closely tracking the actual path. BLS indicators thus successfully capture the amplification mechanisms in the bank lending channel and in the interest rate channel during the 2022-23 tightening episode (Chart B, left panel).

A third counterfactual exercise sheds further light on the relative role of credit supply and demand factors. We repeat the analysis adding either banks' risk perception or firms' loan demand for fixed investment to the "baseline" conditioning set. The results show that heightened risk perception among banks played a bigger role in closing the gap between actual and counterfactual NFC lending growth, especially in late 2022 and early 2023, while the contribution made by the loan demand factor became increasingly relevant after 2023Q3, likely reflecting the usual lags between soft and hard indicators of credit dynamics (Chart B, right panel).

The results of the analysis underscore the increased importance of the bank lending channel in influencing credit dynamics during the 2022-23 monetary policy tightening. Given the usual lag with which tighter financing conditions pass through to the real economy, part of the effect of the tightening on output and inflation may still be lingering in the pipeline, continuing to affect corporate debt burden and possibly dampening the expansionary impulse from lower policy rates.

Chart B

Actual and counterfactual evolution of lending to NFCs

(Year-on-year percentage change)

——	actual
▌▌▌▌▌▌▌▌	counterfactual: monetary policy and business cycle
▌▌▌▌▌▌▌▌	counterfactual: adding banks' risk perception and firms' demand for loans for fixed investment
▌▌▌▌▌▌▌▌	counterfactual: adding banks' risk perception only
▌▌▌▌▌▌▌▌	counterfactual: adding firms' demand for loans for fixed investment only
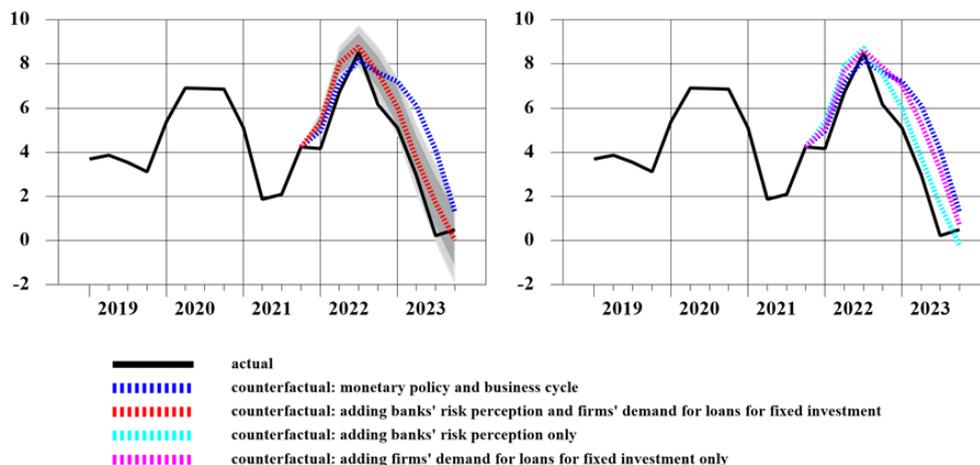
Sources: ECB, Eurostat, LSEG and authors' elaborations.
Note: The dark (light) grey shaded area is the 68% (90%) credible interval obtained from the BVAR posterior distribution. The estimation is conducted over 2003Q1-2021Q4, while the projections refer to 2022Q1-2023Q4.

Box footnotes

[a] This BVAR is a simplified version of the larger model developed by Conti et al. (2023) for the Italian economy but augmented by the two "soft" BLS indicators. For more details on the specification, see Auer and Conti (2024a, 2024b).
[b] See also Bottero and Conti (2023) and Conti, Neri and Notarpietro (2024).
[c] Since 2023Q2, the realised actual evolution of risk perception among banks has been somewhat lower than the counterfactual trend, likely reflecting the delayed adjustment of the model.

Box 2

Comparing the effects of monetary policy across the four largest euro area economies

Prepared by Tim Oliver Berg and Martin Mandler (Deutsche Bundesbank)

This box presents a set of results on the differential impact of common euro area monetary policy on real GDP and HICP across the four largest euro area economies, namely Germany, France, Italy and Spain. The results are derived from a multi-country Bayesian structural vector autoregression. However, instead of a visual comparison of impulse responses to a monetary policy shock between countries, inference is based on the estimated pairwise cross-country differences in impulse responses, as in Mandler et al. (2022).[a]

Charts A and B show selected percentiles of the posterior distributions of the cross-country differences in impulse responses of real GDP and HICP to a +25-basis points monetary policy shock. Each panel summarises information on the posterior distribution of the impulse response difference for all six possible country pairs and at horizons of 1, 4, 8, 12, 16 and 20 quarters after the shock. Chart A shows the results for estimation up to 2019Q4, i.e. up to the pandemic, while Chart B does so up to 2024Q1.[b] Each bar summarises the distribution of the impulse response in the first country minus that in the second country and at the horizon indicated below. The position of this distribution relative to zero conveys information about the differential effects of the monetary policy shock on the two countries.

For example, the first six bars in the panel for real GDP in Chart A concern differences in the output response between Germany and France. In the first two years, the distribution has most of its probability mass in the negative region. A negative difference implies that the impulse response is smaller in Germany than in France. As the results are shown for a restrictive monetary policy shock, which causes real GDP to fall in both countries, this means that real GDP declines more in Germany than in France.[c] As another example, most of the probability mass of the difference between Germany and Spain shown in the HICP panel of Chart A is located above zero, implying that the HICP declines less in Germany than in Spain.

Chart A

Cross-country differences in the effects of a monetary policy shock on real activity and consumer prices

1999Q1 – 2019Q4: Real GDP

Differences in impulse response to a monetary policy shock at selected horizons (percentage points)
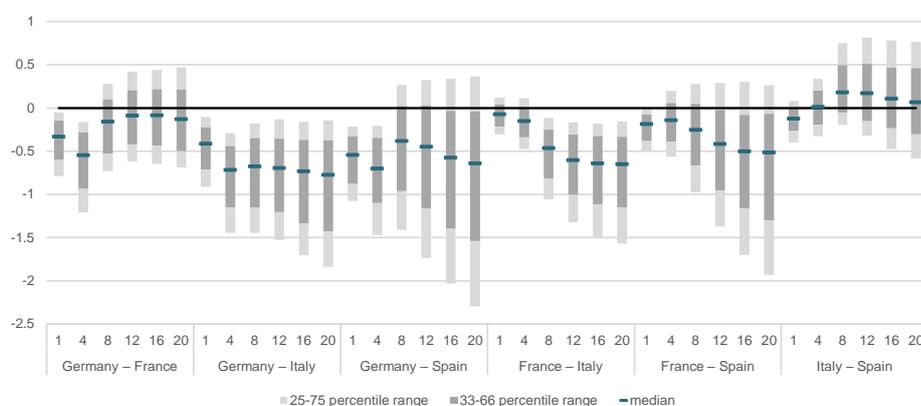
1999Q1 – 2019Q4: HICP

Differences in impulse response to a monetary policy shock at selected horizons (percentage points)
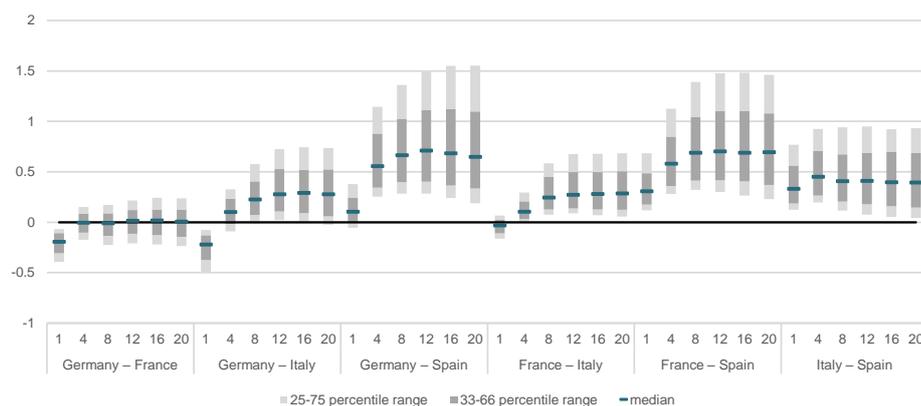
Source: Authors' calculations, based on Mandler et al. (2022).
Notes. Posterior distribution of differences in impulse responses (first country minus second country) to a +25-bp monetary policy shock. Quarters on the horizontal axis.

