Bridging the Gap: How Banks' Maturity Mismatch Shapes Monetary Policy Transmission *

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Abstract

This study examines how maturity mismatches in banks' balance sheets shape the transmission of monetary policy to credit supply. Linking supervisory data on approximately 1,800 euro area banks to loan-level credit records, we show that the role of maturity mismatches is highly 'shock-specific', settling a long-standing debate in the literature. Mismatches amplify the effects of *unconventional* but not *conventional* monetary policies. Banks with larger maturity gaps reduce lending more sharply following monetary policy surprises regarding quantitative tightening (QT) because valuation losses on long-term assets negatively affect their net worth, causing tighter leverage constraints. A New Keynesian DSGE model with endogenous maturity choices explains this asymmetry: banks with high maturity mismatches are more exposed to long-duration losses that compress net worth and amplify real effects. In contrast, standard policy rate shocks, which mainly affect short-term rates, generate little heterogeneity in lending responses.

JEL codes: E32, E43, E51, E52, G21
Keywords: Monetary Policy Transmission, Maturity Mismatch, Bank Lending Channel, DSGE Model

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1 Introduction

In recent years, unconventional monetary policies have shifted from being exceptional interventions to fundamental elements of central banks' toolkits. Following an unprecedented expansion of Quantitative Easing (QE) in response to the COVID-19 pandemic in 2020, which pushed central bank balance sheets to historic highs, major economies have pivoted to a phase of Quantitative Tightening (QT) or Quantitative Normalisation (QN)[1]. This historic shift calls for a more thorough investigation of the transmission mechanisms of unconventional monetary policies, especially compared to conventional monetary policies (i.e., changes in central banks' policy rates).

This study focuses on the bank lending channel and investigates how a maturity mismatch in banks' balance sheets shapes the transmission of conventional and unconventional monetary policies to the credit supply. The core function of banks is maturity transformation: funding long-term assets (e.g., mortgages) with short(er)-term liabilities (e.g., deposits). This fundamentally implies the existence of a maturity mismatch in banks' balance sheets. We show that this mismatch is a key determinant of how monetary policy affects bank lending and, ultimately, the real economic activity.

We assembled a new unbalanced panel of approximately 1,800 supervised euro area banks using quarterly Supervisory Reporting data between 2018Q3 and 2024Q4. The dataset combines detailed financial statements (FINREP), regulatory ratios (COREP), and a maturity breakdown of inflows and outflows from the COREP "Maturity Ladder". This allows us to construct a bank-specific granular measure of the maturity gap. We merge these data with monthly loan-level information from the euro area credit registry (AnaCredit), linking each bank's financial data to information on its credit supply to firms. To identify exogenous monetary policy movements, we rely on high-frequency monetary policy shocks that capture both conventional and unconventional monetary policy surprises.

Our empirical strategy applies local projections to estimate the cumulative effects of these shocks on bank lending. We interact the banks' maturity gap with each shock in our specification, while controlling for a comprehensive set of bank characteristics (size, capital, liquidity, profitability, leverage, funding structure, and asset quality) and fixed effects (bank and country–sector-time fixed effects).

[1] As referred to by the Member of the Executive Board of the ECB Isabel Schnabel in her speech at the ECB Conference on Money Markets 2025 (Schnabel (2025)).

The results reveal a stark asymmetry: maturity mismatches amplify the transmission of unconventional monetary policy but not that of conventional monetary policy. The role of maturity mismatches is highly 'shock-specific'. Following unexpected changes in policy rates, banks with high and low maturity gaps adjust their lending similarly.

In contrast, when policy shocks affect long-term rates, as in QT episodes, banks with greater maturity mismatches reduce the credit supply more sharply. Quantitatively, we estimate that banks in the upper quartile of the maturity gap distribution decrease lending by up to 0.20 percentage points more per basis point of tightening than those in the lower quartile. This stronger contraction reflects valuation losses on long-duration assets, tightening of leverage constraints, and reduced net worth, which jointly compress the credit supply among banks with higher maturity mismatches.

To better understand the implications of these empirical findings, we extend the New Keynesian DSGE model by including financial intermediaries that endogenously choose their maturity structure. We simulate the economy under two distinct regimes: one populated by banks with high maturity gaps and the other by banks with low maturity gaps. The model is able to reproduce the empirical asymmetry between conventional and unconventional policy shocks. In the high maturity gap regime, a QT shock reduces reserves and tightens the leverage constraint, crowding out private lending and generating deeper and more persistent declines in loans, investment, and output. Welfare losses are also larger, reflecting the greater vulnerability of banks that rely on long-term assets, funded by short-term liabilities. By contrast, under a policy rate shock, cross-regime differences are small and short-lived. As prices adjust, funding conditions and lending dynamics converge, consistent with the limited heterogeneity observed in the data.

To further isolate the uniqueness of this balance sheet mechanism, we also test the model's response to non-monetary shocks. We find that this structure creates 'systemic fragility'. An economy with high maturity gap banks not only amplifies negative shocks but also dampens positive shocks. For instance, in response to a financial liquidity shock, a high-maturity-gap economy is much more vulnerable than a low-maturity-gap economy. Conversely, in response to a positive technology shock, a high-maturity-gap banking system acts as a bottleneck, unable to aggressively expand credit and mute the potential economic boom.

Together, these findings demonstrate that the maturity structure of banks' balance sheets is an important state variable that shapes the transmission of both monetary and non-monetary shocks. From a monetary policy perspective, maturity mismatch acts as a powerful amplifier of balance sheet-based (unconventional) policies, where transmission operates through liquidity and valuation channels but is largely neutral under a rate-based (conventional) policy. Beyond monetary policy, our results show that this structure is critical for macroeconomic stability: a high-maturity-gap banking system significantly amplifies negative financial liquidity shocks while constraining credit expansion during positive technology shocks.

By connecting detailed supervisory data with a structural model of banking behavior, this study highlights the central role of maturity transformation in monetary transmission and overall financial and economic stability. Thus, monitoring and managing maturity mismatches is essential not only for prudential oversight but also for understanding how different policy tools and macroeconomic disturbances propagate through the banking system and the broader economy. The remainder of this paper is organized as follows. Section 2 reviews the related literature and positions this study within the context. Section 3 describes our dataset, detailing the supervisory and loan-level data used to construct the bank-specific maturity gap measure. It also outlines the empirical strategy, which is based on local projections and our identification of monetary policy shocks. Finally, it presents the main empirical results, documenting the differential impact of conventional and unconventional monetary policies. Section 4 develops a New Keynesian DSGE model with an endogenous maturity choice. Section 5 discusses the model's simulation results and explores the effects of non-monetary shocks. Section 6 concludes.

2 Literature Review

The recent conduct of monetary policy, which has seen significant deviations from traditional policy rules Nakamura et al. (2025), has renewed interest in the specific transmission channels of both conventional and unconventional monetary policy tools. This context heightens the need to understand the structural features of the banking system that shape policy impact.

Banks' core function in maturity transformation – funding long-term assets with short-term, callable liabilities – is fundamentally linked to the transmission of monetary policy. The foundational theoretical work of Diamond and Dybvig (1983) established the dual nature of this activity: it is the mechanism by which banks provide liquidity, but simultaneously exposes them to fragility and runs. This inherent balance sheet structure creates a direct link to monetary policy through the interest rate risk channel (Van den Heuvel, 2002). This channel shows that when policy rates rise, banks with a large portfolio of fixed-rate long-term assets funded by short-term deposits suffer from an erosion of net worth as funding costs rise faster than asset yields. In turn, this capital hit can force a contraction in lending, thereby amplifying the intended policy tightening.

However, this theoretical link has been met with nuanced and seemingly contradictory empirical literature on whether maturity mismatches ultimately amplify or attenuate monetary policy. A large and growing body of work provides clear evidence of **amplification**, stemming from both sides of the balance sheet. On the asset side, Purnanandam (2007) showed that US banks with large, *unhedged* maturity gaps "cut their lending more" after rate hikes. This amplification mechanism is strongly supported by recent analyses of the 2022–2023 global tightening cycle. Using granular data, Coulier et al. (2023) find that euro area banks with a larger duration gap significantly "contract their lending relatively more when interest rates increase." This effect is economically meaningful and mitigated for banks that actively use interest rate derivatives to hedge their exposure. Separately, on the liability side, (Drechsler et al., 2017) shows that banks with market power in deposit markets also amplify tightening by widening deposit spreads, leading to deposit outflows and a contraction in lending.

In contrast, other studies find evidence of **attenuation**. Flannery and James (1984) provided early evidence that bank stock prices react to interest rate changes in a manner consistent with their maturity gaps. More recently, English et al. (2018) found that banks with larger maturity gaps actually see profits rising from a steepening yield curve. Similarly, Gomez et al. (2021), using a US bank panel, found that banks with a positive "income gap" (assets repricing faster than liabilities) actually *reduced lending less* following a Fed tightening, suggesting that their balance sheet structure acted as a buffer. This debate extends to unconventional policy; for example, during the negative interest rate policy (NIRP) era, high-deposit banks were unable to pass on negative rates, which squeezed their profits and perversely caused them to *reduce* lending (Heider et al., 2019).

Building on this foundation, our study resolves the apparent contradictions in the literature by making two contributions. First, we introduce a novel bank-level maturity gap indicator from the COREP Maturity Ladder to measure maturity transformation more precisely, using a wider sample of banks. Second, we demonstrate that the role of this gap in transmission is highly **shock-specific**, which explains the contradictory findings in the literature. We show that the transmission of conventional policy shocks, which mainly affect short-term rates, is rather homogeneous. using high–frequency shocks from the EA–MPD (Altavilla et al., 2019), we find that lending responses are statistically similar across all maturity gap bins. In contrast, we find that unconventional (QE/QT) shocks, which raise long-term rates, generate substantial and persistent heterogeneity, with high-maturity-gap banks cutting credit supply significantly more than low-maturity-gap banks. Our analysis relies on a novel dataset matching euro area supervisory data (FINREP/COREP) to loan–level AnaCredit from 2018 to 2025, a period uniquely spanning the entire path from negative rates to QT. This empirical design allows us to separate level (short–end) from term–premium (long–end) news and map them into a heterogeneous bank supply.

The related literature finds that bank equity prices react asymmetrically to interest rate shocks, consistent with our shock–specific view. English et al. (2018) show bank equities fall with higher expected short–rate paths and steeper curves, with the balance sheet structure explaining the cross–section. Paul (2022) finds that bank equity reacts more negatively than nonfinancials to short-term rate hikes but more positively to term premia increases, especially for banks with larger maturity gaps. We show that these market–price asymmetries have real consequences for the credit–quantity margin. Exploiting loan–level supply measures, we demonstrate that they translate into materially different lending paths under long–end versus short–end policy surprises.

Theoretically, recent literature has begun to connect these different findings by examining how banks actively manage maturity mismatches. While canonical DSGE models (Gertler and Kiyotaki, 2010b; Bernanke et al., 1999) often ignore this mismatch or treat it as a fixed parameter, the newest models focus on how banks actively choose the length of their assets (Wang, 2023; Varraso, 2024). This new approach offers a clear and testable story. A recent model by Varraso (2024) shows that long periods of low interest rates push banks to "reach for yield" by buying longer-term assets. In a related paper, Di Tella and Kurlat (2021) model this active choice, proposing that banks use the maturity gap as an optimal dynamic hedging tool. They built a model in which banks provide liquidity by issuing deposits that are close substitutes for currency. In a related area, other models by (Gertler and Karadi, 2011) and (Gertler and Karadi, 2013) explain how unconventional policies, such as Quantitative Easing (QE), work. They showed that QE can boost the economy even when interest rates are not zero, mainly by easing the constraints on banks. A unifying view suggests that QE can replace traditional policy when rates hit zero, but reversing it (Quantitative Tightening, or QT) creates its own set of challenges (Sims and Wu, 2021), highlighting the need for a theoretical framework that endogenizes banks' maturity choice in response to different policy regimes.

To formalize our empirical findings and bridge this empirical–theoretical gap, we build a New Keynesian DSGE model that includes a key feature: banks actively choose their maturity gaps. The model delivers and explains the asymmetry we find empirically: when long rates rise because of QT/long–end news via unconventional shocks, high–maturity gap banks suffer valuation losses, tighter leverage, and sharper credit contractions; when short rates rise via conventional shocks, funding costs reprice broadly, and cross–bank heterogeneity is small. We further show that technology and liquidity shocks have distinct implications: maturity mismatches bottleneck expansion under positive technology shocks but amplify liquidity squeezes, mirroring our reduced–form evidence. The microestimated gap targets discipline the model's maturity block, allowing for micro–to–macro counterfactuals for the policy mix (conventional vs. unconventional monetary policies).

3 Empirical Analysis

For our empirical analysis, we construct a novel panel dataset covering around 1,800 supervised euro area banks and collect information from three distinct data sources: Supervisory Reporting data and euro area credit registry (AnaCredit) data from the European Central Bank (ECB), and the Euro Area Monetary Policy Event-Study Database (EA-MPD) from Altavilla et al. (2019). The final dataset is at a monthly frequency and covers a period of six and a half years, from October 2018 to March 2025. It contains the amount of loans outstanding at the bank and counterparty sector of economic activity (NACE sector) level at the end of each month from AnaCredit, a quarterly series of banks' regulatory ratios as well as balance sheet amounts, and income statement figures from Supervisory Reporting data, a measure of maturity mismatch between banks' assets and liabilities, and monthly monetary policy shocks inferred from the EA-MPD. In the next two subsections, we describe in more detail the maturity mismatch measure and the monetary policy shocks that we have used in our analysis, since these are crucial variables for our identification strategy. We refer the reader to Table 4 in Appendix C for more information on the construction of the other variables, which are used as controls in the context of this study.

3.1 A maturity gap measure

To test the hypothesis that banks with different levels of maturity mismatch between their assets and liabilities transmit monetary policy shocks differently, we construct a measure that proxies for the exposure of a bank's net worth to changes in interest rates.

In finance, this measure is generally represented by the Macaulay duration (Macaulay (1938)), which applies to the context of portfolio valuation and interest rate sensitivity. Following the same logic, some studies have computed a net duration measure, known as the *duration gap*, when assessing banks' net exposure to interest rate risk (e.g., Coulier et al. (2023), Esposito et al. (2015)). Other studies have instead relied on a different indicator, the *maturity gap* (Paul (2022)). Although we believe that the duration gap is technically a more accurate measure of the sensitivity of banks' balance sheets to interest rate changes, we found it less suitable in the context of our analysis. This is because the duration gap is mechanically affected by changes in interest rates, since, based on its formula, risk-free rates are used to compute the maturity-weighted present value of the cash flows from assets and liabilities. Considering that our model specifications require lagged effects from monetary policy shocks, we preferred to avoid the introduction of spurious correlations in our identification strategy because of the chosen measure of banks' maturity mismatch in assets and liabilities. Therefore, we privileged the maturity gap indicator for our analysis, following (Paul (2022)).

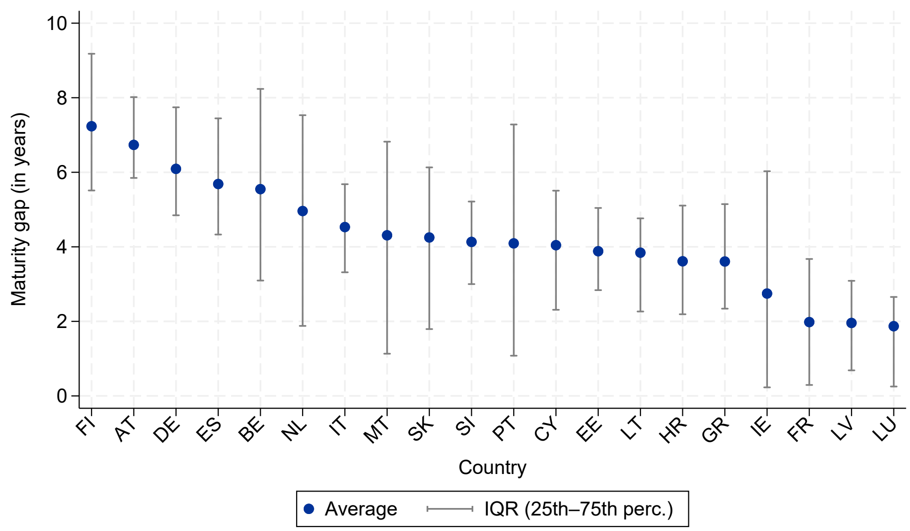
We construct the maturity gap measure for our sample of banks based on the supervisory reporting data collected within the Common Reporting (COREP) framework, specifically in template C66.01 "Maturity Ladder." In this template, banks provide the amount of inflows and outflows from their assets, liabilities, and off-balance sheet items split into 21 maturity buckets (from "Overnight" to "Above 5 years"), depending on their residual maturity. We used this information to compute the maturity-weighted sum of inflows minus the maturity-weighted sum of outflows. This value is normalized by the total assets of the bank to obtain a maturity gap. For bank i in quarter t, the maturity gap is formally calculated as follows:

$$MatGap_{i,t} = \sum_{k=0}^{21} \frac{\tau_k(Inflows_{i,t,k} - Outflows_{i,t,k})}{TotAssets_{i,t}}$$

with τ_k being the maturity of the inflows and outflows reported in maturity bucket k.

It is worth noting that euro area banks have different reporting requirements for the Maturity Ladder template in terms of frequency. Significant institutions are generally required to submit their reports every month, while smaller and less significant institutions must submit them every quarter. We chose to compute quarterly series of maturity gaps to cover the largest possible sample of reporting institutions and euro area countries. Figure 1 displays the average maturity gap and the interquartile range (IQR) for all euro area countries in the sample. Although the average maturity gap for ten out of the 20 countries is within the range of 3.5-4.5 years, there is a significant variance in the maturity gap across the remaining jurisdictions: from below two years for the average bank in Luxembourg up to more than seven years for the average bank in Finland. Moreover, banks' maturity gaps vary substantially also within each country. The largest IQR is recorded in Portugal (approximately 6 years) and the lowest in Austria (just above 2 years).

Figure 1: Bank maturity gap distribution within and across euro area countries



This heterogeneity likely reflects underlying differences in the composition of national banking sectors along several dimensions: size (e.g., prevalence of small cooperative banks versus large universal banks), specialization (retail-focused versus corporate or investment banking models), balance-sheet strategies, and, more generally, banks' business models. Regulatory, legal, and institutional factors could also reinforce the differences observed across countries. From the perspective of our empirical analysis (presented in Section 3.3), the presence of a broad dispersion in maturity gaps is advantageous. First, it increases the statistical power to detect the relationship between the maturity gap and our variables of interest. Second, it improves external validity: results are less likely to be driven by a narrow subset of banks and more likely to generalize across different business models and institutional frameworks. From the perspective of our research question, the cross-country variance in the maturity gap reinforces, if anything, the interest in whether this interacts with monetary policy transmission (after controlling for bank-specific characteristics and balance sheet structure). If so, it may have policy implications. Because all euro area member states are subject to a common monetary policy, policymakers should account for banks' ex-ante maturity gaps when designing and assessing new policies. The pass-through in terms of pace and magnitude might be differentiated with potentially uneven effects across member states when it comes to credit supply, inflation, and broader macroeconomic outcomes.

