BANKS' DECLINING CREDIT-DEPOSIT MULTIPLIER*

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Abstract

This paper quantifies the strength of the feedback loop between bank lending and deposit creation, and traces its evolution with changes in the financial sector. Between 2000 and 2024, each dollar of external deposit inflow ultimately supported an average of $2.02 in deposits, falling from $3.39 in the early 2000s to $1.40 in recent years. We develop a structural model of the U.S. banking sector that departs from standard macro-financial frameworks by endogenizing deposit creation: banks expand funding capacity by creating deposits as they lend, generating a feedback loop between credit supply and money creation. We use the model to conduct quantitative counterfactual exercises to decompose the drivers of the multiplier, finding significant roles for regulation and non-bank competition. Beyond the decline in deposit creation, we find a large decline in credit expansion in recent years, as banks increasingly use deposit inflows to substitute other forms of funding rather than expand their balance sheet. The findings show that the cyclicality of credit provision and the effectiveness of monetary and fiscal policy depend on the strength of banks' credit-deposit multiplier, which in turn reflects the structure and regulation of the financial system.

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1 Introduction

Commercial banks play a unique role among financial intermediaries: when they extend credit to risky borrowers, they simultaneously create "safe" assets in the form of deposits that are liquid, stable in value, and widely accepted as money. Thus, every act of lending has two sides: the creation of credit on the asset side and the creation of money on the liability side. Moreover, when the deposits created by banks remain within the system as stable funding, their circulation expands the deposit base, lowering funding costs and easing liquidity constraints, which in turn spurs further lending. As a result, banks' credit and deposit creation are connected through a feedback loop, or credit-deposit multiplier: deposits support lending, and lending creates further deposits (Tobin, 1963; Friedman and Schwartz, 1963). Yet we know little about the modern day multiplier and forces that determine the strength of this loop or how it evolves as the structure of the financial sector changes. Ignoring this channel risks overlooking an important mechanism, one that shapes the supply of safe assets, the cyclicality of credit provision, and the transmission of monetary and fiscal policy.

We provide a direct quantification of the strength of banks' credit-deposit multiplier and its evolution over time. Our analysis yields two key findings. First, we highlight that the market sizes of deposits and loans are endogenous outcomes of this feedback loop. Much of the literature in banking and macro-finance treats deposit and loan market sizes as exogenous primitives, abstracting away from their joint determination. This endogeneity implies that the instantaneous balance-sheet responses of banks miss the subsequent rounds of lending and re-depositing that determine the total expansion of money and credit. Recognizing this distinction is essential for understanding why reallocating a marginal dollar from the banking sector to a non-bank intermediary is not neutral: it reduces the future quantity of money and the capacity of the financial system to amplify credit provision. Our second finding is that the strength of this feedback loop has weakened over time as a result of stricter regulation and the rise of non-bank competition. As a result, both money and credit creation have become less responsive to deposit inflows or policy easing, dampening the amplification of the business cycle and the transmission of monetary policy.

The credit–deposit multiplier has two components: the deposit multiplier, which captures how deposit inflows expand the deposit base, and the asset multiplier, which captures the corresponding expansion of bank assets after accounting for funding substitution. We formalize

the deposit multiplier as the total expansion of deposits generated by an initial inflow, governed by banks' lending response, λ, which determines how much of each marginal deposit is transformed into new loans, and the extent to which loan proceeds are retained as deposits within the system, θ. Linking this liability-side process to the asset side requires accounting for how new deposits expand banks' balance sheets rather than merely substituting for other funding sources, $\mathcal{A}_D$. Together, these three sufficient statistics fully characterize the credit–deposit multiplier: the total expansion of bank balance sheets and credit that accompanies deposit creation.

We begin by providing reduced-form evidence on the magnitude of the deposit multiplier. Measuring the strength of the feedback loop is not straightforward, since fluctuations in monetary aggregates may reflect external shifts in reserves or policy-driven changes in deposits rather than the banks' credit–deposit multiplier. To isolate the latter, we first exploit regional shale oil and gas discoveries, which generate large and plausibly exogenous deposit inflows (Gilje et al., 2016), and trace these flows through banks' internal capital markets into non-boom regions, where they are orthogonal to local credit demand. Using this strategy, we estimate that between 2000 and 2024 banks' deposit creation averaged 2.02, implying that a \$1 injection of deposits ultimately expanded the aggregate deposit base by \$2.02. As a robustness exercise, we examine weekly changes in the Treasury General Account (TGA), which reallocate liquidity between the government and the private sector. Whereas shale shocks identify geographically localized balance-sheet propagation, TGA movements capture system-wide liquidity dynamics. Their weekly frequency also allows us to estimate the multiplier at horizons where real activity is unlikely to adjust. Both exercises yield similar estimates, reinforcing that our reduced-form results reflect a financial feedback loop operating through bank balance sheets. Notably, when we split our sample into early and late periods, we find that bank deposit creation was substantially larger in the first half (\$3.39) than in the second (\$1.40). Banks' deposit creation is an equilibrium object, and its decline over time may reflect shifts driven by forces such as post-crisis regulation, QE, and the growing role of non-bank intermediation.

To quantitatively decompose the drivers of bank deposit creation, we next develop a structural model of deposit and loan markets in which the credit–deposit multiplier is endogenously determined by bank and household optimization. Our starting point is a setting that closely resembles recent work in the structural banking literature: a monopolistically competitive banking sector that sets deposit and loan rates to maximize profits, subject to capital and liquidity regulations that link their funding and lending decisions (Wang et al., 2022a). In this environ-

ment, the three sufficient statistics that govern the credit-deposit multiplier become endogenous equilibrium objects shaped jointly by banks' optimal portfolio choices and households' portfolio preferences. Their values depend on underlying structural primitives such as market competition and the tightness of regulatory constraints. Our key insight is that once this feedback loop is accounted for, the market size of deposits and loans is no longer an exogenous primitive, as much of the prior literature has assumed, but instead an endogenous outcome determined by the strength of the credit–deposit multiplier.

We estimate the model using a quarterly aggregate time series for the U.S. commercial banking sector from 2001–2024. On the demand side, we discipline deposit and loan elasticities using estimates identified in the literature (Dick, 2008; Xiao, 2019; Buchak et al., 2018; Di Maggio et al., 2020), which capture how households and firms respond to bank rates. On the supply side, we map banks' first order conditions into moment restrictions to recover cost curvature parameters and the shadow values of regulatory constraints, allowing for a regime shift after the beginning of the implementation of Basel III in 2012. We use our reduced-form IV estimate of the magnitude of bank deposit creation as an untargeted test of the model quantification. We find that accounting for the credit–deposit multiplier is quantitatively important for understanding the evolution of deposits, loans, and assets, contributing roughly 30 to 40 percent of the overall quantity response.

Using our model, we recover the model-implied counterpart to traditional monetary aggregates, and trace the evolution of the deposit and asset multiplier over the past two decades, along with the three key equilibrium objects that govern amplification. We find that the multipliers have declined markedly due to the tighter regulatory environment in the post-crisis period, and due to the growth of non-bank intermediaries. We further decompose the drivers of this decline by examining counterfactual changes in regulation, as well as non-bank competition on both sides of the balance sheet. The analysis shows that capital requirements have a particularly strong dampening effect on amplification, and that continued non-bank disintermediation dampens the economy-wide multiplier by reducing the share of funding that flows through the banking sector's amplification mechanism.

We then use the model to show why the strength of the multiplier matters for macroeconomic outcomes. Because the credit–deposit multiplier governs both the scale of credit and the endogenous supply of deposits, it plays a central role in the mechanisms emphasized in modern macroeconomic and banking models, where investment and savings are linked through interest

rates and financial frictions shape the effective supply of credit. In these frameworks, funding inflows relax banks' balance-sheet frictions and expand the supply of safe, liquid claims, reducing credit spreads and the convenience yield on safe assets (Gertler and Kiyotaki, 2010; Gertler and Karadi, 2011; Krishnamurthy and Ma, 2024). Our model quantifies the strength of this amplification channel: repeated rounds of deposit creation and lending generate a substantially larger effect than a one-time balance-sheet adjustment. When we feed the observed evolution of the banking sector into the model, we find that a decline in the multiplier materially weakens these channels. Credit expansion and deposit creation become less responsive to funding inflows, which dampens investment and reduces the cyclicality of credit provision. The model also shows that monetary policy becomes less effective: with a smaller multiplier, a change in the policy rate produces much smaller adjustments in bank balance sheets and credit supply. Together, these results demonstrate quantitatively that the erosion of the multiplier has important implications for business-cycle dynamics and policy transmission.

Literature Review.

The idea that deposits and loans are connected through a feedback loop dates back at least to Tobin (1963), yet remains underexplored. The literature has tended to emphasize two separate views: one in which deposits fund loans, and another in which loans create deposits. In the traditional "intermediary" view, banks collect deposits from savers, hold a fraction as reserves, and lend out the remainder, so deposit market size constrains lending (Kashyap et al., 2002; Bernanke and Blinder, 1988; Xiao, 2019). In the "money creation" view, lending itself creates deposits (Tobin, 1963; Donaldson et al., 2018), with modern analyses emphasizing that this process is shaped by capital regulation, loan demand, and banks' risk appetite. Empirically, micro evidence shows that banks create deposits when they lend (Werner, 2014), aggregate deposits far exceed cash deposits (Thakor and Edison, 2024), and reduced-form estimates document a positive elasticity from lending to deposit growth (Kundu et al., 2021). We bridge these perspectives by quantifying the strength of the endogenous credit-deposit multiplier, the amount of deposits and credit that are ultimately created from an initial deposit inflow.[1] This multiplier highlights that deposits both constrain and are created by lending: the availability and stability of deposits shape banks' willingness to expand credit, while banks' lending decisions feed back into the deposit base. By decomposing the evolution and drivers of the multiplier, we show how

[1]While we estimate a long-term liquidity multiplier that supports credit provision, Denbee et al. (2021) and Piazzesi and Schneider (2018) study a related short-term payments liquidity multiplier, showing how transactional liquidity shapes banks' reserve management and monetary transmission.

the balance between these forces shifts over time.

We also uncover the role of the credit-deposit multiplier relative to traditional macroeconomic models that study financial frictions and the credit cycle. In canonical work, Bernanke and Blinder (1988) introduced the credit channel of monetary policy where credit supply shocks matter separately from traditional credit demand shocks.[2] Gertler and Kiyotaki (2010) and Gertler and Karadi (2011) explicitly model the credit channel to intermediary balance sheets, where net worth governs leverage and credit creation.[3] Our framework builds on this logic by introducing an amplification mechanism through the credit–deposit multiplier, which allows the same inflow of funding to circulate repeatedly through the banking system as new deposits and loans are created. A funding inflow reduces the funding friction wedge for banks, narrowing credit spreads, while simultaneously expanding the supply of safe, liquid assets, lowering their convenience yield (Gorton et al., 2012; Krishnamurthy and Vissing-Jorgensen, 2012; Krishnamurthy and Ma, 2024). Both of these effects tend to spur investment by lowering required returns on productive capital. Through the multiplier, these effects reinforce each other and become larger than what would arise from a one-time balance-sheet adjustment, stimulating investment and magnifying the macroeconomic impact of funding shocks. Because money-like liabilities issued by non-banks ultimately settle through the banking system and do not generate comparable feedback, our findings imply that as intermediation shifts toward non-banks, both credit creation and the supply of safe assets become less responsive to shocks.