Real GDP reacts relatively more strongly to monetary policy in Germany, while activity is affected less in Spain and Italy. Comparing Charts A and B, this ranking is robust to changes in the estimation period, with only the relative position of Italy and Spain changing when the full sample is considered (Italy reacting more than Spain). However, among the existing literature on cross-country heterogeneity, Corsetti et al. (2022) find relatively similar declines in Italian and German

GDP. For prices, estimations up to the pandemic show that the strongest reaction to monetary policy took place in Spain, followed by Italy and then Germany and France, with no clear ranking between the latter.[d] Including more recent data results in a relative shift in the effects of monetary policy on prices: Italy shows the strongest reaction, followed by Germany and Spain, between which there is no clear ranking, while France presents the weakest effects.

Chart B

Cross-country differences in the effects of a monetary policy shock on real activity and consumer prices

1999Q1 – 2024Q1: Real GDP

Differences in impulse response to a monetary policy shock at selected horizons (percentage points)
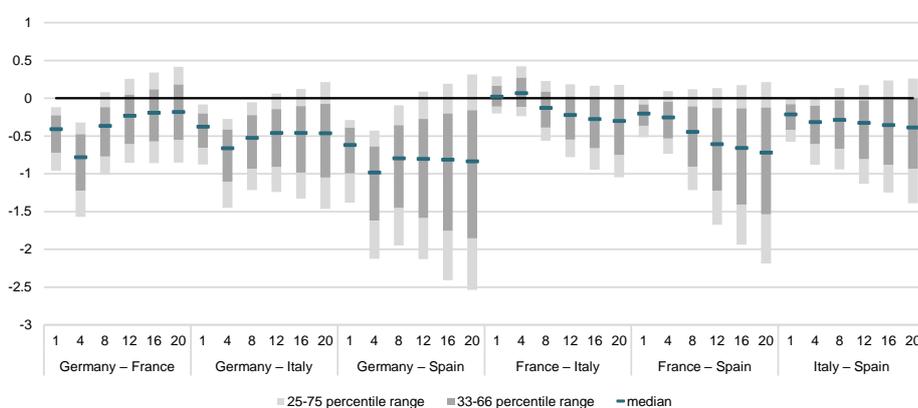
1999Q1 – 2024Q1: HICP

Differences in impulse response to a monetary policy shock at selected horizons (percentage points)
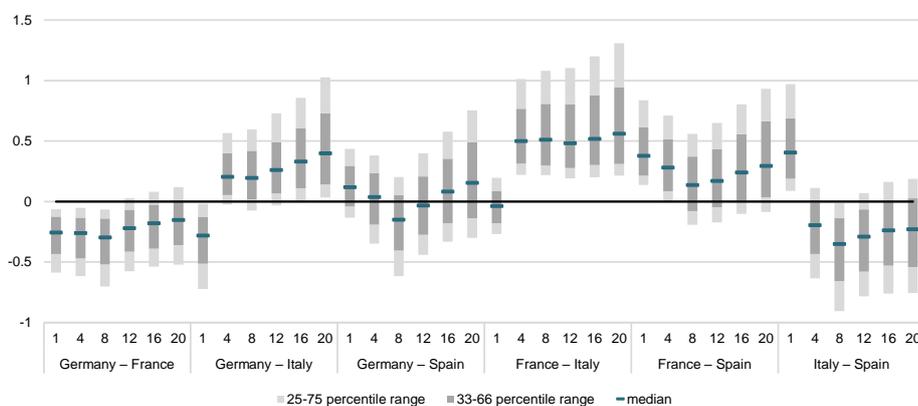
Source: Authors' calculations, based on Mandler et al. (2022).
Notes: Posterior distribution of differences in impulse responses (first country minus second country) to a +25-bp monetary policy shock. Quarters on the horizontal axis.

What explains the differential effects of monetary policy on economic activity across countries? Table A shows signs of correlation coefficients between the estimated peak median impulse response of real GDP and various structural characteristics.[e] The first five characteristics consider the sectoral composition of production: a higher share of more capital-intensive sectors (e.g. industry, manufacturing, construction) is expected to make real GDP more responsive to changes in financial conditions.

Except for the share of construction, the correlation coefficients show that this expectation is indeed consistent with the empirical results. Moreover, the output effect increases with the export share, pointing to the exchange rate channel as a plausible explanation. Stronger employment protection, which makes adjustment of employment and production more difficult, is accompanied by smaller effects of monetary policy, as expected.[f] In addition, a more concentrated banking sector is associated with less effective monetary policy, as the interest rate pass-through may weaken if banks have more market power (e.g. van Leuvensteijn et al., 2013; Brissimis et al., 2014). Monetary transmission also tends to weaken when bank lending becomes a major source of firms' external financing.[g] Finally, the estimated effects of monetary policy increase with household indebtedness, consistent with empirical evidence (e.g. Cloyne et al., 2020).[h]

Table A
Possible drivers of country heterogeneity

Correlation coefficients between countries' structural characteristics and real GDP peak impulse response

indicator	expected sign	estimated sign
industry share	+	+
manufacturing share	+	+
durables manufacturing share	+	+
construction share	+	-
services share	-	-
export share	+	+
export share (non-EU)	+	+
union density	?	-
collective bargaining coverage	?	-
employment protection	-	-
employment protection (temporary contracts)	-	-
banking sector concentration	-	-
share of bank loans in NFC external financing	-	-
ratio of bank loans to NFCs to debt securities issued by NFCs	-	-
mortgage debt/disposable income	?	+

Notes: Correlation with peak median impulse response over 20 quarters. Indicator are averaged from 1999 to end of 2019, or shorter depending on data availability. The sign of the correlation coefficient is reversed, i.e. a positive coefficient indicates that the monetary policy effect becomes stronger when the characteristics increases. Expected sign indicates sign of correlation coefficient based on theory. Further details on the indicators can be found in Mandler et al. (2022).

Box footnotes

[a] This approach allows us to account for the correlation in the estimation error of the impulse responses and yields results even when the impulse responses show considerable overlap. For a discussion and further applications, see Deutsche Bundesbank (2023), p. 44.
[b] The results for estimation up to 2014Q4 are similar to those for estimation up to 2019Q4 and are therefore not shown.
[c] A policy rate hike does not necessarily cause a decline in output and prices beyond the impact period, as the sign restrictions imposed for identification apply only on impact. In later periods after the shock, there is also probability mass above zero in the impulse response distributions. Therefore, a strict interpretation of a negative difference is that output falls more, or rises less, in the first country compared with the second.
[d] Results are not uniform across all impulse response horizons. For estimation up to the pandemic, the price response on impact is stronger in Germany than in France, while the impact effect is weakest in Italy.
[e] The signs of the correlation coefficients are unchanged when using cumulated median impulse responses (20 quarters) instead of the peak. The correlation analysis uses impulse responses from estimating the model up to 2019Q4, as more recent data are not available for some of the structural indicators. The signs of the correlation coefficients are robust when using impulse responses estimated up to 2024Q1 as well, except for the correlation coefficient for mortgage debt relative to disposable income, which drops towards zero.
[f] For union density and coverage of collective bargaining, there is no obvious expected direction of correlation. If unions played a bigger role and this resulted in higher real wage rigidity, this should imply a stronger response in output and employment. However, the effects of collective bargaining have been shown to depend on its degree of centralisation which is not captured by these indicators; see, for example, Calmfors, L. and Driffill, J. (1988).
[g] The evidence is mixed in this regard. For instance, Kho, S. (2023) finds that deposit rates tend to be more rigid in response to policy rate increases but more flexible when policy rates decline, particularly in highly concentrated banking sectors. Meanwhile, Bredl (2024) finds no significant effect of market concentration on the pass-through of monetary policy during the 2022-23 tightening cycle; see also Box 6 in this chapter. Lastly, bank market power weakens

Box 3

Further evidence on cross-country heterogeneity in monetary policy transmission: results from a harmonised exercise

Prepared by Ginters Bušs (Latvijas Banka), André Casalis (Národná banka Slovenska), Nuno Vilarinho Gonçalves (Banco de Portugal), Martin Mandler (Deutsche Bundesbank) and Tomas Reichenbachas (Lietuvos bankas)

This box summarises further evidence on the heterogeneous effects of common euro area monetary policy across countries from a harmonised analysis for Latvia, Lithuania, Portugal and Slovakia. The results for each country are based on a set of Bayesian structural vector autoregressions, each combining the real GDP and HICP of a single country with euro area aggregate data.[a] This approach allows us to compare the impact of a monetary policy shock on real activity and prices in each country with that same impact on the euro area aggregate, which serves as the common reference. The estimation period is 1999Q1 to 2023Q4, except for Latvia, where it starts in 2010Q1 to account for structural changes owing to a strong and prolonged deleveraging process following the great financial crisis.

