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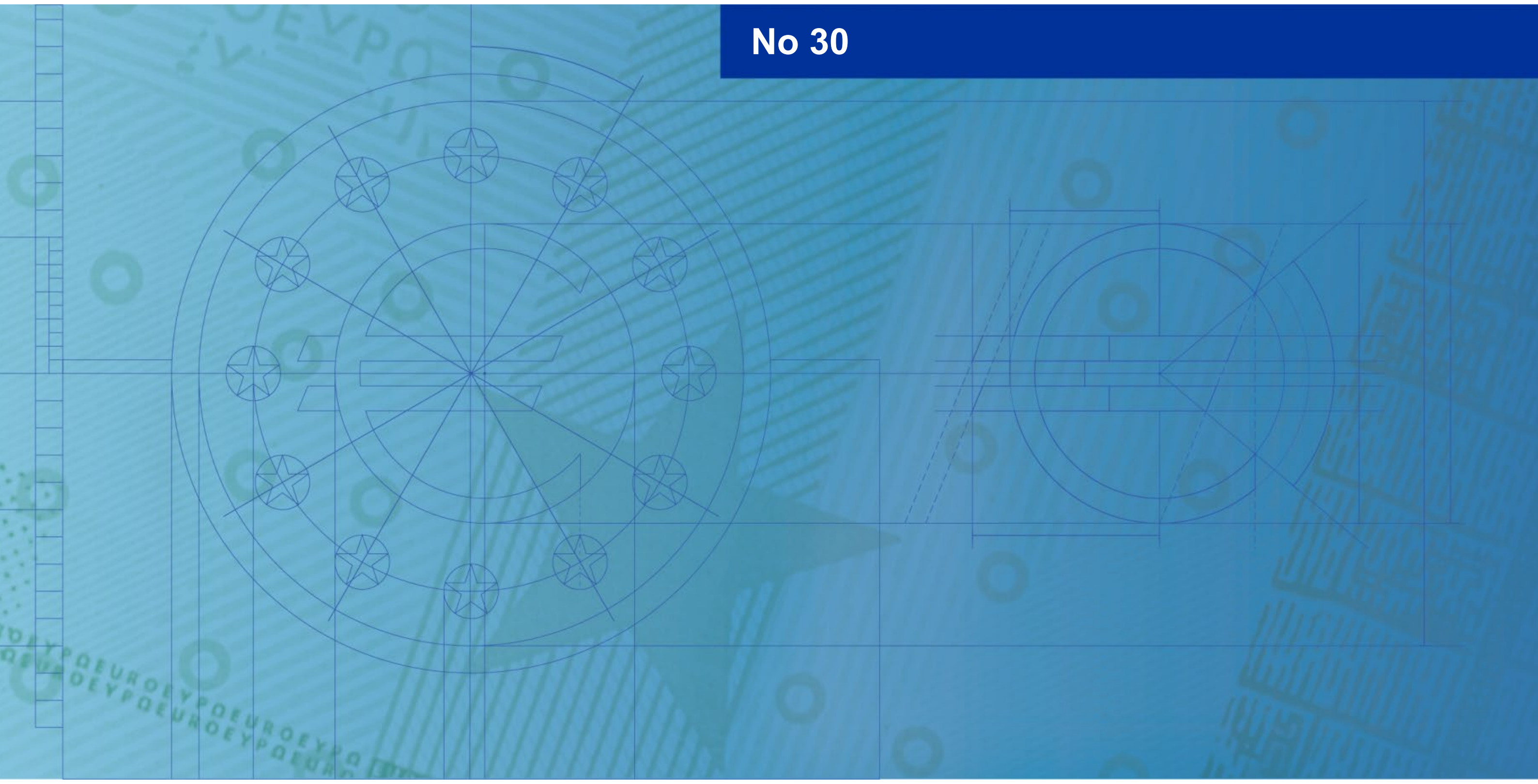
Financial stability considerations for monetary policy at the European Central Bank: conceptual framework and quantitative tools

No 30



Discussion papers

Abstract

The paper documents models used to analyse the interactions and trade-offs between price and financial stability at the European Central Bank. The paper describes a simple conceptual framework to think about the short- and medium-term trade-offs between price and financial stability. Short-term trade-offs arise whenever current inflationary pressure is high, but the financial system is experiencing stress. Medium-term trade-offs arise whenever current inflationary pressure is low, but risk is building up in the financial system. We document four main sets of models used to quantify trade-offs: time series models, balance sheet models, credit risk models and DSGE models with banking and financial frictions.

Keywords: Monetary policy, Financial Stability, Trade-offs

JEL Codes: E44, G28

Non-technical summary

Monetary policy and financial stability are connected: a stable financial system is essential for the effective transmission of monetary policy and the achievement of price stability, while monetary policy itself influences funding costs, leverage decisions, and risk-taking within the financial sector. Although macroprudential tools—strengthened significantly since the Global Financial Crisis through measures like Basel III, enhanced supervision, liquidity requirements, and the creation of the Single Supervisory Mechanism—helped to build the resilience of the financial sector and act as the primary defence against financial imbalances, monetary policy may still need to consider its side effects on financial stability, especially when risks spill over to non-bank intermediaries or arise from exuberant behaviour by households and investors.

Institutional mechanisms to account for theses interactions and the complementarities between monetary policy and macroprudential policies are essential. Reflecting this need, the ECB's 2021 Monetary Policy Strategy Review explicitly integrated financial stability considerations into the policy framework, emphasising the interdependence between economic analysis and monetary-financial analysis. Following the review, the ECB introduced an in-depth assessment of the interaction between monetary policy and financial stability conducted as part of the monetary and financial analysis at regular intervals and considered at the monetary policy meetings of the Governing Council.

This paper describes a set of quantitative tools for assessments of the interaction between monetary policy and financial stability. It documents four sets of models to quantify trade-offs: time series models, balance sheet models, credit risk models and DSGE models with banking and financial frictions. While this paper presents key models currently in use, efforts are made on an ongoing basis to expand the toolkit for the analysis of these trade-offs.

1. Introduction

Monetary policy and financial stability are interrelated. Financial stability is a precondition for the smooth functioning of the monetary transmission mechanism and is therefore a precondition for price stability. In turn, monetary policy determines the cost of funding of banks and their borrowers and is an important element in the choice of leverage and asset-side risk-taking. Therefore, monetary policy may occasionally end up playing a role both in managing episodes of financial stress and in restraining the growth of financial imbalances.

Microprudential and macroprudential policies are the first line of defence against the build-up of financial stability risks. Since the Global Financial Crisis (GFC), the way banks are supervised and regulated has improved significantly, boosting financial system resilience. The Basel III accord has increased the size and quality of banks' equity buffers and introduced new liquidity requirements that limit banks' maturity transformation and mandate them to hold sufficient liquid assets. Bank resolution is now easier due to new 'bail-in' requirements. Bank supervision has strengthened with the creation of the Single Supervisory Mechanism (SSM). Finally, macroprudential authorities have been created and tasked with identifying financial imbalances and building up resilience to avoid them threatening the health of the financial system. Their macroprudential instruments aim at ensuring resilience in the banking sector: while macroprudential capital buffers contribute to sufficient loss absorption capacity in the banking system and to cushioning financial cycle down-turns, borrower-based measures strengthen the resilience of households and can be used to tame the upswing of the financial cycle.

Together, all these capital and liquidity policies should help to restrain imbalances in the financial system through several channels, ensuring the provision of key financial services to the economy. Lower bank leverage and liquidity risk reduces the incentives for excessive risk taking by forcing banks to bear the cost of poor lending decisions. Stronger supervision helps to identify risky behaviours early and macroprudential authorities aim at ensuring the build-up of sufficient resilience, including early in the financial cycle. If these policies can effectively address issues of financial instability and systemic risk, then monetary policy is largely free to focus on price stability without being confronted with potential trade-offs between price and financial stability.

However, there may still be situations in which monetary policy needs to consider the side effects it creates for financial stability. Given existing limitations of macroprudential policy, these situations may arise from several sources such as, for example, the spillovers of lending to the non-bank financial intermediary (NBFI) sector as well as from 'irrational exuberance' by households and investment funds. And even if trade-offs between price and financial stability do not arise (as is normally the case), the interactions between monetary policy and macroprudential policy tools imply that it is vital that official mechanisms exist whereby staff from relevant central bank business areas talk to one another and share analyses of the interactions between monetary policy and financial stability. This is why the ECB examined the interaction of price and financial stability in its 2021 Monetary Strategy Review (MPSR), culminating in the following part of the Governing Council's concluding statement:

"**The Governing Council bases its monetary policy decisions, including the evaluation of the proportionality of its decisions and potential side effects, on an integrated assessment of all relevant factors.** This assessment builds on two interdependent analyses: the economic analysis and the monetary and financial analysis. Within this framework, the economic analysis focuses on real and nominal economic developments, whereas the monetary and financial analysis examines monetary and financial indicators, with a focus on the operation of the monetary transmission mechanism and the possible risks to medium-term price stability from financial imbalances and monetary factors. The pervasive role of macro-financial linkages in economic, monetary and financial developments requires that the interdependencies across the two analyses are fully incorporated. This framework reflects the changes that the ECB's economic analysis and monetary analysis have undergone since 2003, the importance of monitoring the transmission mechanism in calibrating monetary policy instruments and the recognition that financial stability is a precondition for price stability."

This paper documents quantitative tools to support an in-depth assessment on the interaction between monetary policy and financial stability. Section 2 begins with a stylized conceptual framework to explain the short- and medium-term trade-offs between price and financial stability. It then introduces some simple ways to measure the trade-offs and documents how measured trade-offs have evolved over the past years. Section 3 introduces quantitative tools, divided into time-series models (Section 3.1), balance sheet models (Section 3.2), micro-econometric models (Section 3.3) and DSGE models (Section 3.4). Section 4 provides some brief conclusions.

2. Trade-offs between price and financial stability: conceptual framework and measurement

Trade-offs between financial stability and monetary policy arise whenever the stance of monetary policy which is appropriate for achieving the inflation target in the medium term contributes to growing financial stability risks. One type of trade-off ('a short-term trade off') can arise whenever a cost push shock increases inflation in a persistent manner while depressing output and asset prices and triggering stress in the financial system. Then the appropriate tightening of monetary policy to safeguard against a de-anchoring of inflation expectations may conflict with a desire to avoid increasing the short-term pressure on bank and non-bank financial intermediary (NBFI) balance sheets and funding liquidity. We can represent the short-term trade off with the help of the stylized 'quadrant' diagram below.

