Money and Banking in the Shadows: Monetary Policy and (Non)bank Finance

Hanfeng Chen

July 2024

I study the transmission of monetary policy through banks and nonbank financial intermediaries (NBFIs) in the United States. First, I construct a measure of nonbank lending that takes into account the complex linkages within the NBFI sector. Then, I show empirically that following a surprise monetary policy tightening the households substitute away from bank deposits and towards nonbank-created liquidity. Bank lending to firms contracts while NBFIs' provision of credit expands. Thus, the households' portfolio rebalancing diminishes the impact of monetary policy on economic activity. To rationalize these findings, I build a New-Keynesian model with banks and investment funds that provide liquidity to households and lending to firms. The model captures the two channels of monetary policy transmission where the households' portfolio choices take the central stage: "the deposits" and the "shadow banking" channels. Through these channels, the model replicates the portfolio shifts and increased nonbank finance observed in the data, and the presence of investment funds dampens the efficacy of monetary policy.

Department of Economics, Uppsala University. Email: hanfeng.chen@nek.uu.se.

1. Introduction

A long tradition in macroeconomics emphasizes the households' portfolio decisions as fundamental for understanding business cycles and monetary transmission mechanisms (Tobin 1969; Luetticke 2021). Relatedly, a strand of the banking literature stresses liquidity transformation, i.e. the dual role of commercial banks in issuing liquid claims (bank deposits) to households to fund lending to firms (Diamond and Dybvig 1983; Drechsler et al. 2017). Yet, the modern financial system includes entities beside traditional banks that may similarly fulfill this role. Nonbank financial intermediaries (NBFIs) offer alternative chains of intermediation in parallel to the banking sector. With its accelerated growth after the global financial crisis, the nonbank financial sector now accounts for almost 50% of global financial assets (Pascual et al. 2023).

Although much attention has been paid to the significance of NBFIs for financial stability issues, the relationship between monetary policy and the nonbank financial sector remains underexplored. In particular, nonbank liquidity transformation may have important implications for the efficacy of monetary policy both directly and via its connections with the banking sector. In this paper, I study the transmission of monetary policy, through its impact on bank and nonbank financial intermediation, in the United States.

The nonbank financial sector is understood to be a collection of intermediaries that perform bank-like activities and provide services traditionally associated with banks. Examples of NBFIs include money market funds, mutual funds, government-sponsered enterprises, asset-backed security issuers, insurance companies, and pension funds. Previous literature has emphasized the difficulty of measuring nonbank lending to the productive sector due to the entangled linkages among the NBFIs (Pozsar et al. 2010; Gallin 2013; Durdu and Zhong 2023). Therefore, I construct a dataset on bank and nonbank lending to nonfinancial firms using the Financial Accounts (FAs) of the United States. I use the methodology of Gallin (2013) for netting out financial interconnections and the procedure proposed by Herman et al. (2017) to overcome the lack of counterparty information in the FAs. To facilitate comparisons with traditional banks, I choose money market funds and mutual funds as the NBFIs of focus. I refer to these funds collectively as investment funds. This choice is motivated first by the fact that money market funds and mutual funds both issue liabilities that provide liquidity services to investors in ways similar to bank deposits (Krishnamurthy and Li 2023; Ma et al. 2021). Therefore, I denote shares in investment funds "nonbank deposits" to highlight their characteristics as demandable and liquid claims (Xiao 2020; Begenau and Landvoigt 2022). Moreover, investment funds intermediate a significant amount of funding to nonfinancial firms both directly through holdings of firm debt and indirectly through funding of other NBFIs. Thus, investment funds compete with traditional banks on both ends of the liquidity transformation process.

I estimate the empirical effect of monetary policy shocks on financial intermediation and economic activity by means of local projections (Jordà 2005). Monetary policy shocks are identified by the narrative approach (Romer and Romer 2004) and I rely on the extended series constructed by Miranda-Agrippino and Rey (2020). I find that after a one standard deviation monetary policy shock U.S. housholds' holdings of bank deposits fall persistently by around 1.4%. Banks, in turn, reduce their lending to firms by 1% after about one year. Interestingly, nonbank financial intermediation expands. Households' nonbank deposits increases persistently by more than 4% after three years, while nonbank lending to firms increases by about 3%. In other words, I observe credit leakage towards the less regulated nonbank financial sector in the U.S. after monetary policy tightenings. Since funding from the financial sector is critical for investments and output, the results indicate that the presence of NBFIs dampens the contractionary effect of monetary policy.

I study the drivers of the empirical results in a New-Keynesian model with two types of financial intermediaries, banks and investment funds, that engage in liquidity transformation. Recent literature identifies two channels of monetary transmission where the households' portfolio choices take the central stage: the "deposits channel" (Drechsler et al. 2017) and the "shadow banking channel" (Xiao 2020). According to the deposits channel, a monetary tightening induces banks with market power to increase their deposit spreads, the price on deposit products, and consequently deposits flow out of the banking sector and bank lending contracts. At the same time, the shadow banking channel proposes that the proceeds from deposit outflows move instead into "shadow bank deposits" (i.e. money market fund shares) and the nonbank financial sector, which then expands its credit provision. In this paper, I refer to these mechanisms as the *bank deposits channel* and *nonbank deposits channel* of monetary policy respectively, and build the "two deposits channels" into a New-Keynesian model.

I take a liquidity-centric view of financial intermediation similar to that of Piazzesi et al. (2022) and Niepelt (2023). The financial sector provides liquidity services to households in the forms of bank deposits issued by commercial banks and nonbank deposits issued by investment funds (or nonbanks). The households are assumed to value a combination of both types of liquid assets and make portfolio choices between them. Banks are subject to a liquidity constraint that limits their ability to issue deposits. The restriction on the banks' liquidity ratio (i.e. reserves-to-deposits ratio) can capture explicit regulatory constraints such as reserve requirements or more generally the increasing marginal cost of issuing debt (Piazzesi et al. 2022; Rogers 2023). Nonbank "deposits", i.e. investment fund shares, are equities and thus not directly affected by the constraint. Moreover, nonbanks do not have access to central bank reserves. The banking sector is characterized by oligopolistic competition and thus banks have market power in the deposit market. On the other hand, nonbank deposits at different funds are considered identical by the households and I model them as being issued by a competitive fund. A monetary policy tightening increases the banks' opportunity cost of holding reserves and, in turn, the marginal cost of issuing deposits. The bank deposit spread widens as banks keep the deposit rate relatively low even as the nominal rate increases. At the same time, in the absence of any constraint to issue liabilities, the competitive investment funds keep the nonbank deposit spread constant. In other words, the nonbanks pass on the increase in the nominal rate in its entirety to the household. The difference in the sensitivity of deposit spreads to monetary policy then induces the household to shift away from holding bank deposits towards nonbank liabilities. Consequently, bank credit to firms shrinks while nonbank financial intermediation expands.

In this paper, I contribute to the empirical and theoretical literature on the impact of NBFIs on business cycle fluctuations and monetary policy transmission. Following the early seminal work by Pozsar et al. (2010), a series of paper have sought to clarify the inner workings of the nonbank financial sector. Pozsar (2014) builds on Pozsar et al. (2010) and provides an accounting framework for measuring the sources and uses of short-term funding among NBFIs. Gallin (2013) develops a method for netting out financial interconnections and shows how to derive estimates of nonbank lending to nonfinancial firms, households and government. Herman et al. (2017) complements the earlier work and propose a simple procedure to derive estimates of "whom-to-whom" lending among actors in the financial markets using the FAs. The authors then illustrate the historical development of and the differences between bank and nonbank credit cycles.

Combining the methods of Gallin (2013) and Herman et al. (2017), I build a dataset to explore the responses of nonbank financial intermediation to monetary policy shocks. Xiao (2020) offers one of the earliest studies on the relationship between NBFIs and monetary policy in the U.S. Using proprietary industry data, the author finds that shadow bank money (money market fund shares) creation expands after monetary tightenings and thus dampens the impact of monetary policy. Similarly, using loan-level data, Peydró et al. (2021) show that higher policy rates shifts credit supply from banks to nonbanks. Hodge and Weber (2023) take advantage of high-frequency data and show that contractionary monetary policy shocks reduce the assets of nonbanks reliant on long-term funding, while increasing those of nonbanks reliant on short-term funding. The main advantage of the method I employ in this paper is its ability to take into account the various linkages between financial intermediaries. In this way, I reduce the usual risk of overestimating nonbank lending, which is often ignore in other empirical work. The other advantage is the use of the FAs, which are publicly available and typically cover a longer time period than various proprietary data sources.

On the theoretical front, Meeks et al. (2017) and Moreira and Savov (2017) are early examples of incorporating a nonbank financial sector into macroeconomic models to shed light on its role for financial stability. Begenau and Landvoigt (2022) estimate a quantitative general equilibrium model and find that bank capital regulation have unintended positive consequences by reducing the riskiness of the nonbank financial sector. Iasio et al. (2022) study macroprudential policies targeting nonbanks and find that the lack of liquidity regulation for investment funds decreases the economy's resilience to financial shocks. Fève et al. (2022) build a DSGE model featuring heterogeneous banks and argue that the collapse of shadow banking contributed significantly to the slow recovery after the financial crisis in the U.S. Becard and Gauthier (2023) analyze European business and financial cycles by focusing on the ability of traditional banks to offload credit risk to nonbank financial institutions. This paper shares the focus on credit intermediation with Durdu and Zhong (2023), which analyze the structural drivers of bank and nonbank credit cycles and sectoral shocks.

2. Empirical Evidence

This section documents the transmission of monetary policy shocks to the wider economy via banks and NBFIs. First, I describe the institutional background of the nonbank financial sector and the construction of the data on financial intermediation and economic activity. Then, I present the baseline empirical specification and the main results.

2.1. Institutional Background

Despite the lack of a precise definition, the nonbank financial sector can be understood as a collection of financial intermediaries which, while not defined as banks, perform many bank-like activities. Unlike traditional banks, which perform liquidity transformation, i.e. issue short-term liquid claims to fund long-term illiquid assets, under one roof, the nonbank financial sector split the process into several parts. Thus, different NBFIs perform different functions on the financial intermediary chain. For instance, money market funds and mutual funds issue shares that are (under normal circumstances) easily redeemable and thus comparable to various forms of bank deposits. Money market funds, in turn, pass down the proceeds to downstream NBFIs such as finance companies and broker-dealers that originate commercial loans. Mutual funds, on the other hand, tend to invest directly in corporate bonds and bypass downstream entities. Here, I consider a larger class of intermediaries than what earlier literature referred to as "shadow banks."

There is a lack of readily available data on the financial flows intermediated by NBFIs to the nonfinancial sector. Indeed, the literature has long emphasized the difficulty of measuring nonbank financial intermediation (Pozsar et al. 2010; Gallin 2013; Durdu and Zhong 2023). In particular, previous works on the NBFIs' provision of credit to the wider economy often ignore the flows of funds and the entangled linkages within the nonbank financial sector itself.[1] This may drastically overstate the size of nonbank lending and obscure its cyclical properties (Durdu and Zhong 2023).

2.2. Data

I use the Financial Accounts (FAs) of the United States to construct measures of bank and nonbank financial intermediation. The FAs provide a comprehensive overview of the financial assets and liabilities of sectors of the U.S. economy (e.g. households, nonfinancial business, financial intermediaries), broken down into various financial instruments (e.g. deposits, corporate bonds, mortgages). However, the lack of counterparty information in the database provides a challenge. Therefore, throughout the data construction process I use the method proposed by Herman et al. (2017) to obtain estimates of "whom-to-whom" lending among sectors of the economy.

Banks are defined as the collection of U.S.-charted depository institutions and credit unions, following Durdu and Zhong (2023). I choose money market funds and mutual

[1] See Pozsar et al. (2010) for an early attempt at mapping the NBFI sector.

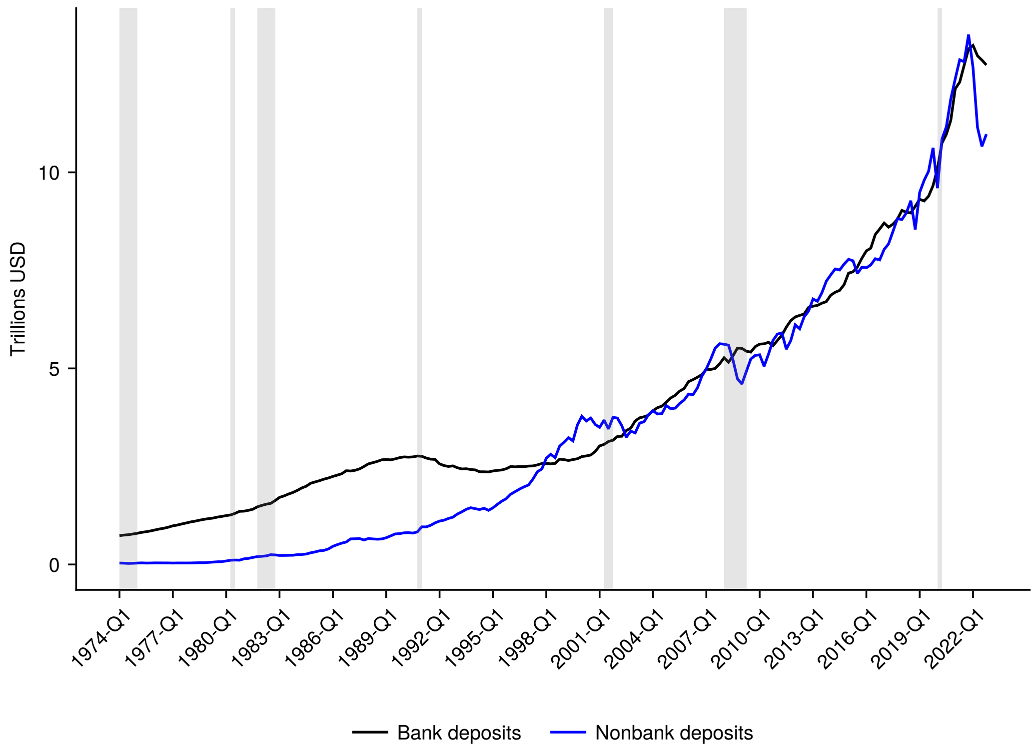
funds, which I refer to collectively as investment funds, as the NBFIs of focus. The reason is that investment funds are the only NBFIs that compete with banks at both ends of the liquidity transformation process. As will be clear in the following, investment funds not only provide liquidity to households and thus compete with bank deposits, they also intermediate substantial amount of funding to nonfinancial firms both directly and through funding of other NBFIs. I exclude foreign banking entities and mutual funds investing exclusively in foreign markets as I am primarily concerned with U.S. domestic financial intermediation.