Chart A below shows, for each country, selected percentiles of the posterior distribution of the difference between its output and price impulse responses to a +25-basis points monetary policy shock and the impulse responses of the euro area aggregate variables 1, 4, 8, 12, 16 and 20 quarters after the shock. A negative difference indicates that output or prices decline more in the country than in the euro area aggregate, while a positive difference indicates that they decline less following an interest rate hike. For Latvia, Lithuania and Slovakia, most of the mass of the probability distribution for the difference in the output effect lies in the negative region, i.e. real activity reacts more stronger in each of the three economies than in the euro area aggregate. For Portugal, there is no clear evidence that output reacts differently from the euro area. The effects of monetary policy on prices are stronger in all four countries than in the euro area, as reflected in the generally negative differences.

Chart A

### Monetary policy impact in selected countries relative to the euro area

Real GDP

Difference in impulse responses to a monetary policy shock at selected horizons (percentage points)

25-75 percentile range 33-66 percentile range — median

HICP

Difference in impulse responses to a monetary policy shock at selected horizons (percentage points)

25-75 percentile range 33-66 percentile range — median
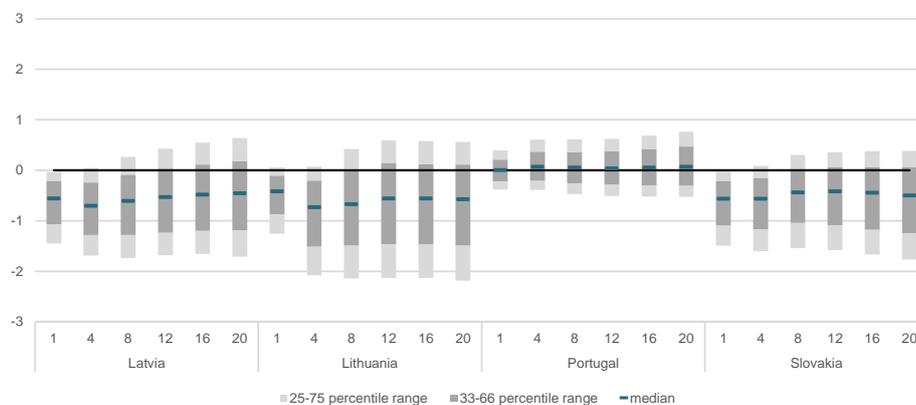
Source: Authors' calculations, based on Mandler et al. (2022).
Notes: Posterior distribution of differences in impulse responses (country minus euro area) to a +25-bp monetary policy shock. Quarters on horizontal axes.

For comparison, Chart B shows the results for the four large euro area economies (Germany, France, Italy and Spain) using the multi-country model in Box 2, but using the euro area as the reference instead of conducting pairwise comparisons between countries.[b] Output is somewhat more affected in Germany than the euro area aggregate, while the response in Italy and Spain is weaker than the euro area average. Monetary policy effects on prices are roughly in line with the euro area average in Germany and Spain but somewhat stronger (weaker) in Italy (France).

Chart B

Monetary policy impact in large countries relative to the euro area

Real GDP

Difference in impulse responses to a monetary policy shock at selected horizons (percentage points)
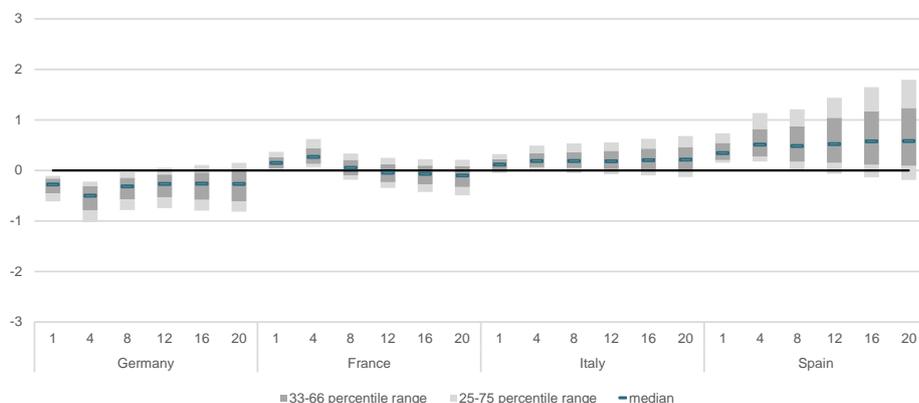
HICP

Difference in impulse responses to a monetary policy shock at selected horizons (percentage points)
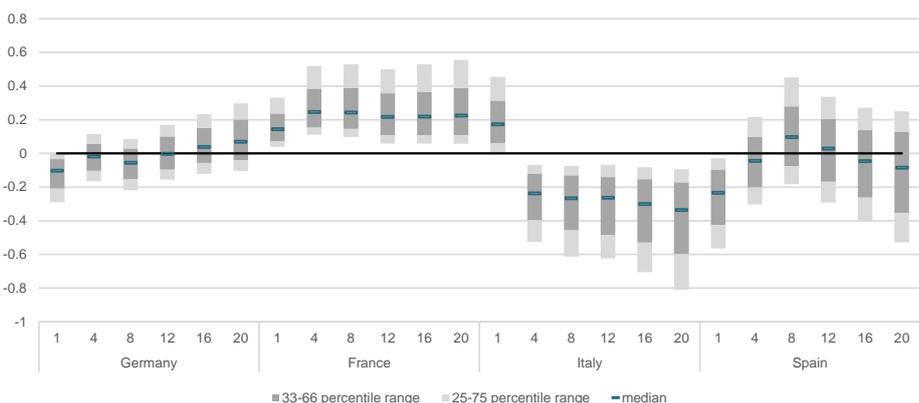
Source: Authors' calculations, based on Mandler et al. (2022).
Notes: Posterior distribution of difference in impulse responses (country minus euro area) to a +25 basis point monetary policy shock. Quarters on the horizontal axis. Euro area aggregate effects approximated as real GDP-weighted averages of country effects.

Possible economic causes of cross-country differences in the sensitivity of economic activity to monetary policy can be identified through a correlation analysis, as shown in Box 1. Table A shows the estimated correlation coefficients between structural characteristics of Latvia, Lithuania, Portugal and Slovakia and the estimated peak median impulse responses, together with the theoretically expected signs of the correlation coefficients.[c] The correlation coefficients on sectoral composition, openness and labour market flexibility are consistent with theoretical expectations.[d]

Table A

Possible drivers of country heterogeneity

Correlation coefficients between countries' structural characteristics and real GDP peak impulse response

indicator	expected sign	estimated sign
industry share	+	+
manufacturing share	+	+
durables manufacturing share	+	0
construction share	+	+
services share	-	-
export share	+	+
export share (non-EU)	+	+
union density	?	-
collective bargaining coverage	?	-
employment protection	-	-
employment protection (temporary contracts)	-	0
banking sector concentration	-	+
mortgage debt/disposable income	?	-

Notes: The countries included are Latvia, Lithuania, Portugal and Slovakia. Peak median impulse response over 20 quarters. Average of indicator from 1999 to end of 2023 or shorter, depending on data availability. Sign of correlation coefficient reversed, i.e. a positive coefficient indicates that the monetary policy effect becomes stronger when characteristics increase. Expected sign indicates sign of correlation coefficient based on theory. "0" indicates a coefficient estimate close to zero.

Box footnotes

[a] Estimation and identification follow the approach in Box 2. However, instead of real GDP and HICP for the four largest euro area economies, each model contains real GDP and HICP for the country under investigation and those of the euro area aggregate.
[b] As euro area real GDP and HICP are not included in this model, the aggregate impulse responses are constructed as the averages of the country-specific impulse responses weighted by real GDP. Results refer to the full-sample estimates.
[c] The signs of the correlation coefficients are unchanged when using cumulative median impulse responses (20 quarters) instead of the peak.
[d] The sign of the correlation coefficient with banking sector concentration depends on the estimation period. Results from estimation up to 2019Q4 point to increased concentration being associated with weaker transmission, while those up to 2023Q4 in the table show the opposite result. This is consistent with an asymmetric impact of concentration on the pass-through of policy rate reductions and hikes, as discussed in OECD (2024), pp. 88-92.