3.2 The euro area monetary policy shocks

Monetary policy shocks in the euro area represent the key exogenous element in our identification strategy. To address our research question, we incorporate these shocks into our model specification by interacting them with the maturity-gap measure. Specifically, we use the Euro Area Monetary Policy Event-Study Database (EA-MPD), which provides comprehensive data on high-frequency financial market surprises in response to European Central Bank (ECB) monetary policy announcements. This database, developed by Altavilla et al. (2019), captures changes in asset prices within narrowly defined time windows around the ECB's press releases and press conferences of the ECB President. By focusing on these narrow windows, the dataset minimizes noise, thereby increasing the likelihood of capturing the causal relationships between policy announcements and observed asset price movements.

Altavilla et al. (2019) identify four monetary policy shocks, of which we primarily employ two: the *Target* shock and the *Quantitative Easing* (QE/QT) shock.[2] The target shock reflects unexpected changes at the short end of the risk-free curve, while the QT shock captures surprises affecting long-term yields and risk premia, which are typically associated with adjustments in market expectations regarding the ECB's non-standard monetary policy measures. As in the original paper, we extract these shocks by estimating a factor model through principal components applied to the matrix of yield changes and then rotating the factors to identify economically meaningful orthogonal policy shocks. This rotation is essential for disentangling the various dimensions of monetary policy surprises. The target shock is derived from the single significant factor identified in the press-release window, with its primary impact concentrated at the very short end of the yield curve (i.e., 1-month maturity) and diminishing at longer maturities.

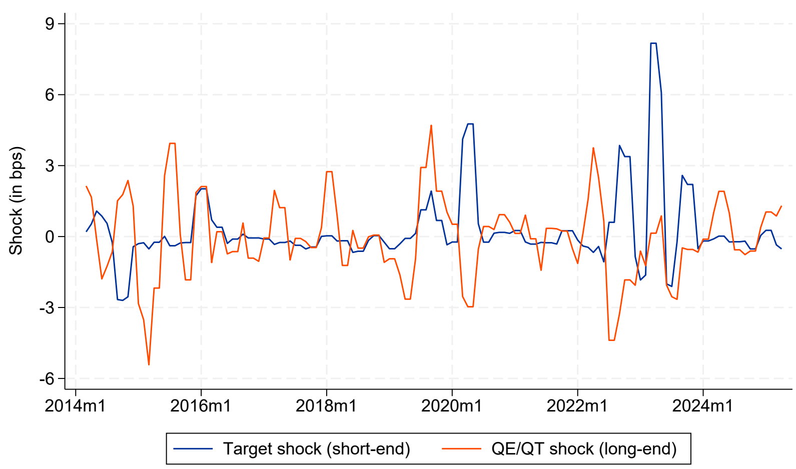
For simplicity and consistency, we define the target shock series as the high-frequency changes in the 1-month OIS rate during the press-release window, as these changes are nearly perfectly correlated with the identified factor. Meanwhile, QT shock is associated with the third significant factor observed in the press conference window, subject to specific restrictions. These include orthogonality to the target shock and other iden-

[2]The authors refer to positive QE shocks as tightening surprises related to non-standard monetary policies and negative QE shocks as easing surprises. Throughout this paper we discuss the results of positive changes in QE shocks, thus we mostly refer to them as *QT* shocks, i.e. *Quantitative Tightening* shocks.

tified shocks, statistical insignificance prior to the Great Financial Crisis (before the advent of unconventional monetary policies), and an increasing factor loading with maturity, peaking at the long end of the yield curve (10-year maturity). The QT shock is rescaled to produce a one-unit effect on the 10-year OIS, with its sign adjusted for interpretability. The resulting monetary policy shocks, expressed in basis points, are interpreted as tightening (positive values) or easing (negative values) policy surprises. For consistency with our monthly model frequency, we extend the shocks from the ECB Governing Council meeting schedule by filling the non-meeting months with zero values.

Figure 2 illustrates the three-month moving sum of the target and QE/QT shocks since 2014. Between 2014 and 2020, QE/QT shocks were more frequent and sizeable (in absolute terms) than other types of shocks, largely reflecting the heightened focus of market participants on unconventional monetary policies as key ECB interest rates approached the effective lower bound. Conversely, from 2022 onwards, the prominence of target shocks re-emerged, driven by surprises related to the timing and pace of the ECB's tightening cycle first and easing cycle later.

Figure 2: Rotated monetary policy shocks (3-months moving sum)



In the following sections of this paper, notably in Section 4, we rely on the economic interpretation that QT shocks capture changes in market expectations concerning the ECB's unconventional monetary policies and, in particular, central bank balance sheet policies, such as the size and duration of asset purchase programs and reinvestments of the principal amounts. This is consistent with the interpretation provided by Altavilla et al. (2019) and the nature of these policies, which aim to steer rates at longer maturities. Instead, Target shocks are interpreted as surprises in market expectations concerning conventional monetary policies, that is, concerning the level of short-term yields steered by the ECB's key interest rates.

3.3 Interaction between banks' maturity gap & monetary policy transmission

Using the novel panel dataset that we constructed and enriched with monetary policy shocks and the bank-level maturity gap series, we empirically study whether banks' heterogeneity in the maturity gap matters for the transmission of monetary policy to the credit supply. The dataset we have available for this study presents the advantage of covering a time span where both a tightening and an easing cycle took place as well as multiple ECB decisions in terms of unconventional monetary policies. In addition, contrary to other studies, we have data from both significant institutions (SIs) and less significant institutions (LSIs). Thus, we can assess a broader spectrum of heterogeneous banks and ensure that all euro-area countries are effectively represented. In this regard, the results of our study are likely to have higher external validity than analyses in which the sample was composed of relatively homogeneous banks. Moreover, as we keep the borrower's economic activity level in our data, we can also control for the loan demand component.

Table 1 summarizes the dataset used in our analysis. [3] The data are at the bank-month-borrower's economic activity level, containing an unbalanced panel of 1,803 banks and a total of 802,311 observations. The firm economic sectors considered in the sample are manufacturing, construction, retail trade, transportation, accommodation, information and communication, professional, scientific and technical activities, and administrative and support service activities. Notably, financial services and public/government-related activities were excluded. Monthly loan growth rates are constructed from outstanding loans to firms as the first difference in the logarithmic value of these amounts.

[3] Minimum and maximum values are excluded from the summary statistics because in our analysis we winsorised the data to attenuate potential outlier effects. Therefore, the 1st and 99th percentiles can be respectively considered as the minimum and maximum values of our dataset.

Table 1: Summary Statistics: Loan growth, monetary policy shocks and controls

	Observations	Mean	SD	P1	P25	P75	P99
Dependent variable:							
Δlog(loans)(%)	785,737	0.7	27.1	-55.0	-2.0	2.5	66.6
Monetary policy shocks:							
QE/QT shock (bps)	802,311	-0.1	0.9	-2.9	-0.4	0.2	2.5
Target shock (bps)	802,311	0.2	1.2	-1.9	-0.2	0.0	8.0
Controls:							
Maturity gap (years)	795,006	5.9	2.5	-0.5	4.6	7.7	11.0
log(total assets)	799,550	7.6	1.7	4.4	6.6	8.4	13.2
CET1 ratio (%)	800,993	17.7	6.7	10.3	14.2	19.1	47.1
Liq. cov. ratio (%)	800,546	236.2	232.4	74.3	141.8	228.0	1626.2
Leverage ratio (%)	800,870	9.4	3.7	3.7	7.4	10.6	24.4
Return on assets (%)	797,268	0.4	0.6	-1.9	0.1	0.6	2.3
NPL ratio (%)	791,271	3.4	5.1	0.1	1.3	3.4	36.6
Loan-to-deposit ratio (%)	792,899	162.4	1063.5	24.5	72.5	104.4	1893.3
Deposit ratio (%)	792,915	68.4	17.6	2.0	64.7	78.9	88.8

We run a preliminary analysis by regressing loan growth rates over a selected set of fixed effects. The aim of this exercise is to understand whether banks' heterogeneity is a relevant dimension to explain the observed loan growth rates. For instance, if most of the variation in loan growth rates is found to be explained by the borrower's (firm) sector-month fixed effects, and only a small residual part by banks' fixed effects (with or without time interactions), we could argue that banks' heterogeneity is a less interesting dimension to look at and that loan demand is a major driver of loan growth. However, the results in Table 2 suggest the opposite. The regression that includes only firm sector-time fixed effects (column 6) covers a negligible share of the loan growth variance ($R^2 = 0.43\%$), while bank-time fixed effects explain a quarter of the entire variance ($R^2 = 24.99\%$, column 5). The interactions between cross-sectional dimensions and time seem necessary to explain lending dynamics. This can be inferred from the result in column 4: including bank fixed effects, time fixed effects, and borrower's economic activity fixed effects without interactions yields a small R^2 of 0.43%. It could be argued that the outcome, including bank x time fixed effects, embeds country-specific dynamics rather than bank idiosyncratic ones. To test this hypothesis, we consider two additional specifications in columns 8 and 9, including country (i.e., bank location) ×

time fixed effects and country-time-borrower's sector fixed effects. The results are an R^2 of 0.77% for the former specification and an R^2 of 2.78% for the latter. Therefore, while country-specific dynamics have non-negligible effects on loan growth rates, these outcomes suggest that they are largely outweighed by bank idiosyncratic reactions to shocks. We also check whether the relationship between banks and specific firm sectors explains a relevant share of the variation in loan growth rates (see column 10). For instance, firm sectors with consistently higher loan demand may be tied to a specific subset of banks, explaining the differences in loan growth observed across banks, time, and firm sectors. While the bank-firm sector dimension is non-negligible (R^2 of 1.43%), the bank-firm sector ties do not explain a large part of the story.

We can conclude from this preliminary analysis that the bank-time dimension is the most interesting to explore when explaining the dynamics of loan growth rates. Specifically, the idiosyncratic features of banks seem to matter in explaining their credit supply following shocks that hit them.

Table 2: R^2 of loan growth regressions on selected fixed effects

R^2 (in %)	0.29	0.04	0.10	0.43	24.99	0.43	25.32	0.77	2.78	1.43
Bank FE	x			x						
Firm sector FE		x		x						
Time FE			x	x						x
Bank × Time FE					x		x			
Firm sector × Time FE						x	x			
Country × Time FE								x		
Country × Time × Firm sector FE									x	
Bank × Firm sector FE										x

Following the above result, we focus on assessing the relevance of banks' maturity mismatch, among other banks' characteristics, in the transmission of monetary policy shocks to lending rates. We use an econometric specification that relies on the maturity gap measure as a proxy for banks' maturity mismatch in assets and liabilities and on the exogenous target and QT shocks described in the previous subsection. Specifically, we identify the effect of these monetary policy shocks on loan growth based on local projections, as in Jordà (2005). We regress the cumulative loan growth rate on each monetary policy shock interacted with the banks' maturity gap in the quarter before the shock materialized and a set of controls for bank size, liquidity, profitability, capitalization, leverage, asset quality, and funding structure. We include country-month-firm sector fixed effects and bank fixed effects. With the former fixed effects, we control for country-specific developments that, on average, affect all banks within a country in a similar way — such as regulatory, legal, or institutional changes, country-level shifts in funding conditions, or changes in competitive pressure — and for sector-specific fluctuations in loan demand within the bank's country, including industry-level shocks that influence firms' borrowing volumes. With bank fixed effects, we instead control for any time-invariant bank characteristics that explain loan growth levels and are potentially correlated with the maturity gap. We run the local projections on a two-year horizon (i.e., 24 months). We allow for the lagged effects of monetary policy shocks on cumulative loan growth by including all interactions with lagged shocks of up to 12 months. We use standard errors clustered at the bank and borrower sector-time levels. In summary, the regression specification is as follows:

$$\begin{aligned}\Delta y_{i,s,t+h} = \alpha_i + \lambda_{c,s,t} + \gamma_h GAP_{i,t-1} + \theta_{1h} X_{i,t-1} \\ + \sum_{l=0}^{12} \delta_h^{(l)} (MP_{t-l} \times GAP_{i,t-l-1}) + \sum_{l=0}^{12} \theta_{2h}^{(l)} (MP_{t-l} \times X_{i,t-l-1}) + \varepsilon_{i,s,t+h}\end{aligned} \tag{1}$$

where,

- $\Delta y_{i,s,t+h}$ is the cumulative bank-firm sector level loan growth rate between t and $t+h$, for $h = (0, ..., 24)$
- MP_{t-l} is the considered monetary policy shock (either target or QT) at lag $l = (0, ..., 12)$
- $GAP_{i,t-l-1}$ is the lagged maturity gap, at lag $l-1 = (-1, ..., 11)$
- $X_{i,t-1}$ is the vector of lagged bank-level controls
- α_i are the bank fixed effects, $\lambda_{c,s,t}$ are the country-sector-time fixed effects

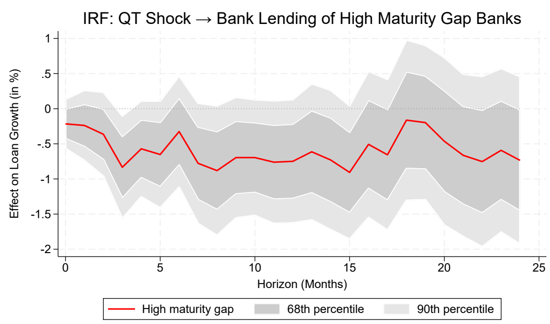
Since local projections require the h-period lead value of the loans outstanding to be in the dataset, as h increases, the number of observations in each sub-regression decreases. To avoid this compositional effect producing instability in our estimates, we perform the baseline regressions on the subsample of observations for which we have a lead of loans outstanding up to horizon $h = 24$.[4] From the specification above, we are

[4]The restricted sample contains 471,215 observations. We provide nonetheless also the results on the "full sample" in Appendix C.

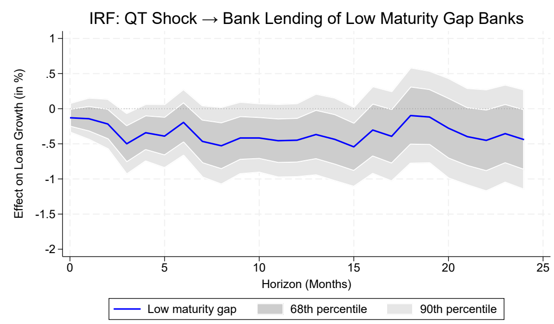
interested in the estimated values for $\delta_h^{(0)}$. These represent the nonlinear impact of the monetary policy shock on the cumulative loan growth up to the horizon h attributable to banks' heterogeneity in their maturity gap. In terms of interpretation, a positive estimate $\hat{\delta}_h^{(0)}$ would suggest that banks with higher maturity gaps increase their lending more than banks with lower maturity gaps after monetary policy tightening and decrease their lending more than banks with lower maturity gaps following an easing. A negative estimate would imply the opposite interpretation.

Across all horizons h we obtain a negative $\hat{\delta}_h^{(0)}$ associated with an unconventional monetary policy shock (a QT shock), with an average of -0.07%. Conversely, we find a statistically insignificant estimate for $\hat{\delta}_h^{(0)}$ associated with a conventional monetary policy shock (i.e., target shock) across the 24-month horizon, with a small but positive average value (0.02%). In figures 3a, 3b and 3c we show the implied difference in cumulative loan growth for banks at the 25% versus 75% percentile of the maturity gap distribution in our sample (around three years of difference in the maturity gap), following a one-basis-point tightening shock from unconventional policies (QT shock). Across the 24-month horizon, the difference ranges between -0.07% and -0.36% and is significant at the 68% percentile level until the sixteenth month following the shock. The corresponding results for a one basis point tightening target shock are included in Appendix C (see figures 9a, 9b and 9c) and show that the difference in loan growth responses between banks at the 25th and 75th percentiles of the maturity gap distribution is rather insignificant. In the same Appendix, the results for the full sample are also reported. Although they display - as expected - noisier impulse responses, the outcome is broadly similar under a QT shock (see figure 10c). Instead, a target shock yields a higher loan growth for the high maturity gap banks compared to the low maturity gap banks when considering the full sample (see figure 11c). We consider the empirical results under the target shock to be less robust because they are not fully consistent between the restricted and full samples. Nevertheless, they are helpful in ruling out the hypothesis that banks with high maturity gaps decrease their loan supply more strongly than banks with low maturity gaps following a conventional monetary policy tightening shock.

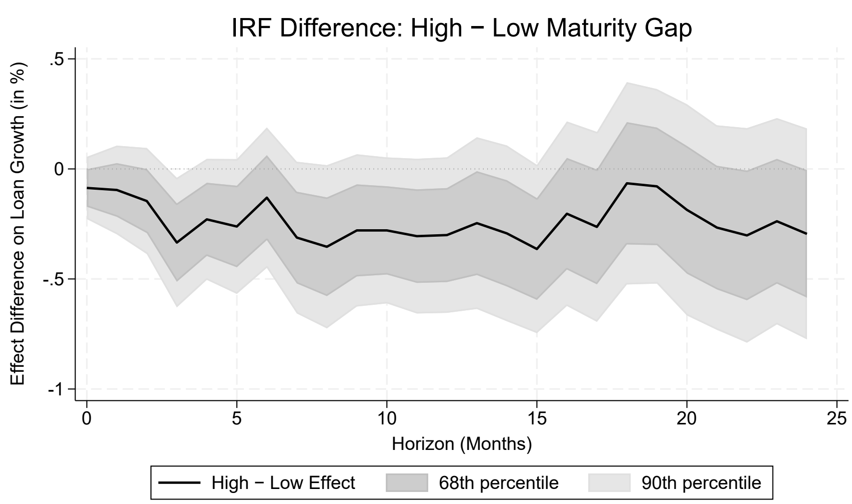
Figure 3: Analysis of bank lending responses to a QT shock, comparing high and low maturity gap banks - Restricted sample



(a) *Response of lending from high maturity gap banks to QT shock*



(b) *Response of lending from low maturity gap banks to QT shock*



(c) *Difference in bank lending response between banks with high vs low maturity gap under a QT shock*

Based on these findings, we can conclude that maturity gaps in banks' balance sheets *amplify* the impact of unconventional monetary policy shocks. Banks with a higher maturity gap decrease their lending more than those with a lower maturity gap after a tightening and increase their lending more compared to banks with a lower maturity gap after an easing policy. The difference is significant. In contrast, maturity gaps in banks' balance sheets do not amplify the impact of conventional monetary policy shocks, suggesting that these shocks have a rather more homogeneous effect across banks that hold different interest rate exposures.

To better understand the implications of this empirical result for real economic variables, notably inflation, economic growth, and investment, we propose a New Keynesian DSGE model with financial intermediaries that endogenously choose the maturity structure of their balance sheets. The model and impulse response functions of the calibrated conventional and unconventional monetary policy shocks are presented in the next section.