The households' holdings of bank liabilities is measured by the sum of checkable, time and savings deposits issued by banks as defined above. Nonbank liabilities are defined as the sum of shares issued by money market funds and mutual funds held by the household sector. Recent literature in finance highlights the money-like attributes of liquid claims issued by money market funds and mutual funds. Krishnamurthy and Li (2023) find that money market fund shares, similar to bank-created money, satisfy the investors' demand for liquidity (see also Xiao (2020); Begenau and Landvoigt (2022)). Ma et al. (2021) show that equity-issuing mutual funds provide liquidity by insuring against idiosyncratic liquidity risks in ways similar to debt-issuing banks (see also Chernenko and Doan (2022); Agarwal et al. (2023)). Although money market fund and mutual fund shares are equity, I follow the literature and refer to them as nonbank "deposits" (see e.g. Xiao (2020) and Begenau and Landvoigt (2022)). This designation highlights their properties as demandable and liquid claims, and facilitates comparisons to bank deposits. For instance, in the U.S., money market funds offer intraday redemption, while mutual funds offer redemption within a week.

Figure 1 shows the U.S. household sector's holdings of bank and nonbank deposits in nominal USD between 1974 Q1 to 2022 Q4. Since the late 1990s, the households' demand for nonbank-created liquidity has been on par with bank deposits, with several periods during which nonbank deposits have exceeded their bank counterparts. Although, nonbank deposits have been somewhat more volatile over time with a standard deviation of 3.5, while it is 3.1 for bank deposits. As can be seen in Figure A1, much of the volume and the volatility of nonbank deposits after the late 1990s are driven by the development of the households' mutual fund assets.

To construct measures of lending, I follow Gallin (2013) and identify the amount of credit provided to nonfinancial firms that can be traced, through the intermediation chains, back to banks and investment funds. Gallin (2013) categorizes financial

FIGURE 1. Households' bank and nonbank deposits



This figure shows the U.S. household sector's holdings of bank and nonbank deposits in nominal trillions USD from 1974 Q1 to 2022 Q4. Bank deposits are defined as the sum of checkable, time and savings deposits issued by U.S.-charted depository institutions and credit unions. Nonbank deposits are defined as the sum of money market fund shares and mutual fund shares. The data are taken from the Financial Accounts of the United States. Gray shaded areas denote NBER recession dates.

intermediaries in the FAs database into upstream and downstream entities.[2] Upstream intermediaries are those who generally take proceeds from the nonfinancial sector (e.g. households) and fund both other financial intermediaries and nonfinancial sector borrowers (e.g. firms). Among upstream intermediaries are banks and investment funds. Downstream intermediaries, on the other hand, do not borrow from households directly but rely on market funding (e.g. from upstream intermediaries) to make loans to firms. Finance companies, asset-backed securities issuers and broker-dealers are examples of downstream intermediaries. Figure A2 shows a simplified representation of the funding of nonfinancial firms through upstream and downstream intermediaries. Thus, banks

[2] Gallin (2013) denotes upstream intermediaries as terminal funders and downstream intermediaries as intermediate funders.

and investment funds provide credit to nonfinancial firms both directly and indirectly. The direct funding of firms is simply measured by the amount of firm debt held by banks and investment funds. The indirect funding is found by allocating all firm debt held by downstream intermediaries to banks and investment funds proportional to the amount of downstream intermediaries' liabilities they hold. Suppose investment funds hold 20% of finance companies' liabilities. Then, 20% of finance companies' lending to firms is allocated to investment funds as their indirect lending to firms. This procedure is also performed on other upstream NBFIs.[3]

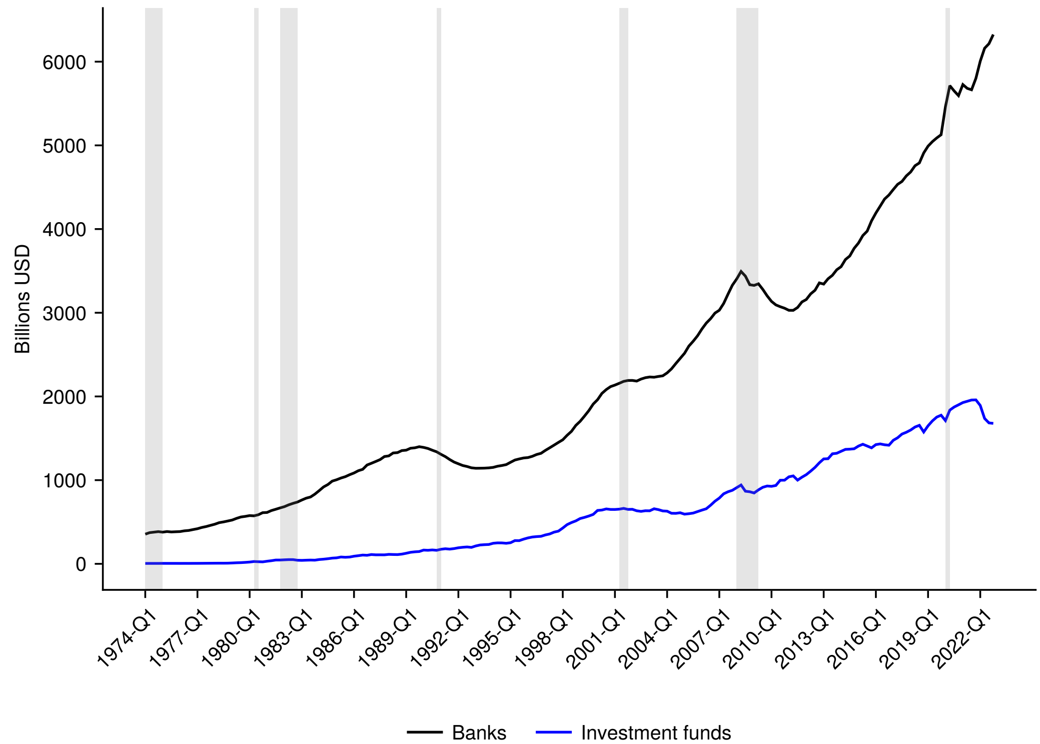
Figure 2 plots bank and nonbank lending to nonfinancial firms in the U.S. over time. Unsurprisingly, banks provide the largest share of lending to firms. Nevertheless, investment funds intermediate a substantial amount of credit to the productive sector. At the highest, investment funds' lending to firms corresponds to 38% of what banks provide. In recent years, that share has fluctuated between 30% to 35% with the average over the whole sample period being about 20%. Figure A3 compares lending to firms from all upstream financial intermediaries as categorized by Gallin (2013), grouped into banks, investment funds and other NBFIs. The total lending from other NBFIs stands closer to that of banks. This is the result of the considerable amount of corporate bonds held by insurance companies and pension funds.[4] I choose to exclude those intermediaries because their roles in the financial sector and the services they provide to the households are notably different from those of banks and investment funds.

The procedure proposed by Gallin (2013) provides a more accurate measure bank and nonbank credit intermediation to nonfinancial firms. Figure A5 contrasts the amount of lending by investment funds, as identified using the methodology of Gallin (2013), with their holding of (non-government) debt instruments. Because of the financial interconnections between investment funds and the rest of the financial sector, using the quantity of debt instruments on the funds' balance sheet as a proxy for their lending would severely overestimate their credit provision to the productive sector. Moreover, there is a significant difference between banks and investment funds in the share of credit to firms that is provided indirectly through the nonbank financial sector. Figure A6 shows that the majority of bank lending is done through banks' direct holdings of firm debt. Banks' funding of downstream NBFIs, which in turn is passed down to firms, has been persistently low over time. On the other hand, investment funds intermediate a sizeable share of its lending through downstream NBFIs, as indicated by Figure A7.

[3]Other upstream NBFIs are private pensions funds, public retirement funds, closed-ended funds, exchange-traded funds and insurance companies.

[4]See Figure A4 for a breakdown of upstream NBFIs' lending.

FIGURE 2. Bank and nonbank lending to nonfinancial firms



This figure shows lending to U.S. nonfinancial firms from banks and NBFIs in nominal billions USD from 1974 Q1 to 2022 Q4. Banks are defined as U.S.-charted depository institutions and credit unions. Investment funds are defined as money market funds and mutual funds. The lending data is constructed using the methods of Gallin (2013) and Herman et al. (2017), with data from the Financial Accounts of the United States. Gray shaded areas denote NBER recession dates.

This was especially the case during the run-up to the global financial crisis of 2007. After the financial crisis, investment funds' indirect lending plateaued while their direct holdings of firm debt rose rapidly.

Lastly, economic activity is represented by aggregate output, consumption and investments. All aggregate quarterly economic variables are obtained from the FRED database of the Federal Reserve Bank of St. Louis. Consumption is measured by real personal consumption expenditures and investments by real gross private investments. Output is calculated as the sum of consumption, investment and government purchases.

2.3. Empirical Responses to Monetary Shocks

I estimate the effect of monetary policy shocks on household portfolios, bank and nonbank lending to firms and economic activity by means of local projections (Jordà 2005). I restrict the sample to between 1974 Q1 to 2007 Q4 to include the popularization of money market funds in the U.S. in the early 1970s, and to avoid the zero lower bound and the unconventional monetary policy brought about by the global financial crisis.

Monetary policy shocks are identified by the narrative approach (Romer and Romer 2004). Specifically, I use the extended monetary policy shock series constructed by Miranda-Agrippino and Rey (2020). The empirical specification closely follows Luetticke (2021)

$$y_{t+j} = \beta_{0,j} + \beta_{1,j} D_t + \beta_{2,j} \bar{\epsilon}_t + \beta_{3,j} \mathbf{x}_{t-1} + \nu_{t+j}, \quad j = 0, \ldots, 15, \tag{1}$$

where y_{t+j} is the endogenous variable of interest at horizon j, D_t is a time trend, $\bar{\epsilon}_t$ is the monetary shock normalized by its standard deviation, $\mathbf{x}_{t-1}$ are lagged controls.[5] The vector $\mathbf{x}_{t-1}$ includes lagged values of output, consumption, investments, effective Fed funds rate, and monetary policy shocks. All quantity variables are real and in log levels. The coefficient $\beta_{2,j}$ captures the response of endogenous variable y_{t+j} at horizon j to the monetary policy shock occurring at time t.

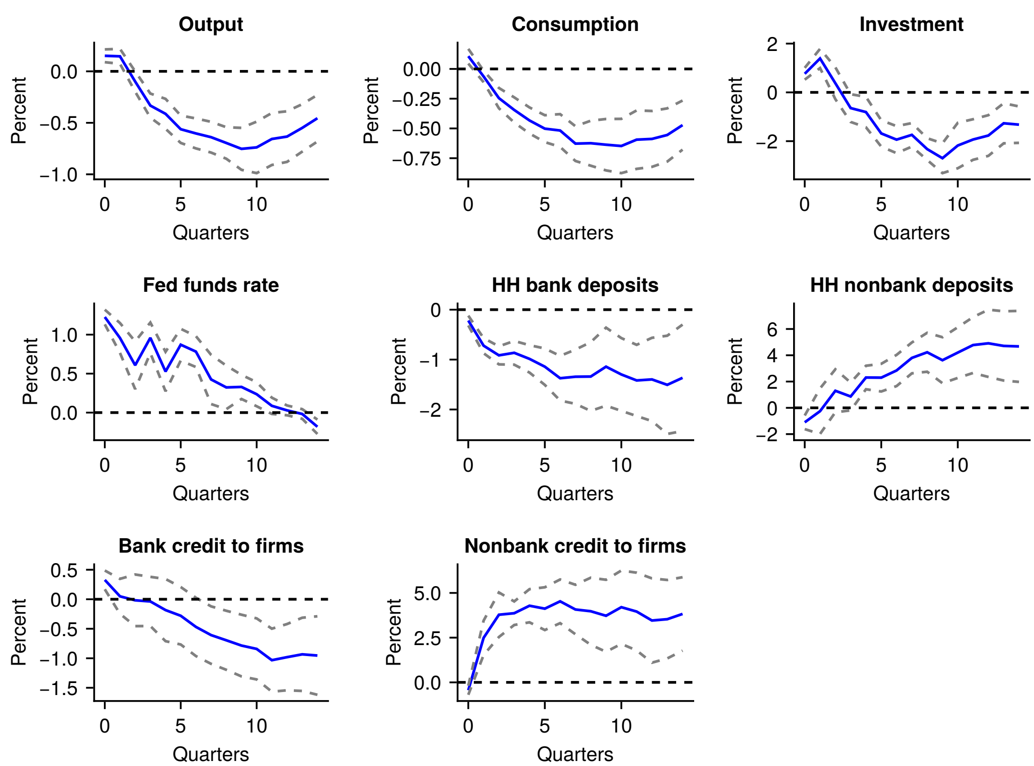
Figure 3 shows the responses of economic activity, effective Fed funds rate, bank- and nonbank-created liquidity to households, and bank and nonbank lending to firms to a one standard deviation monetary shock. The monetary policy tightening pushes up the effective Fed funds rate for about three years. Output and consumption fall by around 0.7% and 0.6%, respectively, after ten quarters before recovering. Investment falls by a much larger margin, with the decrease reaching about 3% after nine quarters. Bank deposits fall persistently by around 1.4% and banks reduce their lending to firms by 1% after about one year. The responses of bank deposits and lending to firms are consistent with the deposits channel proposed by Drechsler et al. (2017). Interestingly, nonbank financial intermediation expands. Households' nonbank deposits increases persistently by more than 4% after three years, while nonbank lending to firms increases by about 3%. In other words, I observe a flight from bank deposits as households seek alternative sources of liquidity and saving opportunities. Consequently, there is a "credit leakage" towards the less regulated nonbank financial sector in the U.S. after monetary policy tightenings. Since funding from the financial sector is critical for investments

[5] For the local projections, I rely on a package written by Chen (2022).

and output, the results indicate that the presence of NBFIs dampens the contractionary effect of monetary policy.

Figure A8 shows the same impulse responses with the addition of the response of NBFIs' holding of debt instruments. As already seen in the previous section, the usual way of using the quantity of NBFIs' holding of debt instruments as a measure of nonbank credit to firms might overstate its size. Figure A8 shows that it might also overestimate the response of nonbank credit to monetary policy shocks. The response of nonbank debt instruments is somewhat higher, although less persistent, than that of nonbank credit as identified by the method of Gallin (2013).

FIGURE 3. Impulse responses to monetary policy shock



This figure shows the estimated response to one standard deviation monetary policy shock, as identified in Miranda-Agrippino and Rey (2020). The gray dotted lines show the 66% confidence bounds, calculated using Eicker-Huber-White heteroskedasticity-robust variance-covariance estimator.

3. A New-Keynesian Model of Two Deposits Channels

To interpret the empirical evidence in the last section, I build a New-Keynesian model with two types of financial intermediaries, banks and investment funds, that engage in liquidity transformation. As such, the model accounts for the "deposits" and the "shadow banking" channels of monetary policy identified in the literature (Drechsler et al. 2017; Xiao 2020). I denote the two channels as *bank deposits* and *nonbank deposits* channels, respectively.

I take a liquidity-centric view of financial intermediation similar to that of Piazzesi et al. (2022) and Niepelt (2023). Financial intermediaries issue liquid savings, in the forms of bank and nonbank deposits, that are valued by the households. Banks are subject to a liquidity constraint that limits their ability to issue debt, which can be satisfied by holding central bank reserves. Nonbank deposits, i.e. investment fund shares, on the other hand, are equities. Investment funds are thus not affected by the constraint and they do not have access to reserves. Moreover, banks have market power because households substitute imperfectly between deposit services at different banks. Investment fund shares, in contrast, are considered identical by the households.