This box provides evidence on the differential impact of euro area monetary policy on the manufacturing, construction and services sectors, based on a multi-sector Bayesian structural vector autoregression. As in Boxes 2 and 3, the comparison is based on the estimated differences between sectoral impulse responses.

Chart A below shows selected percentiles of the posterior probability distributions of sectoral differences between the impulse responses of real gross value added and its deflator to a +25-bp monetary policy shock. Each bar summarises the distribution of the impulse response in the first sector minus the response in the second sector at a selected horizon (1, 4, 8, 12, 16 and 20 quarters). The estimation period is 1999Q1 to 2024Q1.[a] Since prices and activity decline after an interest rate hike, a negative (positive) difference indicates that the first sector reacts more (less) to monetary policy than the second sector. In the panel for real gross value added, the difference between the manufacturing and the services sector is negative on impact, reaches a trough after about one year, and then slowly moves back towards zero. This implies that economic activity declines more in manufacturing than in services in the short run, but that the effects of monetary policy on activity take longer to converge.[b] Initially, there is no evidence of a marked difference between the effects of monetary policy on activity in manufacturing and construction. However, the (positive) difference points to a stronger decline in activity in construction after about two years. The difference between services and construction remains positive throughout, which is indicative of a more negative reaction of activity in construction. Overall, the results suggest that in the short run activity in manufacturing and construction is more sensitive than activity in services to the effects of monetary policy. In the medium term, activity in construction reacts the most to monetary policy, while the effects on manufacturing and services are roughly similar.

The results for the deflator show that monetary policy initially has similar effects on prices in the construction and manufacturing sectors, but that prices in construction fall more sharply thereafter (positive difference). On impact, the difference between manufacturing and services is negative, indicating a stronger price response in manufacturing in the very short run. However, this difference reverts to zero quickly and turns positive after about three to four years, pointing to a stronger effect of monetary policy on prices in services relative to manufacturing at medium to longer horizons. Overall, the results show a stronger sensitivity of prices in manufacturing and construction compared with services in the short run. In the medium to long run, prices respond to monetary policy most strongly in construction, followed by services.

Robustness tests show that the relative short-run sensitivity of prices in the manufacturing sector depends to some extent on identification assumptions.[c] Under less restrictive identification assumptions, the impact response of prices in manufacturing becomes close to that in services and weaker than that in construction.

Chart A

### Sectoral differences in the effects of a monetary policy shock on real activity and prices

Real gross value added

Differences in impulse responses to a monetary policy shock at selected horizons (percentage points)
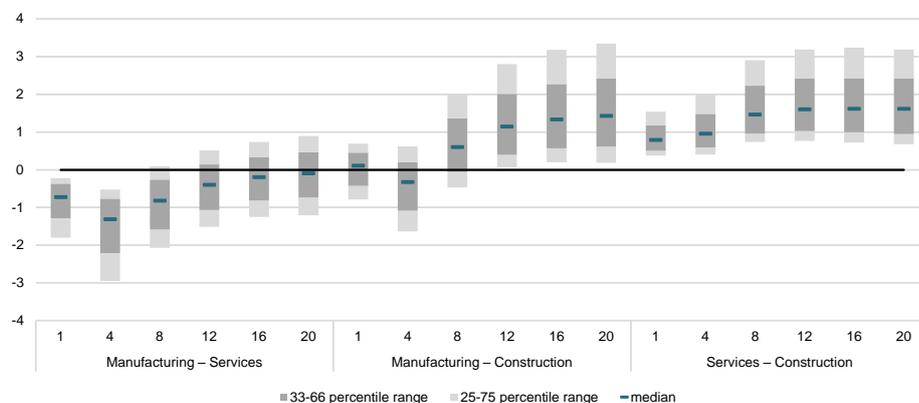
Deflator of real gross value added

Differences in impulse responses to a monetary policy shock at selected horizons (percentage points)
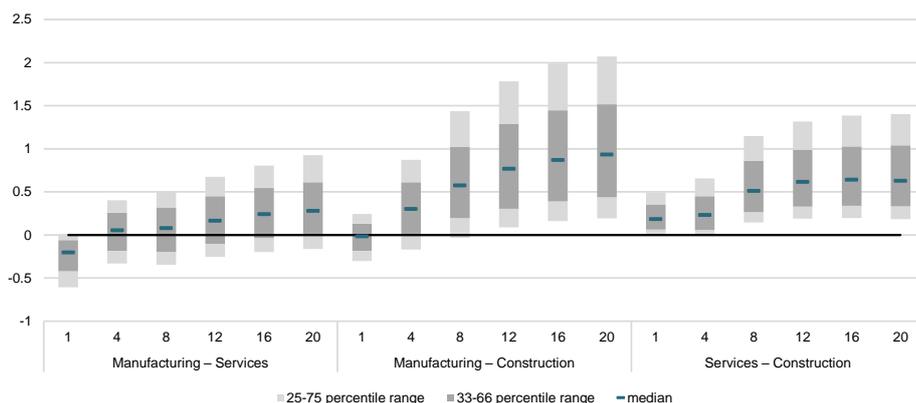
Source: Authors' calculations, based on Mandler et al. (2022).
Notes: Estimations from 1999Q1 to 2024Q1. Posterior distribution of differences in impulse responses (first sector minus second sector) to a +25-bp monetary policy shock. Quarters on the horizontal axis.

Box footnotes

[a] Results are similar for estimation up to 2014Q4 or 2019Q4.
[b] A policy rate hike does not necessarily cause a decline in activity and prices beyond the impact period, as the sign restrictions imposed for identification apply only on impact. In later periods after the shock, there is also probability mass above zero in the impulse response distributions. Therefore, a strict interpretation of a negative difference is that activity falls more, or rises less, in the manufacturing sector than in services.
[c] Monetary policy shocks are identified by sign restrictions on the impulse responses and on the coefficients of the monetary policy reaction function. The baseline model imposes negative responses of prices and activity in all sectors to a restrictive monetary policy impulse. The robustness test imposes less restrictive assumptions and requires only a decline in the cross-sectoral averages (weighted by real gross value added) of output and prices.

Box 5 Price sensitivity to monetary policy shocks in the euro area and the United States

Prepared by Paola Di Casola and Catalina Martínez Hernández (ECB)

Headline inflation in the euro area and in the United States has declined significantly from its 2022 peak. The post-pandemic inflationary shocks triggered historically high, double-digit inflation figures in the euro area Harmonised Index of Consumer Prices (HICP) and in the US Personal Consumption Expenditures (PCE) price index, reaching levels not seen since the 1970s oil crisis.[a] In response, both the European Central Bank (ECB) and the Federal Reserve (Fed) deployed an unprecedented monetary policy tightening process. Among other measures, the ECB raised policy rates by 450 basis points between July 2022 and September 2023, while the Fed increased the Fed funds rate by 525 basis points between March 2022 and July 2023. While headline inflation has dropped considerably in both regions,[b] core inflation, defined as HICP and PCE excluding energy and food, has exhibited persistent dynamics in both parts of the world, particularly within the services component. In contrast, goods inflation has declined more forcefully, showing that past shocks to global supply chains and commodity prices have dissipated and that demand has weakened. This box compares the sensitivity of prices in the core consumption basket to monetary policy shocks in both areas and analyses recent dynamics of core inflation by comparing sensitive with non-sensitive services and goods items.

Core prices in the euro area and the United States are highly sensitive to monetary policy, in the sense that they respond with the expected sign following a monetary policy shock. The effect of monetary policy on the macroeconomy is typically assessed by anaylsing monetary policy shocks.[c] Following this approach, Allayioti et al. (2024) find that 33% of prices in the euro area core consumption basket are sensitive to monetary policy shocks and account for a higher share of goods (44%) than of services (26%).[d] For the United States, Attinasi and Di Casola (2024) find that 50% of the core PCE is sensitive to monetary policy shocks, with sensitive items accounting for a larger share of services inflation (57%) than of goods inflation (34%). It is worth noting that US housing services largely consist of owners' equivalent rents (OER), which are not present in the euro area HICP. The different degree of granularity in both exercises offers valuable insights into the categories most sensitive to monetary policy in both areas.[e]

Chart A below illustrates the relative peak effect of monetary policy shocks on a selection of the most sensitive prices in both regions. In the euro area, there is greater heterogeneity in the mix of goods and services items that are sensitive to monetary policy, while in the United States sensitive items are primarily found in the services sector. Prices of financial services and insurance, which are typically measured using imputed non-market prices, are particularly sensitive to monetary policy in the United States. Services prices related to recreation, accommodation and food are found to be sensitive in both areas. The stronger impact of monetary policy shocks on these categories may be due to their discretionary, leisure-related nature (as noted in Allayioti et al., 2024). In the goods category, car prices are sensitive to monetary policy in both regions, likely reflecting the important role of consumer credit when buying vehicles and the fact that their durable nature makes the purchase easier to put back.