The credit–deposit multiplier also connects to the growing role of non-bank intermediaries and the implications of a shrinking traditional banking sector (Buchak et al., 2024). As non-banks increasingly disintermediate banks on both sides of their balance sheets, we show that the banking sector's credit–deposit multiplier declines and the economy-wide multiplier falls even further. With banks playing a smaller role in financial intermediation, less funding flows through their amplification mechanism, resulting in weaker credit expansion and diminished monetary policy transmission.

Lastly, the credit-deposit multiplier relates to recent work on deposit franchise value and depositor heterogeneity in both the cross-section and the time series (Drechsler et al., 2021a,b; DeMarzo et al., 2024; Blickle et al., 2025; Egan et al., 2025; Lu et al., 2024; Koont et al., 2024).

[2] Kiyotaki and Moore (1997) formalizes the role of credit market imperfections in driving the credit cycle through collateral constraints.

[3] He and Krishnamurthy (2013) extends these insights to relate intermediary capital to variation in risk premia and asset prices.

Although all payments ultimately settle through the banking system and non-bank liabilities are backed by claims on bank deposits or reserves, our framework highlights that only stable, low-margin deposits support the feedback loop between lending and deposit creation. The banking sector's share of deposits can therefore be interpreted as the share of stable funding in the system, relative to more institutional or flightier deposits that do not sustain the credit–deposit multiplier.

2 Defining the Deposit and Credit Multipliers

2.1 A Simple Example

We begin with a simple example that illustrates the amplification of funding inflows through bank balance sheets into deposit and credit creation. In Table 1, Panel (a), Bank 1 receives a new $100 deposit coming from income or wealth generated outside the banking system: a fiscal transfer, corporate profits, or investment income. This inflow expands Bank 1's balance sheet, as it holds $100 in new deposit liabilities as well as $100 in reserves at the central bank. In response to the inflow of low-cost funding, the bank optimally adjusts its balance sheet. It uses part of the new reserves to pay down $10 of more expensive wholesale funding, and chooses to lend out $70 of the new funds, subject to liquidity and capital regulations that limit the extent of balance-sheet expansion. At this point, the banking sector has gained $100 in new deposits, and $70 in new loans, as shown in Table 2.

The borrower who receives the $70 loan from Bank 1 then spends the proceeds by purchasing goods or paying suppliers. Most of these payments remain within the banking system as the recipients deposit them into their own accounts, but some portion may flow to non-bank intermediaries such as money market funds or investment vehicles. While these outflows ultimately end up as balances held by non-banks at their custodial banks, yet they may not return as low-cost, stable deposits that support further lending. Suppose for illustration that 90 percent of the funds, or $63, are redeposited at another institution, Bank 2. As a result, Bank 2 receives a new $63 deposit as shown in Table 1 Panel (b). This inflow expands Bank 2's balance sheet, adding new deposits and reserves, and the bank again adjusts by paying down some wholesale funding and lending out $44 of the new inflow. At this stage, the banking sector has gained $163 in total new deposits and $114 of new loans, as shown in Table 2. This process continues through the process of re-lending and re-depositing, generating successive rounds of balance-

sheet expansion across banks, and in the limit expands overall bank deposits by $270 and loans by $189, as shown in Table 2.

Table 1: Successive Rounds of Deposit Creation: Bank Balance Sheets

(a) Bank 1 Balance Sheet

Before Initial Deposit

Assets		**Liabilities**	
Securities	$100	Wholesale	$100
	$100		$100

After Initial Deposit

Assets		**Liabilities**	
Reserves	$100	Deposits	$100
Securities	$100	Wholesale	$100
	$200		$200

After Balance Sheet Adjustment

Assets		**Liabilities**	
Reserves	$90	Deposits	$100
Securities	$100	Wholesale	$90
	$190		$190

After Loan Origination

Assets		**Liabilities**	
Reserves	$20	Deposits	$100
Securities	$100	Wholesale	$90
Loan	$70		
	$190		$190

(b) Bank 2 Balance Sheet ($\theta = 0.9$)

Before Loan is Deposited

Assets		**Liabilities**	
Securities	$100	Wholesale	$100
	$100		$100

After Loan is Deposited

Assets		**Liabilities**	
Reserves	$63	Deposits	$63
Securities	$100	Wholesale	$100
	$163		$163

After Balance Sheet Adjustment

Assets		**Liabilities**	
Reserves	$56.7	Deposits	$63
Securities	$100	Wholesale	$93.7
	$156.7		$156.7

After Loan Origination

Assets		**Liabilities**	
Reserves	$12.6	Deposits	$63
Securities	$100	Wholesale	$93.7
Loan	$44.1		
	$156.7		$156.7

In contrast, consider a funding shock to a non-bank intermediary, such as a money market fund or finance company, that receives a new $100 inflow from investors coming again from a fiscal transfer, corporate profits, or investment income. The non-bank records a $100 increase in cash and an equal increase in its liabilities: commercial paper, repo, or shares, as shown in Table 3. The non-bank then uses part of this funding, say $70, to extend a new loan. Unlike the

bank in the previous example, this transaction does not create a new deposit within the financial system. When the non-bank wires funds to the borrower's bank, its custodian bank reduces the non-bank's deposit by \$70, transferring reserves to the borrower's bank, which credits the borrower's account by the same amount. Aggregate bank deposits in the system are therefore unchanged: the loan simply reallocates existing deposits from the non-bank's custodian account to the borrower's deposit account. Because the non-bank cannot create new deposits in the act of lending, its credit expansion does not multiply funding within the system, and the feedback loop between credit and deposits that characterizes the banking sector is absent.[4]

Table 2: Banking Sector Totals After Each Step ($\lambda = 0.7,\ \theta = 0.9$)

Step	**New Deposits**	**Total Deposits**	**New Loans**	**Total Loans**
After Initial Deposit (Bank 1)	\$100.0	\$100.0	\$0.0	\$0.0
After Loan Origination (Bank 1)	\$0.0	\$100.0	\$70.0	\$70.0
After Loan Deposited (Bank 2)	\$63.0	\$163.0	\$0.0	\$70.0
After Loan Origination (Bank 2)	\$0.0	\$163.0	\$44.1	\$114.1
After Loan Deposited (Bank 3)	\$39.7	\$202.7	\$0.0	\$114.1
After Loan Origination (Bank 3)	\$0.0	\$202.7	\$27.8	\$141.9
Limit as $h \to \infty$		**\$270.3**		**\$189.2**

Next rounds continue with factors $\lambda = 0.7$ for loans and $\theta = 0.9$ for redeposits.

Table 3: Non-bank Lending Reallocates Existing Deposits

Non-bank: After Funding Inflow

Assets		**Liabilities**	
Cash/Settlement	$+100$	CP/Repo/Shares	$+100$

Non-bank: After Loan Origination

Assets		**Liabilities**	
Cash/Settlement	-70	CP/Repo/Shares	100
Loan	$+70$		

Custodian Bank: Wire Out

Assets		**Liabilities**	
Reserves	-70	Dep. of Non-bank	-70

Borrower Bank: Wire In

Assets		**Liabilities**	
Reserves	$+70$	Deposits (Borrower)	$+70$

[4]The immediate effect of a non-bank inflow on aggregate bank deposits depends on its source. For instance, if the funds come from households transferring money from existing deposits, aggregate deposits are unchanged; if they originate from new income, fiscal transfers, or the unwinding of positions at the Federal Reserve's reverse repo facility, aggregate deposits may initially rise. Regardless of the source, however, subsequent non-bank lending only reallocates existing deposits and does not generate further deposit creation.

2.2 Defining the Credit-Deposit Multiplier

The simple example above illustrates how a single inflow of funding can expand the banking system through successive rounds of lending and re-depositing. Each time a bank receives a new deposit, it faces a portfolio decision: how much of the inflow to hold as liquid reserves or use to repay wholesale funding, and how much to transform into new lending. When borrowers spend those loan proceeds, a portion is redeposited elsewhere in the banking system, continuing the cycle of balance-sheet expansion. The process eventually converges as regulatory constraints, liquidity preferences, or leakages to non-banks limit further re-depositing.

We refer to this self-reinforcing feedback between lending and deposit creation as the *Credit-Deposit Multiplier*. This captures the equilibrium process through which funding inflows expand both sides of banks' balance sheets: the liability side through deposit creation and the asset side through credit expansion. Within this framework, we distinguish between two measurable components. The *Deposit Multiplier*, m_D, quantifies how an initial deposit inflow expands the total deposit base, while the *Asset Multiplier*, m_A, captures the corresponding expansion in bank assets after accounting for banks' funding adjustments. Both arise from the same underlying balance-sheet amplification process governed by banks' lending response and the extent to which loan proceeds are retained as deposits.

Formally, we define the deposit multiplier m_D as the total change in the deposit base, ΔD_{total}, generated by an initial deposit inflow ΔD_0. Two sufficient statistics govern this process. The first is λ, which reflects the supply response of banks in transforming marginal deposits into new lending. The second is θ, which reflects deposit demand, namely the extent to which the proceeds of that lending are held as stable bank deposits. Together, these parameters determine how an initial inflow propagates through the system. Given a deposit inflow ΔD_0, banks extend new loans in the amount $\lambda \Delta D_0$, of which a fraction θ returns as deposits, raising the deposit base to $\Delta D_0 + \lambda\theta\Delta D_0$. This larger base then supports additional lending of $\lambda\theta\Delta D_0$, of which a fraction θ recycles as deposits, and the process continues. Iterating forward, we can express the total deposit expansion from an initial inflow ΔD_0 as a geometric series:

$$\Delta D_{t-1,t+h} = \Delta D_0 \left(1 + \lambda\theta + (\lambda\theta)^2 + \cdots + (\lambda\theta)^h\right). \tag{1}$$

The corresponding deposit multiplier at horizon h is:

$$m_D^h = 1 + \lambda\theta + (\lambda\theta)^2 + \cdots + (\lambda\theta)^h. \tag{2}$$

As $h \to \infty$, the process converges (provided $|\lambda\theta| < 1$), yielding the long-run deposit multiplier:

$$m_D = \frac{1}{1 - \lambda\theta}. \tag{3}$$

While the deposit multiplier measures how deposits expand through the system, an equally important question is how these inflows shape the asset side of bank balance sheets, determining the extent of credit creation that accompanies deposit creation. Let $\mathcal{A}_D = \dfrac{dA}{dD}$ denote the per-round asset pass-through evaluated at a given equilibrium, i.e. the marginal change in total bank assets per marginal dollar of deposits. In practice this response is usually below one, as new deposits are used not only to expand lending but also to adjust funding composition, for example by reducing reliance on wholesale funding. Then, iterating the same geometric recycling that defines the deposit multiplier m_D yields the asset multiplier m_A,

$$m_A = \mathcal{A}_D \cdot m_D = \frac{\mathcal{A}_D}{1 - \lambda\theta}. \tag{4}$$

3 Empirical Analysis

In this section, we begin by providing reduced-form evidence on the magnitude of the deposit multiplier. Subsequently in Section 4, we extend the analysis within a structural model that allows us to measure the corresponding asset multiplier and to trace movements in both multipliers back to the underlying structural primitives such as banks' lending response to new funding, the stability of deposits, and the tightness of regulatory constraints, which jointly determine the strength of the credit–deposit feedback loop.