Production firms use capital and labor as inputs to produce intermediate goods, and purchase capital from specialized capital producers. Following Gertler and Karadi (2011), firms finance their capital acquisition by issuing financial claims on capital to banks and nonbanks in a competitive credit market. Thus, production firms are indifferent between bank and nonbank credit. Retailers costlessly differentiate intermediate goods and face a quadratic price adjustment cost, following Rotemberg (1982), when selling the differentiated goods to the final good producer.

3.1. Household Sector

Consider a representative household that values consumption c_t, liquidity services z_t, and leisure x_t, represented by the utility function

$$u(c_t, z_t, x_t) = \frac{(c_t - hc_{t-1})^{1-\sigma}}{1-\sigma} + \nu\frac{z_t^{1-\psi}}{1-\psi} - \xi\frac{(1-x_t)^{1+\iota}}{1+\iota}, \tag{2}$$

where $\sigma, \psi > 0$ are the inverse intertemporal elasticities of substitution, h captures habit formation in consumption, ν denotes the utility benefit of liquidity services, $\iota > 0$ is the inverse Frisch elasticity, and ξ is the disutility of labor.

In the modern financial system, many financial assets may fill the roles traditionally associated with money and provide liquidity services to households. In this paper, liquidity is understood as services provided by financial assets as a medium of transaction and a safe store of value. As mentioned in the previous sections, recent literature in finance shows that investment funds' liabilities satisfy agents' demand for liquidity in ways similar to bank deposits (Krishnamurthy and Li 2023; Ma et al. 2021). Therefore, I assume in the model that liquidity services z_t are derived from bank deposits d_t and investment fund shares, which I denote as nonbank deposits s_t. I employ a constant elasticity of substitution (CES) aggregator similar to the ones used by Krishnamurthy and Li (2023)

$$z_t = \left(\gamma d_t^{1-\epsilon} + (1-\gamma) s_t^{1-\epsilon}\right)^{\frac{1}{1-\epsilon}}, \tag{3}$$

where $\gamma \in (0, 1)$ measures the liquidity of bank deposits relative to nonbank deposits and $\epsilon \geq 0$ is the inverse elasticity of substitution between the two assets. Moreover, I follow Repullo (2020) in assuming that bank deposits are themselves a composite good issued by a set of n banks. Each bank i has mass $1/n$ and produces deposits at a rate nd_t^i. The household values deposits at different banks such that

$$d_t = \left(\frac{1}{n}\sum_{i=1}^{n}\left(nd_t^i\right)^{1-\eta}\right)^{\frac{1}{1-\eta}}, \tag{4}$$

where $\eta \geq 0$ denotes the inverse elasticity of substitution between deposit products. One common objection to the way aggregate bank deposits are defined using a CES aggregator, as in expression (4), is that it is implausible that all households hold deposits from all banks. Drechsler et al. (2017) justify a similar setup by interpreting the representative household as an aggregation of many individual households with diverse preferences for holding deposits at different banks. Ulate (2021) shows that a heterogeneous depositor approach with stochastic utility and extreme value shocks can work as microfoundation for such CES aggregators. Furthermore, I assume nonbank deposits are considered identical by the household. Therefore, I model nonbank deposits as if they are issued by a competitive fund.

Besides deposits, the household can invest in government bonds b_t which do not provide liquidity services. The household's period budget constraint, in real terms, is given by

$$c_t + \sum_{i=1}^{n} d_t^i + s_t + b_t + \tau_t = w_t(1 - x_t) + div_t + \sum_{i=1}^{n} \frac{d_{t-1}^i R_t^{d,i}}{\pi_t} + \frac{s_{t-1} R_t^s}{\pi_t} + \frac{b_{t-1} R_t}{\pi_t}, \tag{5}$$

where τ_t is the lump-sum tax net of government transfer, w_t is the wage rate, div_t is profits from firms, banks and funds owned by the household, $R_t^{d,i}$ is the nominal gross interest rate on deposits at bank i, R_t^s is the nominal gross return on nonbank deposits, R_t is the nominal gross interest rate on bonds, $\pi_t = p_t / p_{t-1}$ is the gross rate of inflation between $t-1$ and t, p_t is the price of consumption good. I assume that the nominal returns on deposits and bonds are risk-free. The household maximizes the discounted sum of life-time utility

$$\mathbb{E}_t \sum_{j=0}^{\infty} \beta^j u(c_{t+j}, z_{t+j}, x_{t+j}),$$

subject to a sequence of flow budget constraints (5), by choosing sequences of consumption, leisure, deposits, and bonds.

I now turn to the first-order conditions implied by the household program. First, the household allocates between deposit products at different banks according to

$$d_t^i = \frac{d_t}{n} \left(\frac{\chi_{t+1}^{d,i}}{\chi_{t+1}^{d}} \right)^{-\frac{1}{\eta}}, \tag{6}$$

where

$$\chi_{t+1}^{d,i} = \frac{R_{t+1} - R_{t+1}^{d,i}}{R_{t+1}}, \tag{7}$$

$$\chi_{t+1}^{d} = \left(\frac{1}{n} \sum_{i=1}^{n} \left(\chi_{t+1}^{d,i} \right)^{\frac{\eta-1}{\eta}} \right)^{\frac{\eta}{\eta-1}}. \tag{8}$$

$\chi_{t+1}^{d,i}$ shows the interest forgone when holding deposits at bank i relative to holding bonds, $R_{t+1} - R_{t+1}^{d,i} > 0$, discounted by the nominal rate. The return differential is discounted because it is realized in period $t+1$. In other words, holding bank deposits is costly for the household because of the lower return and $\chi_{t+1}^{d,i}$ represents the cost of deposits at bank i. The household is willing to pay a price for holding bank deposits due to the liquidity benefits they provide, and I refer to this cost as the *bank deposit spread.* χ^d_{t+1} is an index of the bank deposit spreads associated with one unit of deposit bundle and can thus be interpreted as the cost of one unit of aggregate bank deposit d_t.[6] Equation 6 shows that the household's relative share of deposits at bank i, d^i_t/d_t, depends negatively on the relative cost, $\chi^{d,i}_{t+1}/\chi^d_{t+1}$. Intuitively, the more expensive the deposit products at bank i are relative to the "average" cost, the lower is the share of total bank deposits invested at bank i.

Next, let χ^s_{t+1} denote the discounted forgone interest associated with nonbank deposits

$$\chi^s_{t+1} = \frac{R_{t+1} - R^s_{t+1}}{R_{t+1}}. \tag{9}$$

This return differential represents the opportunity cost incurred by the household when holding liquidity in the form of nonbank deposits and I denote this cost as the *nonbank deposit spread*. The marginal rates of substitution between consumption and each of the liquid assets must be equal to their respective cost, χ^d_{t+1} and χ^s_{t+1}. This implies that the marginal rate of substitution between consumption and aggregate liquidity z_t must be equal to the *average cost of liquidity*, given by

$$\chi^z_{t+1} = \frac{\chi^d_{t+1}\chi^s_{t+1}}{\left((1-\gamma)^{\frac{1}{\epsilon}}\left(\chi^d_{t+1}\right)^{\frac{1-\epsilon}{\epsilon}} + \gamma^{\frac{1}{\epsilon}}\left(\chi^s_{t+1}\right)^{\frac{1-\epsilon}{\epsilon}}\right)^{\frac{\epsilon}{1-\epsilon}}}. \tag{10}$$

This gives rise to an expression for the household's demand for aggregate liquidity

$$z_t = \left(\frac{\nu}{M_t\chi^z_{t+1}}\right)^{\frac{1}{\psi}}, \tag{11}$$

where M_t is the marginal utility of consumption given by

$$M_t = (c_t - hc_{t-1})^{-\sigma} - \beta h \mathbb{E}_t\left[(c_{t+1} - hc_t)^{-\sigma}\right]. \tag{12}$$

Equation (11) shows that the household's demand for liquidity is decreasing in its average cost χ^z_{t+1}, the marginal utility of consumption M_t and the elasticity of liquidity demand, and increasing in the utility weight ν. In the special case where the household does not

[6] Derivations for d^i_t (6) and χ^d_{t+1} (8) are provided in Appendix B.1

exhibit habit formation ($h = 0$) and the intertemporal elasticities of substitution are identical ($\sigma = \psi$), the consumption velocity is simply given by $c_t/z_t = \left(\chi^z_{t+1}/\nu\right)^{1/\psi}$. Given the demand for aggregate liquidity, the demand for bank and nonbank deposits are found as

$$d_t = z_t \left(\gamma \frac{\chi^z_{t+1}}{\chi^d_{t+1}}\right)^{\frac{1}{\epsilon}}, \tag{13}$$

$$s_t = z_t \left((1-\gamma)\frac{\chi^z_{t+1}}{\chi^s_{t+1}}\right)^{\frac{1}{\epsilon}}. \tag{14}$$

The demand functions for deposits show that the relative demand for each type of asset, a_t/z_t, $a \in \{d, s\}$, is increasing in its liquidity benefit, γ or $1-\gamma$, and decreasing in its cost relative to the average cost, $\chi^a_{t+1}/\chi^z_{t+1}$, $a \in \{d, s\}$. Combining equations (13) and (14) we also see that the household demands more bank deposits relative to nonbank deposits when the nonbank deposits are relatively expensive (higher $\chi^s_{t+1}/\chi^d_{t+1}$). Lastly, the household's Euler equation and labor supply condition are standard

$$M_t = \beta \mathbb{E}_t \left[M_{t+1}\frac{1}{\Pi_{t+1}}\right] R_{t+1}, \tag{15}$$

$$\xi(1-x_t)^{\iota} = w_t M_t, \tag{16}$$

where M_t is given by equation (12).

3.2. Financial Sector

3.2.1. Banks

There is a set of n non-competitive banks that fund themselves with deposits and equity. Each bank i purchases financial claims on physical capital $a^{b,i}_t$, at the relative price q_t, and invests in central bank reserves r^i_t. The balance sheet of a typical bank, in real terms, is

$$q_t a^{b,i}_t + r^i_t = d^i_t + e^i, \tag{17}$$

where e^i is a fixed endowment of bank equity. I interpret the financial claims that the bank holds as credit provided to nonfinancial firms. Banks are subject to a liquidity constraint that limits their ability to issue debt, i.e. they need sufficient collateral to back deposits. The liquidity constraint reads

$$d_t^i \leq \zeta r_t^i, \tag{18}$$

where $\zeta \geq 1$ puts a upper bound on deposits relative to reserves. The liquidity constraint simply states that the banks' reserves-to-deposits ratio, or liquidity ratio r_t/d_t, must be greater or equal to $1/\zeta$. This constraint can be interpreted as an explicit regulatory constraint or alternatively as way to model an increasing marginal cost of debt (Piazzesi et al. 2022; Rogers 2023).

Bank credit earns a real stochastic return R_t^k and the nominal risk-free interest rate on reserves is R_t^r. Furthermore, I assume liquidity transformation is costly for the banks. For each unit of liquid deposits a bank issues, it faces a linear cost of θ_b. The real profit a bank $div_t^{b,i}$ consists of the returns on last-period lending and reserves, net of financing costs and liquidity transformation costs

$$div_t^{b,i} = q_{t-1} a_{t-1}^{b,i} R_t^k + r_{t-1}^i \frac{R_t^r}{\pi_t} - d_{t-1}^i \frac{R_t^{d,i}}{\pi_t} - e^i - \theta_b d_t^i. \tag{19}$$

Each bank is infinitely-lived and seeks to maximize expected discounted profits

$$\mathbb{E}_t \sum_{j=0}^{\infty} \Lambda_{t,t+j}\, div_{t+j}^{b,i},$$

subject to the household's demand schedule (6) for its deposits, the balance sheet constraint (17), and the liquidity constraint (18). The bank chooses the quantities of capital claims, reserves and deposits, and discounts its profits by the household's real stochastic discount factor $\Lambda_{t,t+j} = \beta^j M_{t+j}/M_t$.

The first-order conditions with respect to capital claims is

$$\mathbb{E}_t \left[\Lambda_{t,t+1} \left(R_{t+1}^k - \frac{R_{t+1}}{\pi_{t+1}} \right) \right] = 0. \tag{20}$$

With perfect credit/capital markets, there is no risk adjusted premium on bank loans, i.e. the real return on loans must equal the real rate in expectation. The first-order condition with respect to reserves yields

$$\lambda_t = \frac{\chi_{t+1}^r}{\zeta}, \tag{21}$$

where λ_t is the Lagrange multiplier associated with the liquidity constraint and χ^r_{t+1} is the bank's discounted forgone interest for each unit of reserves it holds

$$\chi^r_{t+1} = \frac{R_{t+1} - R^r_{t+1}}{R_{t+1}}. \tag{22}$$

Similar to the interpretations of deposit spreads, χ^r_{t+1} represents the bank's opportunity cost of holding reserves and I denote it the *reserve spread*. Equation (21) shows that the marginal value of relaxing the liquidity constraint is equal to the opportunity cost of reserves, adjusted for the bound on bank debt. Thus, χ^r_{t+1}/ζ is the shadow price of reserves. We also see that the larger ζ is, i.e. the less restrictive the liquidity constraint is, the lower is the shadow value of reserves.

The first-order condition with respect to deposits gives rise to a classical pricing equation that determines the equilibrium bank deposit spread

$$\chi^{d,i}_{t+1} = \left(\frac{\partial d^i_t}{\partial R^{d,i}_{t+1}} \frac{R^{d,i}_{t+1}}{d^i_t}\right)^{-1} \frac{R^{d,i}_{t+1}}{R_{t+1}} + \lambda_t + \theta_b. \tag{23}$$

Continuing with the interpretation of $\chi^{d,i}_{t+1}$ as a price for deposits, the term $\lambda_t + \theta_b$ in equation (23) constitutes the bank's marginal cost of issuing deposits. This cost consists of the shadow price of reserves λ_t, since investments in reserves are needed to satisfy the liquidity constraint, and the unit cost of liquidity creation θ_b. The leftmost term on the right-hand side can be seen as a "markup" term over the marginal cost, which is inversely related to the demand elasticity for bank deposits. Banks are able to charge a markup due to the non-competitive nature of the banking sector.

All banks are identical and I focus on a symmetric industry equilibrium. Then, the banks' pricing equations can be expressed as they apply to a representative bank

$$\chi^d_{t+1} - \left(\frac{1}{n}\left(\frac{1-\mu_{t+1}}{\psi} + \frac{\mu_{t+1}}{\epsilon}\right) + \left(1 - \frac{1}{n}\right)\frac{1}{\eta}\right)^{-1} \chi^d_{t+1} = \frac{\chi^r_{t+1}}{\zeta} + \theta_b, \tag{24}$$

where $\mu_{t+1} \in [0, 1]$ is

$$\mu_{t+1} = (1-\gamma)^{\frac{1}{\epsilon}} \left(\frac{\chi^z_{t+1}}{\chi^s_{t+1}}\right)^{\frac{1-\epsilon}{\epsilon}}. \tag{25}$$

Note that the markup is written in terms of the bank deposit *spread* instead of the deposit *rate*. We see from equation (24) that the markup depends on the structure of the banking sector, i.e. the degree of market concentration and interbank competition. Lower market concentration (small $1/n$) means that interbank competition, captured by the elasticity of substitution between banks $1/\eta$, matters more banks' ability to charge a markup on their deposit products. Suppose that market concentration is high (high $1/n$), then interbank competition matters less. Instead, the banking sector as a whole faces competition from nonbank deposits and consumption goods, captured by the term $\frac{1-\mu_{t+1}}{\psi} + \frac{\mu_{t+1}}{\epsilon}$. The variable μ_t, which acts as a relative weight, captures whether nonbank deposits or consumption influences the banks' pricing behavior more. For example, a higher nonbank deposits spread χ^s_{t+1} decreases μ_t, so that the elasticity of substitution between bank and nonbank deposits $1/\epsilon$ matters less for banks. Higher nonbank spread makes the household's demand for bank deposits less elastic and thus nonbank deposits less of a competition. It amounts to giving banks more market power.