Chart A

Relative peak effect of monetary policy on the most sensitive core prices in the euro area vs the United States

(ratios of peak impulse responses)

a) Euro area

b) US

Monetary policy has been effective in bringing down inflation, although services inflation remains the most persistent component in both regions. Looking at goods, inflation for both sensitive and non-sensitive items appears to have fallen rapidly in both regions. The bulk of inflation continues to be driven by services items. In the euro area, the largest share of recent core inflation dynamics is attributable to non-sensitive services items, such as rents, medical-related services, and certain types of insurance (Chart B, panel a). The opposite holds for the United States (Chart B, panel b), with housing services inflation showing persistence, particularly in the OER component, which accounts for a high share of sensitive core inflation. Key factors behind this persistence are the slow decline in rent inflation, due to limited housing supply, contract regulations limiting rent increases, and a drop in housing transactions and mobility.

Chart B

Dynamics of sensitive core inflation in the euro area and the United States

(percentage points and percentage points contributions)
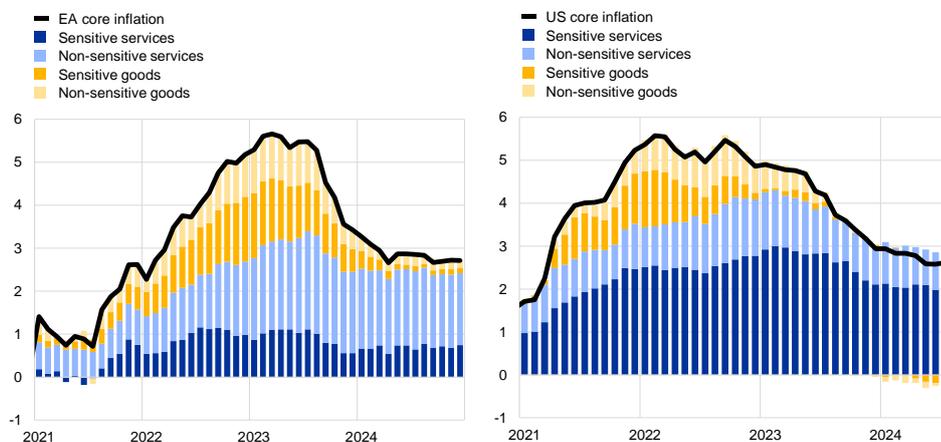
Sources: Eurostat, BLS, and ECB staff calculations.
Notes: Euro area core inflation is constructed as a weighted average of inflation rates categorised as sensitive to monetary policy shocks using HICP weights.
The latest observation for the euro area is October 2024, while for the United States it is July 2024.

Box footnotes

[a] While the US Consumer Price Index (CPI) would be a more appropriate measure of inflation to compare with euro area HICP, our box focuses on US PCE inflation, as this is the "official" measure defined in the Fed's inflation target.
[b] Euro area HICP declined from 10.6% in October 2022 to 2.0% in October 2024, while PCE inflation decreased from 7.2% in June 2022 to 2.1% in September 2024. See also Beschin, A., Bodnár, K., Gómez-Salvador, R., Gonçalves, E., Tirpák, M. and Weißler, M., , *ECB Economic Bulletin Box*, Issue 3/2024.
[c] The total impact of monetary policy on the macroeconomy can be decomposed into (i) a systematic, anticipated component that captures endogenous responses of the interest rate to macroeconomic shocks; and (ii) unexpected deviations from the central bank's policy function (monetary policy shocks). For a discussion, see Christiano, Eichenbaum, and Evans (1999).
[d] For the euro area, see Allayioti, A., Górnicka, L., Holton, S. and Martínez Hernández, C. (2024), and Allayioti, A., Fagandini, B., Górnicka, L. and Martínez Hernández, C. (2025), *Economic Bulletin Box*, Issue 8, 2024. For the United States, see Attinasi, M.G and Di Casola, P. (2024).
[e] Allayioti et al. (2024) focus their analysis on the 72 prices of the euro area HICPX basket following the COICOP-4 item classification, while Attinasi and Di Casola (2024) focus on 14 categories. An additional difference is that the euro area analysis focuses on conventional monetary policy (shocks coming from Jarociński and Karadi, 2020), while the US analysis also encompasses the effects of balance sheet policies (monetary policy shock from Bu, Rogers and Wu, 2021).

Box 6

New micro-level evidence on heterogeneities in the transmission of monetary policy

Prepared by Diana Bonfim (Banco de Portugal), Margherita Bottero (Banca d'Italia), Björn Imbierowicz (Deutsche Bundesbank) and María T. Valderrama (Oesterreichische Nationalbank)

The increasing availability of micro-level data has provided new insights into the differential impact of monetary policy on borrowing, consumption and investment decisions among economic agents. This box builds on earlier findings of the Challenges for Monetary Policy Transmission in a Changing World (ChaMP) research network highlighting the various dimensions of heterogeneity that influence how monetary policy is transmitted to banks, households and non-financial corporations.[a]

While not yet conclusive, the results begin to reveal a multifaceted picture. For instance, in the context of the bank lending channel, the findings highlight that differences in banks' funding composition lead to heterogeneous adjustments to credit supply, as banks respond differently to monetary policy shocks. Banks also adjust their lending decisions differently in response to structural changes. For example, banks are currently reacting to the green transition by taking into account firms' carbon footprint when making credit supply decisions.

In addition, preliminary results suggest that borrowers' characteristics also influence the speed and strength of monetary policy transmission. For households, the impact is stronger as their level of indebtedness increases and depending also on the type of mortgage they hold. For firms, the heterogeneity in their funding mix – such as bank loans, bond financing, or internal funds – affects the transmission of monetary policy. Interestingly, some evidence suggests that firms actively react to monetary policy tightening by shifting their funding towards cheaper sources, potentially diminishing the policy's effectiveness.

Banks

Bank heterogeneity matters for the transmission of monetary policy. Some dimensions of this heterogeneity, such as bank capital and liquidity, are well documented in the literature and have been confirmed by the network's results using more granular data over a longer period. García-Posada and Paz (2024), for example, rely on bank balance sheet and Bank Lending Survey data over a period spanning more than 20 years and show that monetary policy transmission is stronger among poorly capitalised banks (and smaller firms). Altavilla et al. (2024b) find that banks with lower capital and liquidity impose higher external financing premiums on borrowers when monetary policy tightens. Weaker firms are also more affected. Recent research has also underscored the importance of bank liquidity and funding composition in shaping the differential transmission of monetary policy through the bank lending channel. Burlon et al. (2025) exploit a recalibration of the TLTRO to show that a rapid decline in central bank reserves can negatively affect credit supply, due to banks' off-balance-sheet exposures in the euro area. Using the same dataset, Cappelletti et al. (2024) find that large and unexpected increases in monetary policy rates lead to deposit outflows, which in turn reduce credit supply, with stronger effects observed in banks with larger unhedged duration gaps.

Beyond bank-level characteristics, the concentration of the banking system also matters for the transmission. Kho (2025), using data from 13 euro area countries between 2003 and 2022, finds that in more concentrated banking systems, the pass-through of monetary policy tightening to deposit rates is slower. Bredl (2024), however, finds no significant effect of market concentration on the pass-through of monetary policy during the 2022-23 tightening episode. Vilerts et al. (2025) use Anacredit data to document differences in lending practices across all euro area countries. They find that country-level differences in the characteristics of new loans, such as the reference rate and the fixation period, are crucial in explaining transmission heterogeneity. These findings complement those of García-Posada and Paz (2024) and Altavilla et al. (2024b) by showing that loan rates respond differently to monetary policy shocks across euro area countries not only due to bank-specific characteristics, but also as a result of cross-country differences in lending practices. Beyond these heterogeneities, banks also account for structural changes in their lending decisions, which influences monetary policy transmission. Altavilla et al. (2024b), for instance, analyse the role of the green transition in the transmission of monetary policy using loan level data for the euro area between 2018 and 2022. Their findings show that monetary tightening has a less restrictive impact on lending to "green" firms compared with "brown" firms.