Figure 1: Stylized representation of the short-term trade-off between price and financial stability

The x-axis indicates the level of **financial stress** while the y-axis indicates where **inflation** is relative to target. Points above the x-axis indicate that monetary policy should be tightened (all else equal) to bring inflation back to target. Points to the right of the y-axis call for looser monetary policy due to financial stress. The economy would mostly inhabit the points to the left of the y-axis (indicated in green). Financial stress is low most of the time and monetary policy can counter normal business cycle fluctuations in inflation in a standard manner.

Trade-offs occur in the north-east quadrant of the figure which is indicated in red. There the monetary authority needs to consider how its tighter monetary policy stance to bring inflation back to target may exacerbate the stress in the financial system. The south-east quadrant, in contrast, is a situation in which inflation control and financial stability considerations both call for looser monetary policy. This is a recession or even a financial crisis situation like the GFC. It is far from a benign scenario, and it is only indicated in green because it represents no trade-offs for price and financial stability.

The most popular indicator of systemic stress at the ECB is the Composite Indicator of Systemic Stress (CISS) as introduced and described in Chavleishvili and Kremer (2025). More specifically, we use the revised daily version of the CISS which includes 15 individual market-based financial stress indicators that cover the main segments of a typical modern financial system: financial intermediaries, money markets, equity markets, bond markets, and foreign exchange markets. The 15 indicators are aggregated into a single statistic in a way that takes their time-varying cross-correlations into account. As a result, the CISS takes higher values when stress prevails in most market segments. This captures the idea that financial stress is more systemic, and more dangerous for the economy, whenever financial instability spreads widely across different parts of the financial system. The CISS for the euro area (as well as that for the U.S. and other countries) is updated daily and publicly available via the ECB's Statistical Data Warehouse.

Figure 2 shows how the short-term trade-offs between price and financial stability have evolved over the recent past. We can see clearly the way the inflation surge in the early 2020s brought about a short-lived period of elevated inflation and elevated CISS. In contrast, by 2025 Q1, the economy was back in the 'no trade-off' region where inflation was close to target and the CISS was at normal (i.e. low) levels. This is indicated by the green diamond in the chart. The red diamonds in the chart also indicate how the economy was forecast to evolve in the year following Q1 2025.[2] Again, no trade-offs were anticipated with inflation remaining close to target and the CISS staying low.

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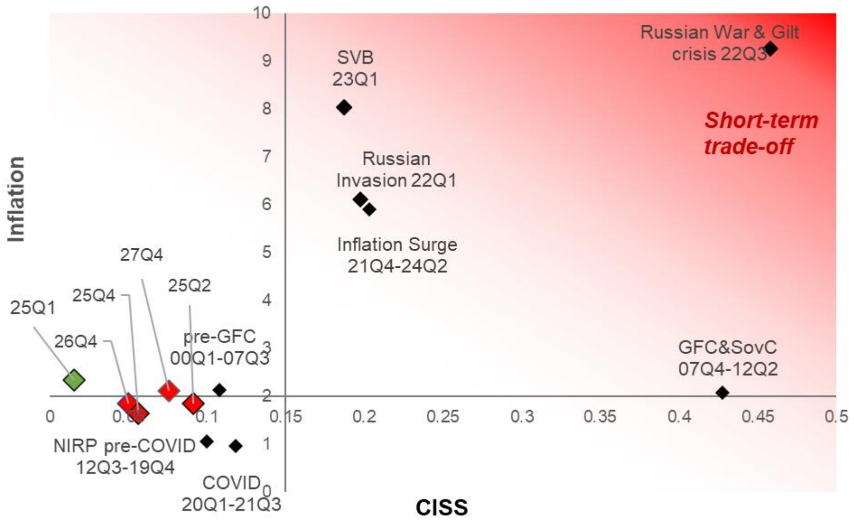
[2] Based on Q1 2025 ECB Staff Projections for Inflation and the CISS.

Figure 2: Short term trade-offs between price and financial stability in the euro area data



Another type of trade off ('a medium-term trade-off') can arise whenever inflation is persistently depressed, requiring looser monetary policy to bring it back to target while the financial system is leveraging up and engaging in risk-taking, increasing the danger of a financial crisis in the medium term. We can represent the medium-term trade-offs by means of the stylized quadrant diagram shown in Figure 3 below. The y-axis again represents inflation's deviation from its medium-term target: points to the north (south) of the x-axis therefore require tighter (looser) monetary policy (all else equal) to achieve the price stability objective in the medium term. The x-axis now represents the extent of financial imbalances which indicate a medium-term vulnerability to a financial crisis. While macroprudential policy is always the first line of defence against building imbalances, points to the right of the x-axis may represent also situations in which monetary policy may be tightened to cool off the exuberance in the financial system. The south-east quadrant in Figure 3 is the especially problematic one hence it is shown in red. It indicates a situation in which inflation is below target, requiring looser monetary policy (all else equal) while financial imbalances are building up and are accentuated by the looser monetary policy (all else equal).[3]

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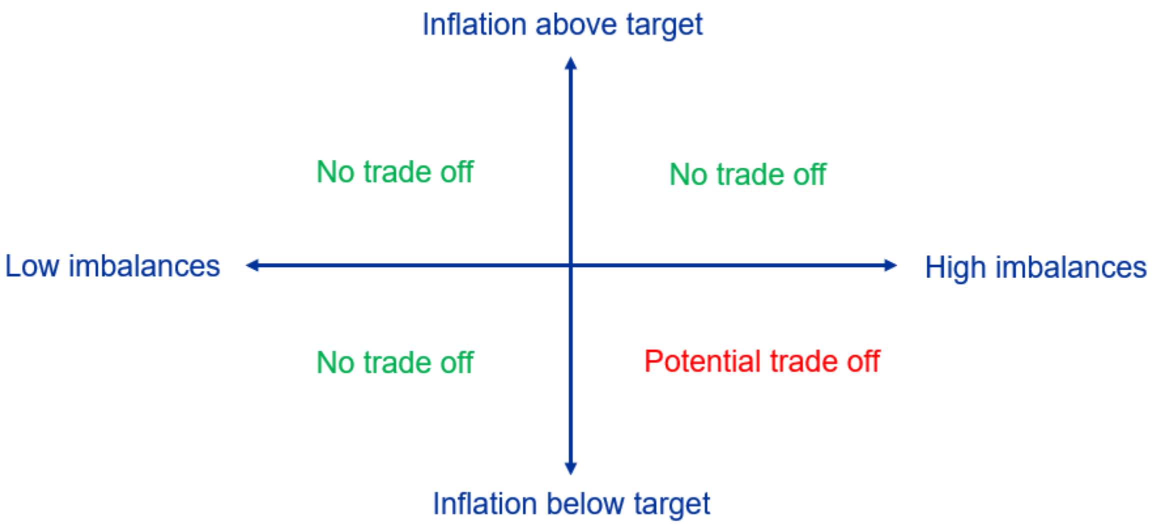
[3] Another type of trade-off may occur in the late stages of the financially driven business cycle when inflation may be high and the financial system may be in a fragile state while actual financial stress (as measured by the CISS) remains low. Then tighter monetary policy may 'prick the bubble' precipitating a financial crisis. Then also points in the north-east quadrant of Figure 3 may give rise to trade-offs between monetary policy and financial stability. This trade-off would clearly call for timely macroprudential measures that allow banks to raise capital while the economy and financial markets remain buoyant.

Figure 3: Stylized representation of the medium-term trade-off between price and financial stability

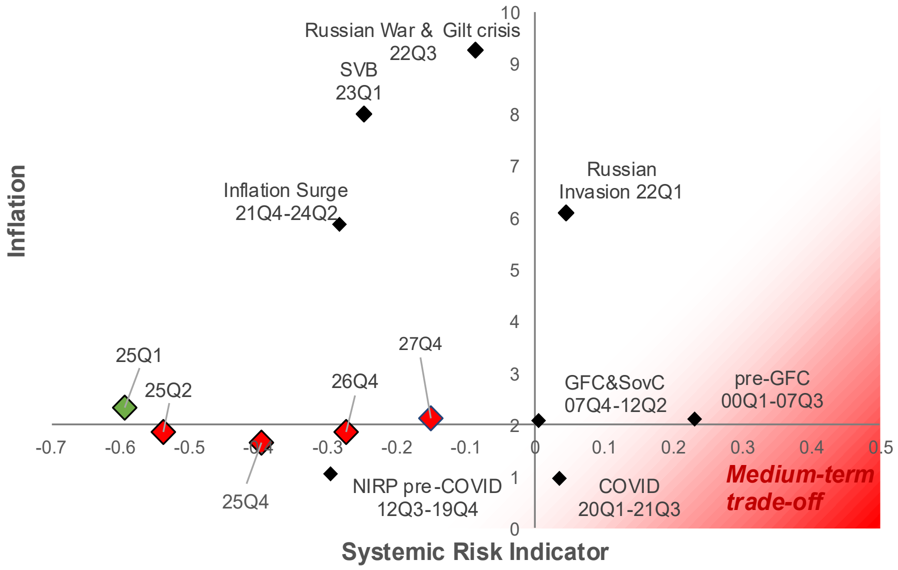


A key measure of financial imbalances is the Systemic Risk Indicator (SRI). This is a composite measure of the financial cycle developed by Lang et al. (2019) to inform macroprudential policy analysis at the ECB. The SRI captures the build-up of medium-term financial stability vulnerabilities related to credit, debt service, real estate markets, asset prices, and external imbalances. Econometric analysis in Lang et al. (2019) shows that the SRI's early warning properties for past financial crises in euro area countries are superior to those of the credit-to-GDP gap, which is a key indicator within the Basel III Countercyclical Capital Buffer (CCyB) framework. Moreover, Lang, Rusnák, Greiwe (2025) show that the SRI contains valuable information about future downside risks to real GDP growth, especially for medium-term horizons of two to three years ahead.

The SRI is constructed as a weighted average of six early warning indicators, where the indicator weights are chosen to maximise the early warning properties of the composite SRI for systemic financial crises. The six sub-indicators are: (i) the two-year change in the bank credit-to-GDP ratio (36% weight); (ii) the two-year growth rate of real total credit (5% weight); (iii) the two-year change in the debt service ratio of the non-financial private sector (5% weight); (iv) the three-year change in the residential real estate price-to-income ratio (17% weight); (v) the three-year growth rate of real equity prices (17% weight); and (vi) the current account-to-GDP ratio (20% weight). The early warning indicators underlying the SRI are normalised to the same scale by subtracting the median and dividing by the standard deviation of the pooled indicator distribution across countries and time. An SRI value of +1 can be interpreted as all sub-indicators being one standard deviation above their median value from the pooled historical indicator distribution.

