Monetary Policy in a Tightening Cycle
Raising nominal rates without causing a financial crisis*

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Abstract

With inflation reaching levels not seen in more than thirty years, central banks in many advanced economies have embarked on a rapid tightening cycle over the past eighteen months. Interest rate hikes impose capital losses on bank balance sheets. As net worth declines, risks to financial stability grow. In recent months, this has rekindled a debate on a potential trade-off between monetary and financial stability. In this paper, I set up a new-Keynesian model of savers and borrowers with frictional financial intermediation to rationalise this. I then show that a limited expansion of the central bank balance sheet can directly address these concerns with little to no costs for the pursuit of monetary stability in a tightening cycle. Differences in the transmission of both monetary instruments are key for this result. A decomposition of bank net worth illustrates this and provides insights into financial sector implications of monetary policy. Further, a simulation exercise implements a U.S. 'pandemic era inflation' scenario as a laboratory to analyse policy counterfactuals against the backdrop of heightened inflation and declining bank net worth. In this environment, a temporary balance sheet expansion is successful in stabilising bank net worth at little cost to inflation.

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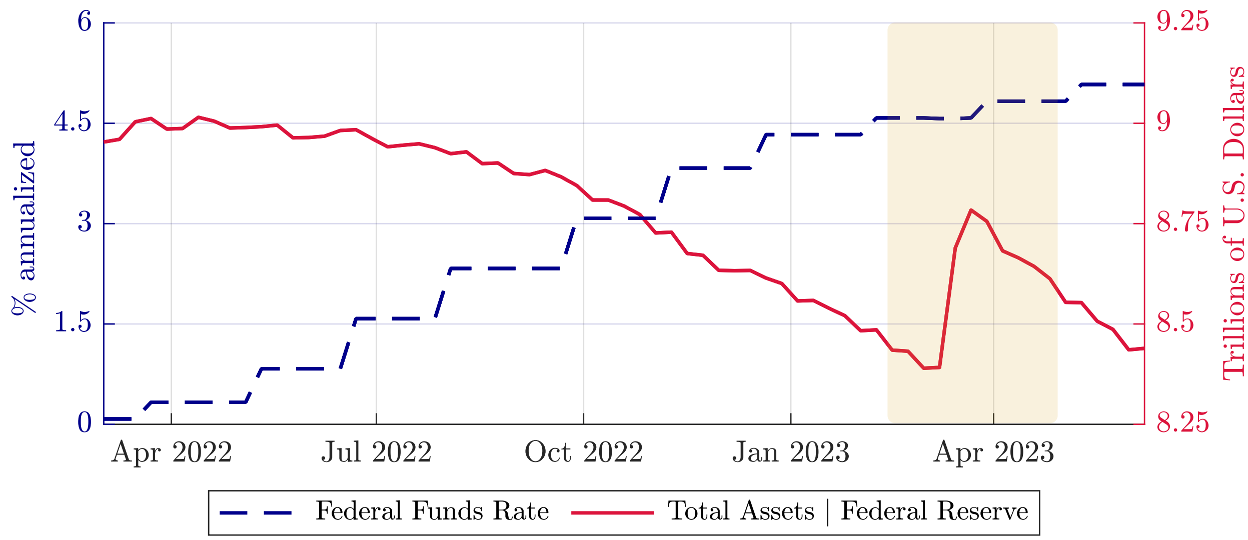
1 Introduction

Over the past eighteen months, inflation in advanced economies has reached levels not seen in more than thirty years. In response, many central banks have been rapidly tightening their monetary stance, raising nominal interest rates and phasing out active asset purchase policies employed ever since the 2007/08 Great Financial Crisis. This contractionary policy has come with adverse effects on financial institutions, leading to cases of financial turmoil, and rekindling a debate on a potential trade-off between monetary and financial stability.[1]

Figure 1. The Federal Reserve in March 2023 | SVB crisis



Note. This Figure plots the Federal Funds Target Rate (left axis, blue) and the stock of total assets on the Federal Reserve balance sheet (right axis, red) around the U.S. regional banking (SVB) crisis in March 2023. Source: Federal Reserve Bank of St Louis.

In practice, institutions such as the U.S. Federal Reserve (FED), the European Central Bank, and the Bank of England reacted to instances of financial instability in recent months with renewed balance sheet expansions while further raising nominal interest rates. Figure 1 illustrates this unconventional pairing of monetary instruments at the example of the FED.

[1] Raghuram Rajan—Professor of Finance at the University of Chicago's Booth School of Business and a former Governor of the Reserve Bank of India—summarized this position in an interview in June 2023, arguing that central banks find themselves in a 'very, very tough situation [. . .] You're damned if you raise rates significantly more and put even more pressure on banks, but you're damned if you don't.'
Wall Street Journal: 'Jerome Powell's Big Problem Just Got Even More Complicated' | 12 June 2023

When in the U.S. in March 2023, several regional banks—including the now defunct Silicon Valley Bank (SVB)—emerged to be at the brink of collapse with consumer price inflation still at 5% far above target, the U.S. Federal Reserve opted to keep raising its main policy rate, the federal funds target rate (Figure 1, blue), while pausing the only recently initiated balance sheet reduction for a sizeable balance sheet expansion (Figure 1, red). At the time, the FED Chair justified this mix of a contractionary interest rate and an expansionary balance sheet policy, arguing 'the balance sheet expansion is really temporary lending to banks [...] It is not intended to directly alter the stance of monetary policy.'[2]

Most conventional models of the macroeconomy characterize the central bank balance sheet as a pure extension or substitute of regular interest rate policy. This is particularly true for a broad range of new-Keynesian models that highlight the aggregate demand stimulus a balance sheet expansion (sometimes termed quantitative easing (QE)) provides when nominal interest rates are constrained at the effective lower bound. Thus, pairing a balance sheet expansion with a contractionary interest rate policy might appear surprising, if not ineffective. So, what are the implications of this unconventional policy pairing? Is there a trade-off between monetary and financial stability in a high inflation environment? And what constitutes effective monetary policy in a tightening cycle?

A monetary tightening comes with adverse effects on financial institutions subject to interest rate risk: as rising nominal interest rates impose capital losses on balance sheets, net worth declines. In a world of imperfect macroprudential regulation, this can turn from a regular transmission mechanism of monetary policy to a concern for financial stability.

In this paper, I set up a new-Keynesian model of borrowers and savers with frictional financial intermediation that rationales these effects. In this environment, I argue that central bank balance sheet expansions, or termed differently, a temporarily repurposed QE intervention is a natural complement to a monetary tightening that can eliminate any trade-off between monetary and financial stabilization. As I show, targeted balance sheet expansions can smooth out the financial stability implications of rapidly rising rates without directly affecting central bank's primary mandate of monetary stabilization.

In the model, financial intermediaries (banks) channel funds from savers to borrowers and are subject to a principal-agent problem limiting leverage and giving rise to a financial accelerator effect. Credit spreads are determined by bank net worth. With pre-determined

[2] Transcript of Chair Powell's Press Conference on March 22, 2023:
https://www.federalreserve.gov/mediacenter/files/FOMCpresconf20230322.pdf

deposit rates and state-contingent returns to lending, banks are subject to interest rate risk. I show that a contractionary rates policy imposes capital losses on bank balance sheets as the value of the portfolio of existing (low-interest) loans declines as interest rates rise. These losses depress bank net worth thereby increasing the likelihood of financial instability. This is one dimension of the supposed trade-off between monetary and financial stability.

Monetary policy in the model is conducted by a central that has two instruments at its disposal: an inertial interest rate policy and a balance sheet policy that exchanges reserves for bank loans. The central bank is not subject to the same principal agent problem as banks, thus a balance sheet expansion eases frictional financial intermediation, stabilizing the value banks' loan portfolio through additional demand and thereby stimulates the economy by compressing credit spreads. In this sense and in normal times, lower nominal interest rates and balance sheet expansions can be thought of as substitutes in an output/inflation space through their effect on aggregate demand. Both policies are not collinear though. I show that an expansionary central bank balance sheet policy can be an effective complement to a contractionary rates policy when bank net worth is a concern. A well-calibrated policy mix smooths out the impact of rising rates on net worth while preserving their contractionary effect on above-target inflation.

Differences in the transmission of both monetary instruments (and a redistributionary cost-push dimension of frictional intermediation) are relevant for this result. A novel decomposition of bank net worth illustrates this and provides further insights the financial sector implications of monetary policy. Furthermore, a simulation exercise implements a U.S. post-pandemic era inflation scenario as a laboratory to analyze policy counterfactuals against the backdrop of heightened inflation and declining bank net worth. In this environment, a temporary balance sheet expansion is successful in smoothing the adverse effects of a contractionary interest rate policy on bank net worth at little cost to inflation.