Households

The speed and strength of monetary policy transmission to households' financing decisions depends on their exposure to changes in borrowing costs. This exposure is influenced primarily by two factors: home ownership and the type of mortgage held (fixed or variable rate), as shown by Pica (2023), who finds that in euro area countries, a higher share of adjustable-rate mortgages and

greater homeownership amplify the effects of monetary policy on economic activity via lower mortgage interest payments (the cash-flow effect). These results are corroborated by Di Casola and Grothe (2024), who show that countries with higher homeownership and elevated household debt exhibit a stronger consumption response to monetary shocks, largely due to the cash-flow channel. Complementary evidence from Emiris and Koulischer (2023) indicates that a 1 percentage point decline in interest rates increases household debt by 7%, with stronger effects for older households with existing housing wealth. Similarly, Ahn et al. (2024) document that in Norway, a USD 100 rise in interest rate expenses reduces annual consumption by USD 30, with the effect being more pronounced among highly indebted households.

Non-financial corporations

The strength and speed of monetary policy transmission are also influenced by firms' financing choices, which are to some extent shaped by monetary policy. Alder et al. (2024) find that French firms partially offset reduced bank lending following a contractionary policy shock by increasing bond issuance, and vice versa, with conventional policy affecting bank-reliant firms more, while unconventional measures have a greater impact on market-based financing. Chitu et al. (2024) show that monetary policy affects the bond market consistently across euro area and US firms, in contrast to bank loan spreads, which are more sensitive to country- and bank-specific factors (Altavilla et al., 2023). Furthermore, Bottero and Schiaffi (2024) show that cash-rich firms benefit from lower lending costs, indicating that firm liquidity plays a crucial role in how policy shocks are transmitted. The variation in the speed and strength of monetary policy across countries and over time is closely linked to micro-level features of lenders (banks) and borrowers (households and non-financial corporations). The breadth and richness of ongoing ChaMP research will continue to shed light on these previously underexplored dimensions.

Box footnotes

Box 7
Non-linear New Keynesian Phillips Curves and monetary policy in the euro area

Prepared by Alex Grimaud (OeNB)

Troubles with the New Keynesian Phillips Curves

Even in its non-linear form, the standard New Keynesian (NK) DSGE model exhibits near-linear structural relationships between real economic activity and wage and price inflation. These quasi-linear dynamics, as captured by the New Keynesian Phillips Curves (NKPCs), imply a weak and highly constrained structural link between inflation or wages, and quantities such as output and employment. This quasi-linearity limits the models' ability to generate inflation dynamics endogenously, as the Phillips curves exhibit low sensitivity to variations in economic conditions.

Consequently, in estimated models, inflation surges and large or persistent swings in price or wage inflation are predominantly attributed to exogenous supply-side shocks (see Fratto & Uhlig, 2020), which introduce trade-offs between inflation stabilisation and output stabilisation. These shocks drive most of the variability in inflation, as the quasi-linear NKPC framework fails to provide a

sufficiently strong mechanism for amplifying endogenous and self-sustaining interactions between inflation and real economic activity. This highlights a fundamental limitation of standard NK models in capturing the nonlinearities and accelerating behaviours of inflationary processes.

This modelling approach also carries significant policy implications embedded in its assumptions. Specifically, the flat and invariant nature of the New Keynesian Phillips Curves (NKPCs) implies that the primary mechanism (demand channel) through which monetary policy (MP) affects inflation is relatively weak. Under this framework, inflation and supply shocks exhibit quasi-unit root behaviour and disinflation requires a substantial contraction in output, resulting in a large and constant sacrifice ratio.

The implication is that the cost of disinflation, measured by the cumulative output loss required to achieve a sustained reduction in inflation, is both high and invariant across different economic conditions. This suggests that monetary policy (MP) operates with minimal efficiency in stabilising inflation without inducing significant economic costs, thus reducing the likelihood of a soft landing. As a result, DSGE models portray MP as having constrained effectiveness in managing inflationary episodes, particularly when faced with large supply shocks that generate trade-offs.

Modelling "curves" in a New Keynesian setup

Building on the growing evidence of non-linearities in the Phillips curve (Cavallo et al., 2024) and state-dependent price setting (Gautier et al., in progress), Ascari et al. (in progress) propose a nonlinear New Keynesian (NK) model that incorporates endogenous adjustment frequencies for price and wage setting, building on the methodology of Gasteiger & Grimaud (2023). The model maintains the foundational nominal friction structure of the Calvo (1983) framework, but extends it by allowing both the extensive margin (frequency of price and wage adjustments) and the standard intensive margin (magnitude of these adjustments) to respond endogenously to inflation dynamics.

In this model, the intensive margin adheres to the Calvo logic, where firms and unions set their optimal prices and wages under the constraint that they might not be able to in the next period. However, the extensive margin of price and wage inflation is driven by variations in the present value difference between holding and resetting prices or wages, minus the resetting costs. Firms and unions face asymmetric incentives due to their nonlinear profit functions, preferring to be stuck with relative prices or wages that are too high (costly in terms of foregone quantity) rather than too low (more costly in terms of foregone profits per unit)). This approach yields steeper (flatter) Phillips curves, alongside economic boom (bust) or elevated (low) price and wage inflation levels.

To quantify this phenomenon, Ascari et al. (work in progress) employ the Fair and Taylor (1983) nonlinear solution method alongside the Bayesian-augmented inversion filter of Cuba-Borda et al. (2019) to solve and estimate their model using euro area data from 1999 to 2023Q4. Their findings indicate that state-dependency becomes quantitatively significant only during the high-inflation period from 2021Q1 to 2023Q4.

Monetary policy implications

One key implication of this model is the state-dependent, size-dependent and sign-dependent nature of shock effects. The endogenous adjustment of the slopes of the price and wage Phillips curves means that the response and propagation of both demand- and supply-side shocks vary across the business cycle.

Using the example of MP shocks, Chart A illustrates the state-dependent conditional responses of macroeconomic variables to a range of underlying supply shocks, ranging from disinflationary to inflationary scenarios. The impulse response functions (IRFs) show deviations from the baseline dynamics, with darker lines representing higher initial inflation levels and lighter lines indicating lower inflation.

The state-dependent nature of wage and price setting implies that higher inflation levels correspond to greater price and wage flexibility. Consequently, MP shocks trigger a stronger response of price and wage inflation when inflation is elevated. This increased flexibility has a direct mechanical impact, dampening the response of output through general equilibrium effects. Additionally, higher inflation levels lead to larger, but less persistent, real wage losses.

Mechanically, this state-dependence has significant implications for the sacrifice ratio and the efficacy of monetary policy. The sacrifice ratio is a proxy for MP efficiency and is defined here as the sum of output-gap deviations divided by the sum of inflation deviations over 20 quarters. In Chart B1, we calculate the sacrifice ratio generated by MP shocks under various inflation paths given by a range of underlying inflationary to disinflationary supply and demand shocks. The x-axis represents the annualised inflation rate implied by these underlying shocks, showing that higher underlying inflation levels correspond to lower model-generated sacrifice ratios.

This exercise can also be extended to analyse the sacrifice ratio across the business cycle by conditioning monetary policy shocks on the filtered and estimated sequence of shocks driving the euro area (EA) business cycle. Chart B2 depicts the evolution of the sacrifice ratio alongside the EA quarterly inflation rate. Consistent with the model's implications, the sacrifice ratio is low when inflation is high, and vice versa. Notably, the model suggests that in 2022, the sacrifice ratio was nearly 12 times smaller than in 2012, showing that prices and wages are more flexible in periods of elevated inflation, together with a strong anchoring of inflation expectations during the recent tightening episode. For a more detailed analysis of the factors behind the lower sacrifice ratio, see the sub-section in main text describing Chart 8.

Conclusions

State-dependent and genuinely convex New Keynesian NKPCs have significant implications for the conduct of monetary policy. They allow for highly non-linear inflation dynamics, along with size, state and history dependence in the effects and propagation of shocks. This illustrates the challenges of relying on linear models and reasoning when monetary policy operates under dynamics that deviate significantly from the steady state.

The model suggests that monetary policy was effective in taming inflation, and despite high inflation levels, the resulting output losses were minimal. By acting aggressively during periods of high inflation, policymakers were able to speed up disinflation while still achieving a soft landing. However, caution is warranted when drawing definitive conclusions, as the model only allows for the intertemporal substitution channel of monetary policy and does not account for investment dynamics or financial frictions, which are crucial in real-world scenarios.