4 The Model

This section outlines the model's primary components: households, labor unions, various production firms, financial intermediaries, a fiscal authority, and a central bank. While the model shares many similarities with canonical medium-scale DSGE models (e.g., Christiano et al. (2005) and Smets and Wouters (2007)), it diverges in several key aspects. First, we assume that production firms use perpetual bonds (Woodford (2001)) to partially finance their new investments. Following Gertler and Karadi (2011);Gertler and Karadi (2013), financial intermediaries fund their operations using net worth and short-term debt (deposits), while their assets consist of long-term firm and government bonds and central bank reserves. Markets are segmented; as households are precluded from holding government bonds, a costly enforcement problem creates an endogenous leverage constraint for intermediaries, resulting in excess returns. This constraint, combined with the requirement for firms to issue long-term bonds for investment, generates an "investment wedge." This wedge provides a channel for QE/QT-type policies to produce real economic effects. Furthermore, the central bank finances its operations by issuing interest-bearing reserves, and the model incorporates an endogenous choice for banks' maturity gap. The following summary focuses on the elements of the model relevant to both conventional and unconventional monetary policies. A comprehensive description of the full model is provided in the Appendix A.

4.1 Model Framework and Innovation:

Our framework extends the New Keynesian DSGE model, building on the work of Gertler and Karadi (2011) and Gertler and Karadi (2013), as well as the recent contribution by Sims and Wu (2021). Its primary innovation is the endogenous choice of the banks' maturity gap. Banks in the model begin with distinct steady-state maturity gaps and the corresponding balance sheets. They can then adjust this gap in response to exogenous conventional and unconventional monetary policy shocks. We define the maturity gap as the difference between maturity-weighted assets and maturity-weighted liabilities, scaled by total assets for comparability. We analyze the economy's dynamics by calibrating different starting steady-state maturity gaps, specifically comparing high (32 quarters) and low (16 quarters) maturity gap scenarios, consistent with the empirical analysis. The model includes representative households that consume, supply labor, pay taxes, and save through deposits. The labor market has two layers: labor unions purchase labor from households and a representative labor packer aggregates this differentiated labor for final production, subject to Calvo-style nominal rigidities. Production is multi-staged: a representative wholesale firm uses capital and labor to create output, which is then purchased by a continuum of retail firms. These retailers repackage wholesale output and sell it to a competitive final goods firm. Capital goods producers create new physical capital and the fiscal authority consumes an exogenous, stochastic amount of final output (G_t). This spending is financed by lump-sum taxes, transfers from the central bank, and issuance of nominal bonds ($B_{G,t}$). Due to financial intermediary frictions, Ricardian Equivalence fails, making the tax-versus-bond financing mix relevant. For simplification, we assume a fixed quantity of real government bonds ($\bar{b}_G$), meaning that nominal bonds ($B_{G,t}$) grow at price level (P_t): $B_{G,t} = P_t\bar{b}_G$. Lump-sum taxes adjust endogenously to satisfy the government's budget constraints in each period. The model is driven by five exogenous variables that follow the AR(1) process in logs: productivity (A_t), government spending (G_t), a liquidity process (θ_t), a decay process for private loans (κ^f), and a decay process for government bonds (κ^b).

4.2 Implications of Maturity Gap Heterogeneity:

This modelling innovation enables a comparison of how economies with different maturity structures respond to aggregate shocks and policy interventions. We analyze the implications for real activity, inflation, and welfare, focusing on the transmission of monetary and non-monetary policies via balance sheet channels, which constrain intermediary leverage and cause haircuts to increase with asset duration. This creates an endogenous maturity gap between banks' assets and liabilities. Our extension introduces heterogeneity by analyzing alternative steady states characterized by high versus low bank maturity gaps, holding all other structural features constant. The maturity gap is computed analogously to our empirical analysis: it is the maturity-weighted value of assets (loans, government bonds, and reserves) minus the maturity-weighted value of liabilities (deposits) scaled by total assets.

4.3 Financial Intermediaries

4.3.1 Maturity Gap

The central novelty of this model lies in its definition of long-term bonds and their role in creating an endogenous maturity gap. We specify that both private firms (wholesale producers) and the government finance their activities by issuing long-term bonds.

4.3.2 Bond structure

We follow Woodford (2001) and model these bonds as perpetuities with geometrically decaying coupon payments. This structure is defined by the decay parameter, $\kappa \in [0, 1]$. A key innovation here is that we assign distinct decay parameters, and thus distinct maturities, to private and government debts. Private Bonds: Issued by firms, their coupons decay at a rate of κ^f. A new one-unit bond issued at price Q_t obligates the firm to pay one dollar in $t+1$, κ^f in $t+2$, $(\kappa^f)^2$ in $t+3$, and so on. Government Bonds: Issued by the fiscal authority, their coupons decay at a rate of κ^b, following an identical payment structure as that of private bonds. This perpetual structure was analytically convenient. We need only track the total outstanding coupon liability from the previous period (e.g., F_{t-1} for firms) and the value of new issuances ($CF_{f,t} = F_t - \kappa^f F_{t-1}$). The total liability evolves as $F_{t-1} = CF_{t-1} + \kappa^f CF_{t-2} + (\kappa^f)^2 CF_{t-3} + \cdots$. The total market value of all outstanding private bonds is $Q_t F_{i,t}$. The same logic applies to government bonds (using $B_{G,t}$, $CB_{G,t}$, κ^b, and $Q_{B,t}$).

4.3.3 Bond maturity (Duration)

The κ parameter directly determines the effective maturity or duration of each bond. A κ value closer to 1 implies slower decay, and thus a longer-maturity bond. The maturity for each bond type is as follows: Private Bond (loan) Maturity: $M_t^f = 1/(1-\kappa^f)$ Government Bond Maturity: $M_t^b = 1/(1-\kappa^b)$.

4.3.4 Endogenous Maturity Gap

Using these definitions, we can construct a maturity gap for financial intermediaries. This variable, a core part of our analysis, becomes endogenous as it depends on the bank's optimal portfolio choices in each period. This gap measures the mismatch between the average maturity of a bank's assets and liabilities scaled by total assets. We calculate it as

$$Maturity\ Gap_t = \frac{f_t \cdot M_t^f + b_t \cdot M_t^b + re_t \cdot M_t^{re} - d_t \cdot M_t^D}{Total\ Assets_t} \tag{2}$$

In this equation, $Loans_t$ represents banks' holdings of private bonds issued by wholesale firms. M_t^L and M_t^b are the aforementioned long-term bond maturities. M_t^{re} and M_t^D are the maturities of the reserves and deposits, respectively (typically assumed to be short term; in our case, they are one). Having established this framework for defining bond duration and the resulting maturity gap, we now turn to the financial intermediaries' optimization problem.

4.3.5 Financial Intermediaries

The structure of the financial intermediaries in this study follows the framework of Gertler and Karadi (2011) and Gertler and Karadi (2013). We assume that a constant number of intermediaries exists in every period. To finance their operations, these intermediaries use their net worth ($N_{i,t}$) and deposits collected from the households ($D_{i,t}$). In each period, a random portion $(1-\sigma)$ of existing intermediaries exits the market. These exiting intermediaries return accumulated net worth to their owners (households). They are immediately replaced by an equal number of new intermediaries starting with a fixed amount of funds (X) provided by their household owners. On the asset side of their balance sheets, intermediaries hold private bonds ($F_{i,t}$), government bonds ($B_{i,t}$), and interest-bearing reserves ($RE_{i,t}$) in the central bank. The balance sheet condition for a representative intermediary is

$$Q_t F_{i,t} + Q_{B,t} B_{i,t} + RE_{i,t} = D_{i,t} + N_{i,t} \tag{3}$$

Intermediaries grow their net worth until they exit the market stochastically. For those that survive, their net worth evolves according to the following equation:

$$\begin{aligned} N_{i,t} =& (R_t^F - R_{t-1}^d) Q_{t-1} F_{i,t-1} + (R_t^B - R_{t-1}^d) Q_{B,t-1} B_{i,t-1} \\ &+ (R_{t-1}^{re} - R_{t-1}^d) RE_{i,t-1} + R_{t-1}^d N_{i,t-1} \end{aligned} \tag{4}$$

R_{t-1}^{re} is the interest rate on reserves set by the central bank and known ahead of time. R_{t-1}^d is the market-based interest rate for deposits and the first three terms in the equation show the excess returns earned by the bank. This is the difference between what it earns on its assets (private bonds, government bonds, and reserves) and what it must pay out in interest on the deposits it holds. The last term shows the cost savings the bank receives from using its own net worth to fund its activities, since it does not have to pay deposit interest to that money; the terms R_t^F and R_t^B represent the total realized returns from holding private and government bonds, respectively, and are defined as

$$R_t^F = \frac{1 + \kappa^f Q_t}{Q_{t-1}} \tag{5}$$

$$R_t^B = \frac{1 + \kappa^b Q_{B,t}}{Q_{B,t-1}} \tag{6}$$

An intermediary aims to maximize the expected value of its net worth until it exists, where the expected terminal net worth is discounted using the household discount factor, $\Lambda_{t,t+1}$. Let us consider an intermediary that still operates after period t. Each period survives with probability σ and exits with probability $1 - \sigma$. Therefore, the probability that it exits at t+1 is $1 - \sigma$, at t+2 is $\sigma(1 - \sigma)$, and so on. Accordingly, its objective is as follows:

$$V_{i,t} = \max(1-\sigma)E_t \sum_{j=1}^{\infty} \sigma^{j-1}\Lambda_{t,t+j} n_{i,t+j}, \tag{7}$$

where $n_{i,t} = N_{i,t}/P_t$ is the real net worth and P_t is the price of the final output.

Following Gertler and Karadi (2011) and Gertler and Karadi (2013), financial institutions face a key constraint known as the "costly enforcement problem. This problem arises because the intermediary can choose to abandon its operations and simply divert (or steal) some of the assets it manages. If this were to happen, depositors who lent money would only be able to recover a portion of their funds, whereas the intermediary would retain the rest.

Depositors must be willing to provide funds for the system to operate. This happens only if the intermediary does not have an incentive to steal assets. We refer to this specific act of diverting funds as "going into bankruptcy." Therefore:

$$V_{i,t} \geq \theta_t(Q_t f_{i,t} + \Delta Q_{B,t} b_{i,t}) \tag{8}$$

The aforementioned inequality compares intermediaries' costs and benefits. The left side of the equation shows the value of operating the business honestly, while the right side shows the (real) value that the intermediary can maintain if it chooses to default. If it decides to divert, the amount it gets away depends on assets. It can maintain the stochastic fraction θ_t of its private bonds. However, for government bonds, it can only maintain a smaller fraction, $\theta_t\Delta$ (because Δ is 1 or less). This assumption simply implies that it is easier to divert private bonds than government bonds. We assume that the third asset–reserves–is fully recoverable by depositors and cannot be stolen. We treat this fraction θ_t as both stochastic and exogenous. This can be seen as a "liquidity shock." When θ_t increases, the intermediary can divert a larger portion of its assets, which means that depositors would recover less. This in turn makes depositors less willing to provide funds. This reluctance to lend is what causes interest rate spreads to rise, a classic sign of a liquidity crisis. To obtain the real version of the net worth accumulation equation, we divide both sides by aggregate price level (P_t). Note that inflation (Π_t) is defined as the current price level relative to the price level in the previous period ($\Pi_t = P_t/P_{t-1}$).

$$\begin{aligned}\Pi_t n_{i,t} = & \left(R_t^F - R_{t-1}^d\right) Q_{t-1} f_{i,t-1} + \left(R_t^B - R_{t-1}^d\right) Q_{B,t-1} b_{i,t-1} \\ & + \left(R_{t-1}^{re} - R_{t-1}^d\right) re_{i,t-1} + R_{t-1}^d n_{i,t-1}\end{aligned} \tag{9}$$

which implies

$$\begin{aligned}\Lambda_{t,t+1}\Omega_{t+1} n_{i,t+1} = \Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1} \Big[& \left(R_{t+1}^F - R_t^d\right) Q_t f_{i,t} \\ & + \left(R_{t+1}^B - R_t^d\right) Q_{B,t} b_{i,t} + \left(R_t^{re} - R_t^d\right) re_{i,t} \\ & + R_t^d n_{i,t}\Big]\end{aligned} \tag{10}$$

Therefore, an intermediary's value function can be written as

$$\begin{aligned}V_{i,t} &= \max(1-\sigma) E_t \Lambda_{t,t+1} n_{i,t+1} + \sigma E_t \Lambda_{t,t+1} V_{i,t+1} \\ &= \max(1-\sigma) E_t \Bigg[\Lambda_{t,t+1} \Bigg(\frac{R_{t+1}^F - R_t^d}{\Pi_{t+1}} Q_t f_{i,t} \\ &\qquad + \frac{R_{t+1}^B - R_t^d}{\Pi_{t+1}} Q_{B,t} b_{i,t} \\ &\qquad + \frac{R_t^{re} - R_t^d}{\Pi_{t+1}} re_{i,t} \\ &\qquad + \frac{R_t^d}{\Pi_{t+1}} n_{i,t} \Bigg)\Bigg] \\ &\quad + \sigma E_t \Lambda_{t,t+1} V_{i,t+1}\end{aligned} \tag{11}$$

A Lagrangian with the constraint

$$\begin{aligned}\mathcal{L}_{i,t} = & \max(1+\lambda_t) E_t \left[(1-\sigma)\Lambda_{t,t+1}\left(\frac{R_{t+1}^F - R_t^d}{\Pi_{t+1}} Q_t f_{i,t} + \dots\right) + \sigma \Lambda_{t,t+1} V_{i,t+1}\right] \\ & - \lambda_t \theta_t (Q_t f_{i,t} + \Delta Q_{B,t} b_{i,t})\end{aligned}$$

In this equation, λ_t denotes the Lagrangian multiplier. As all financial intermediaries are assumed to be identical, they behave in the same way. Consequently, they share the same set of optimality conditions, as presented below:

$$E_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}(R_{t+1}^F - R_t^d)\right] = \frac{\lambda_t}{1+\lambda_t}\theta_t \tag{12}$$

$$E_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}(R_{t+1}^B - R_t^d)\right] = \frac{\lambda_t}{1+\lambda_t}\theta_t\Delta \tag{13}$$

$$E_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}(R_t^{re} - R_t^d)\right] = 0, \tag{14}$$

where

$$\Omega_t = 1 - \sigma + \sigma\theta_t\phi_t \tag{15}$$

$$\phi_t = \frac{1+\lambda_t}{\theta_t}E_t[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}]R_t^d \tag{16}$$

Equations from 12 to 14 represent the key equilibrium conditions of the model, and the term $\lambda_t \geq 0$ is the multiplier associated with the costly enforcement constraint. There are two possible outcomes based on this constraint: First, if the constraint is not active (it ”doesn’t bind”), the expected returns on all three asset types must, to a first approximation, equal the cost of funds (the deposit rate). Second, if the constraint is active (it ”binds”), both long-term private and public bonds will generate excess returns over the deposit rate.The condition $\Delta < 1$ ensures that the excess returns on government bonds are lower than those on private bonds. In principle, Δ can be treated as an external time-varying factor that separates the term premium from corporate spread. Finally, Ω and ϕ are auxiliary variables introduced to simplify the analysis, and we assume the intermediary’s value is a linear combination of its net worth; thus, the value of an intermediary satisfies

$$V_{i,t} = \theta_t\phi_t n_{i,t} \tag{17}$$

When the constraint binds,

$$\phi_t = \frac{Q_t f_{i,t} + \Delta Q_{B,t} b_{i,t}}{n_{i,t}} \tag{18}$$

This term is called the endogenous leverage ratio, and its equilibrium condition is, as stated above. This constraint forces the financial intermediary to be levered less (using less debt) than it would ideally have chosen. Ultimately, this internal leverage constraint allows excess returns.

To find expressions for the auxiliary variables Ω_t and ϕ_t in equations 15–16, we start by assuming that the value function is linear in net worth, as previously mentioned. We then combined this assumption with a binding constraint on the yields and first-order conditions, resulting in the following:

$$\begin{aligned}
&E_t[\Lambda_{t,t+1}\Omega_{t+1}n_{i,t+1}] \\
=&E_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}(R_{t+1}^F - R_t^d)\right](Q_t f_{i,t} + \Delta Q_{B,t} b_{i,t}) \\
&+ E_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\right] R_t^d n_{i,t} \\
&= \frac{\lambda_t}{1+\lambda_t}\theta_t\phi_t n_{i,t} + E_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\right] R_t^d n_{i,t}
\end{aligned}$$

We rewrite the value function in Equation 11 using 15 and 17.

$$\theta_t\phi_t n_{i,t} = \max E_t[\Lambda_{t,t+1}n_{i,t+1}\Omega_{t+1}] = \frac{\lambda_t}{1+\lambda_t}\theta_t\phi_t n_{i,t} + E_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\right] R_t^d n_{i,t}$$

This leads to

$$\theta_t\phi_t = \frac{\lambda_t}{1+\lambda_t}\theta_t\phi_t + E_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\right] R_t^d$$

Simplify,

$$\theta_t\phi_t = (1+\lambda_t)E_t\left[\Lambda_{t,t+1}\Omega_{t+1}\Pi_{t+1}^{-1}\right] R_t^d$$

4.4 Production

The production process involved several stages. We will only discuss wholesale goods producers in the following section because it is important for our model; the rest of the production side is in Appendix A. A representative wholesale firm produces intermediate output ($Y_{m,t}$) using capital and labor. This wholesale output is sold to a continuum of retail firms, indexed by $f \in [0, 1]$. These retailers simply repackage goods, such that their individual output is $Y_t(f) = Y_{m,t}(f)$. These differentiated retail goods are then purchased by a competitive final goods firm that bundles them into a single final good (Y_t) by using a CES aggregation function. The elasticity of substitution between retail goods is $\epsilon_p > 1$, which ultimately determines the demand curve for each retailer. A separate competitive capital good producer also produces new physical capital (I_t).

4.4.1 Wholesale Good Producers

The representative wholesale firm produces output according to Cobb-Douglas technology:

$$Y_{m,t} = A_t(K_t)^{\alpha} L_{d,t}^{1-\alpha} \tag{19}$$

$Y_{m,t}$ represents the total output produced during period t, and $L_{d,t}$ is the labor input used in that same period. The firm owns its stock of physical capital, K_t. Parameter α (alpha) is a value between zero and one, which represents the capital's relative contribution to production. A_t shows overall productivity (e.g., technology), which is exogenous and follows a stochastic process. Finally, the amount of physical capital (K_t) accumulated is based on the standard "law of motion":

$$K_{t+1} = \hat{I}_t + (1-\delta)K_t \tag{20}$$

We follow an approach similar to Carlstrom et al. (2017), assuming that the wholesale firm must issue long-term bonds (debt) to fund its purchases of new physical capital, I_t. However, we make one key change: unlike their model, our firm does not need to finance its entire investment. Instead, we require that the firm finance only a constant fraction ψ (psi) of its new investment, where ψ is a value between zero and one. This requirement creates a "loan in advance constraint," which is expressed as:

$$\psi P_t^k \hat{I}_t \leq Q_t CF_{m,t} = Q_t(F_{m,t} - \kappa^f F_{m,t-1}), \tag{21}$$

where P_t^k is the price at which the wholesale firm purchases the new capital.