Figure 4 below shows how the trade-offs between price and financial stability have looked over recent years. Before the Global Financial Crisis (GFC), the economy was in the risky quadrant with an elevated value for the SRI even while inflation remained on average around the target. During the COVID period, the economy also entered the risky quadrant as the SRI reached above average levels (and was rising rapidly) while inflation was persistently above target. The black diamonds at the top of Figure 3 demonstrate the way tighter monetary policy during the inflation surge led to the rapid fall in measured financial imbalances. As credit growth declined sharply in the 2022-2024 period, the SRI fell to deeply negative territory in 2025 Q1 (the green diamond in the chart). Over the coming quarters, the SRI is forecast to gradually rise towards its sample mean while inflation remains broadly on target.[4] The Figure indicates that the COVID period may have been one of medium-term trade-offs between price and financial stability, but the current period does not feature a trade-off.

Figure 4: Medium-term trade-offs between price and financial stability in the euro area data



The above simple quadrant representations reveal several important aspects of the short- and medium-term trade-offs between price and financial stability. Figure 2 shows that short-term trade-offs come and go fast when the financial system is strong. As a result, the recent sharp rise in the CISS during the monetary tightening in 2022-23 did not constrain monetary policy from bringing inflation back to target. When it becomes clear that banks can easily absorb the likely losses in their ample capital buffers, markets calm down and the CISS falls back down to normal levels. In contrast, Figure 4 reveals that medium-term trade-offs evolve more slowly and more predictably giving macroprudential authorities time to react and strengthen resilience.

The above described conceptual framework for trade-offs is focusing on the measurable cyclical dimension of financial stability as for example the systemic risk indicator (SRI) is a good measure of the financial cycle. More generally, one could argue that there is a trade-off between monetary policy and financial stability whenever systemic vulnerabilities exist in the financial system and the optimal monetary policy reaction to maintain price stability would further stress the system. The latter could happen if e.g. monetary policy is tightened very swiftly or when it remains very accommodative over a long period. If negative effects of monetary policy would be expected in the presence of vulnerabilities, the existence of a trade-off purely depends on the resilience of the financial sector. If it is resilient enough due to effective micro- and macrosupervisory measures in place, the trade-off can be neglected by monetary policy decision makers, and no conflict between price and financial

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[4] Based on Q1 2025 ECB Staff Projections for Inflation and the SRI.

stability exists. [5] Therefore it is important for monetary policy discussion to be aware of the effective resilience of the financial sector at each point in time.

The nature of the trade-offs also determines the types of quantitative tools useful for analysing them. The fast-moving nature of short-term trade-offs highlights the importance of testing the resilience of the banking system to large, unexpected shocks. Balance sheet and credit risk models will therefore feature prominently in the subsequent section as will DSGE and time series models with non-linearities (e.g. QVAR) which allow the analysis of large shocks. Medium-term trade-offs in contrast require models in which monetary policy affects financial imbalances and medium-term vulnerabilities. This is why our quantitative set of tools features models with bank risk taking via the leverage choice (e.g. van der Ghote (2021), bank risk taking via asset side risk shifting (e.g. DMP) as well as non-linear time series models that can track the evolving distribution of economic outcomes (e.g. QVAR and At-Risk models).

3. Quantitative tools for an in-depth assessment on the interaction between monetary policy and financial stability

3.1 Time Series Models

3.1.1. The Chavleishvilli et al. (QVAR) model

The Quantile VAR (QVAR) is a structural quantile vector autoregressive model developed to study macroprudential risk management by Chavleishvili, Engle, Fahr, Kremer, Lund-Thomsen, Manganelli, and Schwaab (2025, “CEFKLMS”).[6] Their model characterizes the joint dynamics of macroeconomic outcomes, financial stress, and systemic risks.

Whereas standard VARs capture the mean dynamic interaction of the endogenous variables in a system, the QVAR extends this logic to any quantile.[7] Modelling the quantiles of future outcomes shows how current conditions affect both the average trajectory of the economy, as well as the surrounding risks, in potentially non-linear fashion. Quantile regressions are now widely used in economics and finance to capture tail risks and non-linear dependencies. Most recently, Chavleishvili, Kremer and Lund-Thomsen (2023), Bochmann, Dieckelmann, Fahr and Ruzicka (2023), Chavleishvili

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[5] See Hempell et al. (2024), Implications of higher inflation and interest rates for macroprudential policy stance, and Detken, Hempell, Pirovano (2025), Macroprudential and monetary policy interaction: the role of early activation of the countercyclical capital buffer.

[6] See also Chavleishvili, Engle, Fahr, Kremer, Manganelli, and Schwaab (2021) for an earlier Working Paper version. Another QVAR model used at the ECB for a similar purpose but that can distinguish conventional from non-conventional monetary policy is Bochmann, Dieckelmann, Fahr and Ruzicka (2023).

[7] Quantiles are thresholds that characterize a distribution; for example, 5% of observations lie below the 5% quantile.

and Manganelli (2024) as well as Falconio and Manganelli (2025) have advanced the application of quantile methods to macro-financial analysis.

The CEFKLMS framework extends the "risk management" approach from monetary to macroprudential policy (Kilian and Manganelli, 2008). It provides policymakers with a tool for weighing the trade-off between risks to price stability and financial stability.

A. Estimation and data

The estimation builds on established Bayesian methods for QVARs but CEFKLMS also introduce an econometric innovation. Their Bayesian approach combines a longer sample of U.S. data (since 1973) with available euro area data since 1990. Specifically, posterior estimates from U.S. data are used to formulate informative priors, and the "weight" given to these priors is itself estimated from the euro area sample. This empirical Bayes strategy sharpens inference and yields credible intervals that remain valid despite the relatively short euro area time series and the high dimensionality of the model.

The QVAR specification includes five endogenous variables: a measure of the financial cycle, real GDP growth, HICP inflation, a financial stress indicator, and a short-term risk-free interest rate.[8] The choice of variables reflects a clear policy motivation: financial stability is a concern when disruptions in the financial system impair real activity. The inclusion of inflation and interest rates ensures that the model also accounts for the interaction between financial stability variables with monetary policy.

To measure the financial cycle, the model uses the systemic risk indicator (SRI) developed by Lang et al. (2019). The SRI captures medium-term dynamics in credit, housing, asset prices, and external imbalances, and serves as an intermediate target for macroprudential instruments. Financial stress is measured by the ECB's composite indicator of systemic stress (CISS; Chavleishvili and Kremer, 2025). CISS takes higher values when stress prevails in most market segments at the same time, capturing the idea that financial stress is more systemic, and more dangerous for the economy at large, whenever financial instability spreads widely across different parts of the financial system.

B. Key elements

By describing the joint evolution of indicators for financial stability and macroeconomic outcomes, the model allows to trace out the severity of trade-offs between price and financial stability at different points in time. As discussed in Section 2, such trade-offs arise when an otherwise appropriate monetary policy response to inflation would risk exacerbating existing financial stability concerns. In the short term, policymakers may face both elevated inflation and financial stress (CISS). Tighter monetary policy should help bringing inflation back to target but risks aggravating financial stress. In contrast, looser policy should ease market tensions, but only at the cost of pushing inflation further above target. In the medium term, another trade-off arises when inflation is below target while vulnerabilities, as measured by SRI, build up (e.g., rapid credit growth, buoyant housing markets, rising

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[8] In addition, an index of global commodity prices index serves as exogenous control variable in the QVAR.

equity valuations). In this case, easier policy should support inflation's return to target but risks amplifying imbalances. Conversely, tighter policy should alleviate vulnerabilities but may depress inflation further. For sake of concreteness, and as illustrated in Figure 2, the event of a short-term trade-off can be defined to arise when the CISS rises above historical range of levels associated with stable markets while inflation runs above the ECB's two-percent inflation targets. Conversely, and as illustrated in Figure 4, the medium-term trade-off can be seen to occur if the SRI rises above its historical average level while inflation runs below 2%.

C. Policy applications

The QVAR is well suited to monitor the risk of encountering a short- or medium-term trade-off in the future. Specifically, at a given forecast origin, the distribution of future outcomes for inflation, CISS and SRI can be simulated from the QVAR and the probabilities of short- and medium-term trade-offs to occur in the future are straightforward to compute. Using the Bayesian methods of CEFKLMS, the simulated distributions reflect not only the risk of future shocks to the economy, but also parameter uncertainty. In a policy context, it may be desirable to focus the analysis on risks around the staff's baseline projection. For this purpose, "entropic tilting" can be used to reweight the distributions generated from the QVAR such that, for example, their median path replicates the staff's baseline, while otherwise retaining their original features as much as possible (Clark and Mertens, 2025).

To quantify the effect of alternative policies on the risks of encountering a trade-off, the QVAR can be used to generate forecast distributions that condition on specific monetary policies. For example, one option to consider the effects of monetary policy is to perturb the path of future interest rates by monetary policy shocks when simulating future outcomes of inflation, CISS and SRI. For other applications, the path of the model's average outlook can be conditioned on alternative trajectories for the policy rate, such as those collected in the ECB's Survey of Monetary Analysts.[9]

In each case, forecast distributions simulated from the QVAR display important non-linear interactions between macroeconomic outcomes, monetary policy and financial stability. For example, when financial stress (as measured by the CISS) is low, a tighter monetary policy can lower inflation with benign effects on financial stability, whereas the same-sized policy tightening has more adverse effects on financial stability when the initial level of the CISS is already elevated. Similarly, a monetary easing has disproportionally larger effects on SRI when financial vulnerabilities are already elevated.

3.1.2. At-risk models

The models build on the recent growing literature linking lower tails of forecast distributions of real GDP growth to financial conditions known as Growth-at-risk models (Adrian, 2019; Adrian, 2022; Figueres and Jarociński, 2020; IMF Global financial stability reports). The follow-up research

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[9] The Survey of Monetary Analysts provides a distribution of policy path expectations from its respondents. The 25% and 75% percentile paths of this distribution can, for example, be used to represent reasonably looser or tighter policy scenarios.

evaluates the role of credit booms, property price booms, current account (Aikman et al., 2019) and the effects of macroprudential policies on growth-at-risk (Duprey and Ueberfeldt, 2018; Galan, 2020). While most of the literature focused on assessing downside risks to real GDP growth, recent literature applied the at-risk framework to house prices (Adrian et al., 2020), bank capital (Lang and Forletta, 2020), and exchange rates (Eguren-Martin et al., 2024).