Chart A

State-dependent responses to a positive monetary policy shock (relative IRFs)

(percentage-point deviation)

1. quarterly inflation in p.p dev.

2. quarterly nominal wage inflation in p.p dev.

3. output in p.p dev.

4. real wage in p.p dev.
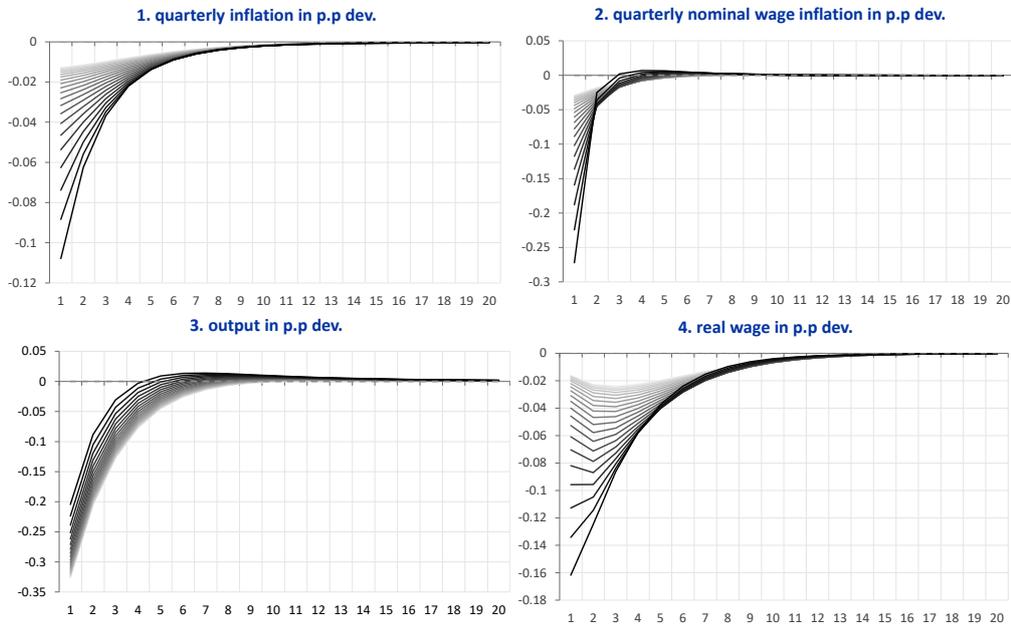
Notes: The shock is a +0.25% AR(1) shock to the quarterly policy rate. Price and nominal wage inflation are expressed in quarterly growth rates. The x-axis represents quarters. The darker lines represent higher initial inflation levels, while lighter lines indicating lower initial inflation.

Chart B

State- and history-dependent nature of the sacrifice ratio

(percentage points)
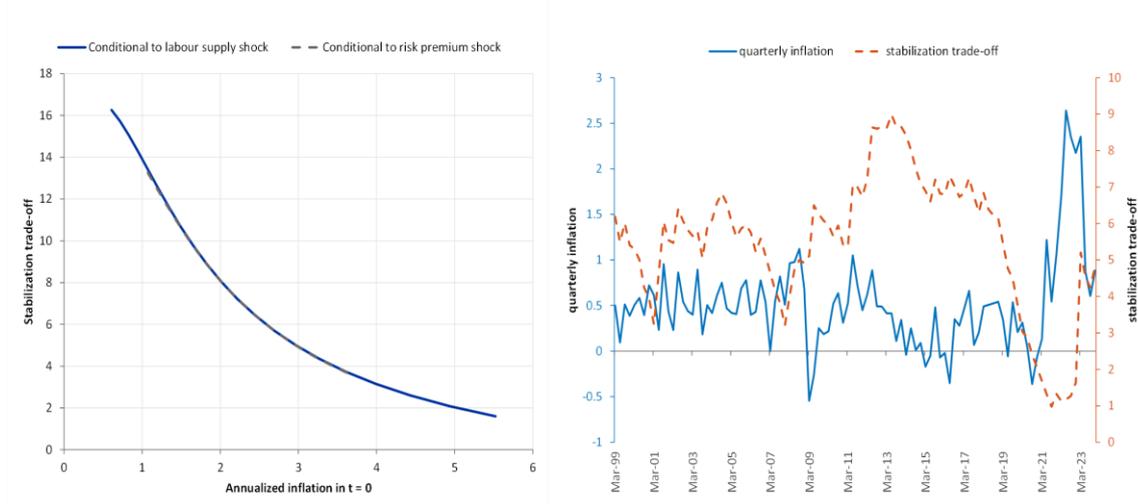
Notes: The sacrifice ratio is computed as the sum of output-gap deviations divided by the sum of inflation deviations over 20 quarters in response to a +0.25% AR(1) MP shock on the quarterly policy rate. Price and nominal wage inflation are expressed in quarterly growth rates. The x-axis represents quarters in Chart B2.

Box 8

The non-linear impact of monetary policy on inflation expectations. Empirical benchmarks from high-frequency event studies

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This box assesses the extent to which ECB and Fed monetary policy transmits to inflation expectations non-linearly. We do so by studying the high-frequency reaction of inflation-linked swap prices to monetary policy announcements, while testing for non-linear effects. Since event studies lend themselves to highly parsimonious specifications, our results provide a useful cross-check on macroeconometric and semi-structural approaches. We assess three forms of non-linear transmission: (i) time-varying parameters, (ii) asymmetry in sign, (iii) state-dependence. Our analysis includes data from the COVID-19 period, with study samples running until late 2023.[a]

Chart A

Rolling estimates of the effect of high-frequency surprises on inflation-linked swaps (1Y)

(percentage point reaction to Jarociński and Karadi (2020) monetary policy surprises. Surprises scaled to raise two-year yields by 1bp)
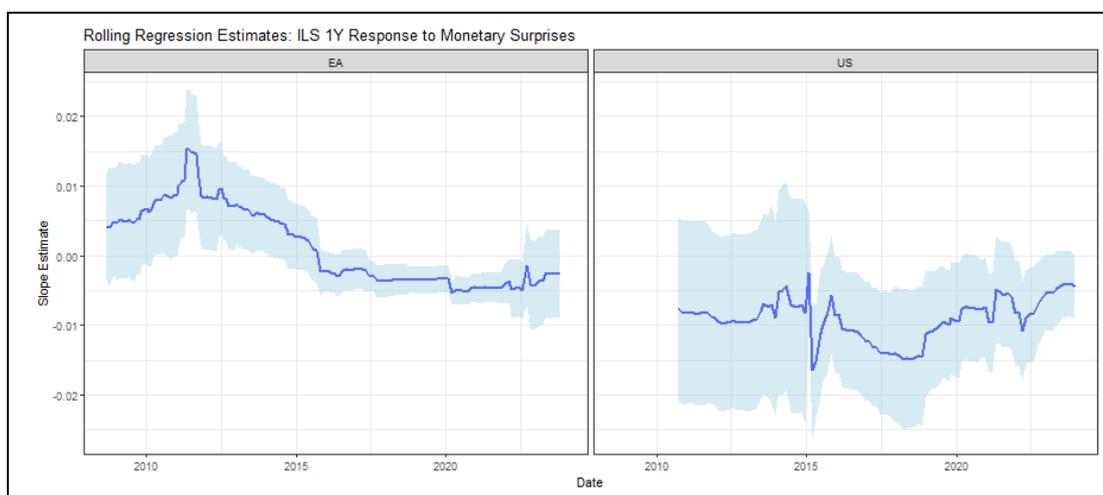
Notes: Confidence bands displayed at 95%. The window size is 50 observations. The estimation period is 2004M8-2023M12.

In Chart A, we display rolling window estimates from regressions of the one-year ILS contract price (percentage point daily difference) on intraday shock measures (Jarociński and Karadi, 2021). The surprises are scaled to raise two-year rates by one basis point.[b] We observe puzzling (positive) estimates for the first portion of the euro area sample, which later turn negative. Rolling coefficient estimates remain negative for the initial period following the COVID-19 shock, before becoming statistically imprecise. For the United States, estimated reactions are typically negative, and larger in absolute magnitude. The puzzling responses to ECB surprises during the financial and European sovereign debt crisis have been noted in other studies (see Altavilla et al., 2019).[c] For this reason, we restrict the euro area sample to the post-2014 period henceforth.