In the special case where the number of banks goes to infinity, the banking sector becomes monopolistically competitive. Thus, banks price their deposits products according to

$$\chi^d_{t+1} = \frac{\chi^r_{t+1}/\zeta + \theta_b}{1-\eta}. \tag{26}$$

Monopolistically competitive banks then charge a constant markup $1/(1-\eta)$ over their marginal cost $\chi^r_{t+1}/\zeta + \theta_b$. Moreover, if the household also substitutes perfectly between banks, then the banking sector becomes perfectly competitive. The bank deposit spread is simply equal to banks' marginal cost

$$\chi^d_{t+1} = \frac{\chi^r_{t+1}}{\zeta} + \theta_b. \tag{27}$$

Lastly, note that a positive deposit spread indicates that the bank's cost of funding is lower than the reference nominal rate in the economy. In other words, deposits are a cheap source of funding and in equilibrium the bank will issue deposits until the liquidity constraint (18) holds with equality.

3.2.2. Investment funds

Competitive investment funds issue "nonbank deposits", i.e. fund equities, to fund purchases of financial claims on capital a^s_t at the price q_t. Similar to banks, I interpret the funds' holding of these claims as credits extended to nonfinancial firms. The balance sheet of the representative investment fund is simply

$$q_t a_t^s = s_t. \tag{28}$$

Since the investment fund cannot issue debt, it is not subject to the liquidity constraint that banks face. On the other hand, the fund also faces costs associated with providing liquid assets to the household. For each share it issues, it incurs a cost of θ_s. I assume that the fund participate in the same competitive credit market as banks and firms do not distinguish between bank and nonbank credit. Hence, nonbank credit earns the same rate of return R_{t+1}^k as the banks. The real profit of the investment fund is the difference between the return on its previously intermediated assets and its financing costs and the liquidity transformation cost

$$div_t^s = q_{t-1} a_{t-1}^s R_t^k - s_{t-1} \frac{R_t^s}{\pi_t} - \theta_s s_t. \tag{29}$$

The fund maximizes the expected discounted profits, by choosing the size of its balance sheet s_t,

$$\mathbb{E}_t \sum_{j=0}^{\infty} \Lambda_{t,t+j} \, div_{t+j}^s,$$

subject to its balance sheet constraint (28).

The first-order condition is then

$$\theta_s + \mathbb{E}_t \left[\Lambda_{t,t+1} \frac{R_{t+1}^s}{\pi_{t+1}} \right] = \mathbb{E}_t \left[\Lambda_{t,t+1} R_{t+1}^k \right] \tag{30}$$

Equation (30) shows that the investment fund issues nonbank deposits up to the point where the cost of issuing liabilities, i.e. the liquidity transformation cost plus discounted interest expenses, equals the discounted return on loans extended to firms. Combining the last equation with the banks' first-order condition (20) for loans yields a simple pricing equation for the equilibrium interest spread on nonbank deposits

$$\chi_{t+1}^s = \theta_s. \tag{31}$$

The investment fund's only marginal cost is the liquidity provision cost θ_s. There is no markup over the marginal cost like for the banks since investment fund is competitive. Consequently, it sets the return on nonbank deposits R_{t+1}^s such that there is a constant spread between it and the nominal risk-free rate R_{t+1}, i.e

$$R^s_{t+1} = R_{t+1}(1 - \theta_s) \tag{32}$$

3.3. Production Sector

3.3.1. Production Firms

Competitive production firms produce common intermediate goods y^m_t using a constant return to scale technology, with capital and labor as inputs. A firm has a production function of the form

$$y^m_t = k^\alpha_{t-1} l^{1-\alpha}_t, \tag{33}$$

where k_{t-1} is the quantity of capital carried over from the previous period, l_t is the current demand for labor, and α is the capital share of output. In the current period, the firm purchases capital k_t at price q_t from specialized capital producers to be brought into the next period. The firm has to finance its capital acquisition in its entirety by obtaining funds from financial intermediaries. It issues financial claims to capital a_t, priced at q_t, that equals the value of capital to be acquired

$$q_t a_t = q_t k_t. \tag{34}$$

Intermediate goods are eventually sold to retailers at price p^m_t. At the end of each period, the firm aquires new capital and sells its stock of undepreciated capital to capital producers. The real profit of the firm consists of the value of its output, plus capital sales, net of capital financing cost and labor cost

$$div^p_t = y^m_t \frac{p^m_t}{p_t} + (q_t - \delta)k_{t-1} - q_{t-1}a_{t-1}R^k_t - w_t l_t, \tag{35}$$

where δ is the rate of capital depreciation. In each period, the firm chooses its current labor demand and next-period quantity of capital to maximize expected discounted profits, given its production technology

$$\mathbb{E}_t \sum_{j=0}^{\infty} \Lambda_{t,t+j}\, div^p_{t+j}. \tag{36}$$

The first-order condition with respect to labor yields the firm's labor demand

$$w_t = mc_t(1-\alpha)\left(\frac{k_{t-1}}{l_t}\right)^{\alpha}, \tag{37}$$

where $mc_t = p_t^m/p_t$. The first-order condition with respect to capital implies a relation determining the firm's demand for capital

$$R_t^k = \frac{mc_t\alpha\left(\frac{k_{t-1}}{l_t}\right)^{\alpha-1} + q_t - \delta}{q_{t-1}}. \tag{38}$$

3.3.2. Retailers and Final Good Producer

A continuum of monopolistically competitive retailers buy intermediate goods from the production firms, costlessly differentiate them, and sell the differentiated goods to a final good producer.

Each retailer i transforms the intermediate goods y_t^m into its variety simply according to $y_t^i = y_t^m$. The final good producer aggregates the varieties into the final output y_t

$$y_t = \left(\int_0^1 \left(y_t^i\right)^{1-\varphi} di\right)^{\frac{1}{1-\varphi}}, \tag{39}$$

where φ is the inverse elasticity of substitution between good varieties. The real profit of the final good producer is

$$div_t^f = y_t - \int_0^1 \frac{p_t^i}{p_t} y_t^i di, \tag{40}$$

where p_t^i is the price of variety i. The demand for variety i is derived from the static profit maximization problem of the final good producer

$$y_t^i = y_t\left(\frac{p_t^i}{p_t}\right)^{-\frac{1}{\varphi}}. \tag{41}$$

Using the last equation, an expression for the price level in the economy in terms of intermediate goods can be found

$$p_t = \left(\int_0^1 \left(p_t^i \right)^{\frac{\varphi-1}{\varphi}} di \right)^{\frac{\varphi}{\varphi-1}}. \tag{42}$$

The real profit of a retailer consists of the value of its output net of the cost of purchasing intermediate goods and a quadratic price adjustment cost following Rotemberg (1982)

$$div_t^{r,i} = \frac{p_t^i}{p_t} y_t^i - mc_t y_t^i - \frac{\theta_p}{2\varphi} \left(\ln \left(\frac{p_t^i}{p_{t-1}^i} \right) \right)^2 y_t, \tag{43}$$

where mc_t is the real marginal cost of the retailer, y_t^i is given by (41), and $\theta_p > 0$ determines the magnitude of the price adjustment cost. The retailer sets its price to maximize

$$\mathbb{E}_t \sum_{j=0}^{\infty} \Lambda_{t,t+j} div_{t+h}^{r,j}. \tag{44}$$

The first-order condition generates the New-Keynesian Phillips curve

$$\ln \pi_t = \frac{1}{\theta_p}(mc_t - (1-\varphi)) + \mathbb{E}_t \left[\Lambda_{t,t+1} \ln \pi_{t+1} \frac{y_{t+1}}{y_t} \right]. \tag{45}$$

3.3.3. Capital Good Producers

Competitive capital good producers purchase undepreciated capital from firms after production, repair depreciated capital and build new capital.

A capital producer values both new and repaired capital at price q_t. I assume there are adjustment costs when making investment decisions. Let I_t^n denote net capital investment, or newly created capital, and $k_t = k_t^h + k_t^c$ be the total stock of capital. Depreciated capital δk_{t-1} is refurbished in its entirety. The gross capital investment, denoted by I_t, is given by

$$I_t = I_t^n + \delta k_{t-1}. \tag{46}$$

The profit of the capital producer at time t is then

$$q_t k_t - (q_t - \delta)k_{t-1} - (I_t^n + \delta k_{t-1}) - f\left(\frac{I_t^n + I}{I_{t-1}^n + I}\right)\left(I_t^n + I\right), \tag{47}$$

where $f(\cdot)$ is the adjustment cost function given by

$$f(x) = \frac{\theta_c}{2}(\ln(x))^2, \tag{48}$$

$\theta_c \geq 0$ controls the magnitude of the adjustment cost, and I is the steady state level of gross investment. The profit of the capital producer can be rewritten in terms of I_t^n

$$div_t^c = (q_t - 1)I_t^n - f\left(\frac{I_t^n + I}{I_{t-1}^n + I}\right)\left(I_t^n + I\right). \tag{49}$$

The capital producer maximizes expected discounted profits by choosing the level of net investment I_t^n, subject to the investment adjustment cost,

$$\mathbb{E}_t \sum_{h=0}^{\infty} \Lambda_{t,t+h} div_{t+h}^c. \tag{50}$$

The first-order condition of the capital producer yields an expression for the price of capital, q_t,

$$q_t = 1 + \frac{\theta_c}{2}\left(\ln\left(\frac{I_t^n + I}{I_{t-1}^n + I}\right)\right)^2 + \theta_c \ln\left(\frac{I_t^n + I}{I_{t-1}^n + I}\right) - \mathbb{E}_t\left[\Lambda_{t,t+1}\theta_c \ln\left(\frac{I_{t+1}^n + I}{I_t^n + I}\right)\frac{I_{t+1}^n + I}{I_t^n + I}\right]. \tag{51}$$

3.4. Consolidated Government

The consolidated central bank and fiscal authority issues reserves to banks and bonds to the household, and collects lump-sum taxes to fund its interest payments. It has the following budget constraint:

$$b_t + r_t + \tau_t = b_{t-1}\frac{R_t}{\pi_t} + r_{t-1}\frac{R_t^r}{\pi_t}, \tag{52}$$

where r_t is the aggregate supply of reserves to banks. The government sets the interest rates on bonds and reserves and the lump-sum tax, and elastically supplies bonds and reserves to meet demand. In the baseline, I assume that reserves are non-interest bearing in all periods. The reserve rate is then

$$R_t^r = R^r = 1, \forall t. \tag{53}$$

The government has as its monetary policy instrument the interest rate on government bonds R_{t+1}. Monetary policy is set according to a Taylor rule that seeks to stabilize inflation

$$\ln(R_{t+1}) = (1-\rho)\ln(R) + \rho\ln(R_t) + \phi(1-\rho)(\ln(\pi_t) - \ln(\pi)) + \upsilon_t, \tag{54}$$

where R is the steady state nominal rate, π is the inflation target, ρ captures monetary policy inertia, ϕ measures the inflation response, and υ_t is the monetary policy shock.

3.5. Market Clearing and Aggregate Resource Constraint

Labor market clearing implies that the production firms' labor demand equal the household's labor supply

$$l_t = 1 - x_t. \tag{55}$$

Clearing in the market for bank deposits requires that the household's total demand for deposits equals the supply of deposits across all banks

$$d_t = \sum_{i=1}^{n} d_t^i. \tag{56}$$

Similarly, the banks' demand for reserves must equal the government's supply

$$r_t = \sum_{i=1}^{n} r_t^i. \tag{57}$$

The total endownment of bank equity e is

$$e = \sum_{i=1}^{n} e^i, \tag{58}$$

and must be such that the balance sheet relation of the banking sector holds

$$a_t^b + r_t = d_t + e, \tag{59}$$

where

$$a_t^b = \sum_{i=1}^{n} a_t^{b,i}. \tag{60}$$

Credit market clearing requires that the production firms' issuance of financial claims equals the sum of the financial intermediaries' holding of claims

$$a_t = a_t^b + a_t^s, \tag{61}$$

which in turn must equal the value of capital purchase from capital producers, as already mentioned in the previous section. Lastly, the total profit distributed to the household in every period equals the sum of profits from banks, funds, production firms, retailers, final good producer, and capital producers

$$div_t = \sum_{i=1}^{n} div_t^{b,i} + div_t^s + div_t^p + \int_0^1 div_t^{r,i} di + div_t^f + div_t^c. \tag{62}$$

The aggregate resource constraint is found by combining budget constraints of the household and the government, market clearing conditions, and total profits

$$c_t + I_t = y_t - \frac{\theta_c}{2}\left(\ln\left(\frac{I_t^n + I}{I_{t-1}^n + I}\right)\right)^2 \left(I_t^n + I\right), \tag{63}$$

where output is

$$y_t = k_{t-1}^{\alpha} l_t^{1-\alpha} \tag{64}$$

gross investment I_t is as defined in equation (46), and the law of motion for capital is given by

$$k_t = k_{t-1} + I_t^n. \tag{65}$$

Following Hagedorn et al. (2019) and Fernández-Villaverde et al. (2023), I assume that the retailers' price adjustment costs and the financial intermediaries' liquidity transformation costs are "virtual". This means that while these costs affect the pricing decision of the agents, they do not result in the transfer of real resources. Thus, these costs do not show up in the aggregate resource constraint.

4. Calibration

I calibrate the model to the U.S. economy. Each period in the model is interpreted as a quarter. Table 1 summarizes the parameters and the chosen targets. I use variables without time subscripts to denote their steady state values.

TABLE 1. Baseline calibration

Parameters	Description	Value	Target/Source
Household sector			
β	Discount factor	0.99	Standard
σ	Inv. intertemporal elasticity of substitution	1	Standard value
ψ	Inv. intertemporal elasticity of substitution	1	Standard value
h	Habit parameter	0.815	Gertler and Karadi (2011)
ι	Inv. Frisch elasticity	1	Chetty et al. (2011)
ξ	Disutility of labor	6.96	$l = 1/3$
ν	Utility weight of liquidity	0.07	$z/y = 2.81$
γ	Liquidity benefit of bank deposits	0.66	$k^s/k^b = 0.21$
ϵ	Inv. elasticity of substitution s and d	0.13	Krishnamurthy and Li (2023)
η	Inv. elasticity of substitution d^i	0.13	$\eta = \epsilon$
Financial sector			
θ_b	Bank deposit issuance cost	0.01	Niepelt (2023)
θ_s	Nonbank deposit issuance cost	0.01	$\theta_f = \theta_b$
ζ	Bound on bank debt	5.1	$r/d = 0.1945$
n	Inverse banking sector concentration	2	Drechsler et al. (2017)
e	Fixed bank equity	0.11	$e/(e+d) = 0.045$
Production sector			
α	Capital share of output	0.3	Standard value
δ	Capital depreciation rate	0.025	Standard value
θ_c	Capital adjustment cost	10	Standard value
θ_p	Price stickiness	20	Calvo price duration 5 quarter
φ	Inv. elasticity of substitution y^i	0.05	Markup 5%
Government			
ρ	Interest smoothing	0.8	Standard value
ϕ	Inflation response	1.25	Standard value
Π	Inflation target	1	Zero inflation

Variables without time subscripts denote steady state values.