3.1 Data

Our reduced-form empirical analysis combines several data sources to empirically measure the strength of the deposit multiplier. We begin by retrieving monetary aggregates from FRED to

motivate our analysis. We then construct a county-year panel spanning 2000 to 2024 by merging deposits data, bank balance sheet data, and shale development data. This dataset allows us to examine the dynamic feedback loop between exogenous deposit creation and future deposit growth.

Annual branch-level deposits come from the FDIC Summary of Deposits (SOD), which reports June balances at each branch. We aggregate these data to the county-year level to construct total deposit volumes and log deposit growth, standardizing county identifiers using five-digit FIPS codes. We construct exogenous funding shocks using regional shale oil and gas discoveries, measured from county-level data on wells (Gilje et al., 2016).[5]

We supplement the deposit data with quarterly financial statements from the Federal Reserve's Y-9C regulatory filings, which cover bank holding companies with total consolidated assets above $500 million. These data provide detailed information on loan portfolios, securities holdings, and funding composition at the institutional level. We focus on fourth-quarter filings to obtain consistent annual measures of balance sheet size and to match the timing of HMDA and SOD aggregation. From these filings, we construct institution-level characteristics such as asset size, capital ratios, and wholesale funding dependence.

Finally, we assemble a high frequency dataset using weekly aggregate deposits and Treasury General Account (TGA) balance at the Federal Reserve to measure the deposit multiplier over shorter horizons.

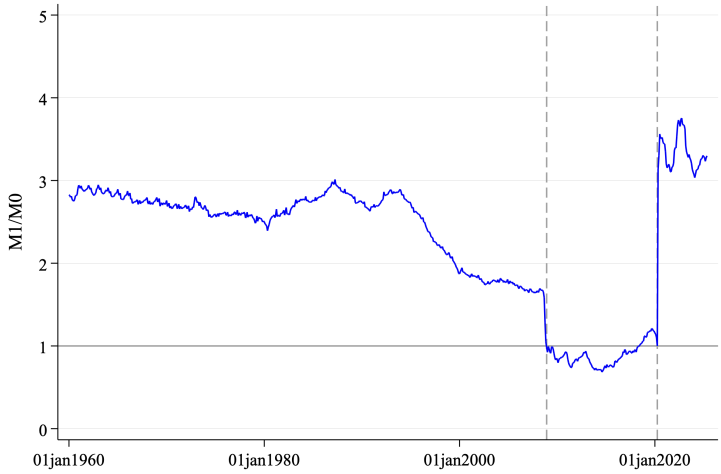
3.2 Aggregate Evidence

To motivate our analysis, we begin at the macro level by examining the evolution of key monetary aggregates over time. This serves as a diagnostic of the deposit multiplier in aggregate. We focus on two standard measures of money that are most directly linked to the banking system's role in money creation. $M0$, or the monetary base, includes currency in circulation and reserves held by banks at the central bank and represents the supply of base money injected by the central bank. $M1$, or narrow money, expands on $M0$ by adding demand deposits and other highly liquid checkable deposits. Comparing these two aggregates illustrates how the stock of bank deposits compares to reserves.

[5]We thank Erik Gilje for making this data available to us.

Figure 1: Evolution of $M1/M0$

Data come from FRED, monthly from 1960 through 2025. The first vertical line corresponds to the beginning of QE following the 2008 financial crisis, and the second vertical line corresponds to the beginning of stimulus following the Covid-19 pandemic. In May 2020, the Federal Reserve reclassified savings deposits as transaction accounts due to the removal of the six-per-month transfer limit, and savings deposits were added to M1.



In Figure 1, we plot the evolution of $M1/M0$ from 1960 through 2025. The fact that the ratio fluctuates over time, and generally exceeds 1, is consistent with banks creating deposits through lending. Notably, while $M1/M0$ offers a macro-level proxy, it reflects two aggregate stocks rather than the marginal propagation of deposits that defines the endogenous deposit multiplier. During periods of quantitative easing (QE) or large-scale fiscal stimulus, both $M0$ and $M1$ are heavily influenced by exogenous policy interventions: QE inflates $M0$ through reserve creation, while fiscal programs (such as PPP loans and stimulus checks during the onset of the Covid-19 pandemic) inflate $M1$ by directly injecting deposits into the banking system. As a result, movements in $M1/M0$ during these episodes may reflect shifts in central bank or government policy rather than changes in the deposit multiplier or banks' lending sensitivity to funding shocks. More broadly, interpreting movements in the time series of $M1/M0$ as changes in the underlying deposit multiplier is challenging, as such fluctuations may stem from exogenous shifts in the supply of base money or policy-induced increases in deposits, rather than reflecting changes in banks' endogenous deposit multiplier.

3.3 Empirical Strategy

To estimate banks' deposit multiplier, we move beyond aggregate monetary ratios and measure directly how an initial inflow translates into a total change in deposits. A natural way to implement this is to estimate local projections of deposits at horizon h on a shock to deposits at time t:

$$\Delta D_{t+h} = \alpha_h + m_D^h \cdot \Delta D_t + \Gamma_h X_t + \varepsilon_{t+h}. \tag{5}$$

In Equation (5), $\Delta D_t \equiv \log D_t - \log D_{t-1}$ captures deposit growth from period $t-1$ to t, $\Delta D_{t+h} \equiv \log D_{t+h} - \log D_{t-1}$ captures cumulative deposit growth from $t-1$ to $t+h$, X_t denotes a vector of controls dated at time t, and ε_{t+h} is the error term. In this setting, the coefficient m_D^h represents the deposit multiplier at horizon h. As h grows large, m_D^h converges to the long-run deposit multiplier m_D.

If all other determinants of deposit growth were fully accounted for in X_t, then local projections would deliver unbiased estimates of m_D^h at each horizon, converging to the true deposit multiplier m_D for large h. However, in practice, many relevant factors that influence deposit dynamics, such as local demand conditions, interest rate expectations, or shifts in portfolio preferences, are difficult or impossible to observe. As a result, ΔD_t may be correlated with the error term ε_{t+h}, giving rise to endogeneity and biasing our estimate of m_D. For instance, we may overestimate m_D if ΔD_t and ΔD_{t+h} co-move positively because of an unobservable factor that drives deposit flows at both horizons, such as a surge in aggregate risk appetite or liquidity demand.

To address this endogeneity concern, we seek a shifter of contemporaneous deposit growth, ΔD_t, that is uncorrelated with the unobservable factors that jointly drive both current and future deposit growth. Our primary specification follows a local empirical strategy that estimates m_D at the county level, while a complementary robustness exercise estimates the multiplier nationally using aggregate variation. By estimating the deposit multiplier within a geographic region, we account for the possibility that deposits created through lending may not remain with the originating bank but may instead flow to other banks operating in the same area. To the extent that created deposits tend to remain within the geographic region, the local method provides a valid measure of the total deposit creation resulting from local lending activity. In effect, it allows us to recover a system-consistent estimate of the deposit multiplier that reflects the full effect of lending on deposit creation, even in the presence of interbank flows.

Our regional instrument exploits exogenous variation in bank funding generated by the discovery and development of shale oil and gas resources. Gilje et al. (2016) document that shale booms generate large and sudden inflows of income into affected regions which are stored as local deposits, and which subsequently result in increased lending by these banks in unaffected regions. We begin by first measuring exposure at the bank level. For bank b, we define:

$$Z_{b,t} = \sum_{c} w_{b,c,t} \cdot \text{log(Shale Wells)}_{c,t}. \tag{6}$$

In Equation (6), $w_{b,c,t}$ is the exposure of bank b to county c in year t, calculated as the share of bank b's deposits in year t that come from county c. $\text{log(Shale Wells)}_{c,t}$ is the log of the number of shale wells that are present in county c by year t.

To construct our county-level instrument, for each county c, we take a weighted average of $Z_{b,t}$ across banks b, where the weights $w_{b,c}$ are defined as each bank's historical deposit market share in county c in 2000, which is the first year of our sample period and prior to the widespread discovery of shale wells in the U.S. This approach captures the funding capacity that banks can bring to the region, regardless of where deposits are collected, and reflects the idea that banks can reallocate liquidity internally across their networks. We restrict our sample to regions unaffected by shale booms, which we define as counties in the top quartile of shale well discoveries. Thus, for county c our instrument is:

$$Z_{c,t} = \sum_{b} w_{b,c} \cdot Z_{b,t}. \tag{7}$$

We implement this strategy in a 2SLS framework. In the first stage, we estimate the change in deposits at the county level as a function of the instrument. In the second stage, we regress cumulative deposit growth at horizon h on instrumented county-level deposit growth at time t within the local projection framework. This specification allows us to estimate how cumulative deposit growth responds to an initial inflow, thereby recovering a causal estimate of the deposit multiplier. For horizon h, the second stage regression equation is,

$$\Delta D_{c,t+h} = m_D^h \widehat{\Delta D_{c,t}} + \Gamma_h X_{c,t} + \varepsilon_{c,t+h}. \tag{8}$$

Instrument validity requires that the relevance and exclusion assumptions be satisfied. The relevance condition is supported by prior work and our first-stage results in Table 4: Shale discoveries generate large deposit inflows into non-boom counties through banks that are locally

Table 4: First Stage Estimates

The table reports first-stage estimates from the instrumental variables specification linking county-level deposit growth to exposure to shale-related funding shocks. The instrument is constructed based on banks' fixed pre-boom geographic exposure to shale regions, aggregated to the county level using historical deposit market shares from 2000, as described in the text. The sample covers 2000–2024. All specifications include county and year fixed effects, and standard errors are clustered at the county level. One, two, and three stars indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