The wholesale firm employs workers from a competitive spot market at nominal wage W_t. The firm's resulting dividend, which is also a nominal value, is

$$\begin{aligned} DIV_{m,t} =& P_{m,t}A_t(K_t)^{\alpha} L_{d,t}^{1-\alpha} - W_t L_{d,t} - P_t^k \hat{I}_t \\ &- F_{m,t-1} + Q_t(F_{m,t} - \kappa^f F_{m,t-1}) \end{aligned} \tag{22}$$

The firm's real dividend is

$$div_{m,t} = p_{m,t}Y_{m,t} - w_t L_{d,t} - q_t^I \hat{I}_t - \frac{F_{m,t-1}}{P_t} + Q_t(f_{m,t} - \kappa^f f_{m,t-1}) \tag{23}$$

A firm's objective is to maximize the present discounted value of its real dividends.

To do this, it chooses its labor ($L_{d,t}$), the next period's capital (K_{t+1}), investment ($\hat{I}_t$), and financing ($f_{m,t}$). Discounting is based on the households' stochastic discount factor, which is solved using a Lagrangian as follows:

$$\begin{aligned}\mathcal{L}_{m,t} = E_t \sum_{j=0}^{\infty} \Lambda_{t,t+j} \Bigg\{ & p_{m,t+j} A_{t+j} K_{t+j}^{\alpha} L_{d,t+j}^{1-\alpha} - w_{t+j} L_{d,t+j} - p_{t+j}^{k} \hat{I}_{t+j} \\ & + Q_{t+j} \left(\frac{F_{m,t+j}}{P_{t+j}} - \kappa^f \frac{F_{m,t+j-1}}{P_{t+j-1}} \Pi_{t+j}^{-1} \right) - \frac{F_{m,t+j-1}}{P_{t+j-1}} \Pi_{t+j}^{-1} \\ & + \nu_{1,t+j} \left(\hat{I}_{t+j} + (1-\delta) K_{t+j} - K_{t+j+1} \right) \\ & + \nu_{2,t+j} \left(Q_{t+j} \left(\frac{F_{m,t+j}}{P_{t+j}} - \kappa^f \frac{F_{m,t+j-1}}{P_{t+j-1}} \Pi_{t+j}^{-1} \right) - \psi p_{t+j}^{k} \hat{I}_{t+j} \right) \Bigg\} \end{aligned} \tag{24}$$

The first-order conditions are as follows:

$$w_t = (1-\alpha) p_{m,t} A_t K_t^{\alpha} L_{d,t}^{-\alpha} \tag{25}$$

$$p_t^k M_{1,t} = E_t \Lambda_{t,t+1} \left[\alpha p_{m,t+1} A_{t+1} K_{t+1}^{\alpha-1} L_{d,t+1}^{1-\alpha} + (1-\delta) p_{t+1}^k M_{1,t+1} \right] \tag{26}$$

$$Q_t M_{2,t} = E_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \left[1 + \kappa^f Q_{t+1} M_{2,t+1} \right] \tag{27}$$

$$\frac{M_{1,t} - 1}{M_{2,t} - 1} = \psi \tag{28}$$

The variable q_t^k is the shadow value of installed capital, which is Tobin's Q; r_t^k is the real rental rate for capital; w_t is the real wage; $p_{m,t}$ is the relative price of the wholesale output; and p_t^k is the relative price of new capital. Equation 25 is the standard static rule that firms use to decide how much labor to hire. $M_{1,t}$ is linked to constraint 21, which forces firms to issue bonds to finance their investments, whereas $M_{2,t}$ is related to another constraint. Equations 26 and 27 represent the optimal choices for holding capital and bonds, respectively. If the constraints are not actually binding, then both $M_{1,t}$ and $M_{2,t}$ would simply equal one, and these equations would look similar to the standard rules for asset pricing. Because these constraints are binding, however, $M_{1,t}$

acts as an "investment wedge" and $M_{2,t}$ as a "financial wedge." These wedges distort the firm's standard decisions, and the central idea is that fluctuations in these wedges are the primary way in which policies such as QE/QT are transmitted to the real economy.

4.5 Conventional monetary policy

Before discussing unconventional monetary policy, we must first define conventional policy. We define this as the central bank's adjustment of the short-term interest rate R_t^{TR}. This adjustment is described by an internal feedback rule, similar to the one proposed by Taylor (1993):

$$\ln R_t^{TR} = (1-\rho_r)\ln R^{re} + \rho_r \ln R_{t-1}^{TR} + (1-\rho_r)[\phi_\pi(\ln \Pi_t - \ln \Pi) + \phi_y(\ln Y_t - \ln Y_{t-1})] + s_r \epsilon_{r,t} \tag{29}$$

In this rule, R^{TR} and Π represent the long-run "steady state" values for the policy rate and the inflation target. The parameters $0 < \rho_r < 1$, ϕ_π, and ϕ_y are all non-negative numbers.To ensure the model has a stable solution (a "determinate equilibrium"), we only consider cases where $\phi_\pi > 1$. This rule simply means that the policy rate adjusts whenever inflation moves away from its target, or when output growth moves away from its trend (which we assume is zero in this model).We also assume that the central bank sets the interest rate on reserves the same as the main policy rate. Therefore, the deposit rate (R_t^d) and the reserve rate (R_t^{re}) are both equal to R_t^{TR}:

$$R_t^d = R_t^{re} = R_t^{TR} \tag{30}$$

4.6 Unconventional monetary policy

Quantitative easing is arguably the most significant unconventional policy employed by central banks. It was first adopted by the Bank of Japan in the early 2000s. After the Great Recession, major economies such as the United States, Euro Area, and United Kingdom implemented this tool, but its use expanded to an unprecedented scale in response to the 2020 COVID-19 pandemic.

While the Federal Reserve's balance sheet reached \$4.5 trillion after its initial post-crisis programs, it surged to a peak of nearly \$9 trillion (around 36% of U.S. GDP) by early 2022. The European Central Bank's (ECB) balance sheet, which stood at €4.7

trillion in late 2018, peaked at €6.89 trillion (approximately 50% of the Euro Area GDP) by the end of 2023. The Bank of Japan's holdings, which long exceeded 100% of its GDP, grew to a high of over 764 trillion JPY.

This era of massive expansion has now begun to pivot. Since 2024, these central banks have entered a new phase of QT, or QN, as the ECB terms it. This shift involves discontinuing reinvestments, such as the ECB's full halt of its APP and PEPP programs by the end of 2024, and actively allowing these massive balance sheets to shrink further.

Following Gertler and Karadi (2011), Gertler and Karadi (2013) and Carlstrom et al. (2017), we define quantitative easing as a central bank's purchase of government bonds. These purchases are made by creating new interest-bearing reserves held by the financial intermediaries. In our model, the central bank's balance sheet is:

$$Q_{B,t} B_{cb,t} = \mathrm{RE}t \tag{31}$$

The central bank holds government bonds ($B_{cb,t}$) as assets financed by issuing interest-bearing reserves (RE_t). Any profit (operating surplus) from these holdings is transferred to the government fiscal authority. The model's market-clearing condition requires that all bonds from the government are held by either financial intermediaries or central banks. QE/QT policies can have real effects on the economy, but only if financial intermediaries are constrained by the costly enforcement problem. When this constraint is active (or "binds"), the central bank's bond purchases (financed by new reserves) help to ease this constraint. In this situation, the central bank's demand for bonds adds to, rather than "crowds out," the intermediaries' demand. This increases total demand for bonds, leading to higher bond prices. Higher bond prices relax the loan-in-advance constraint faced by wholesale good producers. This ultimately results in higher investment and greater aggregate demand. However, if the intermediaries' constraint is not binding, or if wholesale firms do not need to borrow to finance investment (i.e., $\psi = 0$), then QE/QT has no economic effects. Furthermore, assuming $\Delta < 1$ and that both constraints are binding, central bank purchases of private bonds have a stronger impact on excess returns than purchases of government bonds, making them a more powerful stimulus. We treat QE/QT as an exogenous policy. We assume that the central bank's bond holdings follow an external AR(1) process:

$$b_{cb,t} = (1 - \rho_b), b_{cb} + \rho_b b_{cb,t-1} + s_b \epsilon_{b,t} \tag{32}$$

Here, b_{cb} is the steady-state (long-run) level of real central bank bond holdings, ρ_b is a persistence parameter (between 0 and 1), and $\varepsilon_{b,t}$ is a stochastic shock with a standard deviation of s_b.

4.7 Calibration

The model is solved using a linear approximation around the non-stochastic steady state and calibrated at a quarterly frequency. Parameters that are standard in the New Keynesian literature, such as household preferences, production technology, and price or wage rigidities, are set to conventional values. The parameters specific to our framework are listed in Table 3, along with their calibration targets. The key financial and institutional parameters are set as follows: The bond duration parameters (κ^f and κ^b) are chosen to yield an average duration of eight years (32 quarters) for corporate bonds and ten years (40 quarters) for government bonds. We set ψ to 0.35, implying that 35% of new investments are financed by issuing long-term bonds. The intermediary survival probability, σ, is 0.95, which results in an average intermediary lifetime of 20 quarters. We also set Δ to 2/3, ensuring that the steady-state spread on government bonds is two-thirds of that on private bonds. On the fiscal side, the steady-state government debt level (b_G) is calibrated to target an annual debt-to-GDP ratio of 60% ($\frac{B_G Q_B}{4Y} = 0.6$). The steady-state government spending-to-output ratio (G/Y) is set to 20%. Finally, the model is calibrated to generate two distinct types of banks in the steady state, characterized by high (32 quarters) and low (16 quarters) maturity gaps, respectively.

5 Discussion

In this section, we compare the effects of exogenous shocks on both conventional and unconventional policy tools. We compare two types of shocks: (i) a conventional monetary policy shock (i.e., a shock to the desired policy rate, $\varepsilon_{r,t}$ and (ii) a QT shock (a shock to s_b). Subsequently, we examine the effects of technology and liquidity shocks.

5.1 Conventional (Policy Rate) and Unconventional (QT) Shocks

Figure 4: Impulse Response to Conventional (Policy Rate) and Unconventional (QT) Shocks

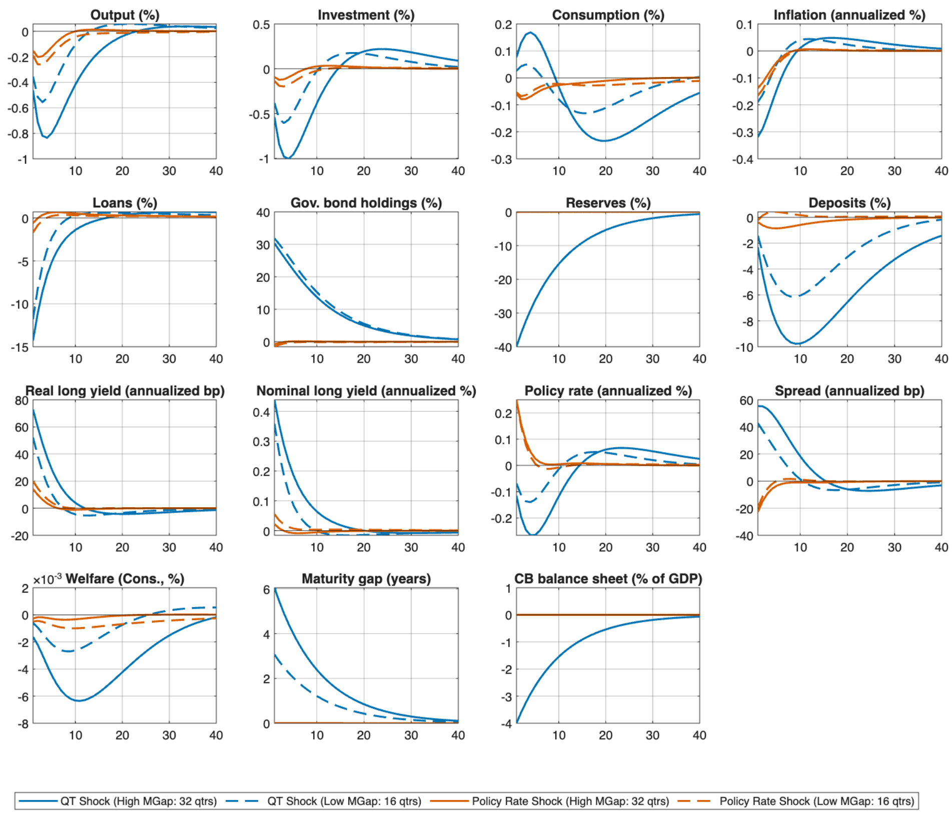


Figure 4 presents a comparison of two contractionary monetary policy actions normalized by their size. The first is a conventional shock: a 0.25 percent (annualized) increase in the policy rate. The second is an unconventional shock: a quantitative tightening (QT) operation equal to a 4 percent of output reduction in the central bank's balance sheet. We analyze these shocks in two different economic environments: one with low-maturity-gap banks (Maturity Gap = 16 quarters, dashed lines) and one with high-maturity-gap banks (Maturity Gap = 32 quarters, solid line).

Both policy actions successfully triggered a macroeconomic contraction, causing output, investment, and consumption to fall. However, unconventional QT shock is dramatically more powerful, and its effects are far more persistent. This is especially true in economies with high-maturity-gap banks, where the QT shock generates a much deeper and longer-lasting economic downturn.

The transmission mechanisms of these shocks are fundamentally different, which explains the varied outcomes. The conventional policy rate hike (orange lines) operates primarily through the intertemporal substitution channel and by raising the funding cost for banks. The central bank raises its policy rate, which immediately increases the deposit rates. This raises funding costs for all banks, decreases net worth, and leads to a modest reduction in loans and deposits. Higher short-term rates also encourage households to save, thereby dampening consumption. Critically, the plot shows that the maturity gap is almost irrelevant to this shock. The solid and dashed orange lines are almost identical. This is because the shock is transmitted through short-term funding costs, which affect both bank types similarly.

In sharp contrast, unconventional QT shock (blue lines) operates directly through the bank balance sheet channel, which is sensitive to maturity mismatches. QT shocks start with the central bank selling government bonds, which simultaneously drains reserves from the banking system and increases the supply of long-term government bonds in the market. Banks that hold long-duration assets (loans and bonds) funded by short-duration liabilities (deposits) are subject to a massive market-to-market valuation loss due to the sudden spike in long-term yields. These valuation losses, combined with higher funding costs (due to an increase in the spread), decrease banks' net worth.

This drop in net worth causes the leverage constraint to bind more severely. To re-establish the leverage ratio, banks are forced to deleverage. To do this, high-maturity-gap banks aggressively sell assets; we can observe this decline in loans and their remaining government bonds. Low-maturity gap banks (dashed blue line) suffer much smaller valuation losses because their assets re-price more quickly. Their net worth is less affected, their leverage constraints are less binding, and their reduction in lending is far milder. The collapse in loan supply from high-maturity-gap banks directly tightens the loan advance constraint for firms, and due to a lack of credit, firms are forced to decrease their investment, which collapses by over one percent. This investment-led downturn drives a deep and persistent fall in output and consumption. There are policy rate responses from the Taylor rule. During the QT shock (blue lines), the Taylor rule lowers the policy rate to fight recession. This highlights that the two tools can work in opposite directions, with QT tightening financial conditions so much that it forces the central bank to ease its conventional policy.

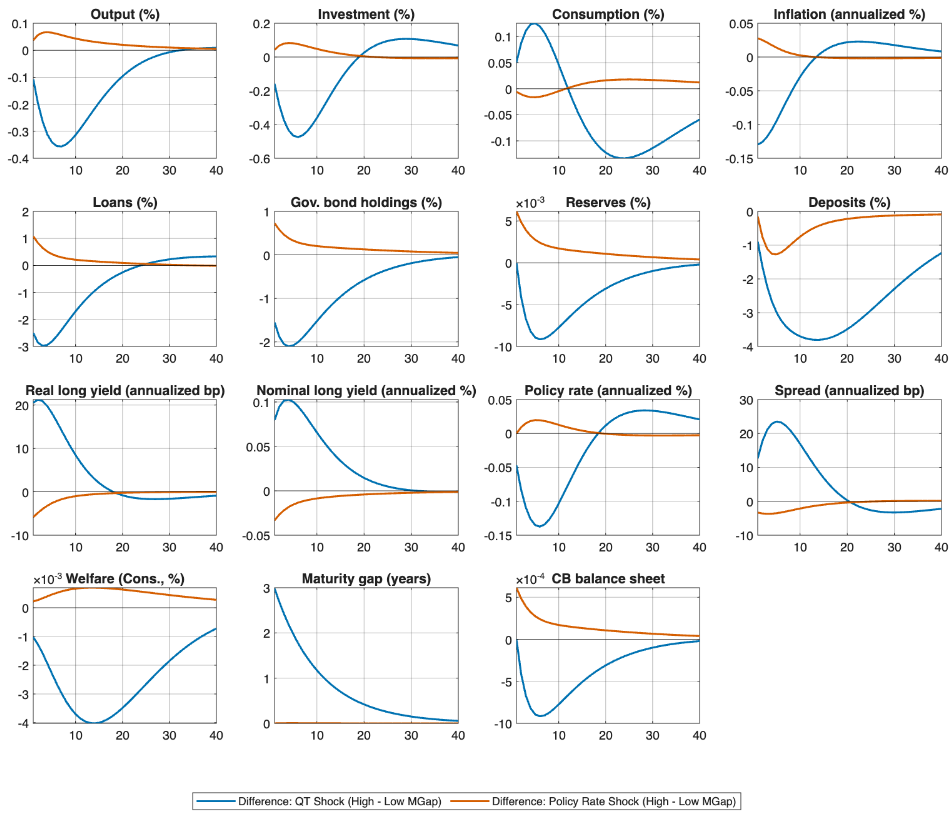
The inflation response is more immediate and consistent following the QT shock, which is driven by its stronger contractionary effect on aggregate demand. Consequently, the welfare analysis confirms the story: the QT shock induces a substantially larger and more persistent welfare loss, which is again amplified in the high-maturity-gap economies. This comparison reveals that the banking system's structure, specifically the degree of maturity mismatch, is a critical determinant of the effectiveness of unconventional monetary policy.

A QT shock causes the maturity gap to shrink, moving it steadily to zero. In an economy that starts with a high maturity gap, this shrinking effect is larger and lasts longer; the gap is cut in half within 8 to 12 quarters and disappears almost completely by 35 to 40 quarters. In an economy starting with a low gap, the same shrinking pattern occurs, but the effect is much smaller. By comparison, a policy rate shock does not change the maturity gap in either type of economy. It remained flat, showing only tiny and brief fluctuations. This is because a high starting maturity gap means that the system is holding more "duration risk," making it more sensitive to balance sheet shocks such as QT. Consequently, the mix of asset maturities changes more dramatically and for a longer time. When the starting gap is low, the system is less sensitive, and the response becomes weaker. This difference in sensitivity is why QT shocks have a stronger and longer-lasting impact when banks have a large mismatch between their assets and liabilities.