A. Quantile Panel Model: Estimation and data

For growth-at-risk and RRE-at-risk applications, we estimate a quantile panel model. The model can be written as follows:,

$$\boldsymbol{y_{i,t+h}} = \boldsymbol{\alpha_i^\tau} + \sum_{\boldsymbol{j \in J}} \boldsymbol{\beta_j^\tau X_{i,j,t}} + \boldsymbol{\varepsilon_{i,t}^\tau},$$

where $y_{i,t+\mathrm{h}}$ is the growth rate of real GDP, and real house prices over the next h quarters ahead. Fixed effects are denoted as α_i^τ and $\boldsymbol{X_{i,j,t}}$ contains a set of macrofinancial indicators J (see table x). We use a two-step procedure for panel quantile regressions following Canay (2011), where in the first step simple unobserved fixed effects are estimated using within-estimators (i.e. assuming country fixed effects remain the same across different quantiles), and in the second step standard conditional quantile regression is estimated using the dependent variable adjusted for the fixed effect from the first step (see Canay (2011) for more details). The model is estimated for horizons of 1 to 12 quarters ahead to understand how the left tail of the distribution varies over the forecast horizon. We bootstrap the standard errors for the vector of coefficients before conducting significance tests, following the recommendation of Besstremyannaya and Golovan (2019) for panels with small n/T. Empirical quantiles of the dependent variable y_{t+h} conditional on macrofinancial variables $Q(y_{t+h}, \tau \mid X_{i,t})$ for a given date t are computed using estimated coefficients $\hat{\alpha}_i^\tau$ and $\hat{\beta}_j^\tau$:

$$Q(y_{t+h}, \tau \mid X_{i,t}) = \hat{\alpha}_i^\tau + \sum_j \hat{\beta}_j^\tau X_{i,j,t}$$

We focus on the 5th percentile ($\tau = 0.05$) in line with the existing literature, as it allows to evaluate downside risks from a financial stability perspective by focusing on the extreme negative growth rates typically observed in crisis periods. Therefore, we denote $Q(y_{t+h}, \tau = 0.05 \mid X_{i,t}) = at - risk(X_{i,t})$ as Growth-at-risk, and RRE prices-at-risk, respectively such that $\mathrm{Prob}(y_{i,t+\mathrm{h}} \leq at - risk(X_{i,t})^\tau) = \tau.$

The Growth-at risk model is estimated on an unbalanced quarterly panel dataset starting in 1970 Q1[10] covering 19 euro area countries, DK, SE, and GB, while RRE prices at risk uses a panel of 19 euro area countries starting mostly in 1999 Q1. For the Growth-at-risk model, explanatory variables

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[10] For the majority of larger Western European nations (e.g., Germany, Italy, Spain, France, the United Kingdom), data availability generally begins in the 1970s or 1980s. In contrast, for some smaller countries (e.g., Austria, Portugal, Greece), certain indicators only become available toward the late 1990s. Meanwhile, for many Eastern European or very small countries (e.g., Cyprus, Estonia, Lithuania, Latvia, Luxembourg, Malta), data for some indicators is only accessible starting in the 2000s.

consist of the lag of the real GDP growth, the cyclical systemic risk indicator (SRI)[11], its lag and a dummy variable equal to 1 if SRI>0 and zero otherwise, the country-level indicator of financial stress (CLIFS)[12], the 2-year change in the debt service ratio (DSR)[13], and an European Commission's economic sentiment indicator and its lag. Further details on the Growth are risk model can be found in Lang et al (2025). The RRE prices-at-risk model contains the lag of real house price growth, overvaluation (average of deviation of house price-to-income ratio from long-term average and econometric model), SRI, European Commission's consumer confidence indicator, financial market conditions indicator capturing stock price growth and volatility, government bond spread, slope of yield curve, euro area non-financial corporate bond spread, and an interaction of overvaluation and a financial conditions index. Selected results from the model can be found in Jarmulska et al. (2022).

B. Local Projections Quantile Regressions for Scenario Distributions

When generating financial stability risk scenarios it is critical to consider the entire predictive distribution around the scenarios paths and not only central tendency. This because the relationship between the level of financial risk and the macroeconomic outlook tends to be characterized by an non-linear behaviour. For example, the distribution of US GDP growth has been shown to have a larger left tail (negative skewness) during periods of financial stress, see Adrian, Boyarchenko and Giannone (2019). As for the euro area, Figueres and Jarociński (2020) show that the lower tail of future GDP Growth (i.e., Growth-at-Risk) can be estimated by using the Composite Indicator of Systemic Stress (CISS). Moreover, Adrian, Grinberg, Liang, Malik and Yu (2022) show that the effect of financial conditions on future GDP growth distribution varies over the projection horizon. Other variables exhibiting an asymmetric distribution are unemployment, real estate prices and inflation (see Adams, Adrian, Boyarchenko and Giannone, 2021).

Against this background, the scenario distribution of macroeconomic indicators (GDP and Real Estate Property prices) can be estimated via a quantile regression local projection model (QR-LP). The model has the following form:

$$y_{t+h} - y_t = const. + \beta\, x_t + \phi y_t + \ \mu_t \tag{1}$$

where y_t is the log level of the variable of interest, hence y_{t+h} is the log level of the same variable h-quarters ahead, thus $\Delta y_{t+h} = \ y_{t+h} - y_t$ is the future growth rate at $t + h$. Moreover, x_t is the level of financial risks measured by the Financial Stress Index (FSI) presented in the Macroprudential Stress Test Extension Report (2025). The FSI adapts the methodology of the CISS index (Kremer, Lo Duca and Holló, 2012) to 13 financial indicators linked to scenarios of financial stress across bond, equity, foreign exchange, and money markets. The key advantage of the FSI is that allow for generating scenarios by stressing its underlying financial components.[14] The predictive scenario tails are drawn by fitting the

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[11] See Lang et al. (2019).

[12] See Duprey et al. (2017).

[13] Calculated based on data from the ECB, Eurostat and the BIS according to the methodology proposed by Drehmann et al. (2015).

[14] In particular, the Financial Stress Index is built to match the paths of the adverse scenario financial variables contained in the Macro-financial scenarios for the EBA EU-wide banking sector stress test exercise. Hence, this framework allows to generate scenario paths for the FSI index by stressing the underlying index indicators in

estimated quantiles to the FSI computed on the scenario financial shocks. The distribution is estimated over a horizon of 12 quarters.

This model has been used for several policy analysis in the EBA EU-wide Stress Test Report analysing the impact of real estate downside risks on the banking sector, and the Macroprudential Stress Test Extension Report studying the severity of stress test scenarios (Figueres et al. 2025b).

3.1.3. Bayesian VAR-Local Projections (BVAR-LP)

Financial stability monetary policy analysis is supported by a suite of time-series models that combines Bayesian VARs and local projection approaches. The toolkit includes the Housing and Commercial Real Estate (CRE) BVAR models, a Large multi-country BVAR for financial shocks, and a Non-linear Local Projection model capturing state-dependent responses of key macro-financial variables. These models allow to generate adverse and tail risk scenarios assessing the macro-financial consequences in case of materialisation of financial stability risks. Among other things, these models also allow to study how monetary policy can affect the propagation of shocks in case of tail risk materialisation.

A. Models

The Housing BVAR is a Bayesian Vector Autoregressive (BVAR) model designed to analyse the main drivers of euro area residential real estate (RRE) dynamics and their interaction with monetary policy. The model jointly captures the evolution of real house prices, mortgage lending, residential investment, disposable income, lending rates and the monetary policy stance, proxied by the shadow rate (Wu and Krippner, 2016; Krippner, 2013). Structural shocks, namely housing demand (income and preferences), housing supply, mortgage supply and monetary policy, are identified using a combination of zero and sign restrictions following Jarociński and Smets (2008), Calza et al. (2013), Nocera and Roma (2017), Gambetti and Musso, (2016), Arias et al., (2018). The model is estimated via Bayesian methods employing a Normal-Wishart prior.

In the CRE BVAR, the Housing BVAR framework has been adapted to cover the CRE market. The model incorporates CRE prices, real estate investments, lending to NFCs, NFC income (gross operating surplus), GDP, CPI, lending rates and the policy rate. The estimation method as well as the identification strategy of structural shocks follow the same logic of the housing BVAR. The model has been used to support the monitoring of property-related vulnerabilities by analysing the main drivers of CRE prices dynamics in the euro area, as well as the impact of a turn in the CRE markets on the macroeconomy (ECB, 2024).

The Large multi-country BVAR and Financial Shock Simulator is a framework composed of two main blocks as described in Figueres et al. (2025), and it has been developed to design scenarios of

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accordance a set of relevance risks. For more details, see the Macroprudential Stress Test Extension Report (2025) and Figueres et al. (2025).

financial stress used for policy analysis. The first block simulates shocks on set of financial indicators (including an index of financial stress) via the Financial Shocks Simulator (FSS) tool based on non-parametric copula estimated via Bootstrap methods. The FSS tool covers a large panel of daily financial indicators and it is the ECB benchmark model used to calibrate the financial shocks of the adverse scenario for the EBA EU-wide banking sector stress test exercises. The second block expands the financial shocks into macroeconomic dynamics via the Scenario Expander Tool based on a large multi-country BVAR model. The large Bayesian VAR models 53 macro-financial indicators (including GDP, inflation, interest rates and real estate prices) covering euro area level variables and country level variables as for France, Germany, Italy and Spain (the four main economies of the region). The model features Minnesota-type independent Normal-Inverted Wishart priors (see Lenza, Primicieri and Giannone, 2015; and Banbura, Giannone and Reichlin, 2010) and it allows for *t*-distributed errors.[15] The posterior distribution of coefficients is obtained via the Metropolized-Gibbs sampler, and the conditional scenario paths are drawn via the Kalman Filter (Durbin-Koopman simulator smoother).[16]

The non-linear Local Projection model, (see Couaillier and Scalone, 2024), is an empirical non-linear macroeconomic framework designed to assess how shocks affect macro-financial variables under different cyclical systemic risk regimes. It highlights that scenarios characterized by higher systemic risk tend to produce more severe macroeconomic outcomes. The model is implemented as a multivariate smooth-transition regime-switching framework estimated through local projections. The model stands at the intersection of the original local projection approach of Jordá (2005) and the non-linear extension proposed by Tenreyro and Thwaites (2016). The transition across regimes is governed by the Systemic Risk Indicator (Lang and Forletta, 2020), a composite measure capturing the evolution of cyclical systemic risks. The model is estimated using aggregate euro area data from 2001Q1 to 2019Q4. Overall, elevated cyclical systemic risk is found to amplify economic fluctuations.