In Table A, we present results from specifications that permit asymmetric transmission of positive and negative monetary policy surprises to ILS contracts.[d] We find evidence that contractionary surprises have weaker effects on inflation than expansionary surprises in the euro area over the 2014-2019 sample. In results available upon request, we find that the statistical significance of this result can be affected by the inclusion/exclusion of announcements relating to asset purchases in 2015. This suggests that the estimate could be capturing the effectiveness of asset purchases in

raising inflation expectations during this time period. The inclusion of the COVID-19 sample period reduces the statistical significance of our estimates throughout. One explanation for this is that the high volatility of supply shocks during the recovery period made the effects of monetary policy more difficult to discern empirically. For the United States, our estimates point to symmetric transmission of policy surprises to inflation expectations.

Table A

Estimating asymmetric responses of ILS contracts to high-frequency surprises

(ILS swaps expressed in percentage point differences; Jarociński and Karadi (2021) surprises scaled to raise two-year yields by 1 bp)

	Euro area (2014M1-2019M12 sample)			United States (2004M8-2019M12 sample)		
	ILS 1	ILS 2	ILS 5Y5Y	ILS 1	ILS 2	ILS 5Y5Y
$MPOL$	-0.010***	-0.008***	-0.005	-0.006	-0.011***	0.002
$Dum\{MPOL \geq 0\}$	0.004	0.005	0.002	-0.023	0.021	0.001
$Dum\{MPOL \geq 0\} \times MPOL$	0.008**	0.006*	0.002	-0.002	-0.006	-0.007

	Euro area (2014M1-2023M10 sample)			United States (2004M8-2023M12 sample)		
	ILS 1	ILS 2	ILS 5Y5Y	ILS 1	ILS 2	ILS 5Y5Y
$MPOL$	-0.009	-0.008	-0.003	-0.004	-0.007**	0.003
$Dum\{MPOL \geq 0\}$	0.017	0.010	-0.003	-0.025	0.009	-0.005
$Dum\{MPOL \geq 0\} \times MPOL$	0.006	0.005	0.002	-0.001	-0.003	-0.005

Notes: Constant term included, estimates not displayed. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$.

Chart B

State-dependent responses of ILS contracts to high-frequency surprises

(ILS swaps expressed in percentage point differences, Jarociński and Karadi (2021) surprises scaled to raise two-year yields by 1 bp)
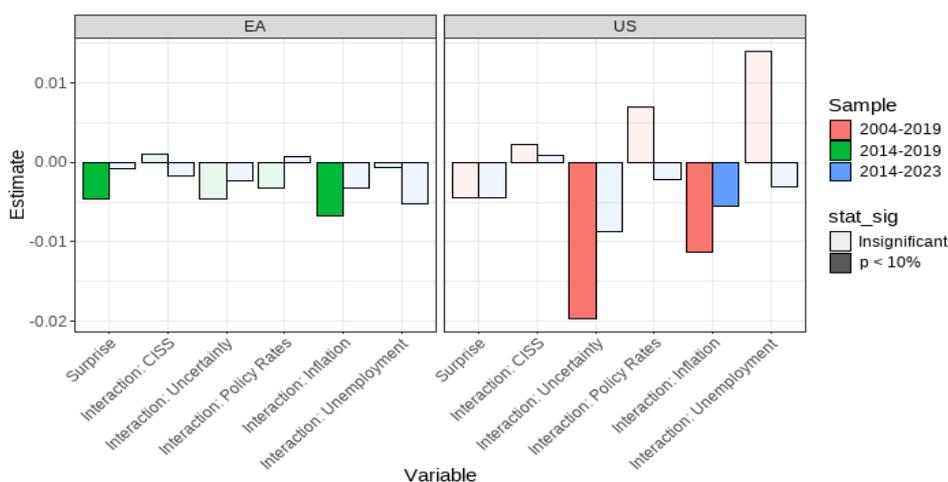
Notes: The figure shows coefficient estimates from event study specifications, which include multiple interaction effects in (lagged) state-dependent variables. Th estimation period is 2014M1-2023M10 for EA and 2004M8-2023M12 for US.

Lastly, we study state-dependent transmission. We interact our surprise measures with a number of (lagged) financial and macroeconomic variables, reporting our estimates in Chart B. We find evidence of state-dependent transmission in the euro area only for the 2014-2019 period. Again, the inclusion of COVID-19 data reduces the statistical significance of the results markedly. With respect

to pre-COVID 19 data, we conclude that there is some evidence for state-dependent transmission in inflation, with stronger pass-through when inflation is high. For the United States, we also find that high inflation increases transmission to market inflation expectations, suggesting that this result is not unique to the euro area. Our findings also point to a potentially large role for uncertainty.

Box footnotes

[a] The euro area sample ends in October 2023, while the US sample ends in December 2023.
[b] To perform this rescaling, we use data from the EA-MPD of Altavilla et al. (2019) and the dataset of Bauer and Swanson (2023). Daily data on ILS swaps are sourced from Bloomberg.
[c] One possible explanation is that information effects persist for this period of the sample, despite the restriction applied when constructing the Jarociński and Karadi (2021) surprise. Another possible explanation is that "save the euro" effects play a role, with expansionary surprises leading to exchange rate appreciation, thus reducing inflation expectations.
[d] Altavilla et al. (2019) find limited evidence for asymmetric transmission to asset prices in their sample period, although they do not report estimates for inflation-linked swaps.

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4. Alice's evidence: concluding remarks

This occasional paper has documented how monetary policy shapes macroeconomic outcomes via several channels, factors and conditions.

Existing models routinely used for policy analysis within the ESCB typically fall within two broad categories: structural and semi-structural. Structural models provide deep theoretical understanding, while semi-structural models prioritise flexibility and alignment with empirical data to ensure timely responses to emerging economic challenges. Both types are essential for the ESCB's policy work. Together, they help guide medium-run projections and inform decision-making.

The second chapter explores the sources of heterogeneity across several ESCB structural and semi-structural macroeconomic models in terms of the transmission of monetary policy. The results show heterogeneous effects across models, which can be rationalised by looking at several features and channels. Structural and semi-structural ESCB models provide consistent and relatively homogeneous responses of output and prices to monetary policy shocks. Model heterogeneity decreases when standardising key assumptions, including the monetary policy rule, Phillips curve slope, and expectations formation mechanisms.

The third chapter reviews the extensive literature on the empirical effects of monetary policy and benchmarks the ESCB models against it. ESCB model results are broadly consistent with the empirical findings of the last 30 years. This robustness persists across different models and meta-analyses, despite variations in policy rule estimation and expectations formation in existing empirical studies. The results using DSGE models are at the far end of the spectrum in terms of effects, while semi-structural models are more closely aligned with empirical (typically VAR-based) analyses.

The final chapter focuses on heterogeneity, non-linearity, and state dependency in the transmission of monetary policy. We find evidence of heterogeneity across countries, sectors and domestic demand components, which can be explained by various structural characteristics of the economy, including sectoral composition (importance of manufacturing or industry), labour market flexibility, export share, competition in the banking sector, and the importance of bank lending in firms' external financing. The findings also highlight the important role played by non-linearity and state dependency in the transmission process. During periods of high inflation, larger endogenous price and wage flexibility amplifies the response of wage and price inflation while concurrently dampening the response of output through general equilibrium effects, leading to a lower sacrifice ratio. The underlying shock driving the monetary policy reaction also matters, as central banks have reacted more resolutely over time to oil supply shocks, indicating a limited inclination to "look through" such matters in the recent tightening episode.

The results reviewed, reported and discussed in this paper provide a useful reference for understanding the impacts of standard monetary policy shocks on key

macroeconomic variables (mainly output and consumer prices), through several transmission channels. While some of these findings have helped support specific analyses of the ECB's 2025 monetary policy strategy assessment, the general results on the impact of monetary policy viewed through the lens of ESCB official models and available literature offer unique insights into the effectiveness and transmission of monetary policy in the euro area. Moreover, these findings based on average impulse response functions of several models and the empirical literature can be reliably used to inform the judgement and complement the model-based analysis undertaken by monetary policy institutions. Judgement based on these "satellite" empirical models can be effective as long as these models are well specified, align with (unconditional) empirical evidence and, thus, capture all the relevant transmission channels, which are typically included in standard projection models. Otherwise, missing channels in the satellite models could induce an over-estimation of the contribution made by the feature they are designed to highlight.

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