Figure 5 isolates the precise impact of bank heterogeneity by plotting the difference in the impulse responses between the high- and low-maturity gap economies. This differential analysis provides a visual test of how and which monetary policy tools,quantitative tightening (QT), and policy rate shocks are amplified by this specific financial structure. The results for unconventional (QT) shocks (the blue line) are evident. For nearly all key macroeconomic indicators— Output, Investment, and Consumption— the difference is significantly large, negative, and persistent. This confirms that an economy with high-maturity-gap banks suffers a dramatically deeper and more prolonged recession.

The mechanism for this amplification comes from the bank balance sheet channels. QT shock, by draining reserves and forcing long-term yields to rise, inflicts severe valuation losses on long-duration assets disproportionately held by maturity gap banks.

Figure 5: Difference in Impulse Responses (High vs Low Maturity Gap Banks)



This immediate capital hit, combined with a system-wide liquidity squeeze, causes their leverage constraints to bind far more tightly than their low-maturity-gap peers. This constraint forces aggressive deleveraging. We see this in the plots for loans and government bond holdings, where the large negative difference shows that banks with high maturity gaps are forced to "fire sell" assets and decrease credit origination far more severely. This amplified credit crunch starves firms of capital, directly causing a larger collapse in investment and, consequently, the entire economy.

In contrast, the red line, representing the difference for conventional policy rate shocks, hovers near zero across almost all variables. This is a critical counter-finding: maturity mismatch does not meaningfully amplify the effects of a conventional policy rate hike. This is because of the transmission mechanism. A conventional rate hike raises short-term funding costs (i.e., the deposit rate). This shock is passed through all banks in a relatively uniform manner, squeezing their net interest margins similarly, regardless of their asset duration. Because the shock does not differentially impact bank balance sheets based on asset maturity, it generates a homogeneous response across both economies. The welfare plot perfectly summarizes this asymmetry. The large negative blue line quantifies the substantial additional welfare loss inflicted on the high maturity gap economy by a QT shock. Conversely, the flat red line confirms that the conventional policy creates no such differential loss.

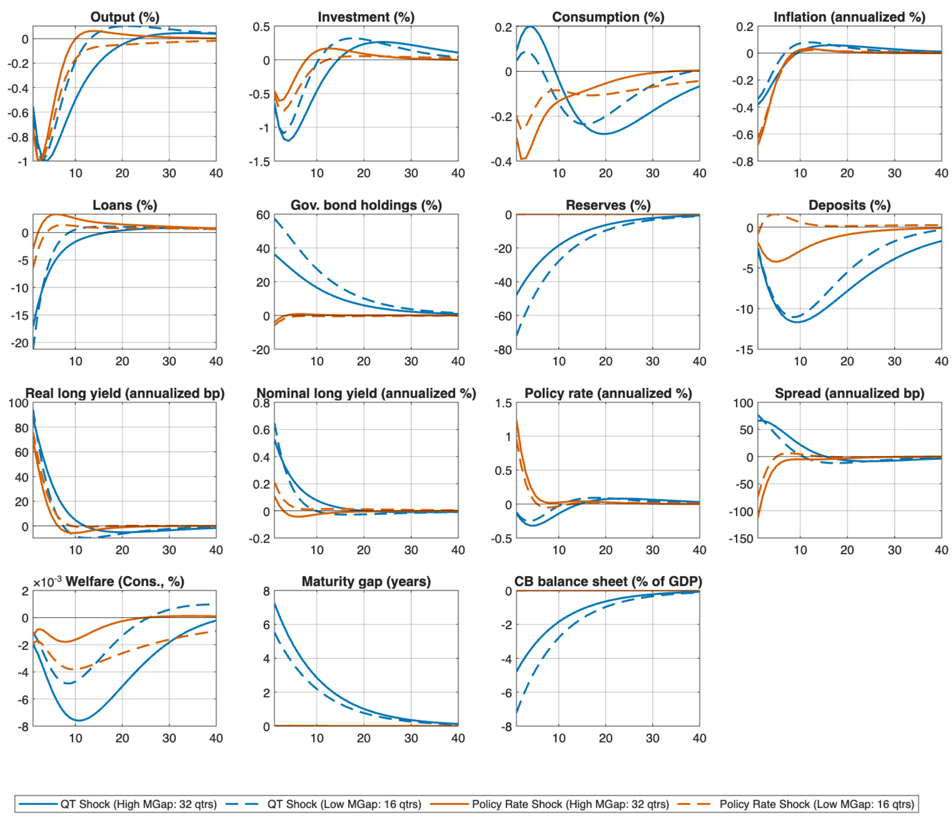
This demonstrates that maturity mismatch functions as a potent systemic amplifier for unconventional shocks. This finding provides a strong rationale for targeted macroprudential policies designed to monitor and constrain excessive maturity transformation. This balance sheet structure is not merely a micro-level risk to individual banks but a critical macro-level vulnerability that can dramatically intensify the economic downturns that balance-sheet-focused policies are meant to manage.

Figure 6 presents a powerful alternative comparison by performing a ”policy equivalence” experiment. Both the conventional and unconventional shocks are re-normalized to produce the exact same peak output contraction of -1 percent.

This normalization shifts the analytical focus from ”What is the effect of a standard policy action?” to a far more potent question: ”What are the full economic costs and trade-offs of achieving a specific stabilization target?

By pinning down the real-sector outcome, we can examine the ”collateral effects” and differential costs associated with each policy tool. To achieve the -1% output drop, the conventional policy rate hike, the drop in investment is comparatively mild (around -0.5%). In contrast, the QT shock (blue lines) achieves the same output drop with a larger investment decrease. Investment collapses by a much larger -1.5%. The reason for the different real sector paths is evident in the financial plots. The conventional policy path achieves its goal with only a minor contraction in bank loans (approximately -2%). The QT path, however, requires a massive and disruptive contraction in bank lending (a 15-20% collapse) to generate the same -1% output decline. This highlights QT's reliance on aggressively tightening the bank lending channel. For the same -1% output stabilization, the conventional rate hike is more disinflationary, causing a sharper drop in inflation. The welfare plot is the ultimate arbiter of the results. This clearly shows that achieving the target via QT incurs a dramatically larger welfare loss than using the conventional policy rate. This welfare cost is significantly amplified in

Figure 6: Impulse Responses to Conventional and Unconventional Shocks (Normalization: Initial output response of -1%)



an economy with high-maturity-gap banks (solid blue line). This comparison is critical for policy design purposes. This demonstrates that the manner in which a central bank tightens its policy is not neutral. A conventional rate hike acts as a broad tool that dampens household consumption. Conversely, QT acts as a surgical instrument that achieves its objective by aggressively targets credit and investment.

5.2 Responses to Real and Financial Shocks

Having established that bank maturity mismatch is a critical determinant for the transmission of unconventional monetary policy but not conventional policy, we now broaden the analysis. We examine two non-policy shocks to understand the wider implications of this financial structure for the economy. First, we introduce a positive technology shock (a real, supply side shock) to test whether the banking system's maturity gap also mediates the economy's ability to capitalize on positive opportunities or whether it acts as a structural drag on growth. Second, we introduce a liquidity shock (a pure financial friction shock) to test whether the high-maturity-gap structure serves as a more general source of systemic fragility, amplifying crises that originate within the financial system itself, independent of any policy action.

5.2.1 Impulse Response to Technology Shock

Figure 7: Impulse Response to Technology Shock

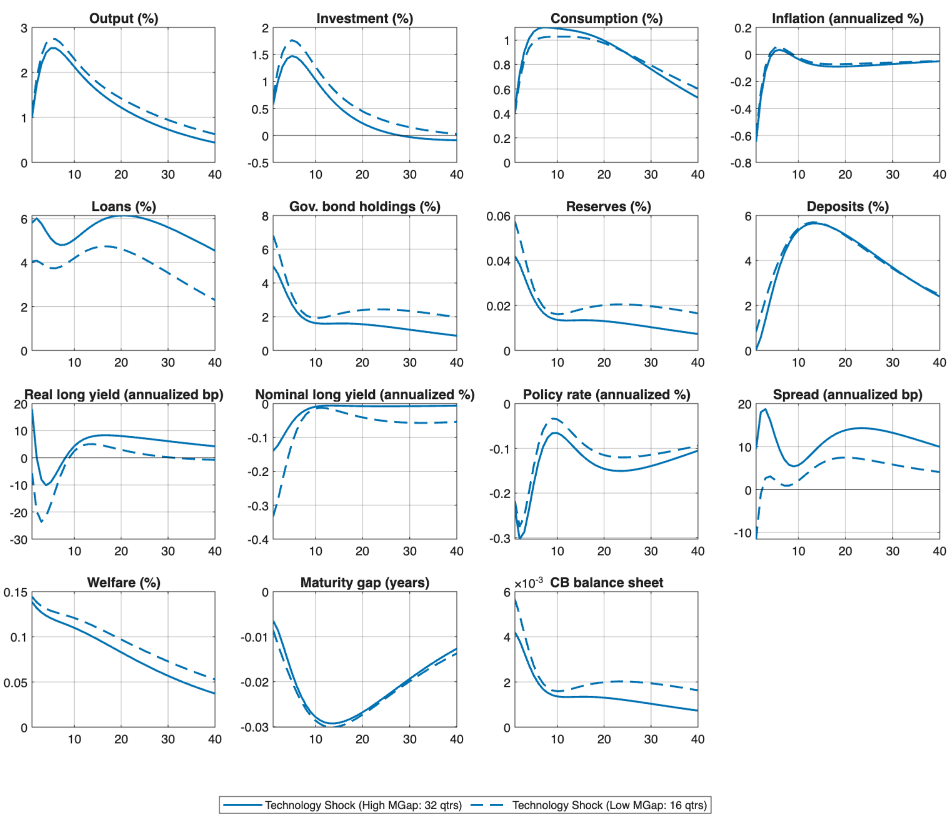
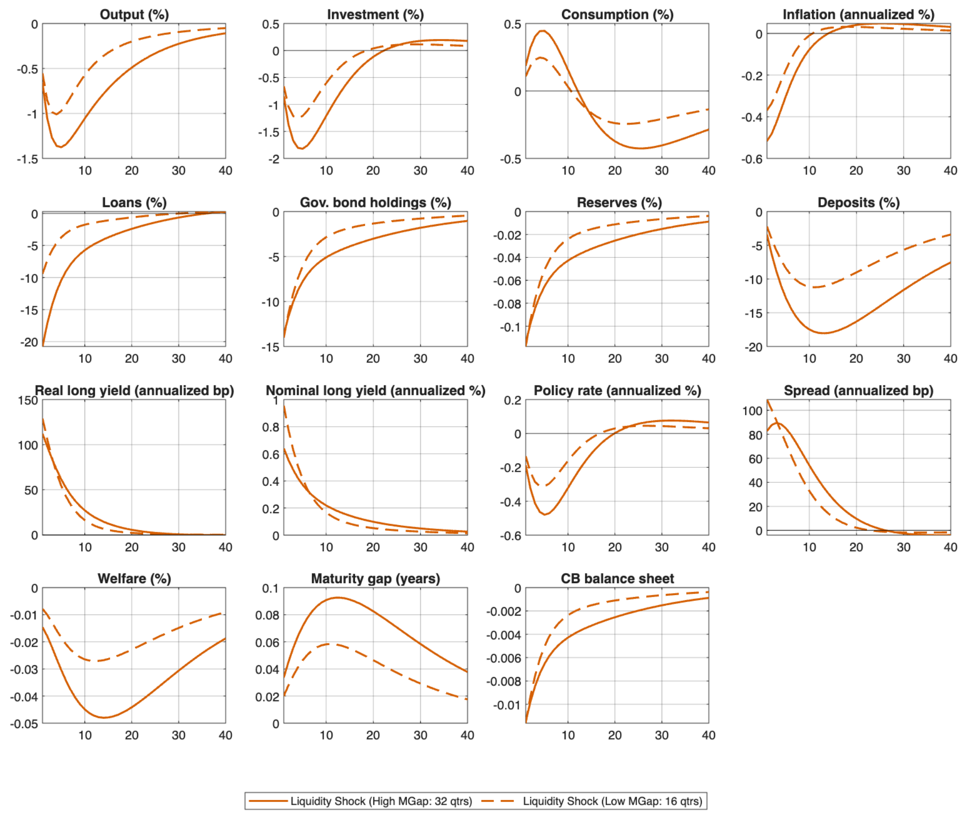


Figure 7 analyzes the economy's response to a positive technology shock. The results align perfectly with the standard macroeconomic theory: the shock leads to a persistent wave of growth, leading to increases in output, investment, and consumption, and a significant, durable improvement in overall welfare. As the economy's ability to supply goods and services expands, it outpaces aggregate demand, putting downward pressure on prices and causing inflation to decrease. This benign disinflationary environment gives the central bank (via the Taylor rule) a clear justification to adopt an accommodative stance, as seen in the marked decline in the policy rate. This real-sector boom increases profitable investment opportunities, which, in turn, fuels a strong demand for credit. Consequently, we observe a broad expansion of the financial system, with both bank loans and deposits growing to finance new economic activity. However, we would like to highlight the quantitative differences between these two banking systems. The financial structure, as defined by the maturity gap, proves to be a critical mediator in the transmission of this positive real shock. A low maturity gap economy with more flexible bank balance sheets can fully capitalize on new opportunities. It experienced a significantly stronger boom in investment and a much larger and more rapid expansion of loans and deposits. Its financial system effectively facilitates the reallocation of capital to new, productive uses. In contrast, high-maturity-gap banks appear to be structurally constrained. Their less flexible balance sheets prevent them from aggressively expanding credit to meet the new, profitable loan demand. This financial friction acts as a bottleneck. This, in turn, results in a more muted investment response and, consequently, a smaller overall increase in the output and consumption. Financial constraints are also visible in the price of credit. In the maturity gap economy, the spread widens more, and the real long yield falls less, indicating that the benefits of the accommodative policy rate are not passed through as effectively to the real economy. This analysis powerfully demonstrates that the banking system's structure is not just a vulnerability that amplifies negative shocks (as seen in the QT analysis). It is also an important factor in determining an economy's capacity to capitalize on positive opportunities. A less flexible, high-maturity-gap banking sector acts as a structural drag on growth, even in the face of productivity gains.

5.2.2 Impulse Response to Liquidity Shock

Figure 8 presents the economy's response to a purely financial disturbance—a sudden, exogenous tightening of bank constraints. This shock, representing a "sudden stop" or a drying up of market liquidity, generates a severe macroeconomic contraction, providing a clear case of financial frictions driving a real-sector downturn. The shock immediately triggers a sharp and immediate decline in output, investment, and consumption. The

Figure 8: Impulse Response to Liquidity Shock



shock tightens bank constraints, forcing banks to deleverage. To repair their balance sheets, banks are forced to "fire sell" their assets. This is visible in the massive collapse of loan origination and the decrease in government bond holdings. This fire sale floods the market and causes asset prices to fall. This is reflected in the explosive, 100+ basis point widening of the spread and the sharp spike in the real long-term yield. This credit crunch, transmitted via the model's loan-in-advance constraint, deteriorates the real economy of financing, causing a collapse in investment and taking the entire economy into a recession. In response to this deflationary crisis, the central bank's Taylor rule responds by aggressively cutting the policy rate because of a decrease in output and inflation. However, this conventional response is rendered ineffective. The financial disturbance is severe, causing the bank borrowing spread to increase by 100 bps. This substantial cost increase fully counteracts the central bank's accommodative response, which involves a 40 basis point cut in the policy rate. This demonstrates how severe financial frictions can impede the transmission of conventional monetary policy, as the intended stimulus from the rate cut does not effectively reach the real economy.

This figure illustrates the significant consequences of maturity transformation. An economy with a high degree of maturity transformation (the blue line) experiences a more pronounced economic contraction across all metrics. This structural reliance on short-term funding makes the banking system highly sensitive to this type of liquidity shock. High-maturity-gap economies observe a significantly larger decline in deposits, a more severe contraction in lending, and a deeper fall in investment. Consequently, this translates into substantially greater welfare loss. This highlights that a high-maturity-gap structure can be a source of systemic financial fragility, increasing the entire economy's susceptibility to financial panics.

6 Concluding Remarks

The analyses presented in the model section provide a comprehensive overview of how various shocks propagate through an economy in a heterogeneous banking sector. A primary conclusion is that the financial system's structure, specifically the degree of maturity transformation in the banking system, is a critical determinant of macroeconomic outcomes. This is most evident when we compare different monetary policy tools.

We find a "shock-specific" difference between conventional (policy rate) and unconventional (QT) policies: conventional policies (policy rate hikes) operate broadly through intertemporal substitution and by raising short-term funding costs. This is the classic "funding cost channel". As shown in Figure 5, its effects are largely indifferent to the banks' maturity gap. This theoretical finding is validated by our empirical analysis using a novel panel dataset of euro area banks, leveraging the granularity of nearly 1800 banks, where we find that the lending response to conventional 'target' shocks is statistically insignificant across banks with different maturity gaps.

In contrast, unconventional policy (QT) operates directly through the bank balance sheet channel. By inflicting valuation losses on long-duration assets, it severely binds the leverage constraints of banks with high maturity gaps. This mechanism is strongly confirmed by our empirical findings, which show that banks with higher maturity gaps significantly and sizably contract their lending supply more than their low-gap peers following an unconventional (QE/QT) tightening shock. This financial structure thus functions as a potent amplifier for unconventional policy, leading to a dramatically deeper and more persistent economic downturn (Figure 4 and 5).

Our normalization experiment in Figure 6 demonstrates that achieving the same output stabilization target via QT requires a catastrophic collapse in bank lending and investment compared to a conventional rate hike, resulting in substantially larger welfare losses.

The effects of banking structure extend beyond monetary policy. We find that a high-maturity-gap economy not only amplifies negative shocks but also dampens positive ones. In response to a financial liquidity shock (Figure 8), a high-maturity-gap economy is catastrophically more vulnerable, experiencing a more severe credit crunch, fire sale, and deeper recession. However, in response to a positive technology shock (Figure 7), the high-maturity-gap banking system acts as a "bottleneck," constraining the credit expansion needed to finance new productive opportunities and thus muting the potential economic boom.

Our combined theoretical and empirical findings have significant policy implications. They suggest that the choice between policy tools (e.g., rate hikes vs. QE/QT) is a fundamental choice and should account for the prevailing financial structure and potential stability risks of the economy. Furthermore, the results provide strong justification for macroprudential policies aimed at limiting excessive maturity transformation, as such measures can be seen as crucial for enhancing macroeconomic resilience and reducing systemic risk.

We have an extensive research agenda to build upon this study. On the theoretical front, our immediate next step is to extend this framework to a Two-Agent New Keynesian (TANK) model. We plan to build a model featuring two distinct banking sectors that can be calibrated to represent the shares of high- and low-mismatch banks observed in the data. Following the financing segmentation literature (e.g., Allen and Gale (1995); Gertler and Kiyotaki (2010a)), this model will feature two sets of financial intermediaries, each restricted to financing its own specific sector. Consequently, the economy comprises two parallel structures (e.g., two labor unions, two capital goods producers, two wholesale good producers, and two sets of retailers), with all assets on intermediary balance sheets being sector-specific. This structure is crucial for examining the differential dynamics of a single monetary policy shock as it propagates through these two distinct financial channels.