4.1. Household sector

The household's time discount factor is set to $\beta = 0.99$. I set the inverse intertemporal elasticities of substitution σ and ψ to the standard values of 1. The habit parameter h is set to 0.815 following Gertler and Karadi (2011). The inverse Frisch elasticity ι is set to 1 to be in line with the estimates of Chetty et al. (2011). The disutility of labor $\xi = 6.96$ is set such that the labor supply is 1/3 in steady state. I calibrate the utility weight of liquidity $\nu = 0.07$ to match the ratio of liquid assets to output of 2.81.[7] I calibrate the relative liquidity benefit of bank deposits $\gamma = 0.66$ to match the ratio of nonbank credit to bank credit of 0.21. The inverse elasticity of substitution between bank and nonbank deposits is set to $\epsilon = 0.13$, in line with the estimates of Krishnamurthy and Li (2023). I assume that elasticity of substitution between bank deposit products is equal to that between bank and nonbank deposits, i.e. $\eta = 0.13$.

4.2. Financial sector

The financial intermediaries' per unit cost of issuing deposits, θ_b and θ_s, are both set to 0.01. This is the midpoint of the range of values calculated by Niepelt (2023) for U.S. banks. I calibrate the upper bound on bank debt $\zeta = 5.1$ to match a steady state bank liquidity ratio (reserves-to-deposits ratio) of 0.1945, as estimated by Niepelt (2023). I set the number of symmetric banks to 2 such that the model equivalent of banking concentration $1/n$ is close to that estimated by Drechsler et al. (2017). I set the total fixed bank equity to 0.11 such that the ratio of bank equity to total asset is 0.045, which is the minimum CET1 capital ratio requirement in the U.S.

4.3. Production sector

The capital share of output $\alpha = 0.3$ and the capital depreciation rate $\delta = 0.025$ are standard. The capital adjustment cost parameter θ_c is set to 10. The parameter capturing price stickiness, θ_p, is set to 20 to match a price duration of 5 quarters in the Calvo setting. To match a steady state markup of 5%, I set the inverse elasticity of substitution between intermediate good varieties φ to 0.05.

4.4. Government

The inertia in the nominal rate setting, indicated by ρ, is assumed to be 0.8. The government's response to inflation ϕ takes on the conventional value of 1.25. I assume that inflation is zero in steady state.

[7] Liquidity assets are the sum of bank deposits, money market fund shares and mutual fund shares held by the household sector, in line with the definition in the empirical analysis.

5. Monetary transmission

5.1. Impulse responses

Figure 4 shows the impulse responses, as deviation from steady state, to a shock in monetary policy rate R_{t+1}. The initial shock pushes the policy rate up by 25 basis points. The solid black lines show the baseline specification in which the household values both bank and nonbank deposits. In the alternative specification, shown by the dotted red lines, the household does not value nonbank deposits for liquidity purposes, i.e. $\gamma = 1$. The alternative specification is a simple way of simulating a scenario where nonbanks are not in competition with banks, and in which the nonbank deposit channel of monetary policy is absent.

In the baseline, as the policy rate increases, the reserve spread χ^r_{t+1} widens by the same magnitude since the government keeps the interest rate on reserves fixed. A higher reserve spread raises the shadow price of reserves. In other words, it becomes more expensive for the bank to hold reserves to satisfy the liquidity constraint. Consequently, the bank's marginal cost of issuing debt increases and that induces an increase of the bank spread χ^d_{t+1}. A wider bank spread implies that the bank keeps its deposit rate relatively low after a monetary policy tightening. On the other hand, the investment fund sets the return on its nonbank deposits such that the nonbank spread x^s_{t+1} is equal to its marginal cost of issuing deposits θ_s, which is constant.[8] Hence, unlike the bank, the investment fund passes on the increase in the policy rate in its entirety to the household according to $R^s_{t+1} = R_{t+1}(1 - \theta_s)$.

The responses of the bank and nonbank spreads are in line with the empirical results on how bank deposit spreads and spreads on money market fund yields react to monetary policy in the United States. Drechsler et al. (2017) and Wang et al. (2022) show evidence for a positive relationship between U.S. bank deposit spreads and the Fed funds rate. Afonso et al. (2023) find that the yields on U.S. money market funds tend to follow the effective Fed funds rate very closely, while the response of the average rate on retail three-month certificates of deposit (CD) is much slower. For example, between 2022 and 2023 the increase in fund yields corresponded to 97% of the increase in the effective Fed funds rate, whereas for the CD rate the number was 8%.

The differential response of the prices of bank and nobank deposits means that bank deposits becomes relatively more expensive for the household as a source of liquidity. Subsequently, according to equations (13) and (14), this should induce a flight from

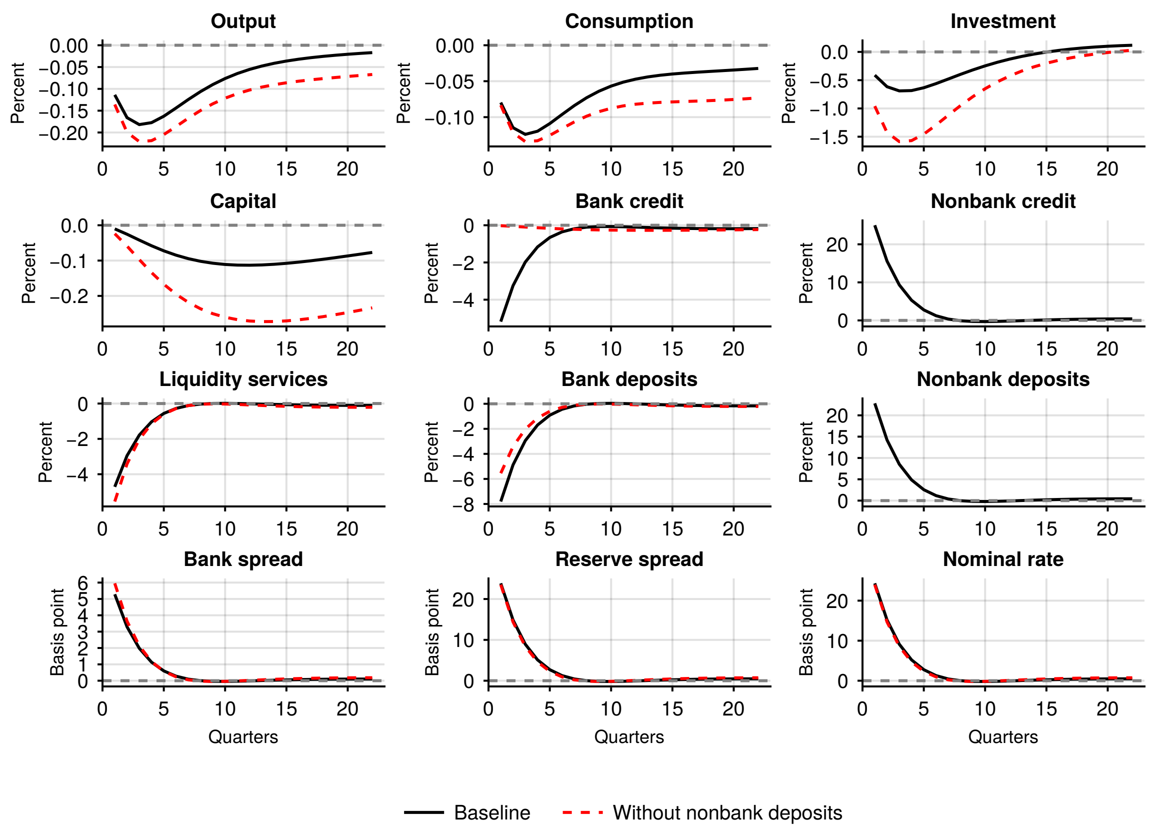
[8] Therefore, $x^s_{t+1} = \theta_s$ is not plotted in Figure 4.

bank deposits and inflows into nonbank liabilities. We observe the household portfolio rebalancing in Figure 4, which is also in line with the empirical results shown in section 2. In turn, the bank in the model reduces the amount of credit it extends to firms as it cannot make up for the loss of deposit funding with other sources. In practice, of course, banks have other sources of funding other than household deposits. However, as shown by Wang et al. (2022), there are substantial costs associated with non-deposit debt financing for banks. Deposits are, in this sense, "special" for commercial banks as they generally cannot compensate large deposit outflows fully with other forms of market financing. The lack of other sources of funding for banks in the model is a simple way of capturing this feature of the financial markets. At the same time, the investment fund expands its balance sheet and channels more of the household's savings to the firms. In other words, the structure of the financial sector (at least the parts examined here) changes after a monetary policy shock. The nonbank financial sector expands while banks play a lesser role in credit intermediation. This suggests that the existence of nonbank financial intermediaries in competition with traditional banks dampens the contractionary effects of monetary policy. This can be seen by comparing the baseline with the alternative specification.

In the alternative specification without nonbank deposits, the qualitative characters of the impulse responses remain the same. However, without the household portfolio rebalancing mechanism, investment falls by more than in the baseline. The decrease in output is also marginally more pronounced and consumption takes longer to recover after the initial fall. In the absence of nonbank liabilities, and the nonbank deposits channel, capital exhibits a deeper decline after a monetary tightening. This is because, in this case, there is no increase in nonbank loans to firms that counteracts the (small) decline in bank credit. In the absence of competition from nonbank liabilities, banks deposits also fall by less than in the baseline. Figure A9 shows the same comparisons for a wider set of variables.

Figure 5 contrasts the impulse responses of the two specifications given the assumption that the banking sector is perfectly competitive in both cases. The responses, and the differences between specifications, are largely similar. In the absence of bank market power, the contractionary responses of the economy is slightly stronger in the baseline. The bank deposit outflow is marginally larger, and as a result investment and capital fall by more in comparison with the baseline in Figure 4. Figure A10 shows a same exercise with the assumption and the banks are monopolistically competitive. Lastly Figures A11 and A12 show the impulse responses in the presence of nonbanks, given different structures of the banking sector. Figure A11 compares the responses given the baseline oligopolistic banking sector with a competitive banking sector. For Figure A12 the comparison is between baseline and a monopolistically competitive banking sector. Again, we see that differences in bank market power do no significantly change the responses of the economy.

FIGURE 4. Impulse responses to 25 basis points increase in policy rate

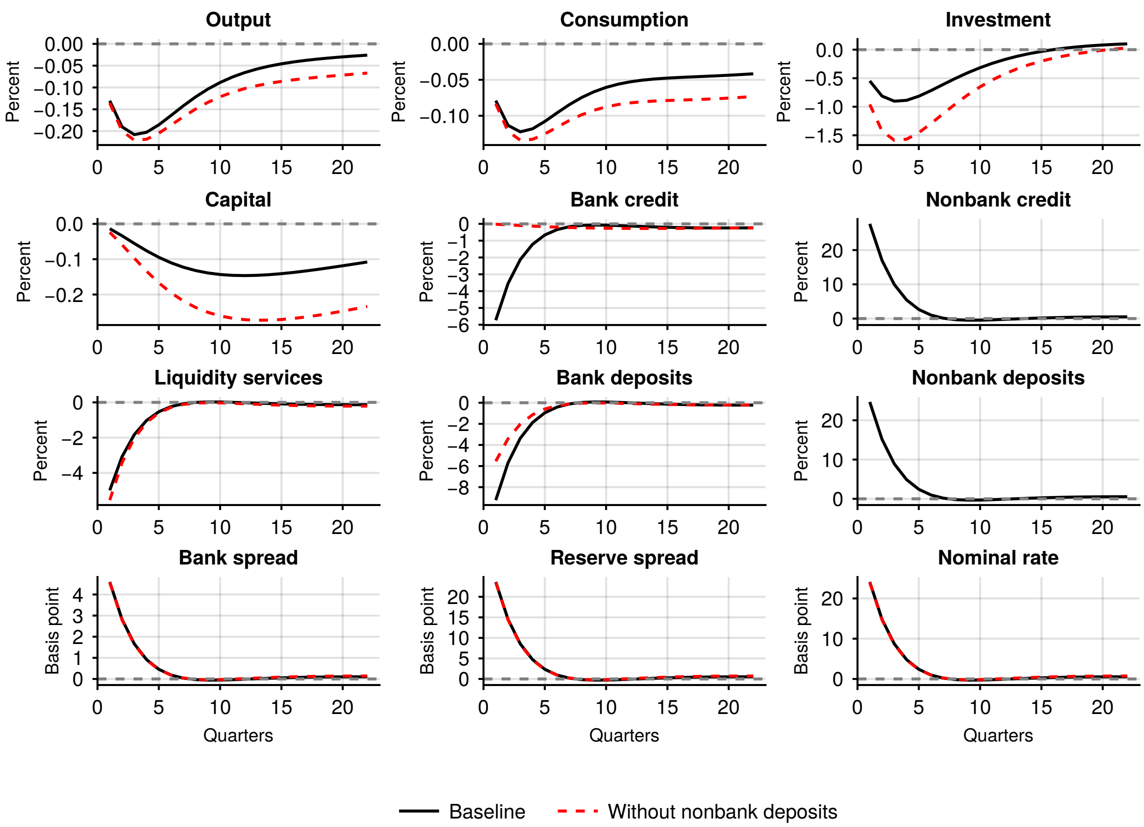


6. Conclusion

In this paper, I study the transmission of monetary policy, through its impact on bank and nonbank financial intermediation, in the United States.

I begin by documenting the empirical response of household portfolios, bank and nonbank lending, and economic activity to monetary policy surprises. I use the Finan-

FIGURE 5. Impulse responses to 25 basis points increase in policy rate - competitive banks



cial Accounts to construct measures of bank and nonbank financial intermediation. By employing methods for netting out financial interconnections between financial market participants, I reduce the usual risk of overestimating nonbank credit intermediation in the construction of my dataset. I find that following a surprise monetary policy tightening U.S. households substitute away from bank deposits and increase holdings of nonbank liabilities. In turn, bank lending to nonfinancial firms contracts and economic activity falls. NBFIs, on the other hand, expand credit intermediation and increase lending to firms. This suggests the households' portfolio reallocation and the presence of NBFIs present a countervailing force to the contractionary effect of monetary policy.