Literature This paper is relates to at least three broad strands of the literature. First, it builds on and connects to the vast literature on monetary policy and financial stability that has emerged since the Great Financial Crisis. A small selection of influential contributions include Woodford (2012) and Cúrdia and Woodford (2016) on optimal monetary policy in an environment of frictional financial intermediation, Korinek and Simsek (2016) focusing on macroprudential policy, and, more recently, Boissay et al. (2021) and Akinci et al. (2023) on endogenous financial crises and the financial stability interest rate. Brunnermeier et al. (2012) and Adrian and Liang (2018) provide excellent overviews on recent developments in the field. Relative to this literature that often focuses on financial stability concerns arising from risk shifting behavior in a low interest rate environment, this paper is about financial instability arising in a tightening cycle. It proposes central bank balance sheet expansions as a tool to address financial turmoil endogenously arising from rising rates.

Second, this paper relates to a large literature on central bank balance sheet policies as a macroeconomic stabilization tool. These contributions break the irrelevance result in Wallace (1981) and extended in Eggertsson and Woodford (2003) to cases at the effective lower bound, typically highlighting the importance of different transmission channels along at least two dimensions. One, in an environment of segmented markets, a portfolio balance channel as theoretically described in Vayanos and Vila (2021) and thoroughly studied in Chen et al. (2012), Ellison and Tischbirek (2014), and Harrison (2012, 2017), amongst others, implies that central bank asset purchases come with a strong aggregate demand dimension and can be a powerful substitute to conventional interest rate policy, in particular at the zero lower bound. In a similar vein, a signaling channel as first empirically described by Krishnamurthy and Vissing-Jorgensen (2011) and Bauer and Rudebusch (2014) implies balance sheet expansions at the zero lower bound provide a further stimulus serving as a commitment device for a 'lower-for-longer' interest rate policy as shown in Bhattarai et al. (2023). Two, in models of frictional financial intermediation, central bank balance sheet policies typically ease some of the pressure on financial institutions, providing safe and liquid assets. This so-called liquidity channel can be powerful, in particular in times of financial turmoil. Contributions in recent years include Gertler and Kiyotaki (2010, 2015), Gertler and Karadi (2011, 2013), Cúrdia and Woodford (2011), and Carlstrom et al. (2017), as well as, Del Negro et al. (2017), Cui and Sterk (2021), Sims and Wu (2021), and Sims et al. (2023), amongst others. The present paper is also very much part of this sequence of papers that highlights the liquidity effects of balance sheet policies. Compared to this literature, it, however, focuses on the substitutability and complementarity of the two monetary instruments.

Third, this paper relates to a small and very recent strand of the literature that looks at the optimal sequencing of a monetary tightening in interest rates and central balance sheet contractions. Benigno and Benigno (2022) and Cantore and Meichtry (2023) are two contributions in this respect. Contrary to the focus of both of these, in this paper I argue that there might be times in an aggressive tightening cycle when balance sheet expansions (rather than contractions) become the more natural complement to a tightening in rates.

The paper proceeds with Section 2 and a tractable model of savers and borrowers subject to frictional financial intermediation. Section 3 presents the key results. Section 4 concludes.

2 Model

This section sets up a model with frictional financial intermediation, nominal rigidities, and a central bank that conducts interest rate and balance sheet policies. The model builds on and extends a model introduced in de Groot and Haas (2023). It combines a setup with patient and impatient households – savers and borrowers – as in Kiyotaki and Moore (1997) and Iacoviello (2005) with credit frictions in financial intermediation and balance sheet policies as outlined in Gertler and Kiyotaki (2010) and Gertler and Karadi (2011).[3] In the model, financial intermediaries (banks) channel funds from savers to borrowers subject to a principal-agent problem and interest rate risk. A contractionary interest rate policy imposes capital losses on bank balance sheets. Central banks are less efficient than banks in intermediating funds but not credit constrained. Balance sheet policies have real affects.[4]

I show the model—to a first-order approximation—can be reduced to six equations that allow for tractable insights regarding the role balance sheet policies can play in a tightening cycle. All results continue to hold when additional features are introduced as shown below.

[3] The model also shares features with Cúrdia and Woodford (2016) and Sims, Wu, and Zhang (2023) even if some assumptions regarding the labor supply of the two households, transfers, and the functional form of the financial friction differ markedly. More details are provided below. Away from the ZLB, the model in this section nests the simple model in de Groot and Haas (2023) while introducing QE/QT and accounting for endogenous effects of monetary policy on financial intermediaries.

[4] For the central bank balance sheet to matter, it must be able to address (or circumvent) existing frictions in financial markets as first argued by Wallace (1981). In this paper, which focuses on the adverse effects of a monetary tightening on financial intermediaries, this is through a liquidity or credit channel of central bank balance sheet policies in the spirit of Gertler and Kiyotaki (2010), Cúrdia and Woodford (2011), and Del Negro et al. (2017). A notion that is already present in contributions before the Great Financial Crisis though such as Sargent and Wallace (1982) and Holmström and Tirole (1998). Further frictions such as market segmentation as in Vayanos and Vila (2021) and limited commitment on the part of monetary policymakers as in Bhattarai et al. (2023) give rise to additional portfolio balance and signaling channels of central bank balance sheet policies. These additional channels are omitted for the purposes of this paper.

2.1 Set up

Four types of agents populate the model: households, banks, firms, and a central bank. Households are either savers or borrowers who supply labor and transact through banks subject to frictional financial intermediation. Monopolistic firms produce employing labor and set prices subject to nominal rigidities. A central bank conducts monetary policy using two instruments: the interest rate on reserves and the size of its balance sheet (QE/QT).[5]

Households A continuum of households consists of savers and borrowers. The two types are ex-ante heterogeneous and distinguished by their relative patience pinned down by the discount factors β_s and β_b, respectively. The discount factors satisfy $0 < \beta_b < \beta_s < 1$.

Saver households are composed of two sets of members with perfect consumption insurance: workers and bankers. At any time t, a fraction b of household members are bankers and a fraction $1 - b$ are workers. To restrain bankers' accumulation of net worth and keep their principal-agent problem binding (outlined below), it is assumed that a fraction $1 - \theta$ of bankers switches their role with workers every period, keeping the overall proportions constant. This makes bankers' horizon finite with an average survival rate of $1/(1 - \theta)$. When bankers exit their transfer their retained earnings to the their respective household.

Saver households consume, $C_{s,t}$, supply labor, $L_{s,t}$, and save in bank deposits, D_t, that earn a gross nominal return $R_{d,t}$. Financial markets are assumed to be incomplete, making bank deposits with their non-state-contingent nominal return savers' only option for intertemporal substitution. The representative saver household's problem is given by

$$V_{s,t} = \max_{\{C_{s,t}, L_{s,t}, D_t\}} \left(\frac{{C_{s,t}}^{1-\sigma}}{1-\sigma} - \chi \frac{{L_{s,t}}^{1+\varphi}}{1+\varphi} \right) + \beta_s \, \mathbb{E}_t V_{s,t+1}, \tag{1}$$

subject to

$$P_t C_{s,t} + D_t = P_t W_{s,t} L_{s,t} + R_{d,t-1} D_{t-1} + \Omega_t - T_t, \tag{2}$$

[5] For the remainder of this paper, and where not explicitly specified differently, the terms central bank balance sheet expansion and quantitative easing (QE) as well as central bank balance sheet contraction and quantitative tightening (QT) are used interchangeably in the interest of conciseness. In doing so, I follow the academic literature which appears to follow a slightly broader definition of what constitutes QE/QT compared to several central banks that use these terms primarily for balance sheet policies targeting the yield curve. Crucially, this broader definition fits the results in this paper that show balance sheet expansions of different forms, including a repurposed QE, can be a very effective complement to a monetary tightening.

where P_t is the aggregate price level, $W_{s,t}$ is the real wage, and Ω_t denotes profits from firm ownership as well as retained earnings from exiting bankers. Further, T denotes a redistributionary lump-sum tax the government collects from savers and pay to borrowers.[6]

Finally, saver households' three first-order conditions can be summarized by an intertemporal Euler equation and an intratemporal labor-leisure trade-off given by

$$1 = \mathbb{E}_t \Lambda_{t,t+1} R_{d,t} / \Pi_{t+1}, \tag{3}$$

$$\chi L_{s,t}^{\varphi} = C_{s,t}^{-\sigma} W_{s,t}, \tag{4}$$

where $\Lambda_{t-1,t} \equiv \beta_s \exp(s_t) \left(C_{s,t+1}/C_{s,t}\right)^{-\sigma}$ is defined as savers' real stochastic discount factor and $\Pi_t \equiv P_t/P_{t-1}$ denotes the gross inflation rate in the economy.

Borrower households only consist of workers. They consume, $C_{b,t}$, supply labor, $L_{b,t}$, and borrow from banks, issuing debt obligations, B_t, that command a state-contingent relative price Q_t.[7] The representative borrower household's problem is given by

$$V_{b,t} = \max_{\{C_{b,t}, L_{b,t}, B_t\}} \left(\frac{C_{b,t}^{\;1-\sigma}}{1-\sigma} - \chi \frac{L_{b,t}^{\;1+\varphi}}{1+\varphi} \right) + \beta_b \, \mathbb{E}_t V_{b,t+1}, \tag{5}$$

subject to

$$P_t C_{b,t} + R_{b,t-1} P_{t-1} B_{t-1} = P_t W_{b,t} L_{b,t} + P_t B_t + T_t, \tag{6}$$

where $R_{b,t}$ is the state-contingent gross nominal interest rate on debt obligations.