On the empirical side, we plan to dig deeper into the mechanism through which banks with higher maturity gaps adjust their lending behavior, relying on more granular loan-level information. This will allow us to answer the following pressing question: Do banks with higher maturity gaps adjust their lending rates and credit standards more quickly than those with lower maturity gaps? Is their appetite for riskier loans disproportionately affected? This next phase will move us from the "what" to the "how", providing an even higher-resolution picture of this critical policy transmission channel.

References

Allen, F. and Gale, D. (1995). A welfare comparison of intermediaries and financial markets in germany and the us. *European Economic Review*, 39(2):179–209. Symposium of Industrial Oganizational and Finance.

Altavilla, C., Brugnolini, L., Gürkaynak, R. S., Motto, R., and Ragusa, G. (2019). Measuring euro area monetary policy. *Journal of Monetary Economics*, 108:162–179.

Bernanke, B. S., Gertler, M., and Gilchrist, S. (1999). The financial accelerator in a quantitative business cycle framework. In *Handbook of Macroeconomics*, volume 1, pages 1341–1393. Elsevier.

Carlstrom, C. T., Fuerst, T. S., and Paustian, M. (2017). Targeting long rates in a model with segmented markets. *American Economic Journal: Macroeconomics*, 9(1):205–242.

Christiano, L. J., Eichenbaum, M., and Evans, C. L. (2005). Nominal rigidities and the dynamic effects of a shock to monetary policy. *Journal of Political Economy*, 113(1):1–45.

Coulier, L., Gardo, S., Pancaro, C., and Reghezza, A. (2023). Assessing risks from euro area banks' maturity transformation. *ECB Financial Stability Review*.

Di Tella, S. and Kurlat, P. (2021). Why are banks exposed to monetary policy? *American Economic Journal: Macroeconomics*, 13(4):295–340.

Diamond, D. W. and Dybvig, P. H. (1983). Bank runs, deposit insurance, and liquidity. *Journal of Political Economy*, 91(3):401–419.

Drechsler, I., Savov, A., and Schnabl, P. (2017). The deposits channel of monetary policy. *The Quarterly Journal of Economics*, 132(4):1819–1876.

English, W. B., Van den Heuvel, S. J., and Zakrajšek, E. (2018). Interest rate risk and bank equity valuations. *Journal of Monetary Economics*, 98:80–97.

Esposito, L., Nobili, A., and Ropele, T. (2015). The management of interest rate risk during the crisis: Evidence from italian banks. *Journal of Banking Finance*, 59:486–504.

Flannery, M. J. and James, C. M. (1984). The effect of interest rate changes on the common stock returns of financial institutions. *The Journal of Finance*, 39(4):1141–1153.

Gertler, M. and Karadi, P. (2011). A model of unconventional monetary policy. *Journal of Monetary Economics*, 58(1):17–34. Carnegie-Rochester Conference Series on Public Policy: The Future of Central Banking, April 16–17, 2010.

Gertler, M. and Karadi, P. (2013). Qe 1 vs. 2 vs. 3: A framework for analyzing large-scale asset purchases as a monetary policy tool. *International Journal of Central Banking*, 9(S1):5–53.

Gertler, M. and Kiyotaki, N. (2010a). Chapter 11 - financial intermediation and credit policy in business cycle analysis. volume 3 of *Handbook of Monetary Economics*, pages 547–599. Elsevier.

Gertler, M. and Kiyotaki, N. (2010b). Financial intermediation and credit policy in business cycle analysis. In *Handbook of Monetary Economics*, volume 3, pages 547–599. Elsevier.

Gomez, M., Landier, A., Sraer, D., and Thesmar, D. (2021). Bank exposure to interest-rate risk and the transmission of monetary policy. Technical report, NBER Working Paper No. 28551.

Heider, F., Saidi, F., and Schepens, G. (2019). Life below zero: Bank lending under negative policy rates. *The Review of Financial Studies*, 32(10):3728–3761.

Jordà, (2005). Estimation and inference of impulse responses by local projections. *American Economic Review*, 95(1):161–182.

Macaulay, F. R. (1938). Some theoretical problems suggested by the movements of interest rates, bond yields and stock prices in the united states since 1856. *NBER Books*.

Nakamura, E., Riblier, V., and Steinsson, J. (2025). Beyond the taylor rule. NBER Working Paper 34200, National Bureau of Economic Research.

Paul, P. (2022). Interest rate risk and bank net interest margins. *Review of Financial Studies*, 35(11):5041–5084.

Purnanandam, A. (2007). Interest rate derivatives at commercial banks: An empirical investigation. *Journal of Monetary Economics*, 54(6):1769–1808.

Schnabel, I. (2025). Towards a new Eurosystem balance sheet. Speech at the ECB Conference on Money Markets 2025.

Sims, E. and Wu, J. C. (2021). Evaluating central banks' tool kit: Past, present, and future. *Journal of Monetary Economics*, 118:135–160.

Smets, F. and Wouters, R. (2007). Shocks and frictions in US business cycles: A Bayesian DSGE approach. *American Economic Review*, 97(3):586–606.

Taylor, J. B. (1993). Discretion versus policy rules in practice. *Carnegie-Rochester Conference Series on Public Policy*, 39(1):195–214.

Van den Heuvel, S. J. (2002). Does bank capital matter for monetary transmission? *Economic Policy Review*, 8(1):259–265.

Varraso, G. (2024). Bank interest rate risk exposure and monetary policy amplification. Working Paper.

Wang, X. (2023). A macro-financial perspective to analyse maturity mismatch and default. *Journal of Banking and Finance*, 151:106468.

Woodford, M. (2001). Fiscal requirements for price stability. *Journal of Money, Credit and Banking*, 33(3):669–728.

Appendix A Full model and derivations

A.1 Households

The model contained a large population of uniform households. We can analyze the behavior of a single representative household because they all act alike. Our framework is based on Gertler and Karadi (2013). Each household consists of two types of members: workers and intermediaries. The proportions of these two types were fixed. However, there is probability $1 - \sigma$ that an intermediary will randomly become a worker. To maintain a fixed proportion, an equal number of workers replace them and become intermediaries. These new intermediaries are given a predetermined amount of initial net worth, and the lifetime utility of the representative household is given by:

$$E_t \sum_{j=0}^{\infty} \beta^j \left(\ln(C_{t+j} - bC_{t+j-1}) - \chi \frac{L_{t+j}^{1+\eta}}{1+\eta} \right) \tag{33}$$

where β is the discount factor (i.e., how much the household values the future between 0 and 1). b shows the internal habit formation (how much past consumption affects current utility, also between zero and one). χ denotes the positive scaling parameter. η is the inverse Frisch elasticity related to people's willingness to work. C_t is the consumption, and L_t is the labor supply.

Households face the following nominal budget constraints:

$$P_t C_t + D_t - D_{t-1} \leq MRS_t L_t + DIV_t - P_t X - P_t T_t + (R_{t-1}^d - 1) D_{t-1} \tag{34}$$

In the budget constraint, P_t is the price of the goods. D_{t-1} represents the household's deposits (money) at the beginning of the period and R_t^d is the nominal interest rate earned on those deposits. The term MRS_t is the payment that the household receives for labor from unions (more on that later). DIV_t is the household income from dividends (from firms) combined with the net worth of intermediaries who are "retiring" or exiting. X is the initial net worth (a real transfer) given to new intermediaries. Finally, T_t is the lump sum tax paid to the government.

The first order conditions for the household are

$$\mu_t = \frac{1}{C_t - bC_{t-1}} - b\beta E_t \frac{1}{C_{t+1} - bC_t} \tag{35}$$

$$\Lambda_{t,t+1} = \beta \frac{\mu_{t+1}}{\mu_t} \tag{36}$$

$$\chi L_t^{\eta} = \mu_t \, mrs_t \tag{37}$$

$$1 = R_t^d E_t \left[\Lambda_{t,t+1} \Pi_{t+1}^{-1} \right] \tag{38}$$

Equation 35 defines the marginal utility of consumption μ_t. The formula for the stochastic discount factor $\Lambda_{t,t+1}$ is given by Equation 36, and Equation 37 represents the standard labor supply condition. This equation also defines the real wage (mrs_t) as the nominal wage (MRS_t) divided by price (P_t). Finally, Equation 38 is the first-order condition for deposits and shows the optimal savings decision. The last equation introduces Π_t as the gross inflation rate, calculated as the current price level (P_t) divided by the previous price level (P_{t-1}).

A.2 Labor Market

The labor market is divided into two stages. In the first stage, there are many individual labor unions (h). These unions buy labor from households at the wage MRS_t and then resell it to a central "labor packer." The amount each union (h) buys, $L_t(h)$, is the same as the amount it sells, $L_{d,t}(h)$. In the second stage, these unions sell that labor to a single "labor packer." This packer buys slightly different types of labor from all unions and combines them into the final labor supply ($L_{d,t}$) that businesses use for production. The packer uses the CES technology with an elasticity of $\varepsilon_w > 1$. The demand curve facing each union is

$$L_{d,t}(h) = \left(\frac{W_t(h)}{W_t} \right)^{-\varepsilon_w} L_{d,t} \tag{39}$$

$W_t(h)$ is the specific wage that union h sets for labor. By contrast, W_t is the overall (or aggregate) wage for the entire economy, which is defined by the following formula:

$$W_t^{1-\varepsilon_w} = \int_0^1 W_t(h)^{1-\varepsilon_w} \, dh \tag{40}$$

Labor Union Profit of a typical labor union in nominal terms is

$$DIV_{L,t}(h) = W_t(h)L_{d,t}(h) - MRS_t L_t(h)$$

By setting $L_t(h)$ equal to $L_{d,t}(h)$ and then using the demand curve from Equation 39, we can rewrite this as:

$$DIV_{L,t}(h) = W_t(h)^{1-\varepsilon_w} W_t^{\varepsilon_w} L_{d,t} - MRS_t W_t(h)^{-\varepsilon_w} W_t^{\varepsilon_w} L_{d,t}$$

In this model, labor union wages are "sticky," following a Calvo-style setup. This means that in any period, a union has only a $1-\phi_w$ probability of being able to set a new wage, whereas the probability that it cannot update its wages is ϕ_w. Wages that are not updated can be "indexed" or partially adjusted for past inflation, determined by the γ_w parameter. When a union can set a new wage ($W_t(h)$), it knows that wages may be stuck for some time. The chance that it is still in effect j in the later periods is ϕ_w^j. If an old wage is still in use and indexed, then its value at time $t+j$ is $W_t(h)\left(\frac{P_{t+j-1}}{P_{t-1}}\right)^{\gamma_w}$.The union's problem is choosing a wage that maximizes its total expected real profits over time. This calculation is discounted using both the household's stochastic discount factor and the probability of non-wage adjustment:.

$$\begin{aligned}\max_{W_t(h)} \; \mathbb{E}_t \sum_{j=0}^{\infty} \phi_w^j \Lambda_{t,t+j} \Bigg[& \left(\frac{P_{t+j-1}}{P_{t-1}}\right)^{(1-\varepsilon_w)\gamma_w} W_t(h)^{1-\varepsilon_w} P_{t+j}^{\varepsilon_w - 1} w_{t+j}^{\varepsilon_w} L_{d,t+j} \\ & - \mathrm{mrs}_{t+j} \left(\frac{P_{t+j-1}}{P_{t-1}}\right)^{-\varepsilon_w \gamma_w} W_t(h)^{-\varepsilon_w} P_{t+j}^{\varepsilon_w} w_{t+j}^{\varepsilon_w} L_{d,t+j} \Bigg]\end{aligned} \tag{41}$$

where $\Lambda_{t,t+j} = \Lambda_{t,t+1} \dots \Lambda_{t+j-1,t+j}$. The first order condition is

$$\begin{aligned}(\varepsilon_w - 1) W_t(h)^{-\varepsilon_w} \; \mathbb{E}_t \sum_{j=0}^{\infty} \phi_w^j \Lambda_{t,t+j} \left(\frac{P_{t+j-1}}{P_{t-1}}\right)^{(1-\varepsilon_w)\gamma_w} P_{t+j}^{\varepsilon_w - 1} w_{t+j}^{\varepsilon_w} L_{d,t+j} \\ = \varepsilon_w W_t(h)^{-\varepsilon_w - 1} \; \mathbb{E}_t \sum_{j=0}^{\infty} \phi_w^j \Lambda_{t,t+j} \, \mathrm{mrs}_{t+j} \left(\frac{P_{t+j-1}}{P_{t-1}}\right)^{-\varepsilon_w \gamma_w} P_{t+j}^{\varepsilon_w} w_{t+j}^{\varepsilon_w} L_{d,t+j}\end{aligned} \tag{42}$$

The reset wage is the same across all labor unions. Hence, drop the h index, and the optimal price W_t^* can be written as:

$$W_t^* = \frac{\varepsilon_w}{\varepsilon_w - 1} \frac{F_{1,t}}{F_{2,t}} \tag{43}$$

where $F_{1,t}$ and $F_{2,t}$ are recursive representations of the infinite sum above.

$$F_{1,t} = \text{mrs}_t P_t^{\varepsilon_w} w_t^{\varepsilon_w} L_{d,t} + \phi_w \tag{44}$$

$$F_{2,t} = P_t^{\varepsilon_w - 1} w_t^{\varepsilon_w} L_{d,t} + \phi_w \Lambda_{t,t+1} \Pi_t^{(1-\varepsilon_w)\gamma_w} F_{2,t+1} \tag{45}$$

In real terms, $w_t^* = W_t^*/P_t$ satisfies the following condition:

$$w_t^* = \frac{\varepsilon_w}{\varepsilon_w - 1} \frac{f_{1,t}}{f_{2,t}} \tag{46}$$

$$f_{1,t} = \text{mrs}_t w_t^{\varepsilon_w} L_{d,t} + \phi_w \, \mathbb{E}_t \left[\Lambda_{t,t+1} \left(\frac{\Pi_{t+1}}{\Pi_t^{\gamma_w}} \right)^{\varepsilon_w} f_{1,t+1} \right] \tag{47}$$

$$f_{2,t} = w_t^{\varepsilon_w} L_{d,t} + \phi_w \, \mathbb{E}_t \left[\Lambda_{t,t+1} \left(\frac{\Pi_{t+1}}{\Pi_t^{\gamma_w}} \right)^{\varepsilon_w - 1} f_{2,t+1} \right] \tag{48}$$

where $w_t = W_t/P_t$ is the aggregate real wage from 40, and $f_{1,t} = F_{1,t}/P_t^{\varepsilon_w}$ and $f_{2,t} = F_{2,t}/P_t^{\varepsilon_w - 1}$

Aggregation Integrate equation 39 across h, noting that $\int_0^1 L_{d,t}(h)\,dh = L_t$. Using the demand function for a union's labor, equation 39, yields

$$L_t = L_{d,t} v_t^w \tag{49}$$

where v_t^w is the wage dispersion measure.

$$v_t^w = \int_0^1 \left(\frac{w_t(h)}{w_t} \right)^{-\varepsilon_w} dh \tag{50}$$

Note that this can be written in terms of real wages since it is a ratio. Because of properties of Calvo wage-setting, we can write this as

$$v_t^w = (1 - \phi_w) \left(\frac{w_t^*}{w_t} \right)^{-\varepsilon_w} + \int_{1-\phi_w}^1 \left(\frac{\Pi_{t-1}^{\gamma_w} W_{t-1}(h)}{W_t} \right)^{-\varepsilon_w} dh \tag{51}$$

$$= (1-\phi_w)\left(\frac{w_t^*}{w_t}\right)^{-\varepsilon_w} + \Pi_{t-1}^{-\gamma_w\varepsilon_w} W_t^{\varepsilon_w} W_{t-1}^{-\varepsilon_w} \int_{1-\phi_w}^{1} \left(\frac{W_{t-1}(h)}{W_{t-1}}\right)^{-\varepsilon_w} dh \tag{52}$$

which may be written as

$$v_t^w = (1-\phi_w)\left(\frac{w_t^*}{w_t}\right)^{-\varepsilon_w} + \phi_w \Pi_{t-1}^{-\gamma_w\varepsilon_w} W_t^{\varepsilon_w} W_{t-1}^{-\varepsilon_w} v_{t-1}^w \tag{53}$$

Expressing this in real terms gives

$$v_t^w = (1-\phi_w)\left(\frac{w_t^*}{w_t}\right)^{-\varepsilon_w} + \phi_w \left(\frac{\Pi_t}{\Pi_{t-1}^{\gamma_w}}\right)^{\varepsilon_w} \left(\frac{w_t}{w_{t-1}}\right)^{\varepsilon_w} v_{t-1}^w \tag{54}$$

From equation 40, we have

$$W_t^{1-\varepsilon_w} = (1-\phi_w)(W_t^*)^{1-\varepsilon_w} + \int_{1-\phi_w}^{1} \left(\Pi_{t-1}^{\gamma_w} W_{t-1}(h)\right)^{1-\varepsilon_w} dh \tag{55}$$

Via a law of large numbers, this is

$$W_t^{1-\varepsilon_w} = (1-\phi_w)(W_t^*)^{1-\varepsilon_w} + \Pi_{t-1}^{\gamma_w(1-\varepsilon_w)} \phi_w W_{t-1}^{1-\varepsilon_w} \tag{56}$$

Dividing both sides by $P_t^{1-\varepsilon_w}$ gives

$$w_t^{1-\varepsilon_w} = (1-\phi_w)(w_t^*)^{1-\varepsilon_w} + \phi_w \Pi_{t-1}^{\gamma_w(1-\varepsilon_w)} \Pi_t^{\varepsilon_w - 1} w_{t-1}^{1-\varepsilon_w} \tag{57}$$

A.3 Rest of the production

A.3.1 Capital Producer

New physical capital is produced from the final output subject to adjustment costs:

$$\hat{I}_t = \Big[1 - S(I_t/I_{t-1})\Big] I_t \tag{58}$$

Here, I_t is the (unconsumed) final output and $S(\cdot)$ is the convex investment adjustment cost. The firm pays dividends

$$\mathrm{DIV}_t^k = P_t^k \Big[1 - S(I_t/I_{t-1})\Big] I_t - P_t I_t, \tag{59}$$

or, in real terms,

$$\text{div}_t^k \;=\; p_t^k\Big[1 - S(I_t/I_{t-1})\Big]I_t \;-\; I_t. \tag{60}$$

It chooses $\{I_t\}$ to maximize the expected discounted value of real profits using the household SDF:

$$\max_{\{I_t\}}\; E_t \sum_{j\geq 0} \Lambda_{t,t+j}\Big\{p_{t+j}^k\Big[1 - S(I_{t+j}/I_{t+j-1})\Big]I_{t+j} - I_{t+j}\Big\}. \tag{61}$$

The optimality condition is the standard q-type Euler equation:

$$\begin{aligned} 1 \;&= p_t^k[1 - S(I_t/I_{t-1}) - S'(I_t/I_{t-1})\,(I_t/I_{t-1})] \\ &\quad + E_t\big[\Lambda_{t,t+1}\, p_{t+1}^k\, S'(I_{t+1}/I_t)\,(I_{t+1}/I_t)^2\big] \end{aligned} \tag{62}$$