To rationalize the empirical results, I introduce banks and investment funds into an otherwise standard New-Keynesian model. Financial intermediaries issue claims, valued by the households for their liquidity services, to fund loans to the productive sector. Restrictions on the banks' ability to issue debt make the price of bank deposits more sensitive to monetary policy relative to nonbank deposits. The change in relative prices after a monetary tightening gives rise to the portfolio shifts and increased nonbank finance in the model. Consequently, in the absence of the nonbank financial sector investment would fall by more and the economy experiences a deeper contraction since, in this case, the decrease in bank lending is not compensated by the increased nonbank credit to firms. Thus, nonbank financial intermediaries act as a conduit for the flight from bank deposits during monetary tightening and nonbank credit intermediation dampen the effect of monetary policy.

References

Afonso, Gara, Catherine Huang, Marco Cipriani, Abduelwahab Hussein, and Gabriele La Spada. 2023. "Monetary policy transmission and the size of the money market fund industry: an update."Technical report, Federal Reserve Bank of New York.

Agarwal, Vikas, Honglin Ren, Ke Shen, and Haibei Zhao. 2023. "Redemption in kind and mutual fund liquidity management." *The Review of Financial Studies* 36 (6): 2274–2318.

Becard, Yvan, and David Gauthier. 2023. "Banks, nonbanks, and business cycles." *European Economic Review* 154: 104408.

Begenau, Juliane, and Tim Landvoigt. 2022. "Financial regulation in a quantitative model of the modern banking system." *The Review of Economic Studies* 89 (4): 1748–1784.

Chen, Junyuan. 2022. "LocalProjection.jl." https://github.com/junyuan-chen/LocalProjections.jl.

Chernenko, Sergey, and Viet-Dung Doan. 2022. "Mutual fund liquidity creation." Available at SSRN: https://ssrn.com/abstract=4019567 or http://dx.doi.org/10.2139/ssrn.4019567.

Chetty, Raj, Adam Guren, Day Manoli, and Andrea Weber. 2011. "Are micro and macro labor supply elasticities consistent? A review of evidence on the intensive and extensive margins." *American Economic Review* 101 (3): 471–475.

Diamond, Douglas W, and Philip H Dybvig. 1983. "Bank runs, deposit insurance, and liquidity." *Journal of political economy* 91 (3): 401–419.

Drechsler, Itamar, Alexi Savov, and Philipp Schnabl. 2017. "The deposits channel of monetary policy." *The Quarterly Journal of Economics* 132 (4): 1819–1876.

Durdu, C Bora, and Molin Zhong. 2023. "Understanding bank and nonbank credit cycles: a structural exploration." *Journal of Money, Credit and Banking* 55 (1): 103–142.

Fernández-Villaverde, Jesús, Joël Marbet, Galo Nuño, and Omar Rachedi. 2023. "Inequality and the zero lower bound."Technical report, National Bureau of Economic Research.

Fève, Patrick, Alban Moura, and Olivier Pierrard. 2022. "The fall in shadow banking and the slow US recovery." *Journal of Economic Dynamics and Control* 139: 104404.

Gallin, Joshua. 2013. "Shadow banking and the funding of the nonfinancial sector." In *Measuring Wealth and Financial Intermediation and Their Links to the Real Economy*, 89–123: University of Chicago Press.

Gertler, Mark, and Peter Karadi. 2011. "A model of unconventional monetary policy." *Journal of Monetary Economics* 58 (1): 17–34.

Hagedorn, Marcus, Iourii Manovskii, and Kurt Mitman. 2019. "The fiscal multiplier."Technical report, National Bureau of Economic Research.

Herman, Alexander, Deniz Igan, and Juan Solé. 2017. "The macroeconomic relevance of bank and nonbank credit: An exploration of US data." *Journal of Financial Stability* 32: 124–141.

Hodge, Andrew, and Miss Anke Weber. 2023. *The Heterogeneous Effects of US Monetary Policy on Non-Bank Finance.*: International Monetary Fund.

di Iasio, Giovanni, Christoph Kaufmann, and Florian Wicknig. 2022. "Macroprudential regulation of investment funds."Technical report, European Central Bank.

Jordà, Òscar. 2005. "Estimation and inference of impulse responses by local projections." *American economic review* 95 (1): 161–182.

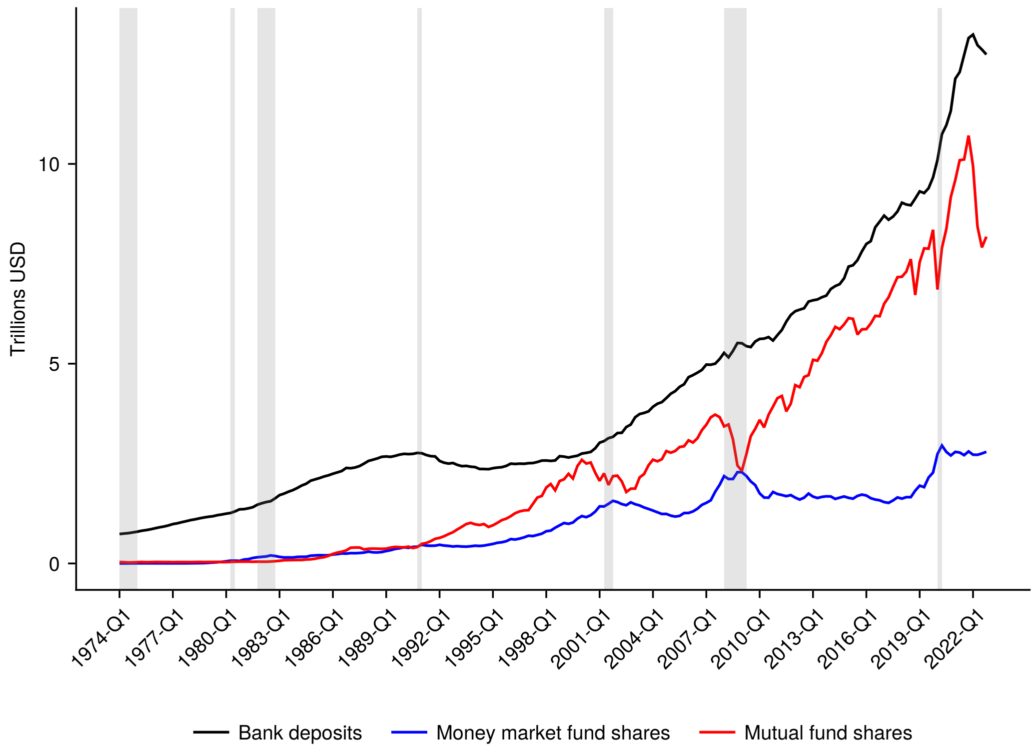
Krishnamurthy, Arvind, and Wenhao Li. 2023. “The demand for money, near-money, and treasury bonds.” *The Review of Financial Studies* 36 (5): 2091–2130.
Luetticke, Ralph. 2021. “Transmission of monetary policy with heterogeneity in household portfolios.” *American Economic Journal: Macroeconomics* 13 (2): 1–25.
Ma, Yiming, Kairong Xiao, and Yao Zeng. 2021. “Bank debt versus mutual fund equity in liquidity provision.” Available at https://business.columbia.edu/faculty/research/bank-debt-versus-mutual-fund-equity-liquidity-provision.
Meeks, Roland, Benjamin Nelson, and Piergiorgio Alessandri. 2017. “Shadow banks and macroeconomic instability.” *Journal of Money, Credit and Banking* 49 (7): 1483–1516.
Miranda-Agrippino, Silvia, and Hélene Rey. 2020. “US monetary policy and the global financial cycle.” *The Review of Economic Studies* 87 (6): 2754–2776.
Moreira, Alan, and Alexi Savov. 2017. “The macroeconomics of shadow banking.” *The Journal of Finance* 72 (6): 2381–2432.
Niepelt, Dirk. 2023. “Money and Banking with CBDC and Reserves.”Technical report, Centre for Economic Policy Research.
Pascual, Antonio Garcia, Fabio Natalucci, and Thoomas Piontek. 2023. “Nonbank Financial Sector Vulnerabilities Surface as Financial Conditions Tighten.” *Financial Stability, IMF Blog. April* 4.
Peydró, J, DE Luis, Ralf Meisenzahl, and Bryce C Turner. 2021. “Nonbanks, Banks, and Monetary Policy: US Loan-Level Evidence since the 1990s.”Technical report, CEPR Discussion Paper 14989.
Piazzesi, Monika, Ciaran Rogers, and Martin Schneider. 2022. “Money and banking in a New Keynesian model.”Technical report, Stanford University.
Pozsar, Zoltan. 2014. “Shadow banking: The money view.”Technical report, Office of Financial Research.
Pozsar, Zoltan, Tobias Adrian, Adam Ashcraft, and Hayley Boesky. 2010. “Shadow Banking.”Technical report, Federal Reserve Bank of New York.
Repullo, Rafael. 2020. “The Deposits Channel of Monetary Policy: A Critical Review.”Technical report, Centre for Economic Policy Research.
Rogers, Ciaran. 2023. “Quantitative Easing and Local Banking Systems in the Euro Area.” Available at https://sites.google.com/view/ciaranrogers/research.
Romer, Christina D, and David H Romer. 2004. “A new measure of monetary shocks: Derivation and implications.” *American economic review* 94 (4): 1055–1084.
Rotemberg, Julio J. 1982. “Monopolistic price adjustment and aggregate output.” *The Review of Economic Studies* 49 (4): 517–531.
Tobin, James. 1969. “A general equilibrium approach to monetary theory.” *Journal of money, credit and banking* 1 (1): 15–29.
Ulate, Mauricio. 2021. “Going Negative at the Zero Lower Bound: The Effects of Negative Nominal Interest Rates.” *American Economic Review* 111.
Wang, Yifei, Toni M Whited, Yufeng Wu, and Kairong Xiao. 2022. “Bank market power and monetary policy transmission: Evidence from a structural estimation.” *The Journal of Finance* 77 (4): 2093–2141.

Xiao, Kairong. 2020. “Monetary transmission through shadow banks.” *The Review of Financial Studies* 33 (6): 2379–2420.

Appendix A. Empirical Appendix

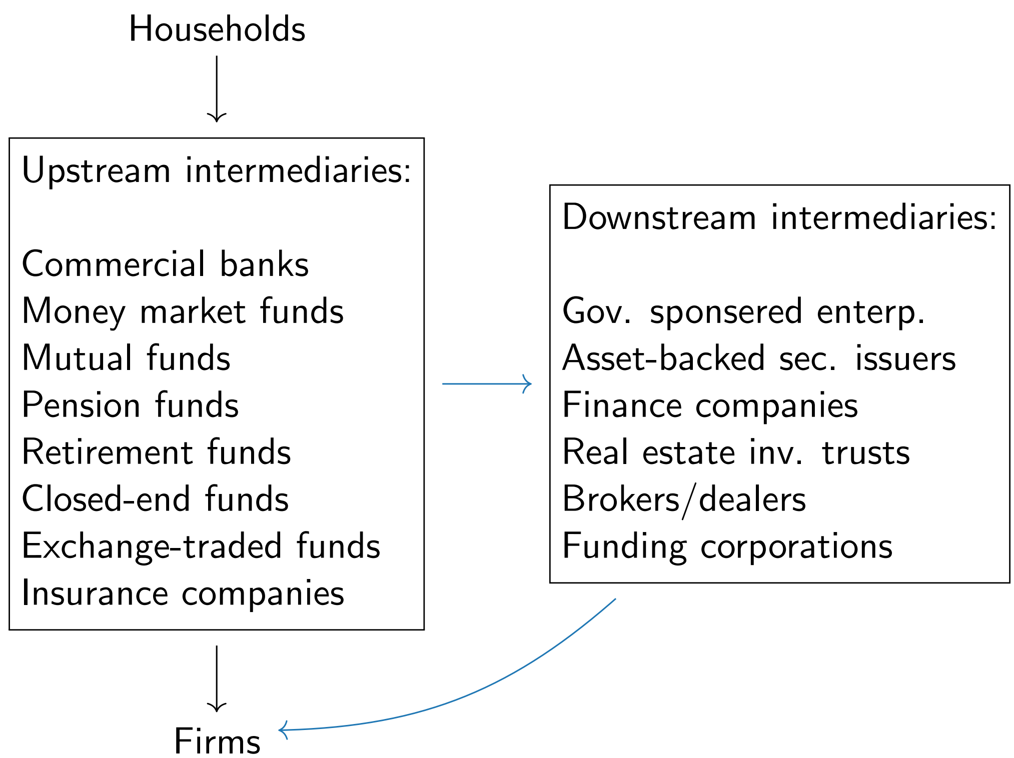
A.1. Additional Figures

FIGURE A1. Households' bank deposits and fund shares



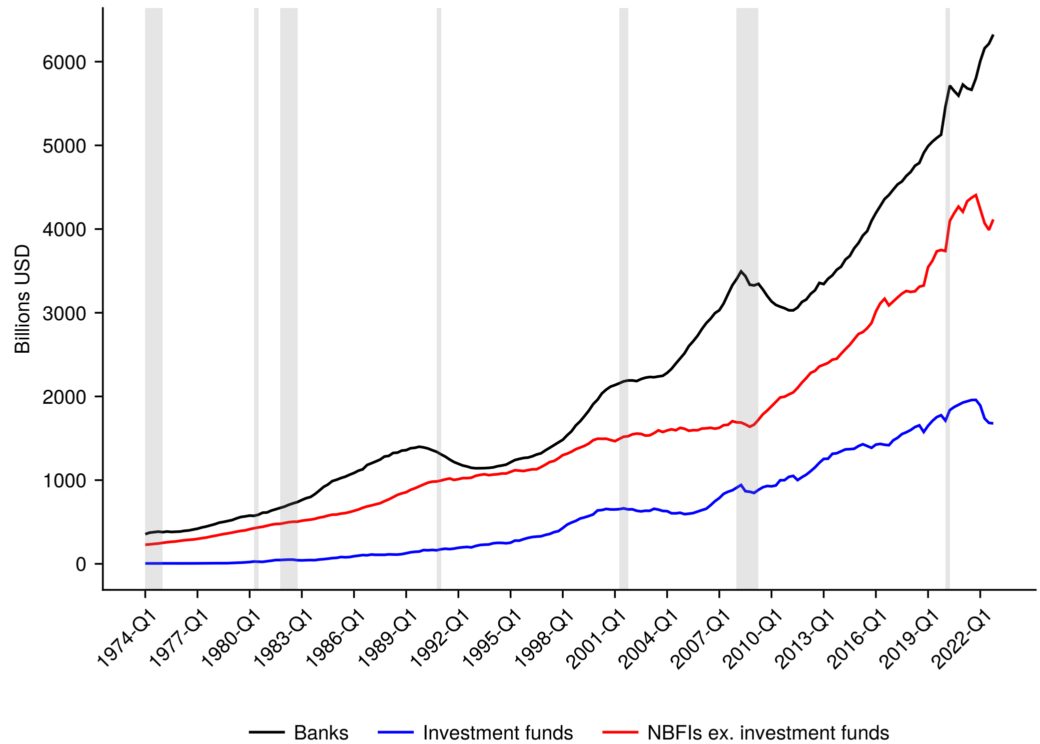
This figure shows the U.S. household sector's holdings of bank deposits, money market fund shares and mutual fund shares in nominal trillions USD from 1974 Q1 to 2022 Q4. Bank deposits are defined as the sum of checkable, time and savings deposits issued by U.S.-charted depository institutions and credit unions. The data are taken from the Financial Accounts of the United States. Gray shaded areas denote NBER recession dates.