Again, borrowers households' three first-order conditions can be summarized by an intertemporal Euler equation and an intratemporal labor-leisure trade-off given by

$$1 = \mathbb{E}_t \, \beta_b \left(C_{b,t+1}^{-\sigma} / C_{b,t}^{-\sigma} \right) R_{b,t+1} / \Pi_{t+1}, \tag{7}$$

$$\chi L_{b,t}^{\varphi} = C_{b,t}^{-\sigma} W_{b,t}. \tag{8}$$

[6] This transfer and its functional form are not crucial for any of the results presented in this paper but facilitates the tractability of the model with a clean set of equilibrium conditions as shown in Section 2.2.

[7] While slightly contrived, this borrowing specification implies that – in the absence of capital – banks engage in maturity transformation in the model, holding a state-contingent portfolio of debt obligations funded with non-state contingent deposits in addition to their own net worth.

Banks The balance sheet of banker j is given by

$$B_t(j) + A_t(j) = D_t(j) + N_t(j), \tag{9}$$

where $N_t(j)$ is net worth and $A_t(j)$ are central bank reserves that earn the gross nominal return R_t. I assume a banker's demand for central bank reserves is given by

$$A_t(j) = \alpha(x_t) D_t(j), \tag{10}$$

where $x_t \equiv R_t/R_{d,t}$, $\alpha(1) = \alpha$, $\alpha(x_t) > 0$, $\alpha'(x_t) > 0$, and $\alpha''(x_t) > 0$. This demand schedule captures the trade-off between banks' preference for holding reserves to self-insure against idiosyncratic liquidity risk and the cost of holding reserves.

Within a period, the timing is as follows: i) Bankers receive loan payments and repay depositors. ii) Bankers exit with probability $1 - \theta$. An exiting banker is replaced by a worker with an endowment of net worth, $\bar{N}$. iii) Bankers accept new deposits and demand reserves. iv) A banker can divert a fraction λ of its assets (net of reserves) to its household, in which case, the depositors force bankruptcy and recover the remaining assets.

This agency problem creates a financial friction and makes bankers' net worth a relevant determinant of equilibrium outcomes. The banker problem is given by

$$V_{n,t}(j) = \max_{\{B_t(j), A_t(j), D_t(j), N_t(j)\}} \mathbb{E}_t \Lambda_{t,t+1} \left((1-\theta) N_{t+1}(j) + \theta V_{n,t+1}(j) \right), \tag{11}$$

subject to the banker's balance sheet, (9), reserve demand, (10), incentive compatibility constraint, (12), and net worth accumulation equation, (13), with the latter two given by

$$V_{n,t}(j) \geq \lambda B_t(j), \tag{12}$$

$$N_t(j) = R_{b,t} B_{t-1}(j) + \frac{R_{t-1}}{\Pi_t} A_{t-1}(j) - \frac{R_{d,t-1}}{\Pi_t} D_{t-1}(j), \tag{13}$$

The central bank sets the reserve rate and supplies reserves elastically. Since banks are competitive, arbitrage ensures $R_t = R_{d,t}$ when $R_{d,t} > 1$. In a symmetric equilibrium, bankers have a common leverage ratio, denoted $\Phi_t \equiv B_t/N_t = B_t(j)/N_t(j)$. The banking sector can thus be summarized in two equations. Aggregate net worth is given by

$$N_{t+1} = \theta \left[R_{b,t+1} (1-\tau) \Phi_t - \left(R_{d,t}/\Pi_{t+1} \right) (\Phi_t - 1) \right] N_t + (1-\theta) \bar{N}, \tag{14}$$

and, the aggregate incentive constraint compatibility constraint is given by

$$\lambda\Phi_t = \mathbb{E}_t\Lambda_{t,t+1}\frac{1-\theta+\theta\lambda\Phi_{t+1}}{\Pi_{t+1}}\left(R_{b,t+1}\Phi_t - R_{d,t}\left(\Phi_t - 1\right)\right), \tag{15}$$

Production Intermediate firm i produces output $X_t(i) = L_{s,t}(i)^{\omega} L_{b,t}(i)^{1-\omega}$, hiring workers in a competitive labor market. Retail firms repackage intermediate output one-for-one, $Y_t(i) = X_t(i)$. Final output, $Y_t = \left(\int_0^1 Y_t(i)^{(\epsilon-1)/\epsilon} di\right)^{\epsilon/(\epsilon-1)}$, is a CES aggregate of retail firm output, where $\epsilon > 0$. Cost minimization results in demand for good i given by $Y_t(i) = (P_t(i)/P_t)^{-\epsilon} Y_t$, where $P_t = \left(\int_0^1 P_t(i)^{1-\epsilon} di\right)^{1/(1-\epsilon)}$. Subject to a Calvo nominal price rigidity, each period, retail firms adjust their prices with probability $1-\iota$. In doing so, they solve $\max_{P_t(i)} \mathbb{E}_t \sum_{\tau=0}^{\infty} \iota^{\tau}\Lambda_{t,t+\tau}\left(\frac{P_t(i)}{P_{t+\tau}} - \mathcal{M}_{t+\tau}\right) Y_{t+\tau}(i)$ subject to the demand for good i, where $\mathcal{M}_t = W_{s,t}^{\omega}W_{b,t}^{1-\omega}/\left(\omega^{\omega}(1-\omega)^{1-\omega}\right)$ denotes marginal cost.

The first-order condition is given by

$$\mathbb{E}_t\sum_{\tau=0}^{\infty}\iota^{\tau}\Lambda_{t,t+\tau}\left(\frac{P_{*,t}}{P_{t+\tau}} - \frac{\epsilon}{\epsilon-1}\mathcal{M}_{t+\tau}\right)Y_t(i) = 0, \tag{16}$$

where $P_{*,t}$ is the optimal reset price and the evolution of the aggregate price index is

$$P_t = \left((1-\iota)P_{*,t}^{1-\epsilon} + \iota P_{t-1}^{1-\epsilon}\right)^{1/(1-\epsilon)}. \tag{17}$$

Monetary Policy The model is closed with two equations describing the conduct of monetary policy. It is assumed the central bank employs both of its primary instrument according to a conventional feedback-type rule while its balance sheet operations come as an exogenous surprise to agents. This assumption is relaxed in the following,

$$R_{d,t} = \rho_r R_{d,t-1} + (1-\rho_t)\left(\kappa_{\pi}\pi_t + \kappa_y y_t\right) + \varepsilon_{i,t}, \tag{18}$$

$$\mathrm{qe}_t = \rho_{\mathrm{qe}}\,\mathrm{qe}_{t-1} + \varepsilon_{\mathrm{qe},t}. \tag{19}$$

2.2 Equilibrium

To a first-order approximation around the deterministic steady state, the private-sector equilibrium in this simple model can be summarized by five (intuitive) log-linear equations: an augmented IS equation, the new-Keynesian Phillips Curve (NKPC), and the financial sector equilibrium in the form of binding incentive compatibility constraint, evolution of net worth, and the nominal borrowing rate.[8] The respective equations are given by

$$y_t = \mathbb{E}_t y_{t+1} - [(1-\mathrm{c})/\sigma]\left(r_{d,t} - \mathbb{E}_t \pi_{t+1} - s_t\right) - \mathrm{c}\left(r_{b,t} - \mathbb{E}_t \pi_{t+1} - s_t\right) \tag{20}$$

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \kappa y_t, \tag{21}$$

$$\phi_t = \theta \mathbb{E}_t \phi_{t+1} + \Phi\left(r_{b,t} - r_{d,t}\right), \tag{22}$$

$$n_t = \theta R\left[n_{t-1} + \left(r_{d,t-1} - \pi_t\right) + \Phi\left(r_{b,t-1} - r_{d,t-1}\right)\right], \tag{23}$$

$$r_{b,t} = \mathbb{E}_t \pi_{t+1} + s_t + \sigma\left(\mathbb{E}_t \phi_{t+1} - \phi_t + \mathbb{E}_t n_{t+1} - n_t\right), \tag{24}$$

where lower-case letters are log-levels of their upper-case counterparts, c is the steady state consumption share of borrowers, and $\kappa = [(1-\iota\beta)(1-\iota)(\varphi+\sigma)]/\iota$ is the NKPC slope. With time-preference shocks only, output and output gap coincide. Equation (20) is the IS curve. When $\mathrm{c} = 0$ or in the absence of frictions in financial intermediation, the model reduces to the canonical 3-equation new-Keynesian model.

[8] Appendix A.1 documents the the derivation of the log-linear model. Note the system of equations could be further reduced and brought even closer to the canonical 3-equation new-Keynesian model substituting for $r_{b,t}$. I refrain from doing so in the interest of tractability for the purposes of this paper.

2.3 Parameterization

The model is parameterized at quarterly frequency based on a combination of established results in the literature and a range of carefully selected calibration targets. The model is calibrated to match empirical moments in the U.S. from 1985 to 2019. Table 1 documents the baseline parameterization. Further information can be found in Appendix A.2.