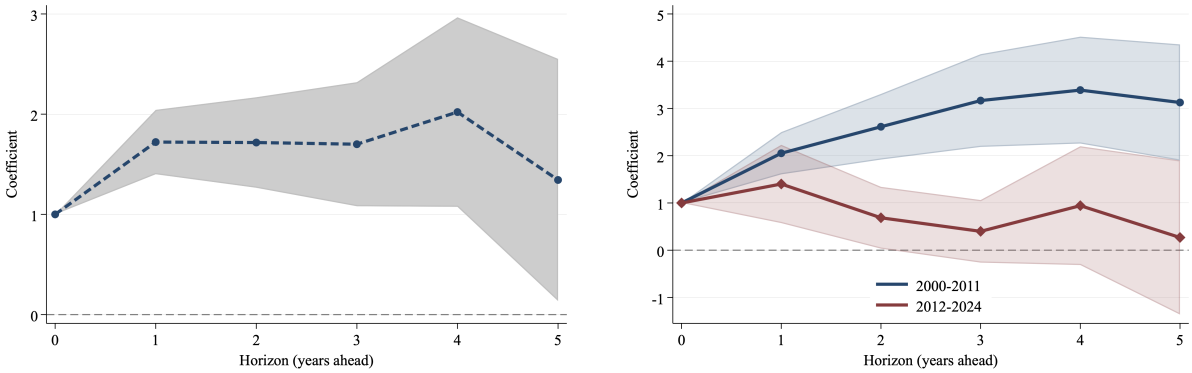
	(1)	(2)	(3)
	2000-2024	2000-2011	2012-2024
Fracking Exposure	0.01***	0.02***	0.01***
	(0.00)	(0.00)	(0.00)
Lag Deposit Growth	-0.01	-0.05***	-0.04***
	(0.01)	(0.01)	(0.01)
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
Observations	72314	34257	38043
Adjusted R^2	0.219	0.074	0.321
F	27.90	38.80	25.78

present and exposed to the boom via their internal capital markets. The exclusion restriction is also plausible: local shale discoveries are largely unpredictable and driven by underlying geological formations and technological breakthroughs, rather than by local credit conditions. One concern may be that shale activity boosts credit demand in addition to providing liquidity windfalls, such as through invigorating the local economy. To ensure that the instrument captures variation in funding rather than contemporaneous shifts in loan demand, we exclude boom counties from the sample, thereby focusing only on deposit growth in counties without large presence of shale wells.

A related concern is that our empirical specification could capture real-side economic activity rather than balance-sheet propagation. In principle, deposit inflows might fuel new lending that stimulates local investment and output growth, and these real responses could in turn raise deposits through higher incomes and spending. While such effects are possible, the marginal investment opportunities financed by these inflows are unlikely to yield returns high enough to sustain for instance, a twofold expansion in deposits. Nevertheless, as a robustness exercise we re-estimate the specification using a higher-frequency, aggregate funding shock, which reallocates liquidity over short horizons that are too rapid to generate real economic effects. The

Figure 2: Deposit Multiplier Estimates

This figure reports local projection estimates of the dynamic response of deposits to a deposit shock at time t, estimated using an instrumental variables approach at the county-year level. Panel (a) shows the baseline estimates from 2000 to 2024. Panel (b) compares estimates for the early versus late samples. Shaded bands denote 95% confidence intervals based on standard errors clustered at the county level.



(a) 2000 to 2024

(b) Early vs. Late

similar results across both exercises support the interpretation that our estimates capture financial propagation through bank balance sheets rather than real-side growth dynamics.

3.4 Estimates of the Deposit Multiplier

Table 5 Panel A reports the resulting coefficient estimates for our IV specification in Equation (8) at horizons h from 0 to 5. This specification captures how an initial funding inflow propagates through the banking system over time, including through flows of funds between banks and across institutions. We take the highest value of the estimated m_D^h coefficient as our deposit multiplier, resulting in a value of 2.02. This implies that a 1 percent deposit inflow ultimately leads to a 2.02 percent increase in total deposits in the banking system. Figure 2 visualizes the results. We plot the IV coefficients from the projected regressions for horizons $h = 0$ to 5, with shaded bands indicating 95% confidence intervals based on standard errors clustered at the county level. The impulse response indicates that initial deposit inflows are gradually re-deposited within the banking system, leading to additional rounds of deposit growth across local institutions. These effects level off after three to four years, suggesting that the cumulative response has converged to the overall deposit multiplier.

We next examine how the multiplier varies over time to assess whether it changes with

Table 5: Deposit Multiplier Estimates

The table reports instrumental variables estimates of the dynamic effect of deposit growth on future deposit growth at the county–year level, at horizons 1 through 5 years ahead. The instrument is constructed based on a county's fixed geographic exposure to shale regions, as described in the text. Panel A reports estimates for the full 2000–2024 sample. Panels B and C report estimates for the early (2000–2011) and late (2012–2024) subsamples, respectively. All specifications include year and county fixed effects and cluster standard errors at the county level. One, two, and three stars indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Full Sample 2000–2024

	(1) $\Delta D_{t-1,t+1}$	(2) $\Delta D_{t-1,t+2}$	(3) $\Delta D_{t-1,t+3}$	(4) $\Delta D_{t-1,t+4}$	(5) $\Delta D_{t-1,t+5}$
Instrumented Deposit Growth	1.72***	1.72***	1.70***	2.02***	1.34**
	(0.16)	(0.23)	(0.32)	(0.48)	(0.62)
Lag Deposit Growth	-0.02***	-0.06***	-0.08***	-0.13***	-0.23***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
County and Year FE	Yes	Yes	Yes	Yes	Yes
Observations	69367	66409	63442	60469	57488
F	79.61	70.71	65.85	83.79	199.10

Panel B: Early Sample 2000–2011

	(1) $\Delta D_{t-1,t+1}$	(2) $\Delta D_{t-1,t+2}$	(3) $\Delta D_{t-1,t+3}$	(4) $\Delta D_{t-1,t+4}$	(5) $\Delta D_{t-1,t+5}$
Instrumented Deposit Growth	2.05***	2.61***	3.17***	3.39***	3.13***
	(0.23)	(0.35)	(0.50)	(0.58)	(0.63)
Lag Deposit Growth	-0.00	-0.02	-0.04	-0.10***	-0.19***
	(0.02)	(0.02)	(0.03)	(0.04)	(0.04)
County and Year FE	Yes	Yes	Yes	Yes	Yes
Observations	34254	34251	34243	34234	34224
F	80.27	61.03	53.74	65.46	99.36

Panel C: Late Sample 2012–2024

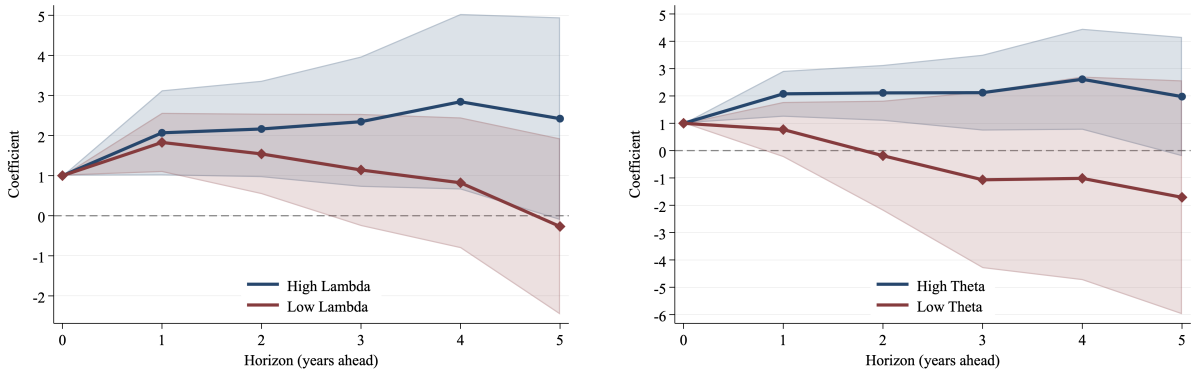
	(1) $\Delta D_{t-1,t+1}$	(2) $\Delta D_{t-1,t+2}$	(3) $\Delta D_{t-1,t+3}$	(4) $\Delta D_{t-1,t+4}$	(5) $\Delta D_{t-1,t+5}$
Instrumented Deposit Growth	1.40***	0.69**	0.40	0.94	0.27
	(0.42)	(0.33)	(0.34)	(0.64)	(0.83)
Lag Deposit Growth	-0.05**	-0.18***	-0.24***	-0.24***	-0.37***
	(0.03)	(0.03)	(0.03)	(0.05)	(0.07)
County and Year FE	Yes	Yes	Yes	Yes	Yes
Observations	35095	32143	29182	26154	23226
F	129.56	208.04	189.08	168.42	208.77

the evolving structure of the financial system. We split our time sample in half, estimating the deposit multiplier over the years 2000-2011 and 2012-2024. Table 5 Panels B and C compares the dynamics of the deposit multiplier across two sample periods. We estimate, for each period, our IV specification in Equation (8) at horizons $h = 0$ to 5. Comparing the magnitudes shows a marked decrease in the deposit multiplier in the latter sample relative to the earlier sample. Figure 2 Panel B again visualizes the results. Banks' deposit multiplier is an equilibrium outcome that evolves with the broader structure of the financial system. Its weakening over time may reflect several forces, including changes in regulation following the financial crisis and the growing role of non-bank intermediaries in both funding and credit provision. We later use the structural model to quantitatively decompose the decline in the multiplier and assess the relative contribution of each of these forces.

Finally, we use our empirical setting to explore whether the sufficient statistics described in Section 2 drive the magnitude of the deposit multiplier, namely how actively banks transform new funding into loans (λ) and on the extent to which loan proceeds remain in the banking system as stable deposits (θ). Because the multiplier is an equilibrium outcome, it is difficult to cleanly separate these components in reduced form. Nevertheless, we exploit cross-sectional heterogeneity in banks' balance-sheet composition to proxy for variation in each channel. Figure 3 shows that counties exposed to banks with greater lending capacity (higher λ), which we proxy for via lower reliance on mortgage-backed securities, exhibit larger deposit multipliers. Similarly, counties exposed to banks with more stable deposits (higher θ), which we proxy for with lower dependence on brokered deposits, also exhibit larger deposit multipliers. We later return to these relationships through the lens of a structural model of the U.S. banking sector, which allows us to isolate and quantify the distinct contributions of λ and θ to the strength of the deposit multiplier.

Figure 3: Deposit Multiplier Estimates as λ and θ Vary

This figure reports local projection estimates of the dynamic response of deposits to a deposit shock at time t, estimated using an instrumental variables approach at the county-year level. We proxy λ with a county's exposure to banks holding a high share of MBS relative to deposits, and θ with exposure to banks relying heavily on brokered deposits. We interpret lower exposure to MBS or brokered deposits as corresponding to higher values of λ and θ, respectively. Panel (a) compares estimates of m_D across counties in the top and bottom quartiles of λ, and Panel (b) does the same for θ. Shaded bands denote 95% confidence intervals based on standard errors clustered at the county level.