B. Policy applications

The housing BVAR supports the assessments of housing-related vulnerabilities and monetary-financial interactions through the following tools:

- ***Historical decompositions***: to trace the relative contribution of structural shocks to the dynamics of euro area house prices over time, identifying periods when price movements were driven mainly by monetary policy, by demand due to shifts in preferences towards housing assets (e.g. in post-COVID period) or supply constraints.

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[15] In particular, the BVAR prior for the dynamic coefficients features the baseline Minnesota priors by Litterman (1986) as implemented by Banbura, Giannone and Reichlin (2010) and two additional priors to account for unit roots and cointegration introduced by Sims (1993) Doan *et al.* (1984).

[16] For further details on the application of the Kalman Filter see Durbin and Koopman (2002) and Jarociński (2015).

- ***Conditional forecasts/scenario analysis***: to simulate the prospective evolution of house prices under alternative monetary policy paths, especially in periods of elevated uncertainty regarding future inflation dynamics and hence interest rate evolutions.
- ***Impulse response analysis***: to quantify how house prices, credit and investment respond to monetary policy, housing demand and supply shocks, providing insight into the transmission of policy and the amplification through housing.

The Large multicounty BVAR with financial shocks is able to design scenarios of financial stress for different policy analyses. The financial block of the model can be used to generate tail risk scenarios. The FSS tool allows to calibrate the financial shocks that would be observed in case of financial tail risks materialization.

The non-linear local projection model has been applied to illustrate how varying levels of systemic risk influence the propagation of shocks. It can evaluate the effectiveness of macroprudential measures through different channels: by mitigating systemic risks, borrower-based measures (BBMs) also dampen the amplification of recessionary shocks when risks materialize. This type of analysis helps quantify the contribution of macroprudential policy to strengthening the resilience of banks and private agents, particularly in scenarios designed to capture the interplay between monetary policy and financial stability.

3.2 Balance Sheet Models[17]

Balance sheet simulation and stress test tools are commonly used to assess distributional effects on the financial sector in case of tail-risk scenarios entailing the materialisation of financial stability risks and allow to assess how endogenous monetary policy can affect such effects. Overall balance sheet simulation and stress test tools in financial stability asses risks and inform buffer calibration in many jurisdictions around the globe.[18] The key advantages of such methodologies are their flexibility in tailoring the simulations towards specific risks of the financial sector, the use of recent and granular bank-level balance sheet data capturing key bank balance sheet characteristics and risk channels, and the potential to handle non-linearities linked to shocks as well as regulation better than traditional econometric models. They can also inform complex interactions with the non-banking financial sector and the real economy. Downsides relate to potential scarcity of some granular variables, making the estimation of model elasticity more challenging. data, difficulties in testing the statistical validity of the projections and the relative complexity of the methodology.

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[17] Prepared by Cyril Couaillier, Alberto Grassi, Aurea Ponte Marques, Elena Rancoita, Matthias Sydow

[18] For example, the Bank of England (BoE) uses Bank Capital Stress Tests (BCSTs) to assess the resilience of the UK banking system in severe but plausible stress scenarios, with the results informing the calibration of, inter alia, the countercyclical capital buffer (Bank of England 2025). Equally, the Federal Reserve Board calibrates the Stress Capital Buffer by using the results of its annual stress test, which estimates a bank's potential capital losses under a severe recession scenario (Federal Reserve Board 2020). In the banking union, several national authorities use stress test or loss simulation tools to inform the calibration of various macroprudential buffer requirements. In addition, the EBA Stress Test is used to set a starting point for the calibration of the microprudential Pillar 2 Guidance (P2G).

The Overlapping Constraints Tool (OCT) is a balance sheet tool focused on the interaction between prudential, monetary and resolution policies with the aim of proving a forward looking coherent and complete picture of banks for policy assessment (Rancoita and Normanno (2026).[19] The tool projects based on accounting equations and key elasticities 8 main regulatory ratios (CET1 ratio, leverage ratio, liquidity coverage ratio, net stable funding ratio and 4 MREL ratios) and compares them with their respective requirements. The projections are conditional on specific macro-financial scenarios and policy paths for a wide range of macroprudential, resolution and monetary policy instruments. It embeds key dynamic balance sheet figures in response to monetary balance sheet policies (TLTRO, central bank reserves and asset purchases) and to specific shocks (e.g. deposit outflows, changes in banks' financing conditions). It allows to evaluate the assessment of prudential policies and monetary policies both on the capital space (hence lending) but also via other less standard channels, such as leverage and liquidity. Additionally, it accounts for overlaps of regulatory requirements (both prudential and resolution) which could reduce the effective available capital.

The Banking Euro Area Stress Test (BEAST) is a top-down stress test model projecting banks' capital, liquidity, and balance-sheet position, and capturing the feedback loop between banks' deleveraging and the real economy, critical to assess the interplay between monetary policy, prudential policy and financial stability (Budnik et al. (2023)). The model covers significant euro area banks alongside the euro area economies is estimated on supervisory and EBA stress test data. Its granularity also for analysing the impact various scenarios, both macroeconomic (e.g. crises, change in monetary policy path) or more specific (e.g. sectoral shock, deposit outflow, financial market shock) through the different key risk channels (net interest income, credit risk, market risk, etc.) on banks' capital and liquidity position, as well as the interplay between banks' solvency and their funding conditions. Critically, it can also allow for banks' endogenous reaction to a crisis, creating a feedback loop between the banking system and the real economy. As banks deleverage in a crisis to restore their capital ratios to meet their different capital requirements (risk-based requirements, leverage ratio, MREL), this aggregate contraction in credit weakens economic activity, hitting back banks with larger losses. This crucial interconnectedness captures the systemic implications of individual banks' behaviour and allows to assess the impact of economic shocks, monetary policy, and macroprudential buffers on banks' credit supply, their capital and liquidity position, and the real economy. As such, BEAST can be used as standard stress test model, but also to explore banks' reaction to a crisis and to policy actions, such as change in monetary rates or the release of macroprudential buffers.

The Holistic Perspective (HP) tool projects bank capital depletion by leveraging both historical and stress test data to assess the impact of adverse scenarios on banks' solvency. This tool aggregates three top-down stress test empirical models that estimate bank-level capital depletion driven by a macroeconomic scenario. The models use one of two types of data: historical supervisory data (1 model) and EBA stress test data (2 models), with different bank-specific and macroeconomic variables driving each model estimation. The historical model aggregates scenario impacts on banks' profit and loss, other comprehensive income and on risk weighted assets under a static balance sheet assumption. Using the historical relationships of the past crises, this model is useful to identify

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[19] For a policy application, see Rancoita et al. (2025).

if current, expected or simulated macro scenarios (e.g. different interest rate paths) are projected to deplete banks' capital and through which component. The models that use stress test data estimate banks' depletions relying on elasticities to macro-financial scenarios from the past EBA stress test exercises data; this way, it abstracts from confounding factors affecting historical data, e.g. fiscal support. By combining the two approaches, the HP can be used to infer banks' resilience to different crisis scenarios and policy paths, balancing information between historical regularities and standard stress test exercises.

The Interconnected System-wide Stress Test Analytics (ISA) model, is a stress-testing framework that analyses short-term interactions among banks, investment funds and insurers (Sydow et al. (2024 a,b)). It assesses the initial impact of external market shocks on the portfolios of banks, investment funds, and insurers (first-round losses) and evaluates the amplification and contagion effects caused by endogenous reactions to solvency and liquidity stress (second-round losses). The ISA model combines portfolio revaluation techniques with satellite models governing the endogenous behaviours, which include flow-performance coefficients to measure redemptions of fund shares and price-impact parameters to estimate fire sales' effects on securities pricing. Built using supervisory, statistical, and commercial data, the model maps a network of bilateral exposures, capturing both direct and indirect contagion channels overlooked in traditional stress tests by accounting for dynamic balance sheet adjustments. It is particularly effective in analysing short-term market reactions stemming from portfolio and risk concentration or counterparty deterioration. Furthermore, the ISA model supports policy evaluation by estimating the financial system's reaction to new policies which might alter the institutions' liquidity management actions (e.g. allowing or restricting certain actions) or the conditions of the markets (e.g. increase/decrease in lending facility rates).

3.3 Credit Risk Models[20]

Credit risk models are used to: i) compute risk weights, probabilities of default, and loss given default in case of materialisation of tail risk scenarios; ii) quantify the mitigation effects of monetary policy under those scenarios. The credit risk models encompass the top-down models of IFRS 9 risk parameters (loan losses) and of risk exposure amount parameters (Figure 1). The IFRS 9 parameters are used to calculate impairments (that enter profit and loss) and affect the numerator of the bank capital adequacy ratio.[21] The regulatory parameters, as prescribed in the Capital Requirements Regulation (CRR)[22], are used to compute the risk exposure amounts and affect the denominator of the

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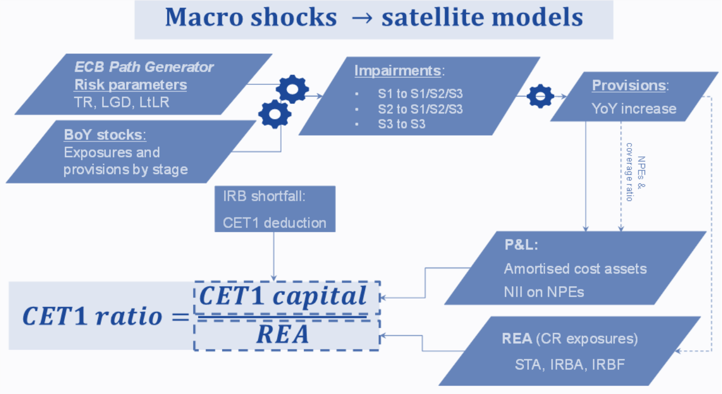
[20] Prepared by Aurea Ponte Marques based on Budnik et al. (2024).

21 On 24 July 2014, the International Accounting Standards Board (IASB) issued IFRS 9 incorporating a new expected loss impairment model, which was effective from 1 January 2018. It introduced a new methodology for incurred losses, which was replaced with a more forward-looking expected loss method. Impairments are also considered in the denominator of the bank solvency ratio via deductions to the exposure at default amounts (for loans under the standardised approach).