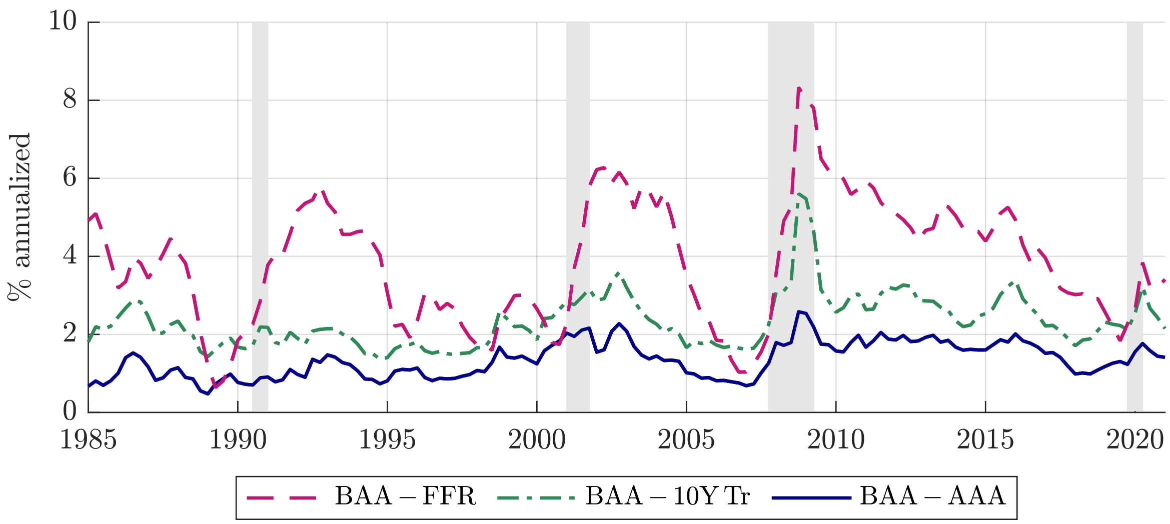
Table 1. Parameterization

Parameter		Value	Parameter		Value
Households					
σ	Risk aversion	1.0000	β	Discount factor, savers	0.9950
c	Consumption share, borrowers	0.5000	β_b	Discount factor, borrowers	0.9925
χ	Utility weight on labor	0.8045	φ	Curvature of labor disutility	1.0000
Financial intermediaries					
λ	Fraction of divertible assets	0.4126	ω	Transfer to new bankers	0.0026
θ	Survival probability of bankers	0.9750			
Producers					
ϵ	Elasticity of substitution	10.000	ι	Probability of fixed prices	0.9265
Monetary Policy					
κ_π	Policy rule inflation response	2.0000	κ_y	Policy rule output response	0.1250
ρ_r	Policy rule inertia	0.8000	ρ_{qe}	Balance sheet (QE/QT) inertia	0.8000

Households' risk aversion σ and the curvature of labor disutility ξ are normalized to 1. In line with the literature, the disutility weight on labor χ is set to 0.8045 to normalize steady state labor supply to 1. The discount factor of savers β_s is set to 0.9950, which pins down the annualized steady state policy rate R_d at 2%. This value is motivated by the mean value of the real effective U.S. federal funds rate of slightly above 1.5% over the sample period. The discount factor of borrowers β_b is set to 0.9925, in order to generate an annualized steady state credit spread, $400\,[(R_b/R_d)-1]$, of 1%. This value corresponds to the sample mean of the "BAA-AAA" corporate bond spread series depicted in Figure 2 (dark blue). The series is widely regarded as an empirically sound measure of the safety or quality premium captured by the financial friction in the model (Krishnamurthy and Vissing-Jorgensen, 2012). Appendix A.2 provides more details on this spread series and alternative measures. Finally, the consumption share of borrowers and savers is normalized to 0.5, respectively. The sensitivity and robustness of the main results with respect to this and other parameter choices is documented further below.

The survival probability of financial intermediaries θ is set to 0.975, yielding a average horizon of 10 years. Given that the steady state credit spread is pinned down by the divergence of borrowers' and savers' discount factors in this model, the remaining two financial sector parameters, $\lambda = 0.4126$ and $\omega = 0.0026$, are jointly calibrated to match a steady state leverage ratio of 4. As Appendix A.2 describes in detail, this value as taken as a approximate estimate of average aggregate leverage across the financial sector in the U.S.

Figure 2. Calibration | Empirical credit spreads in the U.S.



Note. AAA and BAA are Moody's Seasoned AAA and BAA Corporate Bond Yields, respectively; FFR is the Effective Federal Funds Rate; 10Y Tr is the market yield on Treasury Securities at 10-Year Constant Maturity. Source: Federal Reserve Bank of St Louis.

The elasticity of goods substitution is set to $\varepsilon = 10$, yielding a steady state mark up of 10%. The parameter governing the nominal price rigidity in the model is set to $\iota = 0.9265$, implying prices are adjusted on average every 13 to 14 quarters. In the absence of indexation, this relative high degree of price stickiness is the result of targeting an empirically realistic unemployment-inflation slope of 0.0062 as estimated by Hazell et al. (2022). The monetary policy rule coefficients on inflation and output are set to $\kappa_\pi = 2$ and $\kappa_y = 0.125$, standard values in the literature. For comparability, the inertia in interest rate setting and balance sheet adjustments is set to $\rho_r = \rho_{\text{qe}} = 0.8$. This value is at the lower end of empirical estimates of policy inertia but not crucial for the exercises conducted in this paper.[9]

[9] A detailed overview on empirical estimates of policy inertia for different countries using a range of different methodologies is provided in de Groot and Haas (2023), where this parameter is critically determining the signaling effect of negative rate policies. It is much less relevant for the analysis of complementarities between interest rate and balance sheet policies as conducted in this paper.

3 Results

This section presents the main results. First, it shows how a monetary tightening restrains inflation at a cost to financial intermediaries and highlights differences in the transmission of the two monetary instruments considered in this paper: regular interest rate and balance sheet policies. Second, it derives a novel decomposition of bank net worth to provide detailed insights on the financial sector implications of these divergences. Third, it shows how - in light of these divergences - a balance sheet expansion (a form of 'repurposed QE') can be an effective complement to a contractionary rate policy when bank net worth is a concern. In this case, the decomposition of bank net worth can be employed to calibrate the effective use of the central bank balance sheet. Four, it presents results for a U.S. 'pandemic-era inflation scenario' with both anticipated and non-anticipated expansionary bank balance policies addressing financial turmoil in the spirit of interventions seen in March 2023.

3.1 Transmission

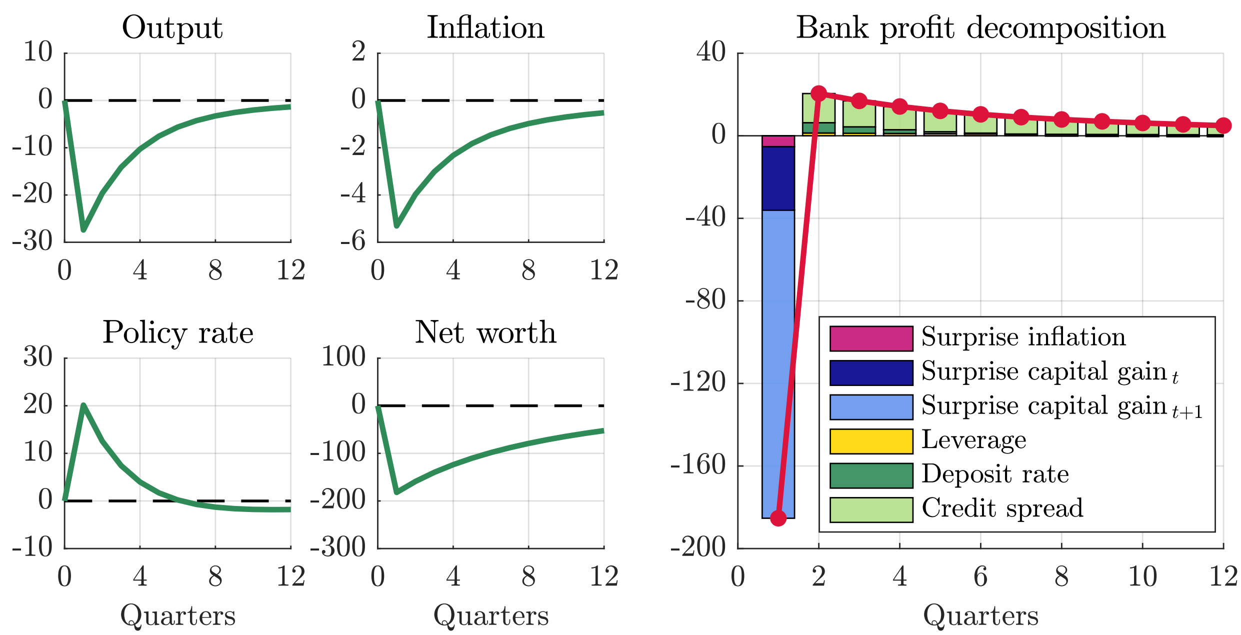
To illustrate the transmission of the two monetary instruments discussed in this paper, this section shows a comparison of impulse responses to two normalized exogenous monetary policy contractions. All impulse responses are depicted in basis point deviation from steady state, annualized for inflation and interest rates. Figure 3 highlights the main results, a more formal (analytical) derivation is to follow in the most recent version of this paper.