(a) λ (b) θ

3.5 Robustness: Changes in Treasury General Account Balances

We next conduct a robustness test that reinforces our main findings along two important dimensions. First, our baseline estimates rely on geographically localized variation in deposit inflows, capturing local balance-sheet propagation within counties. To evaluate whether these effects are similar at the national level, we examine a setting that captures system-wide liquidity dynamics. Second, because our regional shocks are only observed over annual horizons that may allow for real-side adjustments, we next use a high-frequency source of variation to assess whether similar effects appear at horizons where real activity is unlikely to adjust.

Specifically, we exploit weekly changes in the Treasury General Account (TGA) at the Federal Reserve, which represent movements in the Treasury's cash holdings. When the TGA balance increases, reserves and deposits in the private sector must fall one-for-one as funds are transferred from the banking system to the Treasury's account.[6] These week-to-week fluctuations in Treasury cash management provide a natural experiment that reallocates liquidity

[6]Indeed, (Correa et al., 2020) shows that increases in TGA balances are related to worsening dollar funding conditions.

Table 6: Deposit Multiplier Estimate with TGA Instrument

This table reports in column (1) the first-stage estimate, and in column (2) the second-stage estimate for horizon $h = 10$, for specification (9). The instrument is the weekly percentage change in the Treasury General Account balance, ΔTGA_t, and is trimmed at the 5th and 95th percentiles. All specifications are estimated over the 2009 to 2019 sample, and include week-of-year fixed effects. One, two, and three stars indicate statistical significance at the 10%, 5%, and 1% levels, respectively. For the second stage, we use Newey-West standard errors with lag h.

	First stage: ΔD_t	$\Delta D_{t-1,t+10}$
ΔTGA_t	-0.002^{***}	
	(0.001)	
$\widehat{\Delta D}$		1.653^{**}
		(0.705)
Week-of-Year FE	Yes	Yes
First-stage F Stat:	-	13.4
Num. obs.	473	473

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$

between the government and private financial intermediaries.

The exclusion restriction underlying this instrument is that weekly fluctuations in the TGA balance affect private-sector deposits only through their mechanical impact on banking-system liquidity, rather than through changes in economic fundamentals. TGA movements primarily reflect short-term Treasury cash management—such as the timing of tax receipts, debt issuance, and government disbursements, which are largely predetermined and unrelated to contemporaneous credit demand or real activity. To further mitigate any residual seasonality or predictable fiscal patterns, we include week-of-year fixed effects in all specifications, which absorb systematic intra-year cycles in Treasury cash flows. Because these operations simply reallocate reserves between the Treasury and the private sector, the resulting variation provides a plausibly exogenous source of shocks to the aggregate supply of deposits.

As before, we implement this strategy in a 2SLS framework. In the first stage, we regress weekly percentage changes in national deposits on our high-frequency aggregate instrument, weekly percentage changes in the TGA. In the second stage, we regress the cumulative percentage change in deposits at horizon h on the instrumented weekly percentage change in deposit growth at time t within the local projection framework. This specification allows us to estimate how cumulative deposit growth responds to an initial inflow, thereby recovering a causal estimate of the deposit multiplier. For horizon h, the aggregate second stage regression equation

is,

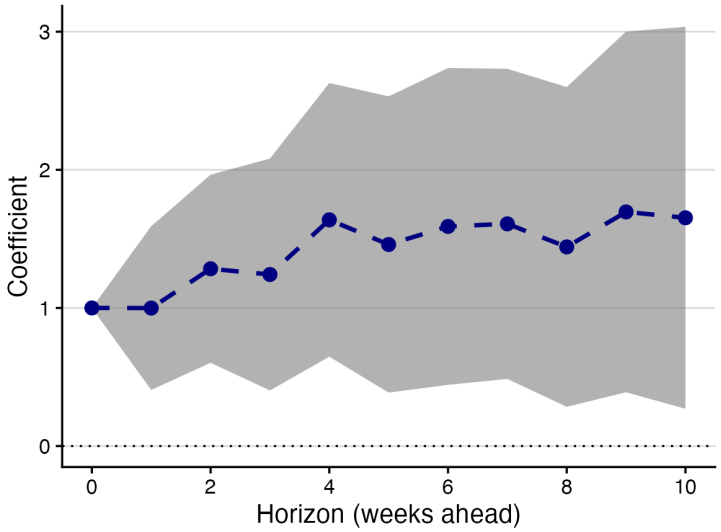
$$\Delta D_{t+h} = m_D^h \widehat{\Delta D_t} + \mu_{w(t)} + \varepsilon_{t+h}\cdot, \tag{9}$$

and where $\mu_{w(t)}$ are week-of-year fixed effects. We trim the 5th and 95th percentiles of $\Delta\text{TGA}_{t-1,t}$ to mitigate the influence of extreme fiscal settlement weeks, such as those associated with debt-limit resolutions or large tax-payment dates. We estimate the deposit multiplier m_D^h for horizons $h = 0, \ldots, 10$ weeks, using Newey–West standard errors with lag h to account for overlapping cumulative windows. Table 6 reports the first stage as well as the estimate of m_D^h at horizon $h = 10$, and Figure 4 plots the estimated impulse response of deposit growth to the TGA-induced liquidity shock.

A negative TGA shock, which injects liquidity into the banking system, leads to an immediate increase in deposits, as reflected in the negative first-stage relationship between changes in the TGA balance and deposit growth. Because the IV coefficient is defined relative to this negative first stage, the positive second-stage estimates imply that these deposit inflows propagate through the system. In other words, a liquidity injection that initially raises deposits sets off further cumulative increases over time, consistent with the operation of the deposit multiplier. As reserves rise, banks expand lending and adjust their balance sheets, which in turn relaxes liquidity constraints and generates an additional, gradual expansion in deposits. We find that a 1 percent increase in deposits ultimately results in a 1.6 percent cumulative rise in total deposits across the banking system, a magnitude similar to that obtained from our baseline deposit multiplier estimated using regional deposit shocks in Table 5. The weekly frequency of the analysis increases confidence that the estimated multiplier reflects financial rather than real-side dynamics, while the aggregate setting suggests that our regional estimates capture the key system-wide propagation.

Figure 4: Cumulative Deposit Response to Treasury Cash Shocks

This figure reports local projection estimates of m_D^h using the weekly percentage change in the Treasury General Account balance, ΔTGA_t, as the instrument, as in specification (9) for horizons $h = 1$ to $h = 10$. The figure shows point estimates $\hat{\beta}_h$ with 95% confidence bands for Newey–West standard errors with lag h. All specifications are estimated over the 2009 to 2019 sample.



4 Model

In this section, we develop a structural model of the U.S. banking sector that endogenizes the credit–deposit multiplier and links its magnitude to underlying structural primitives, allowing us to quantitatively decompose the forces driving its evolution.Within this environment, the three sufficient statistics that govern the multiplier, namely banks' lending response λ, the retention rate of deposits θ, and the asset pass-through $\mathcal{A}_D$, all become endogenous equilibrium objects determined jointly by banks' optimal portfolio and pricing decisions. Our starting point is a framework that closely resembles recent work in the structural banking literature: a monopolistically competitive banking sector maximizes profits by setting rates in deposit and loan markets, subject to frictions such as capital or liquidity regulations which link their deposit and loan-taking (Kashyap et al., 2002; Wang et al., 2022a).[7]

Our key insight is that once this feedback loop is taken into account, the market sizes of deposits and loans are no longer exogenous primitives, as much of the prior literature has

[7]We adopt a static framework to keeps the model tractable while capturing the key economics of the feedback loop, much like other sufficient-statistic methods used in macro-finance to study pass-throughs, wedges, or fiscal multipliers (Farhi and Werning, 2016; Gabaix, 2020). The propagation across "periods" should be interpreted as an iterative recycling of deposits rather than an intertemporal decision problem faced by forward-looking banks.

assumed, but instead are endogenous outcomes that depend on the strength of the credit-deposit multiplier. We bring the model to the data in Section 5, use it in Section 6 to examine the evolution and drivers of the multiplier, and then apply it in Section 7 to study its implications for credit cyclicality and monetary policy transmission.

4.1 Overview

The model features three types of agents. There are depositors, borrowers, and a representative banking system. The key exogenous variables in the model are the current policy rate r^S and the equity capital of the banking sector E, which characterize the state of the world. Given these variables, banks maximize profits by competing for depositors and allocating funds across securities and loans, subject to capital and liquidity constraints. Depositors and borrowers maximize their utility by choosing whether to bank with the banking sector or a non-bank outside option.

4.2 Depositors

Depositor behavior plays a central role in shaping the deposit multiplier. First, it governs the share of new funding retained within the banking system, which matters because only retained deposits generate further rounds of deposit expansion. Second, because deposits provide valuable liquidity and safety services, banks can attract funds while paying rates below the policy rate r^S, a feature that we later show increases the deposit multiplier. We model deposit markets through a simple portfolio choice framework that captures these two key features.

There is a mass W^d of depositors. While taken as fixed by the banking sector, we show the stock of money evolves endogenously over time with the deposit multiplier. Each depositor i makes a discrete choice over a menu that includes a bank deposit, a non-bank savings vehicle, and cash, which differ in the yields they offer and the liquidity services they provide. Funding that flows to non-bank vehicles sits outside the banking system.[8]

Household i's utility from a bank deposit is

$$u_i^d \;=\; \alpha_d r^d + \xi_d + \varepsilon_i, \tag{10}$$

[8]In practice, such funds may re-enter, but typically as less stable, higher-yield institutional deposits rather than core deposits.

while for a money market fund (MMF) it is

$$u_i^M \;=\; \alpha_d r^S + \varepsilon_i^M, \tag{11}$$

and for cash it is

$$u_i^C \;=\; \xi_C + \varepsilon_i^C. \tag{12}$$

Here r^d is the bank deposit rate, α_d is the deposit rate sensitivity of depositors, ξ_d captures the relative liquidity and safety value of bank deposits, and ε_i is the idiosyncratic taste shock for depositor i. The non-bank savings vehicle, such as a money market fund or stablecoin, pays the policy rate r^S but provides no liquidity services. In contrast, cash offers liquidity services ξ_C but pays no interest.