FIGURE A2. Upstream and downstream intermediaries' funding of nonfinancial firms



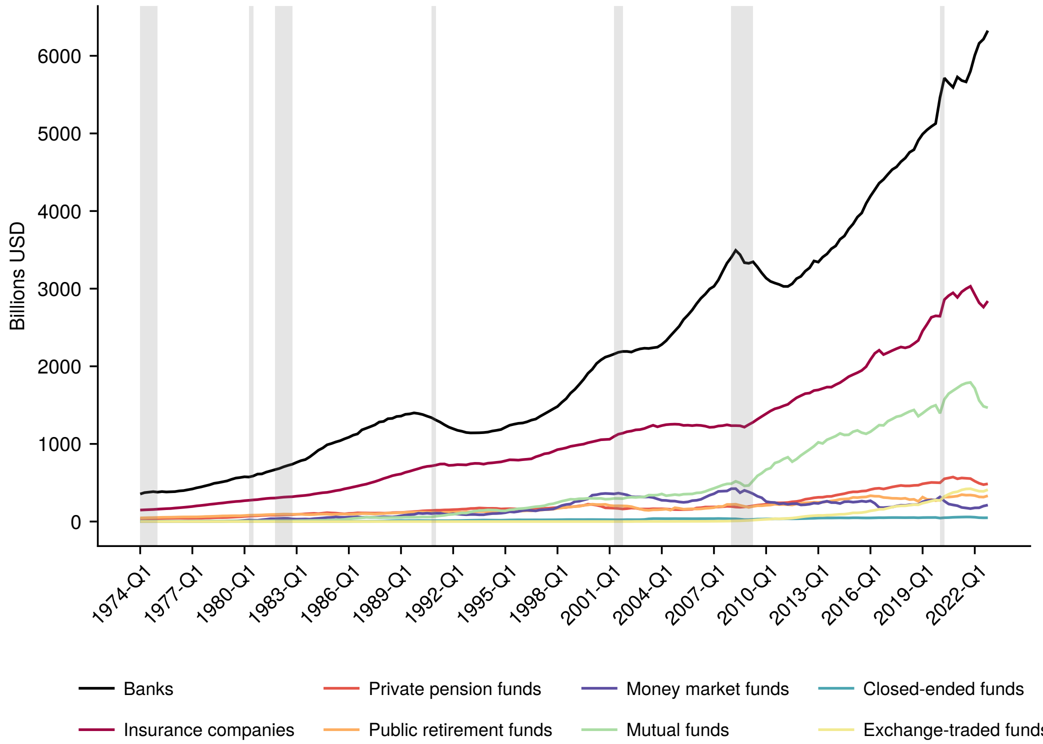
This figures shows the financial intermediaries' funding of nonfinancial firms according to the classification of Gallin (2013). The black line shows the upstream intermediaries' direct funding of firms. The blue lines show upstream intermediaries' funding through downstream intermediaries.

FIGURE A3. Bank and nonbank lending to nonfinancial firms



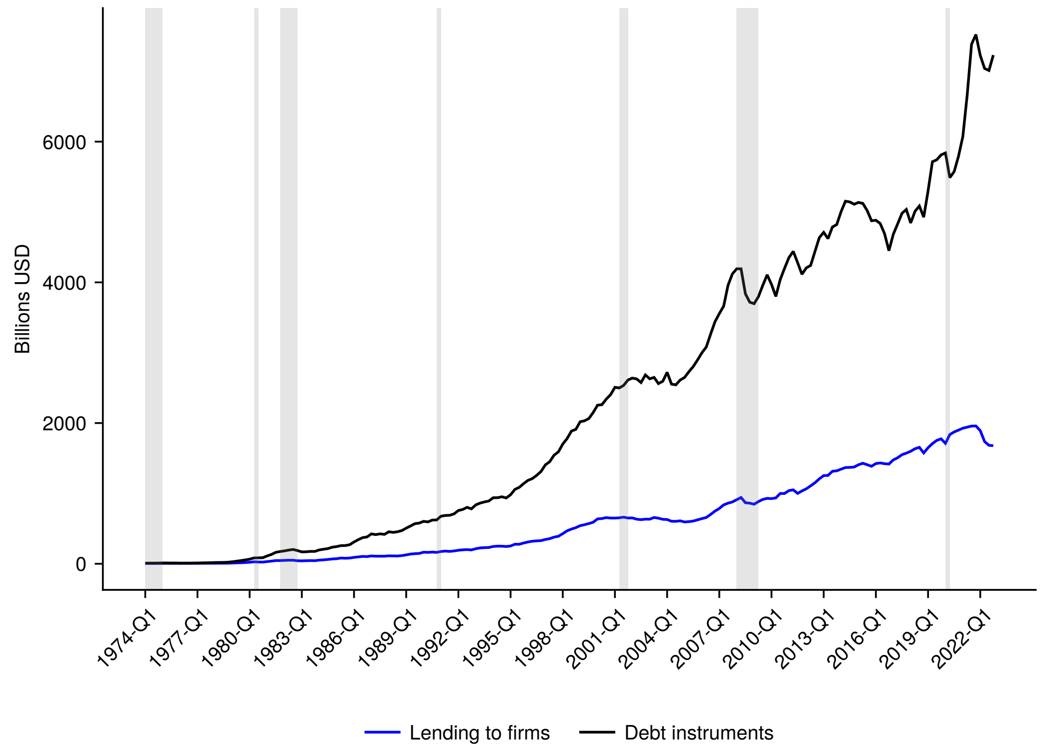
This figure shows lending to U.S. nonfinancial firms from banks and various NBFIs in nominal billions USD from 1974 Q1 to 2022 Q4. Banks are defined as U.S.-charted depository institutions and credit unions. Investment funds are the sum of money market funds and mutual funds. Other NBFIs are private pensions funds, public retirement funds, closed-ended funds, exchange-traded funds and insurance companies. The lending data is constructed using the methods of Gallin (2013) and Herman et al. (2017), with data from the Financial Accounts of the United States. Gray shaded areas denote NBER recession dates.

FIGURE A4. Bank and nonbank lending to nonfinancial firms



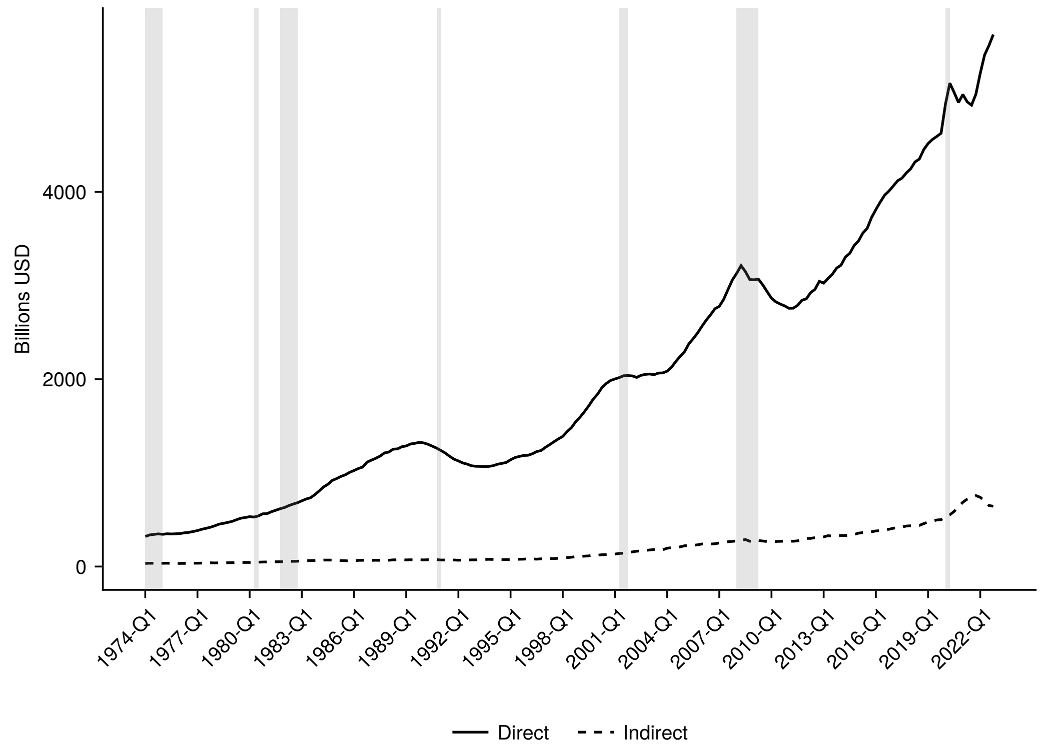
This figure shows lending to U.S. nonfinancial firms from banks and various NBFIs in nominal billions USD from 1974 Q1 to 2022 Q4. Banks are defined as U.S.-charted depository institutions and credit unions. The lending data is constructed using the methods of Gallin (2013) and Herman et al. (2017), with data from the Financial Accounts of the United States. Gray shaded areas denote NBER recession dates.

FIGURE A5. Investment funds' lending to firms vs. holdings of debt



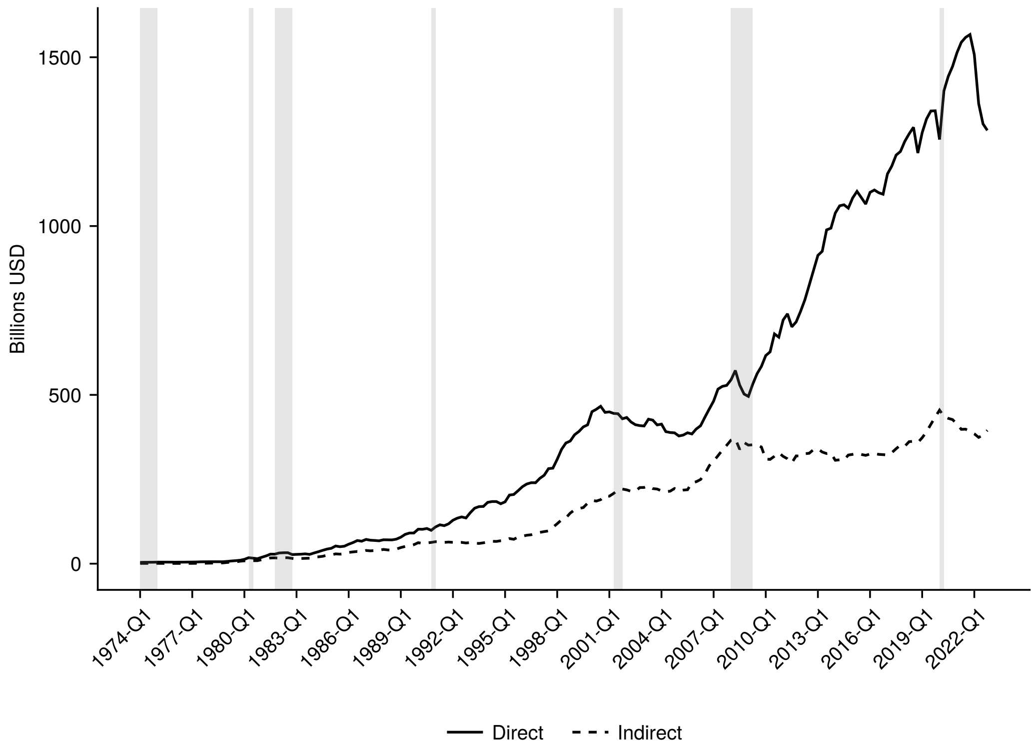
This figure shows lending to U.S. nonfinancial firms from investment funds, as identified using the methods of Gallin (2013) and Herman et al. (2017), and investment funds' holding of non-government debt in nominal billions USD from 1974 Q1 to 2022 Q4. Investment funds are defined as money market funds and mutual funds. The data is taken from the Financial Accounts of the United States. Gray shaded areas denote NBER recession dates.

Figure A6. Direct and indirect bank lending to nonfinancial firms



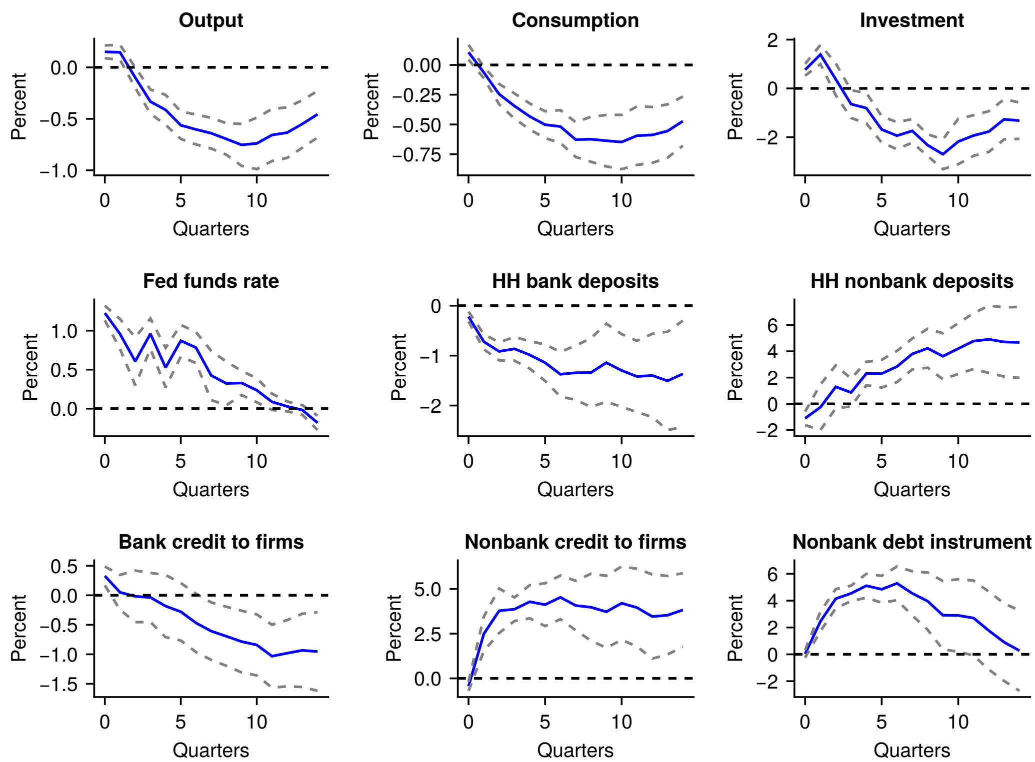
This figure shows the banks' direct and indirect lending to U.S. nonfinancial firms in nominal billions USD from 1974 Q1 to 2022 Q4. Banks are defined as U.S.-charted depository institutions and credit unions. The direct lending is measured by the amount of firm debt held by banks. The indirect lending through the NBFI sector is identified using the methods of Gallin (2013) and Herman et al. (2017). The data is taken from the Financial Accounts of the United States. Gray shaded areas denote NBER recession dates.