22 See https://eur-lex.europa.eu/legal-content/en/TXT/?uri=celex%3A32013R0575.

bank capital adequacy ratio.[23] Jointly, they provide the quantification of credit risk losses conditional on a macro-financial scenario.

Figure 5: High-level overview of top-down credit risk computation



Source: ECB authors.

The ECB benchmarks are based on econometric models conditioned on baseline and adverse macro-financial scenarios[24] used in stress-testing exercises. These models combine time-series and panel data techniques, including quantile approaches, to capture both linear and non-linear relationships between macroeconomic variables and credit risk parameters. Calibration relies on long time series of default rates and transition probabilities reported by national authorities, ensuring country-specific relevance (Table 1). In the projections of IFRS 9 parameters—expected default rates, transition probabilities, loss given default, and lifetime loss rates—are produced at country and market-segment levels for portfolios such as mortgages, non-financial corporates, consumer credit, financials, and sovereigns. Top-down models also include regulatory risk parameters, replicating and challenging banks' reported risk exposure amounts under both the standardised and internal ratings-based approaches.

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[23] This is partly considered in the numerator of bank capital adequacy when computing the IRB shortfall.

[24] As published by the ESRB: Belgium, Bulgaria, Czech Republic, Denmark, Germany, Estonia, Ireland, Greece, Spain, France, Croatia, Italy, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Malta, Netherlands, Austria, Poland, Portugal, Romania, Slovenia, Slovakia, Finland, Sweden, United Kingdom, Norway, United States, Japan, Canada, Switzerland, Australia & New Zealand, Turkey, Russia, Emerging Asia, China, India, Latin America, Brazil, Mexico, Chile, Rest of the World.

A. Models

Table 1: ECB top-down credit risk models

Model/ Parameter	Purpose / Scope	Methodology	Data Sources	Key Outputs / Parameters	References
IFRS 9 Expected Default Rate EU (27 countries) + non-EU; country × portfolio	Project default probability for various portfolios under scenario conditions: NFCs, Households, Financials and Sovereigns	(i) Bayesian SSVS model for EU countries (ii) Panel Quantile Regression for sectoral NFCs (iii) Bridge equations for non-EU portfolios Implemented in a distance-to-default space (see Crosbie and Bohn, 2003).[25] [26]	- National authorities (default rates, transitions) - Orbis (Bureau van Dijk, firm-level data) - Moody's KMV (financials) - Kamakura (sovereigns) - ECB macro scenarios	Point-in-time and scenario-conditional default rates by country, sector, and portfolio Conditional QPD paths capturing tail risk and sectoral heterogeneity	- Budnik et al. (2024) - George et al. (2008) - Figueres and Sarychev (2024) - Sala-I-Martin et al. (2004) - Dees et al. (2017) - Gross and Población (2015, 2019) - Machado and Silva (2019 - Rios-Avila (2020) / Rios-Avila and Maroto (2024) - Konietschke et al. (2024) - Konietschke et al. (2022) - Gourinchas et al. (2020)
IFRS 9 Transition Probabilities EU (27 countries) + non-EU; country × portfolio	Forecast stage transitions for IFRS 9 impairments	Markov chain estimation, scenario extension via bridge equations, mapping to PDs Implemented in a distance-to-default space	- National authorities (default rates, transitions) - ECB macro scenarios	Projected state matrix for stage migration probabilities (S1, S2, S3)	- Budnik et al. (2024)
IFRS 9 Loss Given Default (LGD) EU (27 countries) + non-EU; country × portfolio	Estimate structural and macro-driven loss rates for real estate and other loans not collateralised by real estate, under different scenarios	(i) Real estate: structural model with LTV (ii) Non-real estate: regression (GDP, UR) - Implemented in a distance-to-default space	- ECB macro scenarios - EU-wide stress test data - Bank-level LTV and LGD	- Projected LGD across portfolios; forward paths by RE (and non-RE) collateral	- Budnik et al. (2024) - Georgescu et al. (2024) - Bellotti and Crook (2012) - Caselli and Querci (2008) - Konečný et al. (2017)
IFRS 9 Lifetime Loss Rates EU (27 countries) + non-EU; country	Produce lifetime expected loss, integrating default and migration dynamics	Cumulative expected loss via Markov process; marginal and cumulative transition probabilities; decay of	- ECB macro scenarios - EU-wide stress test data	Lifetime expected loss, per year and stage	- Budnik et al. (2024)

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[25] Some additional references provide insightful explanations on the concept of the distance-to-default measure and its relation to the probability of default, such as Kealhofer (2003), Sun et al. (2012) and Ferry et al. (2012).

[26] To derive bank-specific point-in-time probabilities of default, top-down parameter paths are attached to bank starting points with a locational perspective in a distance-to-default space. Instead of the chosen transformation, alternative options such as a logit, a probit or an inverse normal could have been employed. The top-down benchmarks, sourced from a data collection which aggregates information on the banking system at a country level, are strategically applied in a distance-to-default space. This approach ensures that the starting points of individual banks are duly considered from a country perspective.

Model/ Parameter	Purpose / Scope	Methodology	Data Sources	Key Outputs / Parameters	References
× portfolio		exposures over stress horizon			
Regulatory Risk Weights – STA EU (27 countries) + non-EU; country × portfolio	Model RWA dynamics for standardised approach portfolios, under macro and bank variables	Feasible generalised least squares (FGLS) panel regression	- EU-wide stress test data - ECB macro scenarios	Projected regulatory RWA for STA portfolios (baseline/adverse) considering bank-specific sensitivities	- Budnik et al. (2024) - Regulation (EU) No 575/2013 (CRR)
Regulatory Risk Parameters – IRB EU (27 countries) + non-EU; country × portfolio	Generate scenario-consistent projections for IRB RWA, regulatory PD, LGD	CRR formulas for RWA and downturn LGD, PD moving average, paths via macro and bank-specific dynamics	- EU-wide stress test data - TRIM (PD cycle)	Scenario-adjusted RWA, regulatory PD, and LGD under IRB; bank-specific sensitivities	- Budnik et al. (2024) - Regulation (EU) No 575/2013 (CRR) - ECB Guide to Internal Models (TRIM)

Source: ECB authors.

3.4 Micro-econometric Models

A. Models

Abbondanza et al. (2025) uses a micro-level regression discontinuity design (RDD) to causally identify how euro area banks adjust their voluntary capital buffers in response to higher regulatory capital requirements. The empirical strategy exploits the threshold-based assignment of the Other Systemically Important Institution (O-SII) buffer, which designates banks as systemically important when their European Banking Authority (EBA) systemic score exceeds a fixed cutoff (typically 350 basis points). Because banks just above and just below this threshold are similar in all observable and unobservable characteristics except for the additional capital requirement imposed, the setup mimics a randomised experiment. Using confidential supervisory data from euro area banks, the authors compare the voluntary capital buffers (the capital held above regulatory requirements) of these near-threshold banks to estimate the causal effect of higher requirements. This RDD approach allows them to isolate exogenous variation in capital regulation and show that banks typically offset about half of the higher O-SII capital requirement by drawing down their voluntary buffers rather than raising new equity, particularly among banks with weaker balance sheets.

The Sovereign bond absorption model is an econometric framework designed to estimate an asset demand system based on empirical data of euro area bond holdings by sector (see European Central Bank 2023). The model builds on the methodology introduced by Koijen et al. (2021) in their study on the mechanisms of quantitative easing in the euro area. Its primary objective is to analyse how different financial sectors adjust their sovereign bond holdings in response to changes in bond yields, financial market uncertainty, and other macroeconomic factors, thus providing insights into the dynamics of sovereign bond markets and their impact on financial stability. The model estimates demand elasticities for each financial sector (such as banks, insurance corporations, investment funds, households, and foreign investors) and for different asset rating classes, including higher-rated and lower-rated sovereign debt. The dependent variable in the model is the logarithm of nominal bond holdings by sector from the securities holdings statistics (SHS-S) of the ECB. Among the explanatory variables, the yield to maturity plays a key role in capturing the sensitivity of investor demand to yield changes, while additional factors like U.S. ten-year bond yields and financial market uncertainty, as measured by the VSTOXX index, are used to account for alternative asset returns and volatility. The model also incorporates fixed effects for securities and holder areas, as well as macroeconomic controls such as GDP growth and the ECB's deposit facility rate. To address endogeneity concerns, the yield to maturity is instrumented using high-frequency yield data from European Central Bank (ECB) Governing Council meeting dates (see Altavilla et al. 2019).

The model estimates reveal that demand elasticities in response to changes in bond yields are generally lower for lower-rated sovereign debt compared to higher-rated debt. This suggests that investors are less sensitive to yield changes when dealing with riskier assets. The analysis also establishes a causal relationship, showing that large issuances of sovereign debt are typically absorbed at higher yields, particularly for lower-rated countries. This trend highlights that investors demand additional compensation for the increased risk associated with such issuances. Furthermore, the model identifies that higher yields attract yield-sensitive foreign investors to higher-rated sovereign debt, while households demonstrate a preference for lower-rated sovereign bonds when yields rise, especially in environments where deposit interest rates are increasing. An important implication of the model is the evidence of procyclical behavior among investors. Both banks and non-bank financial institutions have shown an increased sensitivity to past yield changes over time. The model also sheds light on the behaviour of financial sectors under conditions of market stress. For example, during periods of heightened market volatility, such as a one-standard-deviation increase in the VSTOXX index, non-bank investors tend to reduce their sovereign bond holdings. However, banks often step in to absorb some of the additional supply, thereby supporting market stability. While this mitigates immediate disruptions, it also deepens the interdependence between the banking sector and sovereigns, potentially exacerbating the sovereign-bank nexus and its associated risks.

B. Policy applications

Abbondanza et al (2025) finds that euro area banks offset roughly two-thirds of higher capital requirements imposed through the O-SII buffer by reducing their voluntary capital buffers, rather than by raising new equity. Specifically, a 0.5-percentage-point increase in the O-SII capital requirement leads to an average 0.3-percentage-point decline in banks' voluntary common equity tier 1 (CET1) buffer. As a result, only about one-third of the additional requirement translates into higher total capital ratios. The regression discontinuity design confirms this relationship as statistically significant and robust across several bandwidth specifications. Moreover, the offsetting behaviour is strongest among banks with weaker balance sheets — those with higher non-performing loan ratios — which tend to use almost their entire voluntary buffer to meet higher requirements. In contrast, the estimated change in total CET1 ratios is negligible (below 0.01 percentage points), suggesting little or no new capital raising. Overall, the results show that when capital requirements rise, banks predominantly absorb the increase by eroding voluntary buffers, thereby reducing the effectiveness of macroprudential measures intended to strengthen bank resilience.