A.3.2 Retailers

Retail firm f earns nominal profits as follows:

$$\text{DIV}_t^R(f) = P_t(f)Y_t(f) - P_{m,t}Y_{m,t}(f), \tag{63}$$

and with $Y_{m,t}(f) = Y_t(f)$ and demand $Y_t(f) = (P_t(f)/P_t)^{-\varepsilon_p}Y_t$ this becomes

$$\text{DIV}_t^R(f) = P_t(f)^{1-\varepsilon_p}P_t^{\varepsilon_p}Y_t - P_{m,t}P_t(f)^{-\varepsilon_p}P_t^{\varepsilon_p}Y_t \tag{64}$$

With Calvo pricing, measure $1-\phi_p$ of retailers can be reset in t; otherwise, prices are indexed to lagged inflation at rate γ_p:

$$P_{t+j}(f) = P_t(f)\left(\frac{P_{t+j-1}}{P_{t-1}}\right)^{\gamma_p} \tag{65}$$

A retailer chooses $P_t(f)$ to maximize the present discounted value of the real profits returned to households:

$$\begin{aligned} \max_{P_t(f)} E_t \sum_{j\geq 0} \phi_p^j \Lambda_{t,t+j}\,[\,P_t(f)^{1-\varepsilon_p}\left(\frac{P_{t+j-1}}{P_{t-1}}\right)^{(1-\varepsilon_p)\gamma_p} & P_{t+j}^{\varepsilon_p-1}Y_{t+j} \\ - P_{m,t+j}P_t(f)^{-\varepsilon_p}\left(\frac{P_{t+j-1}}{P_{t-1}}\right)^{-\varepsilon_p\gamma_p} & P_{t+j}^{\varepsilon_p}Y_{t+j}\,] \end{aligned} \tag{66}$$

The FOC implies a reset price:

$$P_t^* = \frac{\varepsilon_p}{\varepsilon_p - 1} \frac{X_{1,t}}{X_{2,t}}, \tag{67}$$

with

$$X_{1,t} = \sum_{j \geq 0} (\phi_p \beta)^j \frac{\mu_{t+j}}{\mu_t} P_{m,t+j} \left(\frac{P_{t+j-1}}{P_{t-1}} \right)^{-\varepsilon_p \gamma_p} P_{t+j}^{\varepsilon_p} Y_{t+j} \tag{68}$$

$$X_{2,t} = \sum_{j \geq 0} (\phi_p \beta)^j \frac{\mu_{t+j}}{\mu_t} \left(\frac{P_{t+j-1}}{P_{t-1}} \right)^{(1-\varepsilon_p)\gamma_p} P_{t+j}^{\varepsilon_p - 1} Y_{t+j}, \tag{69}$$

which satisfy

$$X_{1,t} = p_{m,t} P_t^{\varepsilon_p} Y_t + \phi_p \Lambda_{t,t+1} \Pi_t^{-\varepsilon_p \gamma_p} X_{1,t+1} \tag{70}$$

$$X_{2,t} = P_t^{\varepsilon_p - 1} Y_t + \phi_p \Lambda_{t,t+1} \Pi_t^{(1-\varepsilon_p)\gamma_p} X_{2,t+1} \tag{71}$$

In stationary, relative terms let $p_t^* = P_t^*/P_t$, $x_{1,t} = X_{1,t}/P_t^{\varepsilon_p}$, $x_{2,t} = X_{2,t}/P_t^{\varepsilon_p - 1}$ to obtain:

$$p_t^* = \frac{\varepsilon_p}{\varepsilon_p - 1} \frac{x_{1,t}}{x_{2,t}}, \tag{72}$$

$$x_{1,t} = p_{m,t} Y_t + \phi_p E_t \left[\Lambda_{t,t+1} \left(\frac{\Pi_{t+1}}{\Pi_t^{\gamma_p}} \right)^{\varepsilon_p} x_{1,t+1} \right], \tag{73}$$

$$x_{2,t} = Y_t + \phi_p E_t \left[\Lambda_{t,t+1} \left(\frac{\Pi_{t+1}}{\Pi_t^{\gamma_p}} \right)^{\varepsilon_p - 1} x_{2,t+1} \right] \tag{74}$$

Aggregation yields a price-dispersion term v_t^p and wholesale–final output link:

$$Y_t v_t^p = Y_{m,t} \tag{75}$$

$$v_t^p = \int_0^1 \left(\frac{P_t(f)}{P_t} \right)^{-\varepsilon_p} df = (1 - \phi_p)(p_t^*)^{-\varepsilon_p} + \phi_p \left(\frac{\Pi_t}{\Pi_{t-1}^{\gamma_p}} \right)^{\varepsilon_p} v_{t-1}^p \tag{76}$$

The aggregate price index evolves as

$$P_t^{1-\varepsilon_p} = (1-\phi_p)(P_t^*)^{1-\varepsilon_p} + \phi_p\, \Pi_{t-1}^{\gamma_p(1-\varepsilon_p)} P_{t-1}^{1-\varepsilon_p} \tag{77}$$

or, dividing by $P_t^{1-\varepsilon_p}$,

$$1 = (1-\phi_p)(p_t^*)^{1-\varepsilon_p} + \phi_p\, \Pi_{t-1}^{\gamma_p(1-\varepsilon_p)} \Pi_t^{\varepsilon_p-1} \tag{78}$$

A.4 Fiscal Authority

The fiscal authority purchases an exogenous stochastic quantity of the final goods G_t in each period. It finances this with lump–sum taxes T_t, remittances from the central bank $T_{cb,t}$, and issuing nominal government bonds $B_{G,t}$. Ricardian equivalence fails in this environment because financial-intermediary frictions matter for the mix of taxes versus debt. For tractability, the real stock of government debt is held fixed at $\bar{b}_G$, implying $B_{G,t} = P_t \bar{b}_G$. Lump–sum taxes then adjust endogenously to satisfy the period budget constraint.

Let $Q_{B,t}$ be the price of a long-term government bond (perpetuity with coupon decay $\kappa^b \in [0,1]$), and $\Pi_t = P_t/P_{t-1}$ be the gross inflation. The government's nominal budget constraint is

$$P_t G_t + P_{t-1}\, \bar{b}_G \;=\; P_t T_t + P_t T_{cb,t} + Q_{B,t}\, P_t\, \bar{b}_G \left(1 - \kappa^b\, \Pi_t^{-1}\right) \tag{79}$$

$T_{cb,t}$ denotes the (real) transfer from the central bank to fiscal authority; its exact expression is given in the central bank block of the model.

A.5 Aggregation and Exogenous Processes

The model features five exogenous variables—neutral productivity A_t, government spending G_t,the liquidity process θ_t and evolution of decay parameter for each private and government bonds—each following an AR(1) in logs:

$$\ln A_t = \rho_A \ln A_{t-1} + s_A \varepsilon_{A,t} \tag{80}$$

$$\ln G_t = (1-\rho_G)\ln \bar{G} + \rho_G \ln G_{t-1} + s_G \varepsilon_{G,t} \tag{81}$$

$$\ln \theta_t = (1-\rho_\theta)\ln \bar{\theta} + \rho_\theta \ln \theta_{t-1} + s_\theta \varepsilon_{\theta,t} \tag{82}$$

$$\ln \kappa_t^f = (1-\rho_\kappa^f)\ln \bar{\kappa}^f + \rho_\kappa^f \ln \kappa_{t-1}^f + s_\kappa^f \varepsilon_{\kappa^f,t} \tag{83}$$

$$\ln \kappa_t^b = (1-\rho_\kappa^b)\ln \bar{\kappa}^b + \rho_\kappa^b \ln \kappa_{t-1}^b + s_\kappa^b \varepsilon_{\kappa^b,t} \tag{84}$$

$$\tag{85}$$

Autoregressive parameters satisfy $0 < \rho_. < 1$ and shocks are standard normal; $\bar{G}$,$\bar{\theta}$, $\bar{\kappa}^f$ and $\bar{\kappa}^b$, are steady-state values and steady-state productivity is normalized to one.

Privately issued and government bonds must be held by either intermediaries or the central bank (real terms):

$$\bar{b}^G = b_t + b_t^{cb} \tag{86}$$

where $f_t = \sum_i f_{i,t}$ and $b_t = \sum_i b_{i,t}$

Aggregating the intermediary balance sheet and writing in real terms (with $d_t \equiv D_t/P_t$):

$$Q_t f_t + Q_{B,t} b_t + re_t = d_t + n_t \tag{87}$$

Aggregated net-worth dynamics:

$$\begin{aligned} n_t = \sigma \Pi_t^{-1} \Big[&(R_t^F - R_{t-1}^d) Q_{t-1} f_{t-1} + (R_t^B - R_{t-1}^d) Q_{B,t-1} b_{t-1} \\ &+ (R_{t-1}^{re} - R_{t-1}^d) re_{t-1} + R_{t-1}^d n_{t-1} \Big] + X \end{aligned} \tag{88}$$

where σ is the survival probability of intermediaries and X is start-up funds for new ones.

Aggregated costly-enforcement (leverage) constraint:

$$Q_t f_t + \Delta Q_{B,t} b_t \leq \phi_t n_t \tag{89}$$

which binds when the intermediary constraint 8 binds.

Resource constraint:

$$Y_t = C_t + I_t + G_t \tag{90}$$

Appendix B Equilibrium Conditions

Households

$$\mu_t = \frac{1}{C_t - b\, C_{t-1}} - \frac{b\, \beta}{C_{t+1} - b\, C_t} \tag{B.1}$$

$$\chi\, L_t^{\eta} = \mu_t\, mrs_t \tag{B.2}$$

$$R_t^d\, \mathbf{E}_t \Lambda_{t,t+1}\, \Pi_{t+1}^{-1} = 1 \tag{B.3}$$

$$\Lambda_{t,t-1} = \frac{\beta\, \mu_t}{\mu_{t-1}} \tag{B.4}$$

Financial Intermediaries

$$Q_t\, f_t + Q_{B,t}\, b_t + re_t = d_t + n_t \tag{B.5}$$

$$R_t^F = \frac{1 + \kappa_t^f\, Q_t}{Q_{t-1}} \tag{B.6}$$

$$R_t^B = \frac{1 + \kappa_t^b\, Q_{B,t}}{Q_{B,t-1}} \tag{B.7}$$

$$\begin{aligned} n_t = \sigma\, \Pi_t^{-1} \Big(& (R_t^F - R_{t-1}^d) Q_{t-1} f_{t-1} \\ & + (R_t^B - R_{t-1}^d) Q_{B,t-1} b_{t-1} \\ & + (R_{t-1}^{re} - R_{t-1}^d) re_{t-1} \\ & + R_{t-1}^d n_{t-1} \Big) + X \end{aligned} \tag{B.8}$$

$$\mathbf{E}_t \Pi_{t+1}^{-1}\, \Lambda_{t,t+1}\, \Omega_{t+1}\, (R_{t+1}^F - R_t^d) = \frac{\lambda_t}{1 + \lambda_t}\, \theta_t \tag{B.9}$$

$$\mathbf{E}_t \Pi_{t+1}^{-1}\, \Lambda_{t,t+1}\, \Omega_{t+1}\, (R_{t+1}^B - R_t^d) = \frac{\lambda_t}{1 + \lambda_t}\, \theta_t\, \Delta \tag{B.10}$$

$$\mathbf{E}_t \Pi_{t+1}^{-1}\,\Lambda_{t,t+1}\,\Omega_{t+1}\,(R_t^{re} - R_t^d) = 0 \tag{B.11}$$

$$\Omega_t = 1 - \sigma + \sigma\,\theta_t\,\phi_t \tag{B.12}$$

$$Q_t\,f_t + \Delta b_t\,Q_{B,t} = n_t\,\phi_t \tag{B.13}$$

$$\theta_t\,\phi_t = (1+\lambda_t)\mathbf{E}_t \Pi_{t+1}^{-1}\,R_t^d\,\Omega_{t+1}\,\Lambda_{t,t+1} \tag{B.14}$$

$$MVf_t = Q_t\,f_t \tag{B.15}$$

$$MVb_t = Q_{B,t}\,b_t \tag{B.16}$$

Labor Market

Labour Unions

$$f_{1,t} = mrs_t\,w_t^{\epsilon_w}\,L_{d,t} + \phi_w \mathbf{E}_t \Lambda_{t,t+1}\,\Pi_{t+1}^{\epsilon_w}\,\Pi_t^{-\epsilon_w \gamma_w}\,f_{1,t+1} \tag{B.17}$$

$$f_{2,t} = w_t^{\epsilon_w}\,L_{d,t} + \phi_w \mathbf{E}_t \Lambda_{t,t+1}\,\Pi_{t+1}^{\epsilon_w - 1}\,\Pi_t^{\gamma_w(1-\epsilon_w)}\,f_{2,t+1} \tag{B.18}$$

$$w_t^* = \frac{\epsilon_w}{\epsilon_w - 1}\frac{f_{1,t}}{f_{2,t}} \tag{B.19}$$

Aggregation

$$L_t = L_{d,t}\,v_t^w \tag{B.20}$$

$$v_t^w = (1-\phi_w)\left(\frac{w_t^*}{w_t}\right)^{-\epsilon_w} + \phi_w\,w_t^{\epsilon_w}\,\Pi_t^{\epsilon_w}\,\Pi_{t-1}^{-\epsilon_w \gamma_w}\,w_{t-1}^{-\epsilon_w}\,v_{t-1}^w \tag{B.21}$$

$$w_t^{1-\epsilon_w} = (1-\phi_w)(w_t^*)^{1-\epsilon_w} + \phi_w\,\Pi_{t-1}^{\gamma_w(1-\epsilon_w)}\,\Pi_t^{\epsilon_w - 1}\,w_{t-1}^{1-\epsilon_w} \tag{B.22}$$

Production

Retail firms

$$p_t^* = \frac{\epsilon_p}{\epsilon_p - 1}\frac{x_{1,t}}{x_{2,t}} \tag{B.23}$$

$$x_{1,t} = p_{m,t}\,Y_t + \phi_p \mathbf{E}_t \Lambda_{t,t+1}\,\Pi_{t+1}^{\epsilon_p}\,\Pi_t^{-\epsilon_p \gamma_p}\,x_{1,t+1} \tag{B.24}$$

$$x_{2,t} = Y_t + \phi_p \mathbf{E}_t \Lambda_{t,t+1}\,\Pi_{t+1}^{\epsilon_p - 1}\,\Pi_t^{\gamma_p(1-\epsilon_p)}\,x_{2,t+1} \tag{B.25}$$

Aggregation

$$Y_t^m = Y_t \, v_t^p \tag{B.26}$$

$$v_t^p = (1-\phi_p)(p_t^*)^{-\epsilon_p} + \phi_p \, \Pi_t^{\epsilon_p} \, \Pi_{t-1}^{-\epsilon_p \gamma_p} \, v_{t-1}^p \tag{B.27}$$

$$1 = (1-\phi_p)(p_t^*)^{1-\epsilon_p} + \phi_p \, \Pi_t^{\epsilon_p - 1} \, \Pi_{t-1}^{\gamma_p(1-\epsilon_p)} \tag{B.28}$$

Wholesale Firms

$$Y_t^m = A_t \, K_{t-1}^{\alpha} \, L_{d,t}^{1-\alpha} \tag{B.29}$$

$$K_t = \hat{I}_t + K_{t-1}(1-\delta) \tag{B.30}$$

$$\hat{I}_t \, \psi \, p_t^k = Q_t \left(f_t - \Pi_t^{-1} \kappa_t^f f_{t-1} \right) \tag{B.31}$$

$$w_t = K_{t-1}^{\alpha} \, A_t \, p_{m,t} (1-\alpha) \, L_{d,t}^{-\alpha} \tag{B.32}$$

$$p_t^k M_{1,t} = \mathbf{E}_t \Lambda_{t,t+1} \left(\alpha \, p_{m,t+1} A_{t+1} K_t^{\alpha-1} L_{d,t+1}^{1-\alpha} + (1-\delta) p_{t+1}^k M_{1,t+1} \right) \tag{B.33}$$

$$Q_t M_{2,t} = \mathbf{E}_t \Lambda_{t,t+1} \Pi_{t+1}^{-1} \left(1 + \kappa_t^f Q_{t+1} M_{2,t+1} \right) \tag{B.34}$$

$$\frac{M_{1,t} - 1}{M_{2,t} - 1} = \psi \tag{B.35}$$

Capital Producers

$$\hat{I}_t = I_t \left(1 - \frac{\kappa_I}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 \right) \tag{B.36}$$

$$1 = p_t^k \left(1 - \frac{\kappa_I}{2} \left(\frac{I_t}{I_{t-1}} - 1 \right)^2 - \frac{I_t}{I_{t-1}} \kappa_I \left(\frac{I_t}{I_{t-1}} - 1 \right) \right) + \mathbf{E}_t \kappa_I \Lambda_{t,t+1} p_{t+1}^k \left(\frac{I_{t+1}}{I_t} - 1 \right) \left(\frac{I_{t+1}}{I_t} \right)^2 \tag{B.37}$$

Government

Fiscal Authority

$$G_t + \Pi_t^{-1} \bar{b}_G = T_t + T_{cb,t} + Q_{B,t} \bar{b}_G \left(1 - \kappa_t^b \Pi_t^{-1} \right) \tag{B.38}$$

Monetary Policy

$$\log(R_t^{tr}) = (1-\rho_r)\log(R^{re}) + \rho_r \log(R_{t-1}^{tr}) + (1-\rho_r)\left[\phi_\pi(\log(\Pi_t) - \log(\Pi)) + \phi_y(\log(Y_t) - \log(Y_{t-1}))\right] + s_r\epsilon_{r,t} \tag{B.39}$$

$$R_t^{re} = R_t^{tr} \tag{B.40}$$

$$R_t^d = R_t^{re} \tag{B.41}$$

$$b_{cb,t} = (1-\rho_b)b_{cb} + b_{cb,t-1}\rho_b + s_b\epsilon_{b,t} \tag{B.42}$$

Central Bank Balance Sheet

$$Q_{B,t}\, b_{cb,t} = re_t \tag{B.43}$$

$$T_{cb,t} = (1+\kappa_t^b Q_{B,t})\Pi_t^{-1} b_{cb,t-1} - re_{t-1}\Pi_t^{-1} R_{t-1}^{re} \tag{B.44}$$

Aggregation

Exogenous Processes

$$\log A_t = \rho_A \log A_{t-1} + s_A\epsilon_{A,t} \tag{B.45}$$

$$\log G_t = (1-\rho_G)\log G + \rho_G \log G_{t-1} + s_G\epsilon_{G,t} \tag{B.46}$$

$$\log \theta_t = (1-\rho_\theta)\log\theta + \rho_\theta \log\theta_{t-1} + s_\theta\epsilon_{\theta,t} \tag{B.47}$$

$$\kappa_t^f = (1-\rho_{kf})\bar{\kappa}^f + \rho_{kf}\kappa_{t-1}^f + s_{kf}\epsilon_{kf,t} \tag{B.48}$$

$$\kappa_t^b = (1-\rho_{kb})\bar{\kappa}^b + \rho_{kb}\kappa_{t-1}^b + s_{kb}\epsilon_{kb,t} \tag{B.49}$$

Goods market clearing

$$\bar{b}_G = b_t + b_{cb,t} \tag{B.50}$$

$$Y_t = G_t + C_t + I_t \tag{B.51}$$

Returns and Spreads

$$R_t^{L,F} = \kappa_t^f + Q_t^{-1} \quad \text{(Nominal Long yield (Private))} \tag{B.52}$$

$$R_t^{L,B} = \kappa_t^b + Q_{B,t}^{-1} \quad \text{(Nominal Long yield (Government))} \tag{B.53}$$

$$return_t^f = R_t^F - R_{t-1}^d \quad \text{(Excess Return on Private Bond)} \tag{B.54}$$

$$return_t^b = R_t^B - R_{t-1}^d \quad \text{(Excess Return on Government)} \tag{B.55}$$

$$return_t^{fb} = R_t^F - R_t^B \quad \text{(Excess return between Private vs Government Bonds)} \tag{B.56}$$

$$S_t^f = R_t^{L,F} - R_t^d \quad \text{(Term spread-Private bonds)} \tag{B.57}$$

$$S_t^b = R_t^{L,B} - R_t^d \quad \text{(Term Spread-Government Bonds)} \tag{B.58}$$

$$return_t^{fR} = R_t^F - \Pi_{t+1} \quad \text{(Real Rate)} \tag{B.59}$$

$$f_t^r = R_t^{L,F} - \Pi_{t+1} \quad \text{(Real Long Yield, Private)} \tag{B.60}$$

$$b_t^r = R_t^{L,B} - \Pi_{t+1} \quad \text{(Real Long Yield, Government)} \tag{B.61}$$

Maturity Gap

$$mgap_t = \frac{f_t M_t^f + b_t M_t^b + re_t M^{re} - d_t M^d}{re_t + f_t + b_t} \tag{B.62}$$

$$M_t^f = \frac{1}{1 - \kappa_t^f} \tag{B.63}$$

$$M_t^b = \frac{1}{1 - \kappa_t^b} \tag{B.64}$$

Welfare

$$W_t = (C_t - b\,C_{t-1}) - \psi \frac{L_t^{1+\eta}}{1+\eta} + \beta \mathbf{E}_t W_{t+1} \tag{B.65}$$

The full set of equilibrium conditions:

- **Households** (4 eqs): (B.1)–(B.4).
- **Financial Intermediaries** (12 eqs): (B.5)–(B.16).
- **Labor Market** (6 eqs): (B.17)–(B.22).
- **Production** (15 eqs): Retailers (B.23)–(B.28); Wholesale firms (B.29)–(B.35); Capital producers (B.36)–(B.37).