In response to a contractionary to +25 basis point iid policy rate contraction (panel a.), output in the model falls slightly more than one-for-one by 28 basis point, annualized inflation drops by 5 basis points. As the nominal policy rate tightens, the real interest rate increases, incentivizing both savers and borrowers to postpone consumption and increase (decrease) their savings (borrowing). In line with empirically observed inflation-output trade-offs, the inflation response is significantly smaller than the output response following this aggregate demand contraction. Due to policy inertia and frictional financial intermediation, the adjustment to the policy shock in the model is gradual and persistent, even in the absence of investment and capital accumulation.

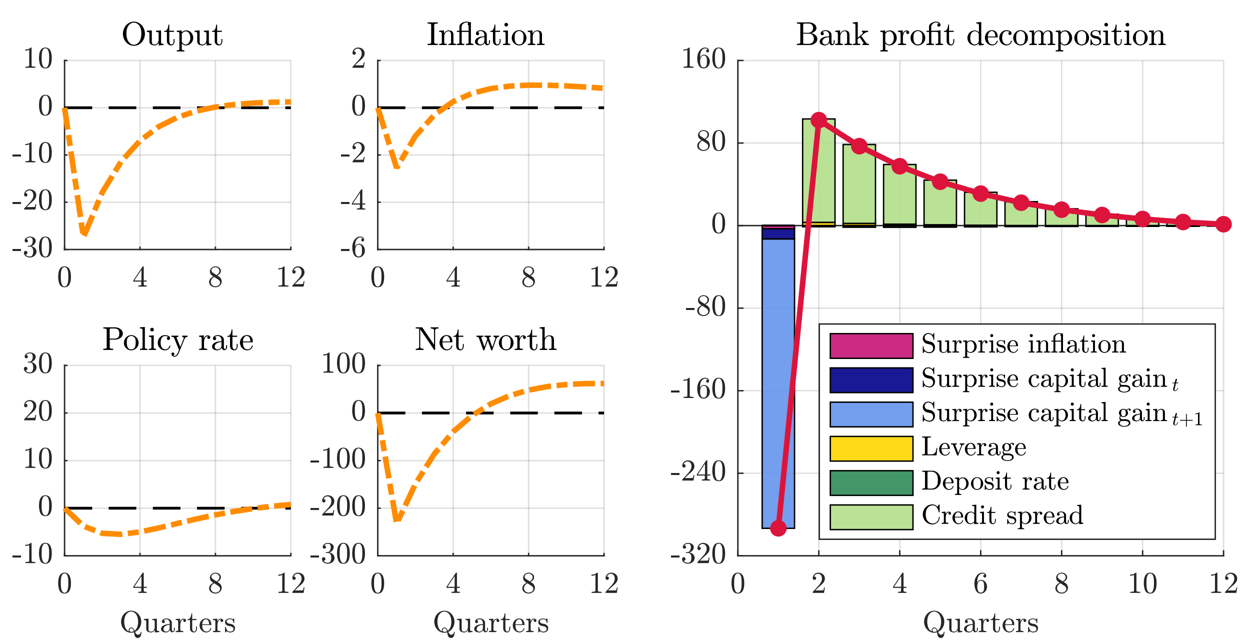
Bank net worth contracts by around 2% in response to the contractionary monetary policy, leading to a tightening of frictional financial intermediation as banks' agency problem becomes more as the ratio of own equity to lending volume declines. This causes an increase

Figure 3. Transmission | Monetary Policy & Financial Sector

a. Policy rate contraction



b. Balance sheet contraction



Note. Impulse responses to a) a +25bp policy rate shock, and b) a −80bp balance sheet shock. Bank profits are decomposed as described in Section 3.2. All variables are in basis point deviation from steady state. Inflation and the policy rate are annualized.

in credit spreads, exacerbating the aggregate demand contraction due to the monetary tightening. The financial friction comes with a financial accelerator property in the model and, importantly, a policy rate contraction results in a deterioration of bank net worth.

A −80 basis point balance sheet contraction calibrated to yield the same normalized output loss of 28 basis points on impact (panel b.), yields comparable qualitative but very different quantitative results.[10] While the balance sheet contraction comes with the expected aggregate demand contraction, moving both output and inflation in the same direction, the drop in annualized inflation is significantly smaller at 2 basis point than for the contractionary interest rate policy. At the same time, the drop in bank net worth is slightly larger at 2.25%. This hints at non-trivial differences in the monetary transmission. A thorough investigation of the financial sector transmission provides insights on this.

3.2 Bank net worth

Bank net worth is adversely affected in a monetary tightening. Both policy rate and balance sheet contractions depress net worth, thereby compounding frictions in financial intermediation. This is explored with a novel decomposition of bank profits as first derived and explored in a different environment in de Groot and Haas (2023).

In the model, the evolution of net worth – conditional on not exiting – is given by

$$N_t = \left(R_{b,t}\Phi_{t-1} - \left(R_{d,t-1}/\Pi_t\right)(\Phi_{t-1} - 1)\right) N_{t-1}. \tag{25}$$

Defining gross nominal profits as $\texttt{prof}_t \equiv \Pi_t N_t / N_{t-1}$ and rearranging terms yields

$$\texttt{prof}_t = \left(\Pi_t R_{b,t} - R_{d,t-1}\right)\Phi_{t-1} + R_{d,t-1}. \tag{26}$$

Adding and subtracting $\mathbb{E}_{t-1}\Pi_t R_{b,t}\Phi_{t-1}$, gross nominal profits can be written as

$$\texttt{prof}_t = \left(\Pi_t R_{b,t} - \mathbb{E}_{t-1}\Pi_t R_{b,t}\right)\Phi_{t-1} + \texttt{cs}_{t-1}\Phi_{t-1} + R_{d,t-1}, \tag{27}$$

where $\texttt{cs}_t \equiv \mathbb{E}_t\Pi_{t+1}R_{b,t+1} - R_{d,t}$. This non-linear expression can be log-linearized and

[10] As described in Section 2.3, exogenous balance sheet variations are implemented with a persistence $\rho_{\text{qe}} = 0.80$ to make their transmission comparable to iid interest rate shocks on an inertial policy rule with $\rho_r = 0.80$. This is just for illustrative purposes, all results continue to hold in the absence policy persistence.

decomposed into two surprise terms and three predetermined terms given by

$$\hat{\texttt{prof}}_t = \underbrace{\frac{R_b \Phi}{\texttt{prof}} \left(\hat{\pi}_t - \mathbb{E}_{t-1}\hat{\pi}_t\right)}_{\text{Surprise: Inflation}} + \underbrace{\frac{R_b \Phi}{\texttt{prof}} \left(\hat{r}_{b,t} - \mathbb{E}_{t-1}\hat{r}_{b,t}\right)}_{\text{Surprise: Return}} + \underbrace{\frac{\texttt{cs}\Phi}{\texttt{prof}} \hat{\texttt{cs}}_{t-1}}_{\text{Credit spread}} + \underbrace{\frac{\texttt{cs}\Phi}{\texttt{prof}} \hat{\phi}_{t-1}}_{\text{Leverage}} + \underbrace{\frac{R_d}{\texttt{prof}} \hat{r}_{d,t-1}}_{\text{Deposit rate}}. \tag{28}$$

where hats denote log-deviations from steady state and variables without subscripts are steady states. Surprise returns on the loan portfolio can further be decomposed into capital gains on short- and long-term lending. This completes the derivation.

Bank net worth is inertial and slow-moving. As an exogenous shock – such as an unexpected monetary contraction – materializes, on impact, three windfall components drive the response in gross nominal profits and thereby net worth. These directly result from banks' role in maturity transformation. As outlined in Section 2.1, banks derive a state-contingent nominal return from a portfolio of short- and long-term debt obligations, $R_{b,t}$ while having committed to pay a predetermined nominal deposit rate on their liabilities, $R_{d,t-1}$. It is because of this that banks are subject to interest rate risk in the form of surprise inflation and surprise capital gains on short-term and long-term assets.[11] The three predetermined terms are the evolution of the credit spread, leverage, and the policy rate. These predetermined terms adjust in the period following the shock and govern the endogenous return of nominal net worth back to equilibrium as the impact of the exogenous disruption subsides.