In the Sovereign bond absorption model, **simulations based on the model further illustrate the impact of hypothetical scenarios**. For instance, an increase in sovereign debt issuance equivalent to 1% of outstanding euro area debt would likely be absorbed at higher yields, with the magnitude of the yield increase being more pronounced for lower-rated debt. If such issuance coincided with increased financial market volatility, banks would likely compensate for the reduced demand from other sectors, but this would amplify their exposure to sovereign debt and the associated risks. In summary, the Sovereign bond absorption model provides a comprehensive tool for understanding the dynamics of euro area sovereign bond markets. By capturing the heterogeneous behaviour of different investor sectors and the effects of yield changes and market conditions, the model offers valuable insights into the capacity of the financial system to absorb sovereign debt issuance and the potential risks to financial stability. This framework is particularly relevant for policymakers and regulators seeking to evaluate vulnerabilities in sovereign debt markets and to anticipate the implications of macroeconomic and financial shocks.

3.5 DSGE Models

3.5.1. The Darracq Pariès, Müller and Papadopoulou model

The "DMP" model in Darracq Pariès et al. (2023) was developed to contribute to the debate on the macroeconomic effectiveness of expansionary monetary policy measures other than interest rate decisions and fiscal measures in a regulated banking environment which may also be impaired by sovereign riskiness. It introduces financial intermediation, bank capital requirements and banking and sovereign riskiness into an otherwise standard dynamic stochastic general equilibrium (DSGE) model, that builds on the “DKP” macro-finance model of Darracq Pariès, Körner and Papadopoulou (2019). It aims to examine the interactions between sovereign and banking risks as well as the role of policy tools, including interest rate policy, other monetary policy instruments and macroprudential regulation, in mitigating financial instability in the euro area. Darracq Pariès et al. (2019) investigates the interaction between central bank asset purchases and financial policies, focusing on their combined impact on financial stability and macroeconomic performance. Subsequently, Darracq Pariès et al. (2023) extends the model by adding sovereign riskiness and sovereign banking nexus to quantify the size of fiscal multipliers in an economy with sovereign and bank default risks to better understand fiscal stabilization in an economy where sovereign and financial risks interact.

A. Key model ingredients

The model builds on the foundations of standard New Keynesian DSGE frameworks by incorporating financial and sovereign frictions and role for interest rate policy and other monetary policy and supervisory policies. It consists of households, intermediate labour unions and labour packers, intermediate and final goods-producing firms, capital producers, non-financial firms investing in capital projects, bankers, retail lending branches and loan officers who intermediate funds to the projects of non-financial firms and government, monetary and supervisory authorities. Both entrepreneurs and banks are subject to endogenous borrowing constraints and may default. Since the loan market operates under imperfect competition, financial frictions and market power in the loan market create inefficiencies in borrowing conditions. The real sector is standard as in New Keynesian models and features staggered prices and wages. Government bonds carry a default risk and let the banking sector have direct and indirect exposure to it. The model estimation is meant to provide a realistic mapping of the euro area conditions and sufficient validity for the qualitative and quantitative implications of the analysis.

B. Key mechanisms

The model features a banking sector that engage in portfolio re-balancing frictions based on risk taking motives. Firstly, the risk-taking behaviour of banks is related to bank's limited liability under a deposit insurance scheme. Bankers face idiosyncratic risks on their loan book return and default when the return on asset is not sufficient to cover for the repayments of household deposits. Consequently, the bank has an incentive to take on risks and engage in excessive leverage. Secondly this provides a rationale for bank capital regulation which is implemented by imposing penalty costs if bank capital ratios fall below the minimum bank capital regulatory requirements. The set of frictions also includes adjustment costs on bank government bond holdings, which affect banks' portfolio decision between sovereign bonds and loan origination. Thirdly, the model accounts for feedback loops between risky banks and sovereign debt to highlight the role of fiscal decision-making, sovereign bond issuance, and sovereign default due to the government's inability to raise funds necessary to honour its debt obligations. This probability of default is nonlinearly linked to the level of public debt, it impacts sovereign risk premia and opens the sovereign bank riskiness channel that raises the cost of financial intermediation. This setup allows the investigation of the structural layers that make up the sovereign-bank nexus, these being the ‘’exposure channel’’ relating to the sovereign bond valuation risk affecting bank balance sheets and the ‘’safety-net channel’’ relating to the agents' belief in the capacity of governments to fulfil direct and indirect deposit guarantees.

C. Policy applications

The model is a useful tool in the debate on the macroeconomic effectiveness of expansionary monetary policy measures other than interest rate decisions in a regulated banking environment and to explore the interactions between central bank asset purchases and bank capital-based financial policies (regulatory, supervisory or macroprudential) through its influence on bank risk-shifting motives. It is found that weaker-capitalised banks display excessive risk-taking which reinforces the credit easing channel of central bank asset purchases, at the cost of higher bank default probability and risks to financial stability. In such a case, adequate bank capital demand through higher minimum capital requirements curtails the excessive credit origination and restores a more efficient propagation of central bank asset purchases. As supervisors can formulate further capital demands, uncertainty about the supervisory oversight provokes precautionary motives for banks, leading to the build-up of extra capital buffer attenuating the impact of monetary policy measures other than interest rate policy. In a weaker-capitalised banking system, countercyclical macroprudential policy attenuates banks risk-taking and dampens the excessive persistence of the monetary policy impulse. On the contrary, in a well-capitalised banking system, macroprudential policy should look through the effects of central bank asset purchases on bank capital position, as the costs in terms of macroeconomic stabilisation seem to outweigh the marginal financial stability benefits. Furthermore, the model has been used to explore potential trade-offs between interest rate policy and financial stability. Particularly in a weaker-capitalised banking sector environment, due to risk-shifting as described above, expansionary monetary policy may eventually lead to medium-term trade-offs due to excessive loan origination.

The model can also be used to quantify the size of fiscal multipliers in an economy with sovereign and bank default risks. Following a calibration of the model on sovereign and bank riskiness reminiscent of the euro area Sovereign Debt Crisis, it is shown that adverse financial channels may significantly depress the transmission of expansionary government spending shocks. In such a case, it is shown that there is scope for monetary and regulatory policies to mitigate financial setbacks and restore the effectiveness of fiscal interventions. In a similar manner, the model has been used in the policy process to explore implications from an increase in sovereign yields and riskiness in the euro area, for both less vulnerable and vulnerable countries.

3.5.2. The Karadi and Nakov (2021) model

The Karadi–Nakov model studies quantitative easing (QE) within a New-Keynesian DSGE framework that includes a banking sector facing occasionally binding balance-sheet constraints. When a negative financial shock erodes bank capital, QE can mitigate the ensuing credit crunch. The authors analytically derive the Ramsey-optimal QE path and identify conditions under which asset purchases are both "effective" in stabilizing output but also "addictive" in that they endogenously delay exit. The central insight is that QE restores credit supply during crises but flattens the yield curve, compresses banks' profits, and slows their recapitalization. This implies that, even after the acute phase passes, the optimal reduction of central-bank balance sheets should be very gradual.

The economy features households, banks, intermediate-goods and capital-goods producers, Calvo-price retail firms, a fiscal authority, and a central bank. Banks issue deposits, hold long-term government and corporate bonds, and are subject to an endogenous leverage constraint that arises from a moral-hazard incentive problem (Gertler-Karadi, 2011). This constraint binds only when bank equity falls below a critical threshold, at which point credit spreads widen and real activity declines. The central bank can conduct QE by purchasing long-term government bonds, financed by short-term liabilities. The reduction in long-term government bonds in banks' balance sheet eases leverage constraints, freeing up capacity for additional lending. To capture potential fiscal or political frictions, QE carries a small quadratic efficiency cost. The model is calibrated to euro-area parameters from

Coenen et al. (2018), and it is solved under Ramsey commitment using Dynare's (2011) perfect-foresight algorithm.

The core mechanisms operate as follows. QE is effective when a financial shock reduces bank equity and renders the leverage constraint binding. By transferring long-term bonds from bank balance sheets to the central bank, QE expands banks' capacity to extend private credit. This alleviates the credit crunch and stabilizes output and inflation. If QE is costless, the central bank can fully offset the adverse effects of the financial shock. At the same time, QE is addictive in the sense that by compressing credit spreads it diminishes banks' net interest margins and profitability. Lower profits slow the rebuilding of bank equity, lengthening the period during which the constraint would bind absent support. Consequently, the Ramsey-optimal policy does not abruptly unwind QE but instead follows a persistent, autoregressive decline linked to the slow pace of bank recapitalization.

These dynamics give rise to an asymmetry between entry and exit. When QE entails positive costs, the optimal policy may delay deployment at the onset of stress, tolerating temporarily wider spreads that accelerate bank recapitalization through higher margins. By contrast, once the central bank has built a large balance sheet, the optimal exit is gradual. A rapid withdrawal would re-tighten credit conditions and impose welfare losses by reigniting the constraint and widening spreads. Thus, even as macroeconomic conditions improve, the model implies a slow and cautious normalization path.

The model also highlights the shock-specific nature of optimal QE. Asset purchases are powerful in response to disturbances that impair credit supply by weakening bank balance sheets and making the leverage constraint bind. By relaxing the constraint, QE directly targets the friction at its source. In contrast, for standard demand or supply shocks that do not bind bank constraints, QE is largely ineffective, even when the policy rate is at the zero lower bound. In such cases, other instruments that act through aggregate demand or price-setting channels are more appropriate.

Taken together, the Karadi–Nakov framework provides an integrated rationale for using QE as a targeted tool during financial crises and for unwinding it slowly afterward. It reconciles the strong short-run stabilization benefits of balance-sheet policies with the longer-run trade-offs arising from profitability, bank recapitalization dynamics, and the fiscal or political costs associated with sustained central-bank intervention.