We assume that the error term ε_i is distributed according to a Type-1 extreme value distribution, allowing for a closed form solution of the choice probabilities. This leads to the market share of deposits $s_d(r^d|r^S)$,

$$s_d(r^d|r^S) \;=\; \frac{e^{\xi_d+\alpha_d r^d}}{e^{\xi_d+\alpha_d r^d} \;+\; e^{\alpha_d r^S} \;+\; e^{\xi_C}}. \tag{13}$$

Given this, the demand for deposits can be written as,

$$D(r^d|r^S) \;=\; s_d(r^d|r^S)\cdot W^d. \tag{14}$$

4.3 Borrowers

The strength of the credit–deposit multiplier influences banks' lending behavior through funding frictions that determine the loan rates offered to borrowers. To analyze these credit-side implications, we model loan markets in parallel with deposit markets.

There is a mass of borrowers with wealth W^b. Each borrower j makes a discrete choice over a menu that includes borrowing from the bank, borrowing from non-bank lenders, and not borrowing. Borrower j's utility for a bank loan is

$$u_j^\ell \;=\; -\alpha_\ell r^\ell + \xi_\ell + \eta_j, \tag{15}$$

where r^ℓ is the bank loan rate, α_ℓ is the rate sensitivity of borrowers, ξ_ℓ captures the relative desirability of bank services, and η_j is the idiosyncratic taste shock for borrower j.

Similarly, borrower j's utility for a non-bank loan is defined as

$$u_j^{nb} \;=\; -\alpha_\ell r^{nb} + \xi_{nb} + \eta_j, \tag{16}$$

where r^{nb} is the non-bank loan rate and ξ_{nb} captures the relative desirability of non-bank services. We normalize the utility of not borrowing to 0. We assume that the error term η_j is distributed according to a Type-1 extreme value distribution. This leads to the market share of bank loans $s_\ell(r^L)$,

$$s_\ell(r^\ell) \;=\; \frac{e^{\xi_\ell - \alpha_\ell r^\ell}}{1 + e^{\xi_\ell - \alpha_\ell r^\ell} + e^{\xi_{nb} - \alpha_\ell r^{nb}}}. \tag{17}$$

The demand for bank loans can thus be written as,

$$D(r^\ell) = s_\ell(r^\ell) \cdot W_l. \tag{18}$$

4.4 Banking System

4.4.1 Profit Maximization

We model a representative banking sector that chooses the deposit rate r^d, loan rates r^ℓ, and wholesale borrowing W to maximize profits. It takes as given the policy rate r^S, equity capital E, and the demand functions of depositors $D(r^d)$ and borrowers $L(r^\ell)$. Non-negative securities holdings S are then determined residually by the balance sheet constraint,

$$L(r^\ell) + S = E + D(r^d) + W. \tag{19}$$

The banking sector's profit maximization problem is given by,

$$\max_{r^d, r^\ell, W} \; (r^\ell - r^S)L \;+\; (r^S - r^d)D \;-\; \frac{\kappa_W}{2}W^2 \;+\; \xi \ln\big(K\big) \;+\; \tau \ln\big(\Lambda\big). \tag{20}$$

In (20), the first two terms capture profits from loan and deposit markets respectively.[9] The

[9]Securities and wholesale funds both earn the policy rate r^S. With equity E fixed, their returns affect the level

remaining terms represent costs: a quadratic wholesale funding cost κ_W, reflecting the expense of external financing outside the bank's deposit base (Kashyap and Stein, 1995), and penalties from capital and liquidity requirements, which we describe in detail below. These frictions link deposit-taking to loan supply: without them, deposit inflows would have no effect on lending, and the credit-deposit multiplier would reduce to one.

We model banks' regulatory capital and liquidity constraints with log penalties, which reduce profits by raising marginal costs as the capital or liquidity slack approaches zero. First, the bank faces a risk-invariant capital constraint captured by $\xi \ln\big(K\big)$. Letting $\kappa > 0$ denote the level of the capital requirement, let the capital slack K be defined as

$$K \;=\; E - \kappa\,(L + S) \;=\; (1-\kappa)E \;-\; \kappa(D+W) \geq 0. \tag{21}$$

Thus, the capital slack K is the excess of equity capital E over a fixed fraction κ of total assets, with loans and securities weighted uniformly. This risk-invariant leverage ratio is similar to the Supplementary Leverage Ratio (SLR) implemented in the Basel III regulatory framework. By rearranging with the balance sheet identity, we see that higher deposits D and wholesale funding W tighten the constraint, while greater equity E relaxes it. As the balance sheet grows relative to equity, the capital slack K shrinks, and the penalty $\xi \ln(K)$ reduces profits, making additional asset expansion increasingly costly.

Second, the bank faces a liquidity requirement captured by $\tau \ln\big(\Lambda\big)$. Let $\chi \in [0,1]$ be the required ratio of liquid asset holdings relative to runnable liabilities, and $\psi \in [0,1]$ governs the runnable fraction of deposits in the liquidity rule. Define the liquidity slack Λ as,

$$\Lambda = S - \chi(\psi D + W) \geq 0 \tag{22}$$

Here, the liquidity slack Λ is the excess of liquid securities S over a required fraction χ of runnable liabilities, given by the runnable share ψ of deposits D and all wholesale funding W. This formulation is in the spirit of the Liquidity Coverage Ratio (LCR) in Basel III, which requires banks to hold sufficient high-quality liquid assets to cover a fraction of their runnable short-term liabilities. From (18), higher runnable liabilities such as wholesale funding W or runnable deposits ψD tighten the constraint, while greater securities holdings S relax it. As runnable funding rises without a matching increase in liquid assets, the liquidity slack Λ shrinks,

of profits but not the bank's profit maximization.

and the penalty $\tau \ln(\Lambda)$ reduces profits, making reliance on unstable funding increasingly costly.

The parameters $\xi, \tau > 0$ govern the severity of the capital and liquidity constraints. They determine how sharply profits decline as the corresponding slacks K and Λ shrink, with larger values implying that the constraints impose higher marginal costs when balance-sheet capacity becomes scarce. Intuitively, higher ξ or τ capture a more stringent regulatory environment or a greater sensitivity of bank funding costs to tight capital or liquidity positions.[10]

4.4.2 First Order Conditions

Given the profit maximization problem above, we next derive the corresponding first order conditions. We begin with the condition for the loan rate $r^{\ell *}$,

$$r^{\ell \star} = r^S + \frac{1}{\alpha_\ell (1 - s_\ell(r^{\ell \star}))} + \frac{\tau}{\Lambda^*} \tag{23}$$

This expression shows that the banking sector's optimal loan rate $r^{\ell \star}$ can be written as the sum of three terms. The first is the policy rate, which provides the baseline cost of funds in the economy. The second is a demand markup, reflecting the bank's market power arising from borrower's preference for bank loans: when loan demand is less elastic, the bank sets a higher rate above the policy rate. The third is a liquidity wedge, which arises when the bank must hold liquid assets against runnable liabilities, increasing the effective marginal cost of extending loans.[11] This term, τ/Λ, can be interpreted as the shadow cost of liquidity: the marginal value of relaxing the liquidity constraint by one unit. When liquidity is scarce and Λ is small, this shadow cost is high, raising lending rates; when liquidity is ample, the shadow cost approaches zero, and the loan rate converges toward the policy rate plus the demand markup.

Next, we solve for the optimal deposit rate $r^{d \star}$,

$$r^{d\star} \;=\; r^S \;-\; \frac{1}{\alpha_d \left(1 - s_d(r^{d\star} \mid r^S)\right)} \;+\; (1 - \chi\psi)\frac{\tau}{\Lambda^\star} \;-\; \kappa \frac{\xi}{K^\star} \tag{24}$$

[10] Notice that both the capital and liquidity constraints tighten mechanically with the quantity of deposits, as higher deposits increase total liabilities and runnable funding. However, a deposit inflow can relax these constraints in equilibrium as banks optimally reallocate their balance sheets, to the extent that it lowers the shadow cost of liquidity and does not substantially raise the shadow cost of capital. In this sense, the effective tightness of funding constraints depends on how deposit inflows are absorbed and distributed across assets and liabilities.

[11] Notice that the capital requirement does not enter the optimal loan rate because, in the first order condition, loans increase holding deposits and wholesale funding fixed, so securities adjust one-for-one and total assets remain unchanged.

The deposit first order condition shows that the banking sector's optimal deposit rate $r^{d\star}$ is determined by four terms. The first is the policy rate, which provides the baseline return on funds. The second is a deposit markdown, reflecting the bank's market power arising from depositors' preference for bank deposits: when deposit demand is less elastic, the bank can offer a lower rate below the policy rate. The third is a liquidity wedge, which raises the deposit rate banks are willing to pay because deposits help satisfy the liquidity requirement; however, as the share of runnable deposits increases, this effect is dampened. The fourth is a capital wedge which depends on the shadow cost of capital, $\kappa, \xi/K^\star$, which increases the marginal cost of expanding the balance sheet and thereby lowers the deposit rate that banks are willing to offer.

Lastly, we have the first order condition for wholesale funding,

$$W^* = \frac{\tau}{\Lambda^*}\frac{(1-\chi)}{\kappa_W} - \frac{\xi}{K^*}\frac{\kappa}{\kappa_W} \tag{25}$$

This expression has two components. The first is a liquidity wedge, which increases wholesale funding as the liquidity buffer Λ shrinks. In the first order condition, deposits and loans are held fixed, so an increase in wholesale funding raises securities one-for-one through the balance sheet identity. Wholesale liabilities tighten the liquidity requirement directly, but the associated increase in securities offsets this, leaving a positive net effect when $\chi < 1$. The second is a capital wedge, which reduces wholesale funding as the capital buffer K shrinks, increasing the marginal cost of expanding the banking system's balance sheet. Both effects are scaled by the quadratic cost of wholesale borrowing, κ_W.

4.5 Equilibrium

An equilibrium consists of deposit and loan rates $\{r^{d\star}, r^{\ell\star}\}$, wholesale borrowing $W^\star$, and resulting allocations of deposits $D(r^{d\star})$, loans $L(r^{\ell\star})$, and securities S^* such that:

1. Depositors maximize utility over bank deposits, cash, and the non-bank savings vehicle, yielding deposit demand $D(r^{d\star})$.

2. Borrowers maximize utility over bank loans, non-bank loans, and not borrowing, yielding loan demand $L(r^{\ell\star})$.

3. The representative banking system maximizes profits given in (20), subject to its balance

sheet identity and the definitions of capital slack K in (21) and liquidity slack Λ in (18).

4. The first order conditions (23)–(25) are satisfied.

4.6 Recovering the Deposit and Asset Multipliers

With the equilibrium in hand, we can now return to the central objects of interest: the deposit multiplier m_D and the asset multiplier m_A implied by the equilibrium. The equilibrium conditions highlight the key trade-offs the banking sector faces when behaving optimally: how deposit-taking, lending, and funding decisions adjust given capital and liquidity constraints. To characterize these responses, we recover the three sufficient statistics that drive the multipliers, namely banks' lending response λ, the retention rate of deposits θ, and the asset pass-through $\mathcal{A}_D$, all as endogenous equilibrium objects. The multipliers then translate these optimal responses into the total amplification of a funding shock through successive rounds of re-depositing and balance-sheet expansion.