The right-most panels in Figure 3 make use of this decomposition, plotting bank profits in response to the policy rate and balance sheet contraction, respectively. On impact, profits sharply decrease as both instruments impose capital losses in the form of revaluations of banks' debt portfolio. These losses are complemented by an additional small decline due to deflation in the case of the interest rate contraction (less relevant for the balance sheet contraction given the more muted inflation response). More importantly, the absolute size of capital losses is significantly larger for the contractionary balance sheet policy and concentrated in revaluations of the long-term portfolio. As the central bank shrinks the size

[11] In the absence of capital in the model, I term leveraged surprise changes in the price of the loan portfolios 'capital gains'. The bank balance sheet can easily be expanded to include additional assets. This would change the composition of windfall gains and losses – adding further surprise terms – but not the overall quantity, in so far as additional assets would not eliminate the maturity mismatch between assets and liabilities.

of its balance sheet and cuts its role in credit intermediation, the supply of debt relative to demand increases and the price of debt falls. From the following period on, wider credit spreads – due to a tighter incentive compatibility constraint – boost earnings and return net worth back to target. To a lesser degree, higher leverage and deposit rates also have a role to play in this but it is much smaller across a wide range of model specifications. This is in line with empirical evidence on banks' exposure to interest rate risk and the role of interest margins in the transmission of monetary policy through the banking sector.[12]

3.3 QE in a Tightening Cycle

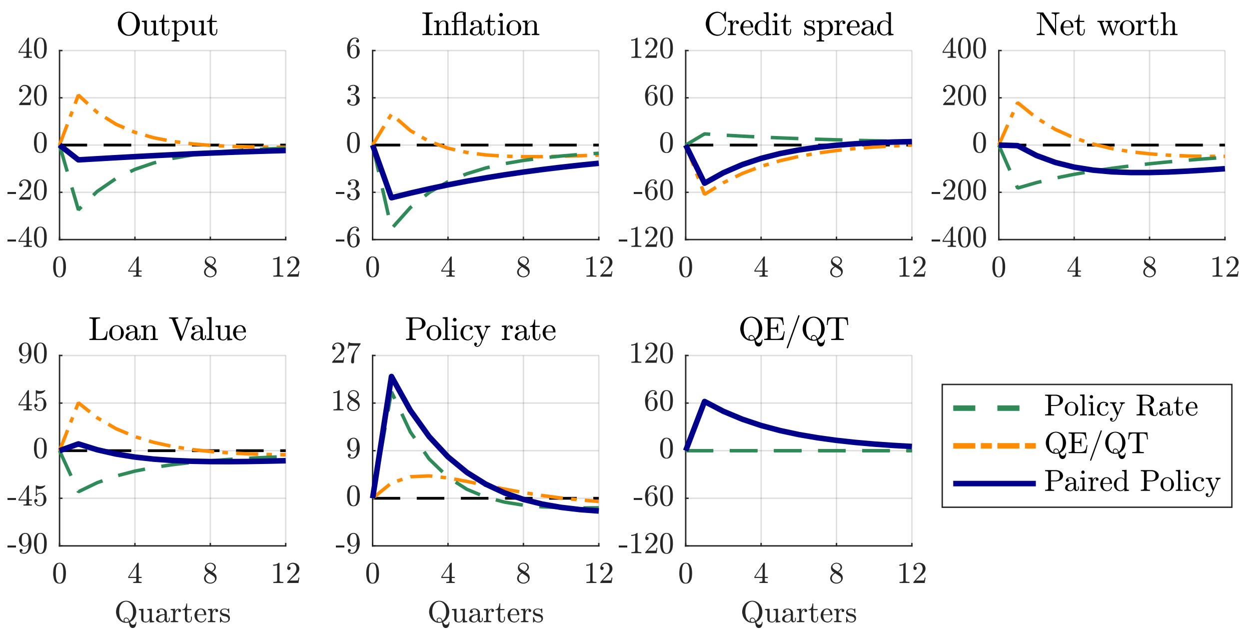
A monetary tightening in policy rates restrains inflation at a cost to financial intermediation. With banks exposed to interest rate risk, higher nominal interest rates impose capital losses on bank balance sheets and depress net worth. Central bank balance sheet policies have qualitatively similar effects but are quantitatively different. Rather than through intertemporal substitution and households' IS equation, their transmission directly affects loan values and thereby bank net worth through a change in loan supply and demand.

This implies that both monetary instruments – despite their expected dominant aggregate demand dimension moving output and inflation in the same direction – have a widely differential impact in an inflation-net worth space. Figure 4 illustrates this, depicting a full set of impulse responses to a +25 basis point contractionary monetary policy shock (as seen before, green dash) and a recalibrated +62 basis point balance sheet expansion (orange dot-dash). This time, making use of the bank balance sheet decomposition, the size of the expansionary balance sheet policy is normalized to neutralize the sum of banks' capital losses on short- and long-term loans due to the contractionary interest rate policy.[13] In line with the previous discussion, in the baseline calibration of this model, the interest rate policy has comparably strong effect on inflation while the balance sheet policy directly affects frictional intermediation through loan values, bank net worth, and credit spreads.

[12] Berry et al. (2019) offers a concise overview on empirical evidence on interest margins in tightening cycles. Begenau et al. (2015) and Begenau and Stafford (2022) provide evidence on banks' heavy exposure to interest rate risk while Drechler et al. (2021) argue maturity transformation by itself does not necessarily expose banks to interest rate risk if the deposit franchise comes with market power and an insensitive cost structure.

[13] This full stabilization policy is adopted to illustrate the potential of a forceful 'Repurposed QE in a Tightening Cycle' intervention. It is descriptive and not to be taken as an optimal policy prescription at this point. All results continue to hold with a more nuanced balance sheet operation as Section 3.4 illustrates.

Figure 4. 'Repurposing QE in a Tightening Cycle' | Impulse Responses

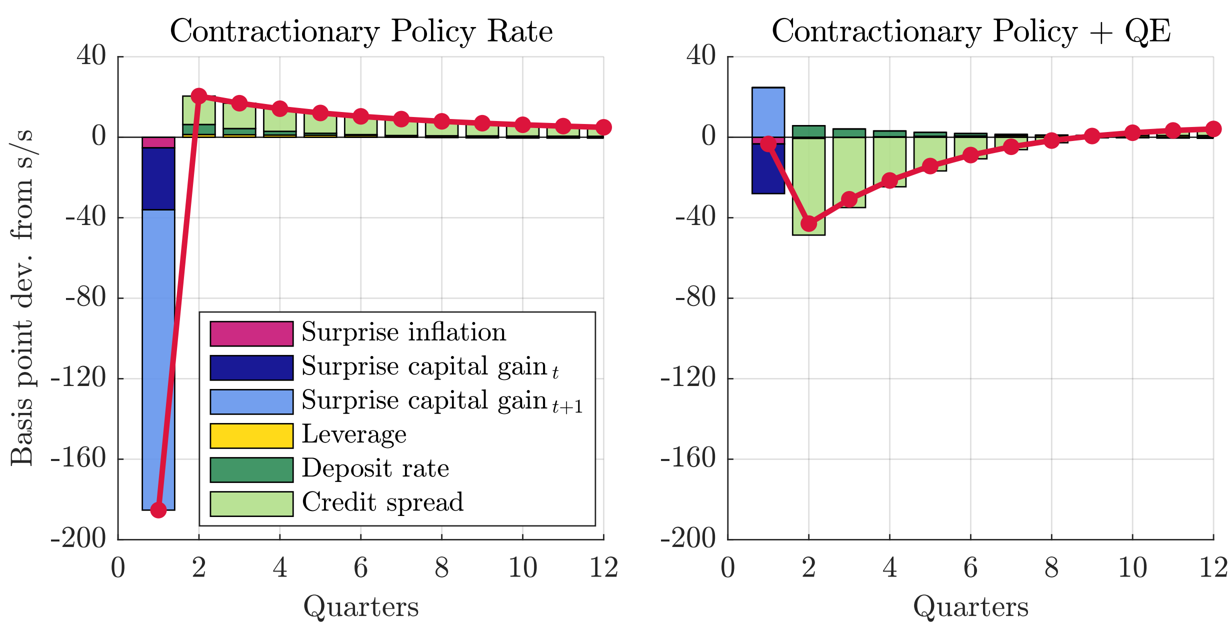


Note. Impulse responses to a contractionary +25bp policy rate shock (green dash), an expansionary +62bp balance sheet shock (orange dot-dash), and the pairing of both policy shocks (dark blue). All variables are in basis point deviation from steady state. Inflation, credit spread, and the policy rate are annualized.

Considering these divergent transmission channels, pairing both policies in an illustrative 'Repurposing QE in a Tightening Cycle' scenario (dark blue) indicates possibly attractive properties from a monetary and financial stability angle. The paired policy creates demand for loans, counteracting capital losses and the decline in loans values due to the monetary contraction, and fully stabilizes bank net worth on impact (as calibrated). Credit spreads fall as the decline in net worth is attenuated and spread out over the following quarters. This more gradual decline does not imply though that the tightening in policy rates is without effect on inflation. In fact, in the baseline parametrization of the model, output losses are strongly diminished while 60% of the contractionary effect on inflation are preserved. Figure 5 provides insights on this, comparing the bank profit implications of a contractionary interest rate shock with its adverse effect on net worth (as seen before, left panel) with the paired policy (right panel). The policy pairing fully attenuates and smooths the bank balance sheet impact of a contractionary interest rate policy. The highly interventionist balance sheet policy shown here reduces the peak decline in bank net worth to slightly more than 40 basis points in the period following the interest rate tightening, compared to a 180 basis point deterioration on impact without the intervention.