FIGURE A7. Direct and indirect nonbank lending to nonfinancial firms



This figure shows the investment funds' direct and indirect lending to U.S. nonfinancial firms in nominal billions USD from 1974 Q1 to 2022 Q4. Investment funds are defined as money market funds and mutual funds. The direct lending is measured by the amount of firm debt held by investment funds. The indirect lending through the NBFI sector is identified using the methods of Gallin (2013) and Herman et al. (2017). The data is taken from the Financial Accounts of the United States. Gray shaded areas denote NBER recession dates.

FIGURE A8. Impulse responses to monetary policy shock



This figure shows the estimated response to one standard deviation monetary policy shock, as identified in Miranda-Agrippino and Rey (2020). The gray dotted lines show the 66% confidence bounds, calculated using Eicker-Huber-White heteroskedasticity-robust variance-covariance estimator.

Appendix B. Model Appendix

B.1. Household's Demand for Individual Bank Deposits

The household's first-order condition with respect to d_t^i implies that for any two banks i and j the following relation must hold

$$\chi_{t+1}^{d,i}\left(d_t^i\right)^{\eta} = \chi_{t+1}^{d,j}\left(d_t^j\right)^{\eta}, \tag{A1}$$

where $\chi_{t+1}^{d,i} = 1 - R_{t+1}^{d,i}/R_{t+1}$ and $\chi_{t+1}^{d,j} = 1 - R_{t+1}^{d,j}/R_{t+1}$ denote the interest rate spreads on deposits at bank i and j, respectively. Let T denote the sum of deposits spreads over all banks

$$T = \sum_{i=1}^{n} d_t^i \chi_{t+1}^{d,i}.$$

I use the relation (A1) in the expression for T to find the demand for deposit at bank i as function of spreads

$$d_t^i = \frac{T\left(\chi_{t+1}^{d,i}\right)^{-\frac{1}{\eta}}}{\sum_{j=1}^{n}\left(\chi_{t+1}^{d,j}\right)^{\frac{\eta-1}{\eta}}}. \tag{A2}$$

Plugging equation (A2) into the definition of aggregate deposits yields

$$d_t = n^{\frac{\eta}{\eta-1}} T \left(\sum_{i=1}^{n}\left(s_{t+1}^{d,i}\right)^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{1-\eta}}. \tag{A3}$$

By setting $d_t = 1$ in equation (A3), T has the interpretation of being the interest spread associated with one unit of aggregate deposit. I denote this spread by χ_{t+1}^{d}

$$\chi_{t+1}^{d} = \left(\frac{1}{n}\sum_{i=1}^{n}\left(\chi_{t+1}^{d,i}\right)^{\frac{\eta-1}{\eta}}\right)^{\frac{\eta}{\eta-1}}. \tag{A4}$$

Using the aggregate spread (A4), I write equation (A2) as

$$d_t^i = \frac{T}{\chi_{t+1}^{d} n}\left(\frac{\chi_{t+1}^{d,i}}{\chi_{t+1}^{d}}\right)^{-\frac{1}{\eta}}. \tag{A5}$$

Inserting equation (A5) into definition of aggregate deposits, it turns out that

$$T = d_t \chi_{t+1}^{d},$$

which I use in equation (A5) to find the demand for deposit at bank i

$$d_t^i = \frac{d_t}{n}\left(\frac{\chi_{t+1}^{d,i}}{\chi_{t+1}^{d}}\right)^{-\frac{1}{\eta}}. \tag{A6}$$

B.2. Equilibrium Bank Deposit Spread

The profit-maximizing behavior of bank i can be summarized by its first-order conditions for capital claims

$$1 - \chi^r_{t+1}\lambda = \mathbb{E}_t\left[\Lambda_{t,t+1}R^k_{t+1}\right]$$

and deposits

$$\chi^{d,i}_{t+1} + \chi^{d,i}_{t+1}\left(\frac{\partial d^i_t}{\partial \chi^{d,i}_{t+1}}\frac{\chi^{d,i}_{t+1}}{d^i_t}\right)^{-1} = \frac{\chi^r_{t+1}}{\zeta} + \theta^b, \tag{A7}$$

where $\chi^r_{t+1} = 1 - R^r_{t+1}/R_{t+1}$ is the interest spread on reserves.

I focus on a symmetric industry equilibrium where all banks set identical deposit spreads. The aggregate deposit spread, χ^d_{t+1}, is then identical to the individual spread, $\chi^{d,i}_{t+1}$, as seen from equation (A4). Given the industry equilibrium, the demand elasticity of deposits facing bank i can be found using equation (A6)

$$\frac{\partial d^i_t}{\partial \chi^{d,i}_{t+1}}\frac{\chi^{d,i}_{t+1}}{d^i_t} = \frac{1}{n}\left(\frac{\partial d_t}{\partial \chi^d_{t+1}}\frac{\chi^d_{t+1}}{d_t}\right) - \left(1 - \frac{1}{n}\right)\frac{1}{\eta},$$

where the first bracketed term on the right-hand side denote the aggregate demand elasticity. The aggregate demand elasticity is found using the household's demand for aggregate deposits

$$\frac{\partial d_t}{\partial \chi^d_{t+1}}\frac{\chi^d_{t+1}}{d_t} = -\frac{1-\mu_{t+1}}{\psi} - \frac{\mu_{t+1}}{\epsilon},$$

where

$$\mu_{t+1} = (1-\gamma)^{\frac{1}{\epsilon}}\left(\frac{\chi^z_{t+1}}{\chi^s_{t+1}}\right)^{\frac{1-\epsilon}{\epsilon}}.$$

Finally, I write condition (A7) as it applies to a representative bank to get the optimality condition that determines the equilibrium (aggregate) deposit spread

$$\chi^d_{t+1} + \chi^d_{t+1}\left(-\frac{1}{n}\left(\frac{1-\mu_{t+1}}{\psi} + \frac{\mu_{t+1}}{\epsilon}\right) - \left(1 - \frac{1}{n}\right)\frac{1}{\eta}\right)^{-1} = \frac{\chi^r_{t+1}}{\zeta} + \theta^b.$$

B.3. Additional figures

FIGURE A9. Impulse responses to 25 basis points increase in policy rate

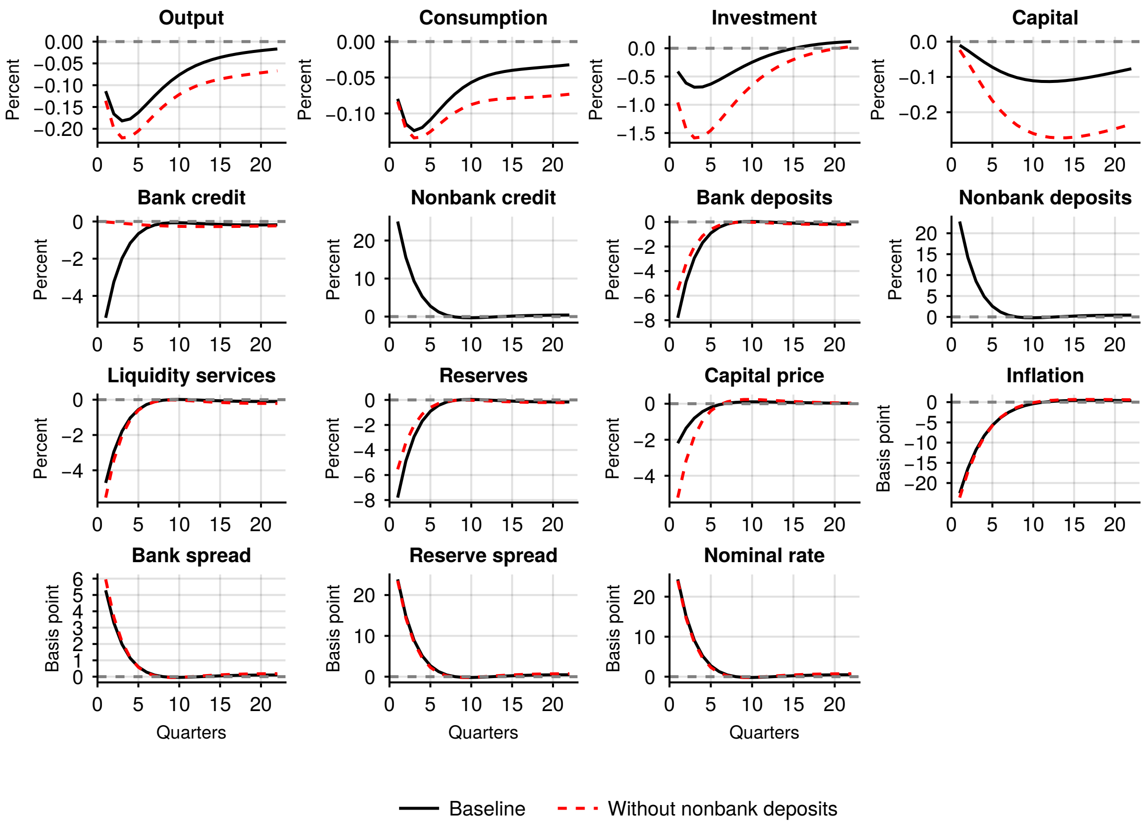


FIGURE A10. Impulse responses to 25 basis points increase in policy rate - monopolistically competitive banks

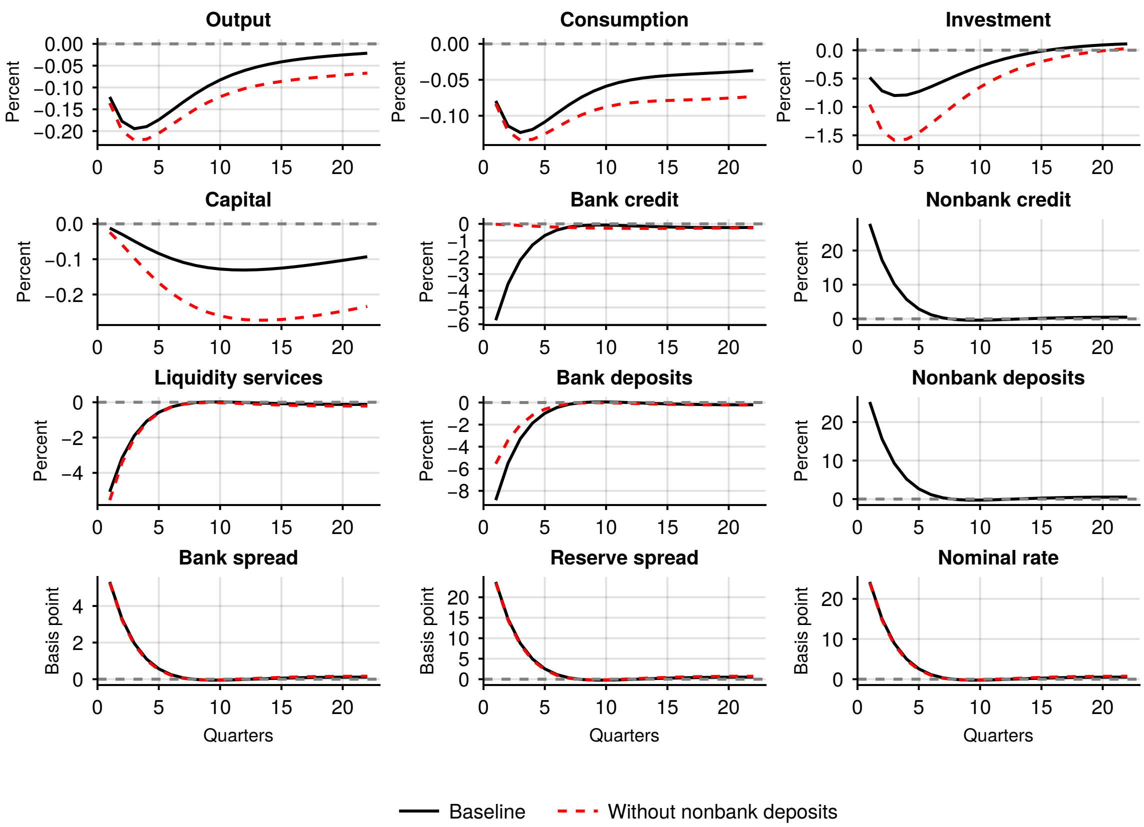


FIGURE A11. Impulse responses to 25 basis points increase in policy rate

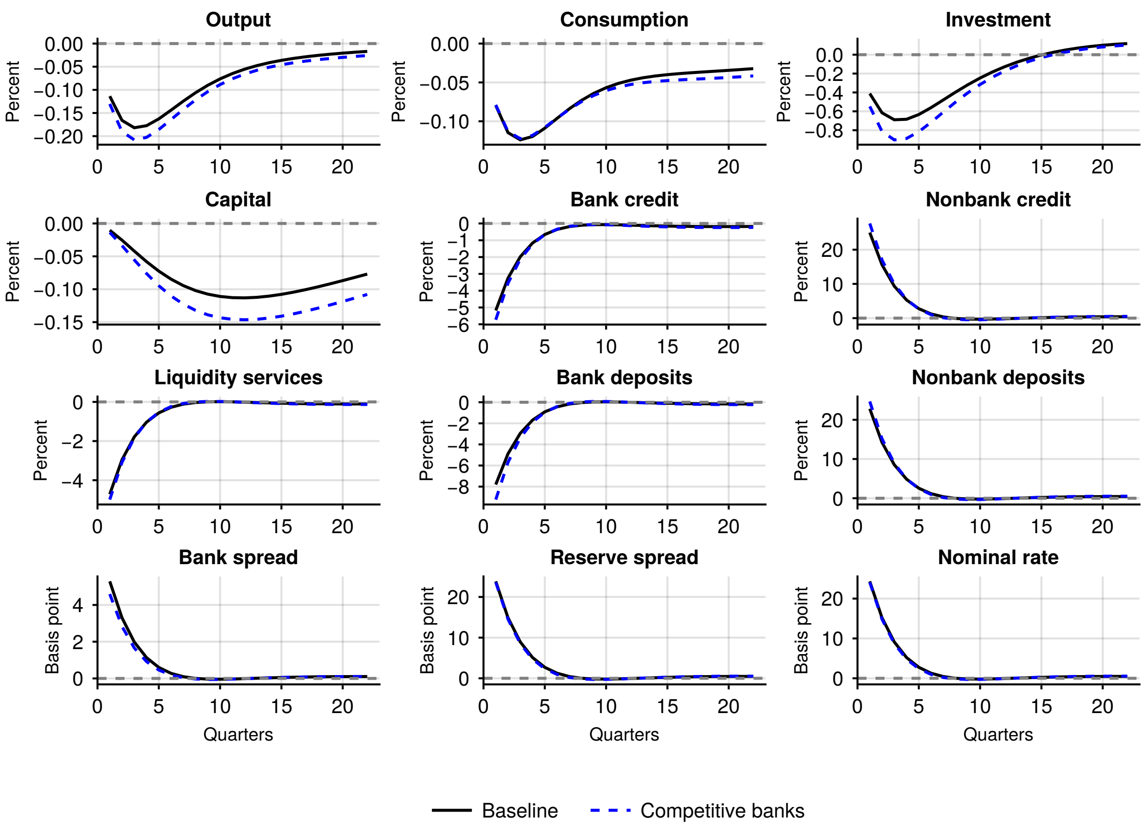


FIGURE A12. Impulse responses to 25 basis points increase in policy rate