Recall that the deposit multiplier captures the amplification of an initial deposit inflow through repeated rounds of lending and redepositing and is defined as,

$$m_D \;=\; \frac{1}{1-\lambda\theta}$$

Similarly, the asset multiplier captures the expansion of banking sector assets generated by a deposit inflow, accounting for any funding substitution, and is defined as,

$$m_A \;=\; \frac{\mathcal{A}_D}{1-\lambda\theta}$$

Three parameters are central to determining the strength of the feedback loop between deposits and lending. The first parameter is θ, which we map to the banking sector's share of the deposit market, $s_d(r^d|r^S)$. In the context of the multiplier, θ represents the fraction of new funding that is retained in the banking system as deposits rather than flowing to non-bank assets. By equating θ to the banking sector's market share, we implicitly assume that depositor preferences are stable, so that this share serves as a sufficient statistic for the recycling of funds into the banking system, without needing to explicitly model flows through firms and households (for example, wages paid out of loan proceeds that are later reallocated between deposits and

non-bank assets).

The second parameter is λ, which captures the extent to which banks expand lending in response to additional deposits. In the model, this responsiveness maps naturally to the partial derivative $\lambda = \frac{dL}{dD}$, which measures the sensitivity of loan supply to deposit inflows. We derive the analytical expression for the pass-through $\lambda = \frac{dL}{dD}$ in Appendix A.1. Under standard regularity conditions, the Implicit Function Theorem ensures that the local equilibrium map $x = (r_d, r_\ell, W, D, L)$ is differentiable in any small driver, such as a policy rate or deposit shock. This allows us to take total differentials of the bank's liquidity identity, wholesale funding condition, and loan-supply first-order condition around the interior equilibrium, and solve the resulting linear system for the local co-movements of $dL, dD, dW, d\Lambda$. The resulting expression is,

$$\lambda = \frac{dL}{dD} = \frac{\left[(1-\chi\psi) \; - \; (1-\chi)\,\dfrac{\xi\kappa^2/K^2}{\kappa_W + \xi\kappa^2/K^2}\right]}{1 + \dfrac{1}{\alpha^\ell L(1-s_\ell)^2}\left(\dfrac{\Lambda^2}{\tau} + \dfrac{(1-\chi)^2}{\kappa_W + \xi\kappa^2/K^2}\right)} \tag{26}$$

λ captures how the banking system responds in equilibrium to a marginal deposit inflow. First, λ is shaped by the degree of loan market competition through the term $\alpha^\ell L(1-s_\ell)^2$: More competition makes loan demand more elastic, so that deposit inflows translate into larger credit expansion. Second, λ is higher when deposits are more stable (low χ or ψ), because they provide greater liquidity relief, and lower when wholesale funding is inexpensive (low κ_W), which reduces the marginal liquidity value of deposits. Third, λ is higher when liquidity slack is low (smaller Λ or higher τ), because funding shocks have larger effects. Fourth, λ is lower when capital slack is low (smaller K or larger ξ, κ), because the leverage constraint is closer to binding, so deposit inflows primarily substitute away from wholesale funding rather than expanding lending.

The third parameter is $\mathcal{A}_D$, the marginal change in total banking sector assets per marginal dollar of deposits. Using the banking sector's balance sheet constraint, we can rewrite this as,

$$\mathcal{A}_D = \frac{dA}{dD} = \frac{dE}{dD} + \frac{dD}{dD} + \frac{dW}{dD} = 1 + \mathcal{W}_D \tag{27}$$

where we have used the fact that equity is fixed, and where we denote $\frac{dW}{dD}$ by $\mathcal{W}_D$. This formulation makes it clear that the asset multiplier depends on the sensitivity of wholesale funding to

deposit inflows. We derive $\mathcal{W}_D$ in Appendix A.1. The resulting expression is,

$$\mathcal{W}_D = \frac{dW}{dD} = -\frac{\frac{\tau(1-\chi)}{\Lambda^2}(1-\chi\psi-\lambda)+\frac{\xi\kappa^2}{K^2}}{\kappa_W+\frac{\xi\kappa^2}{K^2}+\frac{\tau(1-\chi)^2}{\Lambda^2}} \tag{28}$$

When deposits flow in, the marginal value of liquidity falls and the banking sector cuts W to restore the optimality condition, so that $\mathcal{W}_D$ is negative. The adjustment is stronger when liquidity slack is scarce (small Λ or large τ), since the marginal value of liquidity is more sensitive in that region. Likewise, when capital slack is tight (small K or large ξ, κ), expanding the balance sheet is costly, so banks substitute more aggressively away from wholesale funding. In contrast, the magnitude of wholesale substitution $\mathcal{W}_D$ is smaller when deposit inflows are either absorbed by lending, provide little incremental liquidity, or occur when wholesale funding is inexpensive. Concretely: (i) a higher loan response (λ) means that a larger share of deposit inflows is used for new lending rather than for replacing wholesale funding; (ii) less stable deposits (large χ or ψ) have lower liquidity value and thus move W less; and (iii) cheap or elastic wholesale markets (small κ_W) make holding W less costly, again reducing the magnitude of $\mathcal{W}_D$.

4.7 Multiplier-Driven Evolution of the Banking System

Having established how deposits shape lending and funding decisions in equilibrium, and how these decisions recycle back into the banking sector through deposit demand, we now turn to the propagation implications of these linkages. The multipliers m_D and m_A summarize the self-reinforcing mechanisms through which deposit inflows propagate across the banking system, and more generally, they define the law of motion linking the evolution of deposits, loans, and assets through successive rounds of intermediation.

Let ΔD_0 denote the initial level of deposits at time $t = 0$, or equivalently the initial deviation of deposits from equilibrium (arising from a shock such as monetary policy, quantitative easing, or fiscal transfers, or from the gradual expansion of deposits over the business cycle). Then deposits, loans, wholesale funding, and assets evolve as

$$\Delta D_{t+1} = \theta\,\Delta L_t = \theta\,\lambda\,\Delta D_t, \qquad t = 0, 1, 2, \ldots \tag{29}$$

$$\Delta L_t = \lambda\,\Delta D_t, \qquad \Delta W_t = \mathcal{W}_D\,\Delta D_t, \qquad \Delta A_t = \mathcal{A}_D\,\Delta D_t \tag{30}$$

Iterating the deposit law yields the geometric sequence

$$\Delta D_t = (\theta\lambda)^t \, \Delta D_0, \qquad t \geq 0 \tag{31}$$

which converges provided $|\theta\lambda| < 1$. The resulting aggregate quantities implied by this propagation are the cumulative multipliers,

$$m_D \equiv \sum_{t\geq 0} \Delta D_t = \frac{1}{1-\theta\lambda} \Delta D_0 \qquad m_A \equiv \sum_{t\geq 0} \Delta A_t = \frac{\mathcal{A}_D}{1-\theta\lambda} \Delta D_0 \tag{32}$$

$$m_W \equiv \sum_{t\geq 0} \Delta W_t = \frac{\mathcal{W}_D}{1-\theta\lambda} \Delta D_0 \qquad m_L \equiv \sum_{t\geq 0} \Delta L_t = \frac{\lambda}{1-\theta\lambda} \Delta D_0 \tag{33}$$

5 Model Estimation

5.1 Data

We assemble a quarterly aggregate panel for the U.S. commercial banking sector from the FDIC Quarterly Banking Profile, supplemented with policy rates from the Federal Reserve and two outside option aggregates: money market fund assets and the sum of outstanding U.S. corporate bonds and equity. We define market sizes using aggregate data. The deposit market size is the sum of bank deposits, money market fund assets, and cash. The borrower market size is defined as the sum of bank loans, corporate bonds and equity (e.g., non-bank financing), and commercial paper. Economically, we interpret cash and commercial paper to be the outside options in depositor and borrower markets. The sample runs from 2001Q1 to 2024Q4. We split the sample into a pre- and post-regulation period in 2012 to capture the influence of regulation.[12]

From the QBP we obtain aggregate stocks of deposits, loans, total liabilities, equity capital, and total assets, together with interest expense on deposits and interest income on loans. Wholesale funding is measured as total liabilities net of deposits. Deposit and loan rates are constructed from interest flows divided by the corresponding average quarter stocks and then annualized to percent. The policy rate is the effective federal funds rate at quarter end, retrieved from FRED.

[12] 2012 corresponds to the beginning of the implementation of the Basel III enhanced bank regulation effort.

5.2 Demand Parameters

To bring the demand systems that the banking sector faces in deposit and loan markets to the data, we first estimate the market sizes of deposit markets W^d and loan markets W^b. In a given year t, we define the deposit market as the sum of deposits held in the U.S. commercial banking sector and assets held by money market funds. Similarly, for year t we define the loan market as the sum of loans held by the U.S. commercial banking sector and outstanding U.S. corporate bonds and equity.

Next, we obtain price sensitivity parameters from the literature, which allow us to uncover the empirical markups. In particular, we use a deposit rate sensitivity of 1.27 from Xiao (2019), and a loan rate sensitivity of 5.56 from Diamond et al. (2024).

Finally, we recover the non-price utility of deposits ξ_d and cash ξ_c, along with the non-price utility of bank loans ξ_l and non-bank loans ξ_{nb} by inverting the demand functions to match the data.

5.3 Supply Parameters

We use the Generalized Method of Moments (GMM) to estimate the three main structural parameters $\{\kappa_W, \tau, \xi\}$. The logic follows the minimum-distance tradition in macroeconomics, for example Christiano and Eichenbaum (1992), who estimate structural parameters by choosing values that align model-implied moments with their empirical analogs. Our approach also parallels recent work in structural banking, such as Wang et al. (2022b), which recovers bank-level primitives by matching moments derived from optimal pricing and balance sheet conditions. In this spirit, we construct four overidentifying mean-zero moment conditions that translate the first-order conditions of our model into restrictions on the structural parameters. Three moments target the levels of the optimality conditions, and the fourth moment captures the change in balance sheet pressure induced by regulation. This final restriction requires that the model-implied difference-in-difference in optimal deposit rates matches its empirical counterpart. We display the stacked moments in the function $g_T(\kappa_W, \tau, \xi)$.

$$g_T(\kappa_W, \tau, \xi) \equiv \begin{bmatrix} \underbrace{\frac{1}{T_0}\sum_{t\in\mathcal{T}_0}\left[\kappa_W W_t - \tau\frac{1-\chi_t}{\Lambda_t}\right]}_{\text{(1) Pre wholesale FOC}} \\ \underbrace{\frac{1}{T_1}\sum_{t\in\mathcal{T}_1}\left[(r_t^S - r_t^d) - \frac{1}{\alpha_d(1-s_t^d)} + \tau\frac{1-\chi_t\psi_t}{\Lambda_t} - \xi\frac{\kappa}{K_t}\right]}_{\text{(2) Post deposit FOC}} \\ \underbrace{\frac{1}{T_1}\sum_{t\in\mathcal{T}_1}\left[(r_t^\ell - r_t^S) - \frac{1}{\alpha_\ell(1-s_t^\ell)} - \tau\frac{1}{\Lambda_t}\right]}_{\text{(3) Post loan FOC}} \\ \underbrace{\left\{\frac{1}{T_1}\sum_{t\in\mathcal{T}_1}\left[(r_t^S - r_t^d) - \frac{1}{\alpha_d(1-s_t^d)} + \tau\frac{1-\chi_t\psi_t}{\Lambda_t} - \xi\frac{\kappa}{K_t}\right] - \frac{1}{T_0}\sum_{t\in\mathcal{T}_0}\left[(r_t^S - r_t^d) - \frac{1}{\alpha_d(1-s_t^d)} + \tau\frac{1-\chi_t\psi_t}{\Lambda_t}\right]\right\}}_{\text{(4) Deposit FOC DID (post} - \text{pre; pre has } \xi = 0)} \end{bmatrix} = \mathbf{0} \quad (34)$$

Importantly, we do not match the multipliers within the model, such that the ability of the model to match the estimated multipliers from the reduced form section serves as an important validation of the model.