Interest rate and balance sheet policies are often perceived as mere substitutes. In times of below-target inflation – as experienced in most advanced economies from 2007/08 to 2020/21 – this is very much in line with both lived practice and the literature on this subject. As concerns about financial stability peaked during the Great Financial Crisis and the March-2020 COVID crisis, cuts in policy rates and central bank balance sheet expansions provided liquidity in times of turmoil. At the effective lower bound on nominal rates, central bank balance sheet expansions became a natural extension of a conventional rates easing. The results in this paper indicate that in times of above-target inflation, a contractionary interest rate and balance sheet policy might not necessarily be mere substitutes. As a contractionary interest rate policy imposes capital losses on banks and concerns about financial instability arise, an expansionary central balance sheet policy can address the deterioration of bank net worth without impeding monetary stabilization. In this sense, in an environment of high inflation and financial instability, an expansionary balance sheet policy can be an effective complement to a contractionary rates policy. The differential transmission of the two monetary instruments in an inflation-net worth space allows for this temporary pairing in the interest of both monetary and financial stabilization.

Figure 5. 'Repurposing QE in a Tightening Cycle' | Financial Sector

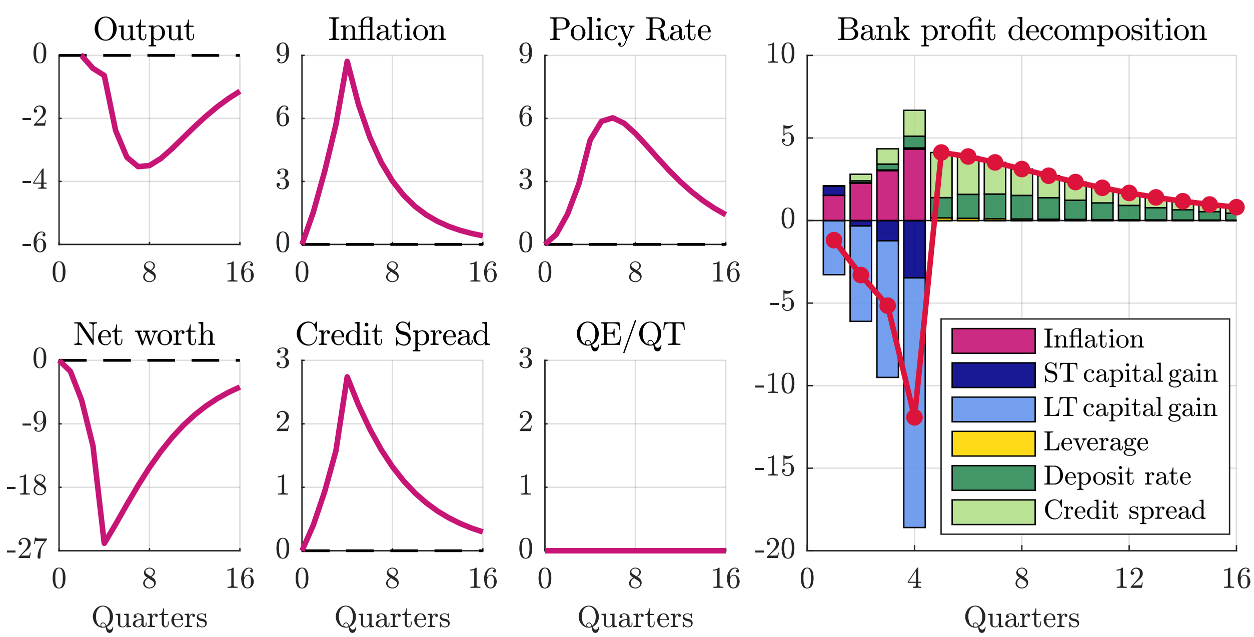


Note. Bank profits and their decomposition for a contractionary +25bp policy rate shock only (left panel), and a combination of contractionary policy shock and a +62bp expansionary balance sheet shock (right panel).

3.4 A Pandemic-Era Inflation Scenario

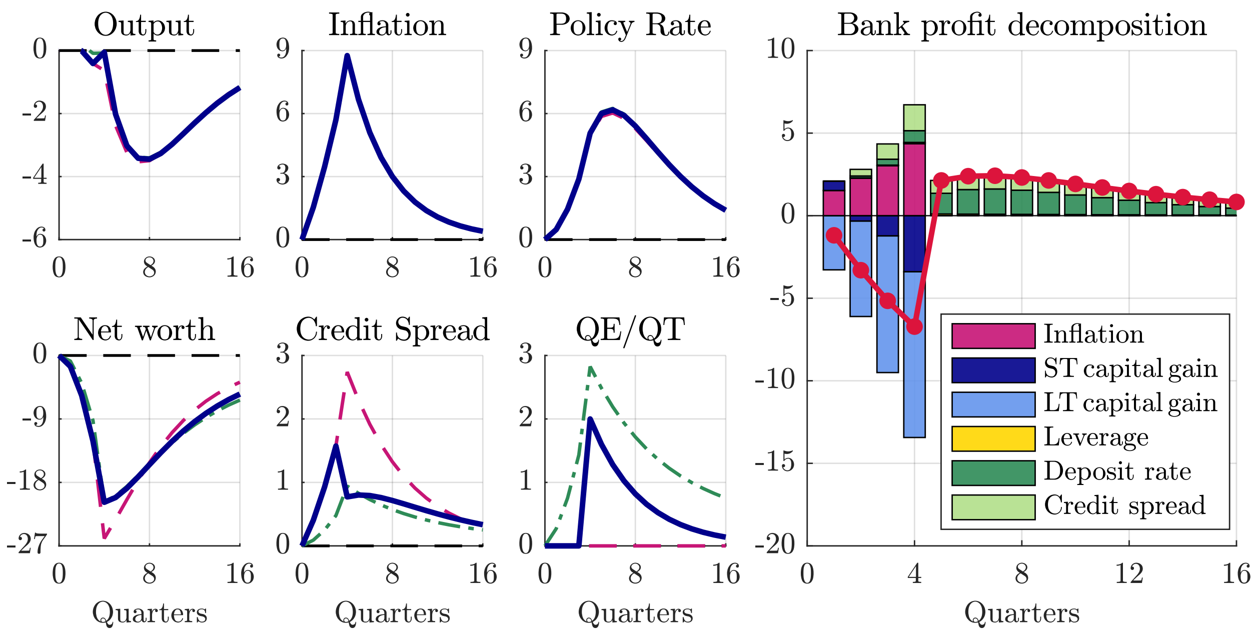
Figure 6 plots the evolution of a several endogenous variables in response to a sequence of four unexpected aggregate demand and cost-push shocks that generate a U.S. 'pandemic-era inflation' scenario. Contrary the Federal Reserve's expansionary balance sheet intervention at the height of the regional banking crisis in March 2023, it is assumed that the balance sheet is not used in the policy counterfactual. In response to the sequence of adverse shocks, inflation reaches a peak value of 9%. The endogenous contraction in the policy rate implies the policy rate gradually increases to 6%. Over the course of the tightening cycle, this imposes significant capital losses on financial intermediaries. Bank net worth drops by 25% over the course of a year, credit spreads rise to 3%. Given the combination of aggregate demand and cost-push shocks as observed through post-pandemic fiscal stimulus and supply-bottleneck, output only falls gradually and ultimately declines by about 3.5%.

Figure 6. 'Pandemic-Era Inflation' | No policy intervention



Note. This Figure plots the evolution of a several endogenous variables in response to a sequence of four unexpected aggregate demand and cost-push shocks that generate a U.S. 'pandemic-era inflation' scenario. Monetary policy endogenously contracts but there is no balance sheet intervention. All variables are in basis point deviation from steady state. Inflation, credit spread, and the policy rate are annualized.

Figure 7. 'Pandemic-Era Inflation' | One-off QE intervention



Note. This Figure plots the evolution of a several endogenous variables in response to a sequence of four unexpected aggregate demand and cost-push shocks that generate a U.S. 'pandemic-era inflation' scenario. Monetary policy endogenously contracts. Three balance sheet policies are depicted: no use of the balance sheet (Figure 6, purple dash), an endogenous balance sheet expansion as a function of credit spreads (green, dot-dash), and an unexpected one-off balance sheet intervention as net worth losses peak (dark blue). The bank profit decomposition shows the results for the one-off intervention. All variables are in basis point deviation from steady state. Inflation, credit spread, and the policy rate are annualized.

Figure 7 depicts results for the same 'pandemic-era inflation' scenario but with two additional central bank policy interventions modelled: first, an endogenous balance sheet expansion in the form of a Taylor-type rule with the size of the balance sheet increasing in credit spreads (green, dot-dash); second, a unexpected 2% one-off balance sheet expansion – gradually phased out over the following periods – at the height of the crisis as inflation and net worth losses peak and risks for financial stability rise. Both 'repurposed QE'-type policies are broadly successful in stabilizing bank net worth without adding to inflationary pressures in this policy scenario. A comparison of the bank profit decompositions in Figures 6 and 7 clearly illustrates this for the case of the unexpected one-off policy intervention. This finding underlines and confirms the more abstract discussion in Section 3.1-3.3 on divergences in the transmission of both monetary instruments. In times of rapidly rising inflation and mounting pressures on financial intermediaries due to their exposure to interest rate risk, an expansionary balance sheet policy can be an effective complement to a monetary tightening in rates. A more thorough investigation of this is to follow.