3.5.3. The 3D model

The "3D" model in Clerc et al. (2015) was developed in the context of the Macroprudential Research Network (MaRS) of the European System of Central Banks.[27] It introduces financial intermediation and default into an otherwise standard closed-economy dynamic stochastic general equilibrium (DSGE) model to use it for the analysis of optimal bank capital requirements. The model has been extended further over the years. Mendicino et al (2018) developed a rigorous euro area calibration and derived optimal average capital requirements as well as the optimal countercyclical response. In

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[27] See Clerc, Derviz, Mendicino, Moyen, Nikolov, Stracca, Suarez and Vardoulakis (2015), "Capital Regulation in a Macroeconomic Model with Three Layers of Default" by, as well as xxxx

Mendicino et al (2020), the model is extended by adding nominal rigidities and the paper considers how the conduct of monetary policy affects the optimal setting of capital requirements. Mendicino et al (forthcoming) shows that taking non-linearities into account implies a much higher optimal capital requirement. Herrera et al (2024) examines how counter-cyclical capital requirement and LTV policy can help the economy weather a period of high interest rates. Falasconi et al (2024) examines cross-country spillovers of capital requirement changes in a monetary union.

A. Key model ingredients

The model is a standard macroeconomic model with a household sector that consists of households, firms and banks. Households are either impatient borrowers who borrow from banks to purchase housing and consume or patient savers who consume, buy housing outright and deposit in banks. A fraction of households can buy equity in banks and in firms. The corporate sector raises equity from households and loans from banks to invest in physical capital and produce the final good using capital and labour. Banks raise equity and deposits from households to lend to mortgage and corporate borrowers. A fraction of banks' deposits is insured while the rest are uninsured, and banks are subject to a minimum capital requirement as well as the Countercyclical Capital Buffer (CCyB). All debt liabilities (corporate debt, mortgage debt and bank deposits) are subject to default and limited liability. Final goods firms face nominal rigidities (sticky prices) which creates room for monetary policy to affect real activity and inflation. Monetary policy is conducted using a simple Taylor rule.

B. Key mechanisms

The model features a bank capital requirement trade-off which arises from four types of distortions: (i) limited liability by banks, (ii) bank funding cost externalities, (iii) costly default and (iv) limited participation in equity markets. The first two distortions weaken market discipline and ensure that banks do not suffer the full consequences of their risk-taking decisions. Due to opaque bank balance sheets and the presence of insured deposits, individual banks do not capture the full benefit in terms of lower deposit rates of raising their capital ratio and becoming safer. As a result, they take excessive risk and choose a level of leverage that is too high from a social point of view. This leads to higher than socially optimal bank default rates which is negative for welfare both because of default costs (distortion (iii) above) but also because of the resulting disruption to financial intermediation. Higher capital requirements increase household welfare in the model because they help to correct the above three distortions leading to a more stable and better functioning financial system. The fourth distortion (limited participation in the equity market) implies that equity as a form of funding is scarce and is more expensive than debt. In line with empirical evidence, the model assumes that only a small share of households participate in the equity market and their scarce wealth is the only source of equity capital for banks and firms. This scarcity creates a risk-adjusted 'equity premium': equity pays a higher risk-adjusted return compared to debt or bank deposits.

As a result, a higher capital requirement increases weighted average bank funding cost (other things equal) by forcing them to fund using a more expensive liability. Because the banking system is competitive, this is passed on in higher lending rates to final borrowers who end up investing a little less in capital and housing, reducing economic activity. This makes very high capital requirements costly for the real economy.

C. Policy applications

The above trade-off is resolved by choosing an intermediate level of bank capital requirements which reduces the externalities caused by banks' excessive risk taking without imposing an excessive cost on financial intermediation and economic activity. The optimal level of bank capital requirements is chosen to equalize the marginal costs and marginal benefits of bank capital requirements. As bank capital ratios are increased from low levels, the risk of bank failure starts to fall a lot bringing a lot of marginal benefits in terms of reduced excessive risk taking and limited liability distortions. At the same time, the marginal cost of higher capital requirements is low because debt becomes cheaper partially offsetting the negative impact for banks' average funding costs of relying more on expensive equity. The financial system becomes safer without a significant cost for the real economy in normal times. However, once capital requirements are already high and banks are relatively safe, further increases in bank capital requirements bring relatively small marginal benefits but they impose a higher and higher marginal cost in terms of lower financial intermediation and economic activity. As a result of this trade-off, the model features an intermediate optimal bank capital requirement which achieves a low level of bank default risk but does not seek to eliminate bank failure entirely.

The model can also be used to examine the role of the Countercyclical Capital Buffer (CCyB) in the mitigation of a specific risk scenario[28]. The activation of the CCyB (before the shock hits) leads to a small transitional cost in terms of lower economic activity while the economy adjusts to the higher bank capital ratio. A gradual implementation of the CCyB helps to reduce the size of this cost of the activation. Once the CCyB is fully implemented, it can guard the economy and the financial system from the realization of negative shocks. This happens through two distinct mechanisms. First of all, banks are less leveraged, and any given loss transmits into a smaller fall in bank capital when the bank starts off with a higher capital ratio. Second, the presence of a loaded CCyB allows it to be released thus stabilizing credit supply and economic activity following the materialization of the shock.

3.5.4. The Van der Ghote (2021) model

The "VdG" model is a macroeconomic model with endogenous buildup of financial risks during normal times and abrupt unwinding of those risks during crisis times. The model generates economic cycles that recurrently fluctuate between periods of booms and periods of busts. It is based on Van der Ghote (2021), and it has been refined since publication by its author, to quantitatively study: (i) how credible rules for macroprudential policy set in normal times affect credit supply, financial risk-taking, and the likelihood of financial distress in the medium term; (ii) how rules for monetary policy set either in normal times or in crisis times influence the buildup of financial risks; (iii) relatedly to (ii),

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[28] For example, a sharp increase in policy rates or a large deterioration in the economy.

how those rules affect, ex ante, the likelihood of financial distress and, ex post, the pace of recovery; (iv) the interactions between monetary policy and macroprudential policy and their implications for financial stability; and (v) how unanticipated changes in monetary policy (i.e., monetary surprises) affect credit provision, economic activity, and consumer price inflation depending on systemic financial conditions. The model assumes economic agents form expectations about future events rationally. Based on historical accounts of financial crises by Kindleberger (1978), Camous and Van der Ghote (2025) extend the model to incorporate non-rational extrapolation in expectation formation.

A. Key model ingredients

The model is a dynamic stochastic general equilibrium economy featuring a financial intermediary sector that channels funds from households to firms. Financial intermediaries can issue short-term debt to households (i.e., deposits) subject to a bank capital constraint. Financial intermediaries use their net worth together with the raised funds to extend credit to non-financial corporate (NFC) firms and to hold financial securities (bonds and equities) issued by those firms. Importantly, NFC firms face aggregate fundamental risks, which implies that financial intermediaries concentrate aggregate risk in their balance sheets when they take on leverage to hold claims on those firms. As far as their business activities are concerned, NFC firms can only reset their price with some limited frequency, which implies that inflation can only change sluggishly over time and, hence, that the nominal interest rate can affect the real interest rate and the real course of the economy. Monetary policy sets the benchmark nominal interest rate in the economy while macro-prudential policy sets a limit on leverage to financial intermediaries beyond that implied by the collateral constraint. Both policy instruments can be set contingent on the aggregate state of the economy. The model is solved globally, meaning that its exact outcome is computed for each state point, without relying on approximation methods.

B. Key mechanisms

The model generates financial amplification effects of exogenous disturbances to economic fundamentals. These effects are highly non-linear in the state of the economy and critically depend on the tightness of the collateral constraint. To fix ideas, sufficiently large adverse disturbances to the profitability of NFC firms trigger net worth losses on financial intermediaries. When the constraint is slack, financial intermediaries have enough net worth buffers to absorb the losses without cutting credit supply or selling assets. By contrast, when the constraint is binding, the intermediaries must shrink their balance sheets to meet pressing collateral requirements, forcing them to reduce credit and to liquidate financial securities at distressed prices. Moreover, declines in security prices, in turn, further erode intermediaries' net worth, creating a positive feedback loop between balance-sheet losses and fire sales that ultimately leads to severe decapitalization and a sharp contraction in credit supply. As far as economic cycles are concerned, the financial amplification effects tend to generate abrupt fluctuations between episodes with well-capitalized financial intermediaries, a slack collateral constraint, high credit, and elevated security prices (booms) and episodes with poorly capitalized intermediaries, a binding collateral constraint, low credit, and depressed security prices (busts).

C. Policy applications

Financial amplification effects critically influence the impact of monetary surprises. When the collateral constraint is binding – and hence amplification is strong – unanticipated changes in the policy rate have large effects on the capitalization of financial intermediaries, security prices, and credit provision to the NFC sector. By contrast, when the constraint is slack and amplification is thus weak, those effects are small. Given the high non-linearity of the amplification mechanism over the state space, solving the model globally is essential to accurately quantify the effects as a function of intermediaries' capitalization – the key aggregate state variable. The model also yields important implications for the design of rules for monetary policy and for macro-prudential policy. Financial amplification in general is destabilizing, because it features a pecuniary externality: Specifically, financial intermediaries do not internalize how their leverage and portfolio choices affect ex post security prices and, in turn, the need for other intermediaries to liquidate assets. Regarding macroprudential policy, moderate reductions in leverage during booms – below the level implied by the market-imposed capital constraint – entail only marginal losses in credit provision while substantially lowering the likelihood of financial distress. Given such a macroprudential rule, the additional stabilization role of monetary policy in financial markets is limited. By contrast, when macroprudential policy is constrained and cannot sufficiently contain leverage, monetary policy can contribute more meaningfully to financial stability. Specifically, it can stimulate the economy beyond what is required for price stability when intermediaries are poorly capitalized – helping to speed recovery from financial distress – and tighten more aggressively when intermediaries are well capitalized, thereby curbing risk-taking and the buildup of financial imbalances.

4. Conclusions

Monetary policy and financial stability interact in important ways. Financial stability is a vital precondition for price stability through its effect on the monetary transmission mechanism, and monetary policy determines the cost and availability of credit thus impacting leverage, financial imbalances and financial stability. Macroprudential policy and bank supervision are the most direct ways to ensure financial stability, while price stability is the primary objective for monetary policy. Nevertheless, the existence of interactions and possible trade-offs creates the need for coordination and joint quantitative analyses of the key issues that link monetary policy and financial stability.

This paper describes key quantitative tools that have been developed to analyse the interactions and trade-offs between price and financial stability at the European Central Bank up until the end of 2025. The emphasis is on clarifying the underlying conceptual framework and providing some basic descriptions of models used. This toolkit can be used to inform on the trade-offs between price and financial stability, both in the short to medium run. This continuous effort to further develop new tools reflects the importance the ECB attaches to analysing financial stability considerations in monitoring the transmission mechanism and the recognition that financial stability is a precondition for price stability.

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