- **Fiscal Authority** (1 eq): (B.38).
- **Monetary Policy** (4 eqs): Rule (B.39), rate setting (B.40)–(B.41), and QE/QT rule (B.42).
- **Central Bank** (2 eqs): Balance sheet (B.43) and remittance (B.44).
- **Exogenous Processes** (5 eqs): (B.45)–(B.49).
- **Aggregation & Market Clearing** (2 eqs): (B.50)–(B.51).
- **Definitions** (13 eqs): Returns and Spreads (B.52)–(B.61); Maturity Gap (B.62)–(B.64).
- **Welfare** (1 eq): Welfare (B.65)

These comprise 65 equations for the 65 endogenous variables listed below:

$$\{A_t, b_t, b_{cb,t}, MVb_t, C_t, d_t, f_t, f_{1,t}, f_{2,t}, f_t^r, MVf_t, G_t, I_t, \hat{I}_t, K_t, \kappa_t^f, \kappa_t^b, L_t, L_{d,t}, \lambda_t, \Lambda_t,$$

$$M_{1,t}, M_{2,t}, M_t^f, M_t^b, mgap_t, mrs_t, \mu_t, n_t, \Omega_t, \omega_t, p_t^*, p_t^k, p_{m,t}, \phi_t, \Pi_t, Q_t, Q_{B,t}, R^{tr,t}, R_t^{re}, R_t^d,$$

$$R_t^F, R_t^B, R_t^{L,F}, R_t^{L,B}, re_t, return_t^f, return_t^b, return_t^{fb}, return_t^{fR}, S_t^f, S_t^b, T_t, T_{cb,t}, \theta_t, v_t^p, v_t^w, w_t,$$

$$w_t^*, W_t, x_{1,t}, x_{2,t}, Y_t, Y_t^m\}$$

Table 3: Calibrated Parameters

Parameter	Value or Target	Description
Parameters		
β	0.995	Discount factor
b	0.70	Habit formation
η	1	Inverse Frisch elasticity
χ	$L = 1$	Labor disutility scaling parameter / steady state labor
α	0.30	Production function exponent on capital
δ	0.025	Steady state depreciation
κ_I	2	Investment adjustment cost
Π	1	Steady state (gross) inflation
ε_p	11	Elasticity of substitution goods
ε_w	11	Elasticity of substitution labor
φ_p	0.75	Price rigidity
φ_w	0.75	Wage rigidity
γ_p	0	Price indexation
γ_w	0	Wage indexation
$\bar{b}_G$	$\frac{b_G Q_B}{4Y} = 0.6$	Steady state government debt
G	$\frac{G}{Y} = 0.2$	Steady state government spending
b_b	$\frac{b_{cb} Q_B}{4Y} = 0.005$	Steady state central bank Treasury holdings
Δ	2/3	Government bond recoverability
σ	0.95	Intermediary survival probability
ψ	0.35	Fraction of investment from debt
κ^f	$1 - 40^{-1}$	Private bond duration
κ^b	$1 - 32^{-1}$	Government bond duration
$Hmgap$	32	High maturity gap
$Lmgap$	16	Low maturity gap
ρ_r	0.8	Taylor rule smoothing
φ_π	1.8	Taylor rule inflation
φ_y	0.0	Taylor rule output growth
ρ_A	0.95	AR productivity
ρ_G	0.95	AR government spending
ρ_b	0.90	AR central bank treasury
ρ_θ	0.95	AR liquidity
ρ_{κ^f}	0.95	AR decay - private
ρ_{κ^b}	0.95	AR decay - government
Shock sizes		
s_A	0.0065	SD productivity
s_G	0.01	SD government spending
s_θ	0.04	SD liquidity
s_{κ^f}	0.01	SD decay - private
s_b	0.01	SD decay - government

Note: This table lists the values of calibrated parameters or the target used in the calibration.

Appendix C Empirical analysis

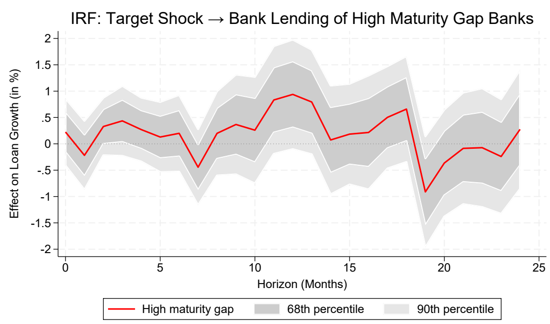
Table 4: Description of the variables

Variable	Unit and Frequency	Data Source	Description
Dependent and core variables			
Loan growth	Percentages, monthly	AnaCredit	Computed from the (recognized) outstanding loans reported in *AnaCredit*, where the counterparty is a euro area non-financial corporation. Aggregations are done at the bank–month–economic activity of the counterparty (NACE sector) level.
Maturity gap	Years, quarterly	ECB Supervisory Reporting data	The maturity gap proxy is calculated based on the future cash flows, both inflows and outflows, reported by euro area banks in template COREP C66.01 – *Maturity Ladder*. Cashflows are reported in 21 maturity buckets. The maturity of inflows and outflows in each bucket is proxied by the bucket's midpoint (for example, 1.5 years for flows in "Greater than 12 months and up to 2 years"). A maturity of 15 years is assigned to cash flows allocated in "Greater than 5 years." The maturity-weighted difference between inflows and outflows is scaled by the bank's total assets (from the FINREP template F01).
Monetary policy shocks: Target and QT	Basis points, monthly	EA-MPD (Altavilla et al. (2019))	Conventional and unconventional monetary policy shocks refer to the "Target" and "QT" shocks, respectively, as defined by Altavilla et al. (2019). These are computed as the rotated factors explaining high-frequency changes in Overnight Index Swap (OIS) rates around monetary policy events (i.e., between the press release of the ECB monetary policy decision and the end of the ECB President's press conference). The Target shock is scaled to yield a unit effect on the one-month OIS rate. The QT shock is scaled to yield a unit effect on the ten-year OIS yield.

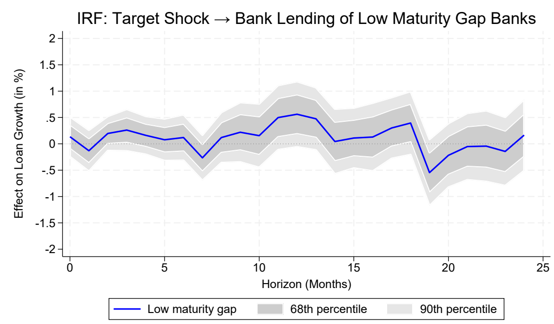
Variable	Unit and Frequency	Data Source	Description
Controls			
Bank size	No unit (log), quarterly	ECB Supervisory Reporting data	Defined as log(Total Assets). Total Assets are the carrying amounts sourced from template F01 of FINREP.
Non-performing loan (NPL) ratio	Percentages, quarterly	ECB Supervisory Reporting data	Defined as non-performing loans over total loans. Only loans granted to the non-financial private sector (i.e., non-financial corporations and households) are considered in both the numerator and the denominator. The carrying amounts are sourced from the FINREP template F18.
Liquidity coverage ratio (LCR)	Percentages, quarterly	ECB Supervisory Reporting data	The liquidity coverage ratio is sourced from the COREP template C76. Banks report this value in line with the definition outlined in Article 4(1) of the Delegated Regulation (EU) 2015/61.
Profitability: Return on assets	Percentages, quarterly	ECB Supervisory Reporting data	Defined as Total Profit/Loss over Total Assets. The numerator is sourced from the FINREP template F02 and adjusted such that it represents the four-quarter trailing sum of profits (i.e., a year-on-year measure). The denominator is sourced from FINREP template F01.
Capital: Common Equity Tier 1 (CET1) ratio	Percentages, quarterly	ECB Supervisory Reporting data	Defined as the CET1 capital over the total risk exposure amount (i.e., risk-weighted assets). This value is reported in COREP template C03, in accordance with point (a) of Article 92(2) of the CRR.
Leverage ratio	Percentages, quarterly	ECB Supervisory Reporting data	Defined by the regulator as the Tier 1 capital amount over the total leverage ratio exposure measure. We use the fully phased-in definition. The denominator includes on-balance sheet assets, securities financing transactions, derivatives exposures, and other off-balance sheet items, net of exemptions (e.g., intragroup exposures, promotional loans,...). The leverage ratio is sourced from the COREP template C47.

Variable	Unit and Frequency	Data Source	Description
Controls			
Loan-to-deposit ratio	Percentages, quarterly	ECB Supervisory Reporting data	Defined as the total loans to the non-financial private sector (i.e., non-financial corporations and households) divided by the total deposits from the non-financial private sector. The carrying amount of loans is sourced from the FINREP template F18, summing the amounts reported under the different accounting rules (i.e., at fair value and amortized cost). The carrying amount of deposits is sourced from the FINREP template F8, which sums the amounts reported under the different accounting rules.
Deposit ratio	Percentages, quarterly	ECB Supervisory Reporting data	Defined as the total deposits from the non-financial private sector (i.e., non-financial corporations and households) divided by total assets. The carrying amount of deposits is sourced from the FINREP template F8, summing the amounts reported under the different accounting rules. Total Assets are carrying amounts sourced from template F01 of FINREP.

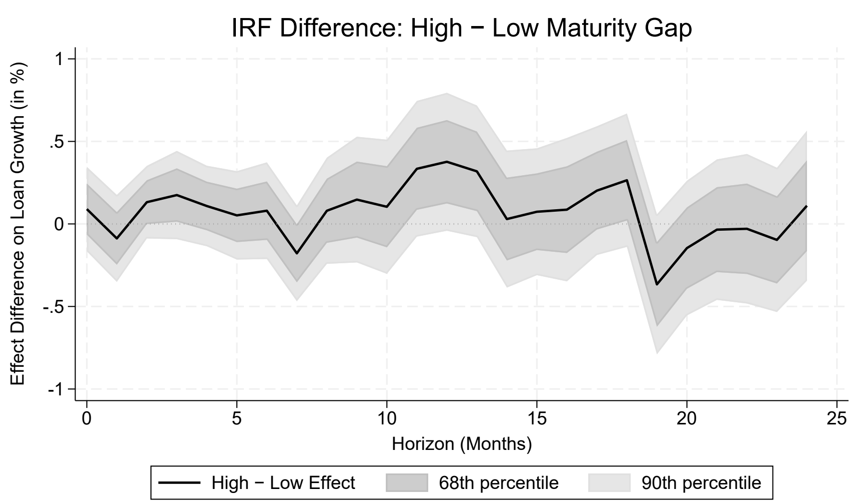
Figure 9: Analysis of bank lending responses to a target shock, comparing high and low maturity gap banks - Restricted sample



(a) *Response of lending from high maturity gap banks to target shock*

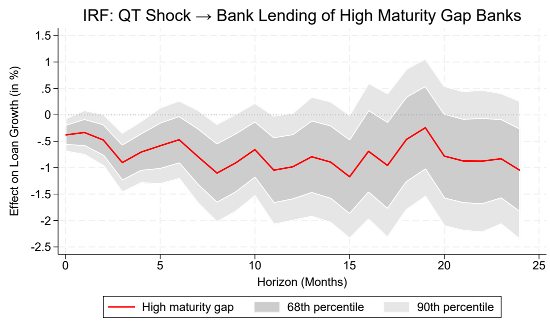


(b) *Response of lending from low maturity gap banks to target shock*

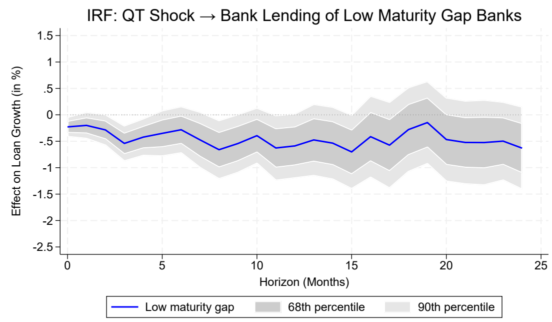


(c) *Difference in bank lending response between banks with high vs low maturity gap under a target shock*

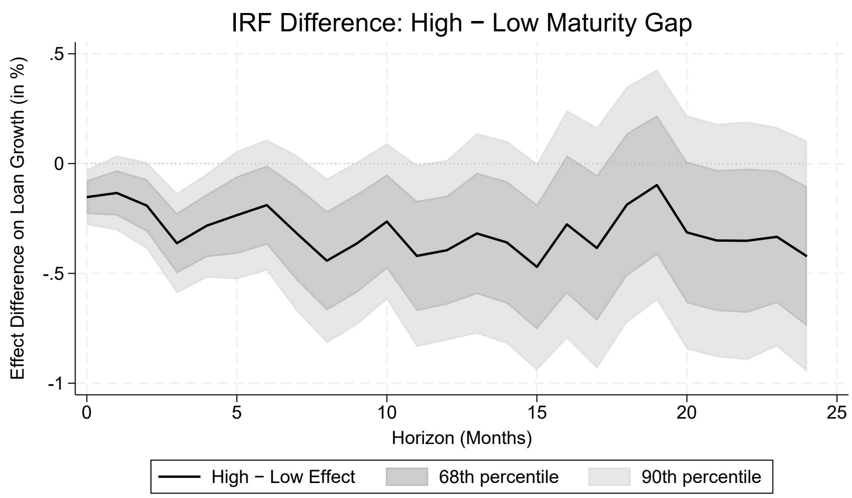
Figure 10: Analysis of bank lending responses to a QT shock, comparing high and low maturity gap banks - Full sample



(a) *Response of lending from high maturity gap banks to QT shock*

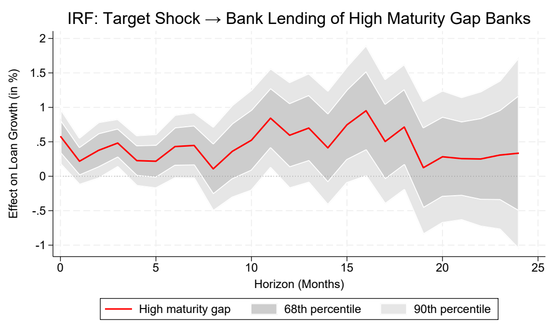


(b) *Response of lending from low maturity gap banks to QT shock*

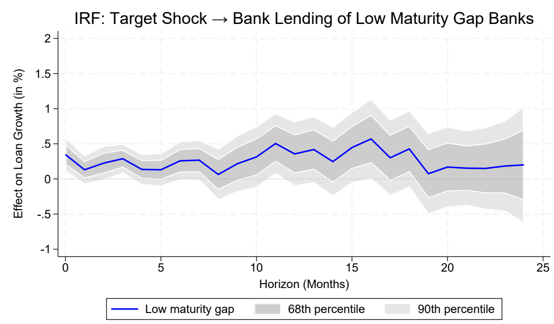


(c) *Difference in bank lending response between banks with high vs low maturity gap under a QT shock*

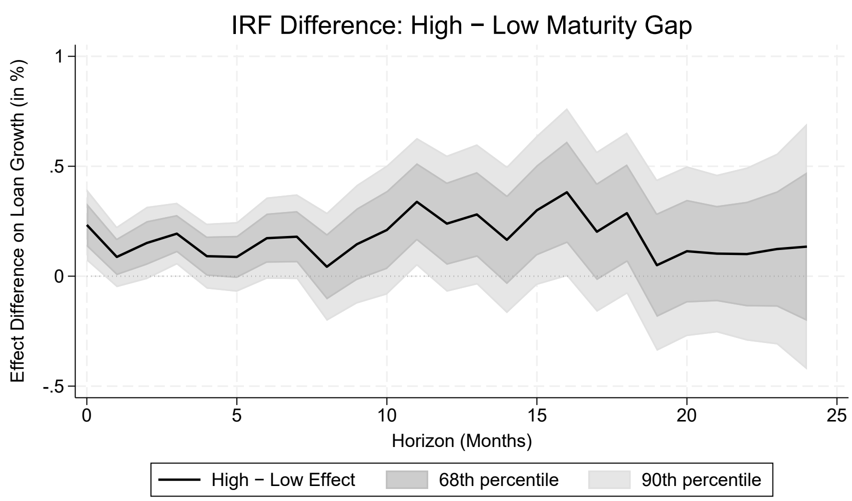
Figure 11: Analysis of bank lending responses to a target shock, comparing high and low maturity gap banks - Full sample



(a) *Response of lending from high maturity gap banks to target shock*



(b) *Response of lending from low maturity gap banks to target shock*



(c) *Difference in bank lending response between banks with high vs low maturity gap under a target shock*