4 Conclusion

With inflation reaching levels not seen in more than thirty years, central banks in many advanced economies have embarked on a rapid tightening cycle over the past eighteen months. The regional bank crisis in the U.S. and the collapse of Credit Suisse in Europe earlier this year are examples of the adverse effects of rising rates on financial institutions. This has rekindled a debate on trade-offs between monetary and financial stability.

Interest rate hikes impose capital losses on bank balance sheets. As net worth declines, risks to financial stability grow. In the paper, I set up a new-Keynesian model with frictional financial intermediation to rationalize this. I then show that an expansionary central bank balance sheet policy can be an effective complement to a contractionary rates policy when bank net worth is a concern. A well-calibrated policy mix smooths out the impact of rising rates on net worth while preserving their contractionary effect on above-target inflation.

Differences in the transmission of both monetary instruments (and a redistributionary cost-push dimension of frictional intermediation) are relevant for this result. A novel decomposition of bank net worth illustrates this and provides insights on the financial sector implications of monetary policy. Furthermore, a simulation exercise implements a U.S. post-pandemic era inflation scenario as a laboratory to analyze policy counterfactuals against the backdrop of heightened inflation and declining bank net worth. In this environment, a temporary balance sheet expansion is successful in smoothing the adverse effects of a contractionary interest rate policy on bank net worth at little cost to inflation.

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— Appendix —

Monetary Policy in a Tightening Cycle

A Model

A.1 Log-linear equilibrium: derivation [Section 2.2]

New-Keynesian IS equation The household problems and first-order conditions are given in the main text. In steady state, $R_d = 1/\beta_s$. The log-linear form of the first-order conditions for the saver household are given by

$$c_{s,t} = \mathbb{E}_t c_{s,t+1} - \frac{1}{\sigma}\left(r_{d,t} - \mathbb{E}_t \pi_{t+1} - s_t\right), \tag{A1}$$

$$\varphi l_{s,t} = -\sigma c_{s,t} + w_{s,t}, \tag{A2}$$

where lower case letters refer to log-levels. The borrower household's conditions are

$$c_{b,t} = \mathbb{E}_t c_{b,t+1} - \frac{1}{\sigma}\left(r_{b,t} - \mathbb{E}_t \pi_{t+1} - s_t\right), \tag{A3}$$

$$\varphi l_{b,t} = -\sigma c_{b,t} + w_{b,t}, \tag{A4}$$

where, in steady state, $R_b = 1/\beta_b$. The log-linear aggregate resource constraint is given by $y_t = (1 - \mathrm{c})\, c_{s,t} + \mathrm{c} c_{b,t}$, where $\mathrm{c} \equiv C_b/Y$. Combining this definition with the two individual Euler equations gives the aggregate Euler equation:

$$y_t = \mathbb{E}_t y_{t+1} - \frac{1-\mathrm{c}}{\sigma}\left(r_{d,t} - \mathbb{E}_t \pi_{t+1} - s_t\right) - \frac{\mathrm{c}}{\sigma}\left(\mathbb{E}_t r_{b,t+1} - \mathbb{E}_t \pi_{t+1} - s_t\right). \tag{A5}$$

Next, substituting the transfer from savers to borrowers into the borrower household's budget constraint gives the following simple borrower household consumption function: $C_{b,t} = B_t$. Using the definition for leverage, $\Phi_t = B_t/N_t$, the log-linear form of the borrower household consumption function is given by $c_{b,t} = \phi_t + n_t$. Rearranging the borrower household's Euler condition, $\frac{1}{\sigma}\left(r_{b,t} - \mathbb{E}_t \pi_{t+1} - s_t\right) = \mathbb{E}_t c_{b,t+1} - c_{b,t}$, and combining it with the consumption function above, I can rewrite the aggregate Euler equation as

$$y_t = \mathbb{E}_t y_{t+1} - \frac{1-\mathrm{c}}{\sigma}\left(r_{d,t} - \mathbb{E}_t \pi_{t+1} - s_t\right) - \mathrm{c}\left(\mathbb{E}_t \phi_{t+1} - \phi_t + \mathbb{E}_t n_{t+1} - n_t\right). \tag{A6}$$

New-Keynesian Phillips curve Log-linearizing the production sector's first-order conditions yields the textbook new-Keynesian Phillips curve in terms of marginal cost,

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \frac{(1-\iota\beta)(1-\iota)}{\iota} mc_t. \tag{A7}$$

Log-linear marginal cost and aggregate output are given by $mc_t = \omega w_{s,t} + (1-\omega) w_{b,t}$ and $y_t = \omega l_{s,t} + (1-\omega) l_{b,t}$, respectively. Using the two labor-supply first-order conditions from the household problem, we can rewrite marginal cost as follows:

$$mc_t = (\varphi + \sigma) y_t, \tag{A8}$$

and the Phillips curve as

$$\pi_t = \beta \mathbb{E}_t \pi_{t+1} + \frac{(1-\iota\beta)(1-\iota)(\varphi+\sigma)}{\iota} y_t. \tag{A9}$$

Note that since we only consider disturbances to households' subjective discount factors, the output gap coincides with output and hence y_t can be relabeled as the output gap.

Financial sector equilibrium conditions Steady state leverage is given by $\bar{N}$. The log-linear net worth evolution equation is given by

$$n_{t+1} = \theta R \left(n_t + \Phi\left(r_{b,t+1} - \pi_{t+1}\right) - (\Phi - 1) r_{d,t} - \pi_{t+1}\right). \tag{A10}$$

When $\theta = 0$, then $n_{t+1} = 0$. The log-linear incentive compatibility constraint is given by

$$\phi_t = \left(\mathbb{E}_t m_{t,t+1} - \pi_{t+1}\right) + \theta \mathbb{E}_t \phi_{t+1} + \left(\Phi r_{b,t+1} - (\Phi-1) r_{d,t}\right). \tag{A11}$$

where $m_{t,t+1}$ is the log-linear stochastic discount factor of the saver household.

Substituting for $r_{b,t}$ using the borrower household's Euler equation gives

$$\begin{aligned}\phi_t = {} & -r_{d,t} + \theta \mathbb{E}_t \phi_{t+1} + \Phi\sigma\left(\mathbb{E}_t \phi_{t+1} - \phi_t + \mathbb{E}_t n_{t+1} - n_t\right) \\ & + \Phi\left(\mathbb{E}_t \pi_{t+1} + s_t\right) - (\Phi-1) r_{d,t}.\end{aligned} \tag{A12}$$

When $\theta > 0$, the model is described by five endogenous variables, $\{\pi_t, y_t, \phi_t, n_t, r_{d,t}\}$, and four private-sector conditions, (A6), (A9), (A10), and (A12).

A.2 Calibration: further details [Section 2.3]

Table 1 in the main text presents the baseline parameterization of the model. This section provides details on the financial sector calibration, in particular leverage and credit spreads.

Leverage Obtaining an appropriate data counterpart for aggregate leverage in the model poses a challenge. During the period from 2009 to 2019, the US commercial banking sector maintained an average leverage ratio of 9.4.[14] This calculation excludes non-bank financial institutions like hedge funds and broker-dealers, which are generally more leveraged. In 2021, estimates for the total assets of the non-bank financial sector exceeded the total assets of commercial banks by a factor of 1.86. Additionally, also from 2009 to 2019, the non-financial corporate business sector exhibited a leverage ratio of 1.9, indicating a substantially lower leverage ratio across the entire economy. I follow the approach taken in de Groot and Haas (2023) in the spirit of Gertler and Karadi (2011), aggregating across these heterogeneous sectors while assuming that leverage in the non-bank financial sector is approximately twice that of the commercial banking sector. This conservative approach yields an estimate of aggregate leverage, amounting to 3.6. Given the inherent uncertainty in these calculations, we have chosen to calibrate the model to a leverage ratio of 4.

Credit Spreads Calibrating the steady-state credit spread presents its own set of challenges. Figure 2 shows three alternative spread measures commonly used in the literature. The first measure represents the spread between the BAA corporate bond yield and the federal funds rate (purple dash). The interest rates that constitute this spread align with the expected return on capital and the short-term policy rate in the model. However, when it comes to matching the steady-state credit spread, this measure is less than ideal given a maturity mismatch. The corporate bond yields are derived from long-term bonds with a maturity of 20 years and above, while the federal funds rate is a short-term rate. As a result, this series likely encompasses not only a pure risk premium but also liquidity and term premia. To get a sense of these distinct premia, the spread between the BAA corporate bond yield and the 10-year Treasury yield (green dot-dash) and the spread between the BAA and AAA corporate bond yields (dark blue) are also depicted in Figure 2. For the credit spread in the model, I match its steady state to 1% annualized, which corresponds to the mean of the "BAA-AAA" series in the sample. This series is widely regarded as an empirically sound measure of the safety or quality premium captured by the financial friction in the model (Krishnamurthy and Vissing-Jorgensen, 2012).

[14] Where leverage is defined as $A/(A-L)$, with A being total assets and L total liabilities.