5.4 Statutory Parameters

Last we use a set of fixed statutory parameters. We assign regulatory exogenously. First, we have the capital requirement (κ), and two liquidity parameters governing the tightness of runnable funding, denoted ψ (the runnable share of deposits) and χ (e.g., the reserve ratio or the liquidity coverage ratio (LCR)). These enter the static supply conditions through the capital and liquidity slacks and are held constant across the sample.

5.5 Calibrated Parameters

We display the calibrated parameters in Table 7.

First, in Panel A, we display the statutory parameters that govern the regulatory regimes in the pre- and post- periods. First, we define the capital requirement to be 6% in the post-period, consistent with the label of being 'well capitalized' at the depository institution level.

Table 7: Model Calibration

The table reports statutory parameters, calibrated preference parameters, and structural parameters estimated by GMM. Panel A lists statutory capital and liquidity parameters fixed by regulation. Panel B lists the deposit and loan rate sensitivities. Panel C reports the GMM estimates of wholesale curvature κ_W, the liquidity wedge scale τ, and the capital wedge scale ξ, with standard errors displayed in brackets. Panel D shows the untargeted match between the deposit multipliers implied by the model relative to those calculated using the IV methodology.

Symbol	Description	Value
A. Statutory Parameters		
κ_{post}	Capital requirement ratio	0.060
χ_{pre}	Liquidity ratio (pre)	0.150
ψ_{pre}	Runnability (pre)	0.050
χ_{post}	Liquidity ratio (post)	0.250
ψ_{post}	Runnability (post)	0.500
B. Price Elasticities		
α_d	Depositors' rate sensitivity	1.270
α_ℓ	Borrowers' rate sensitivity	5.560
C. Calibrated Parameters		
κ_W	Wholesale curvature	13.248 [3.121]
τ	Liquidity wedge	0.748 [0.160]
ξ	Capital wedge	1.545 [0.718]
D. Untargeted Moments		
$m_{\text{pre, model}}$	Deposit multiplier, early: model	2.68
$m_{\text{pre, IV}}$	Deposit multiplier, early: IV	3.39
$m_{\text{post, model}}$	Deposit multiplier, late: model	1.69
$m_{\text{post, IV}}$	Deposit multiplier, late: IV	1.40

We assume an unconstrained capital regime in the pre-period (e.g., $\kappa_{\text{pre}} = 0$). Next, we specify liquidity regimes in the pre- and post- periods. χ governs the level of the liquidity requirement relative to runnable liabilities, while ψ governs the amount of deposits which are considered to be runnable.[13] The pre-reform liquidity parameters imply a much lower effective liquidity requirement, consistent with pre-crisis liquid-asset ratios of around 5% despite the nominal 10% reserve requirement applying only to a subset of deposits. Our post-reform liquidity parameters χ_{post} and ψ_{post} are chosen so that the implied liquid-asset requirement $\chi_{\text{post}}\psi_{\text{post}}$ corresponds to around 15% once wholesale funding is taken into account, which is slightly below the high quality liquidity asset ratio for LCR banks post-regulation (Yankov, 2020), consistent with a liquidity buffer.

[13] We plot the full quarterly series of the quantities K_t and Λ_t in Appendix Figure A.1.

Next, in Panel B, we display the asset market elasticity parameters which we take from the literature (Xiao, 2019; Diamond et al., 2024). Panel C display the calibrated marginal wholesale funding cost parameter κ_W and slack parameters τ and ξ for liqudity and capital requirements, respectively. These parameters govern the degree to which banks benefit from being farther from their regulatory requirements as specified by the statutory parameters. We display the standard errors for each parameter in brackets. We are able to reject that the model is misspecified using Hansen's J-test which produces a p-value over the traditional threshold of .1. Last, in Panel D, we display the model implied deposit multipliers along with the multipliers from the instrumental variable exercise. We observe that the model matches well the estimated deposit multipliers without specifically targeting them in the calibration of the cost and slackness parameters.

5.6 Quantitative Importance of the Credit-Deposit Multiplier

With the model estimated, we begin by demonstrating the quantitative importance of taking into account the credit-deposit multiplier when considering the equilibrium evolution of deposits, loans, and assets as described in Section 4.7. Figure 5 illustrates this by comparing the immediate balance-sheet response, shown in red, to the fully propagated quantities implied by the credit-deposit multiplier, shown in blue. We evaluate the economy as of 2021Q4 and consider a 1% of GDP increase in deposits, denoted by $S = 1\% \times \text{GDP}$.[14]

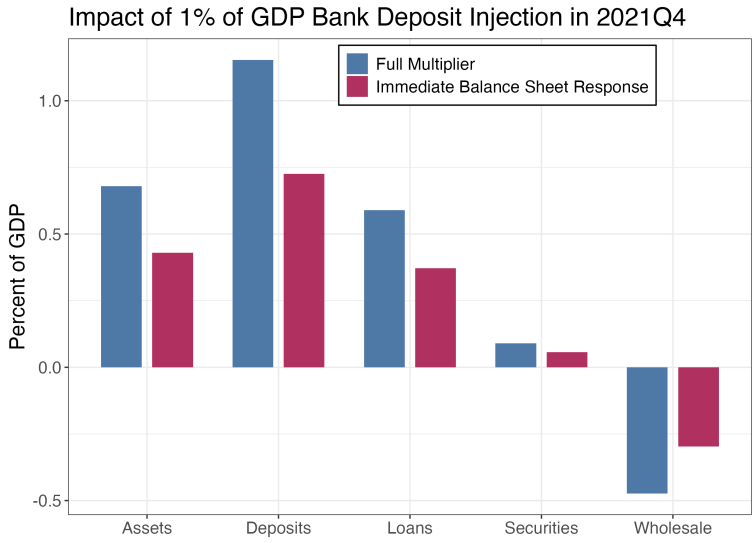
The red bars capture the immediate balance-sheet response when banks receive a deposit inflow, before any multiplier effects take place. In this stage, deposits increase by the portion of the inflow that enters the banking sector, equal to their deposit market share θ times the overall deposit inflow S; $\Delta D_1 = S \times \theta$. Loans expand by bank's equilibrium lending share λ scaled by the deposit inflow; $\Delta L_1 = \lambda \times \Delta D_1$. Wholesale funding adjusts by the bank's equilibrium funding adjustment $\mathcal{W}_D$ scaled by the deposit inflow; $\Delta W_1 = \mathcal{W}_D \times \Delta D_1$, and assets rise by the net change in funding $\mathcal{A}_D = 1 - \mathcal{W}_D$ scaled by the deposit inflow; $\mathcal{A}_D \times \Delta D_1$.

The blue bars then depict the amplification that occurs as the initial deposit inflow is recycled through successive rounds of lending and redepositing, illustrating how the credit–deposit multiplier magnifies the overall expansion of deposits, loans, and assets in equilibrium. We see

[14] In the analytical derivation, capital and liquidity slacks (K, Λ) are evaluated at the pre-shock equilibrium, since the key equilibrium objects λ, θ, and $\mathcal{A}_D$ are defined locally around that point. However, when applying the model to a discrete funding shock, these variables are re-evaluated at the post-shock equilibrium after the slacks adjust endogenously to reflect the new balance-sheet configuration and regulatory conditions.

Figure 5: Quantitative Importance of Credit-Deposit Multiplier

This figure compares the model-implied balance sheet adjustments to a one-time 1% of GDP deposit inflow across the full multiplier (blue), and the partial-equilibrium balance sheet response (red). The exercise studies the impact on the banking sector as of 2021Q4.



that accounting for the multiplier adds roughly 30–40% to the quantity response across balance-sheet items, indicating a quantitatively significant amplification effect. Indeed, the multiplier's amplification is large enough that, despite some of the initial inflow $(1-\theta)$ leaking to non-banks, the total stock of deposits created ultimately surpasses the original depositor-wealth shock. Because this feedback loop endogenously expands the equilibrium stock of deposits and loans, models that hold the market sizes of these quantities fixed overlook an essential mechanism linking banking activity to aggregate credit and funding capacity.

6 Evolution and Drivers of the Credit-Deposit Multiplier

6.1 Evolution of the Credit-Deposit Multiplier

We can now construct a model-implied counterpart to the aggregate deposit multiplier shown in Figure 1, illustrating how the banking sector's role in deposit creation has evolved. The model allows us to trace not only the deposit multiplier but also the asset multiplier, and provides a structurally interpretable measure of how bank deposit and credit creation have changed over

time.

Figure 6 plots the evolution of our three key endogenous equilibrium objects, λ, θ, and $\mathcal{A}_D$, together with the model-implied deposit and asset multipliers. At each date, the model is evaluated at the realized quantities and interest rates, using these to recover the implied value of λ, θ, and $\mathcal{A}_D$, which jointly determine the equilibrium degree of balance-sheet amplification. Importantly, by evaluating the model at realized quantities and interest rates, the time series captures the evolving equilibrium of the banking sector, shaped by regulatory changes, large-scale asset purchases, and the growing presence of non-banks in both lending and funding markets.

Figure 6: Declining λ and Model-Implied Multipliers

This figure reports model-implied series computed snapshot-by-snapshot from the estimated model. Panel (a) plots the estimated structural parameters λ (bank lending elasticity), θ (bank funding share), and $\mathcal{A}_D$ (bank balance sheet expansion). Panel (b) plots the bank deposit and asset multipliers. The vertical line at 2012 marks the start of the post-Basel III regime.

(a) Structural Parameters λ, θ, and $\mathcal{A}_D$ (b) Credit-Deposit Multiplier Declines

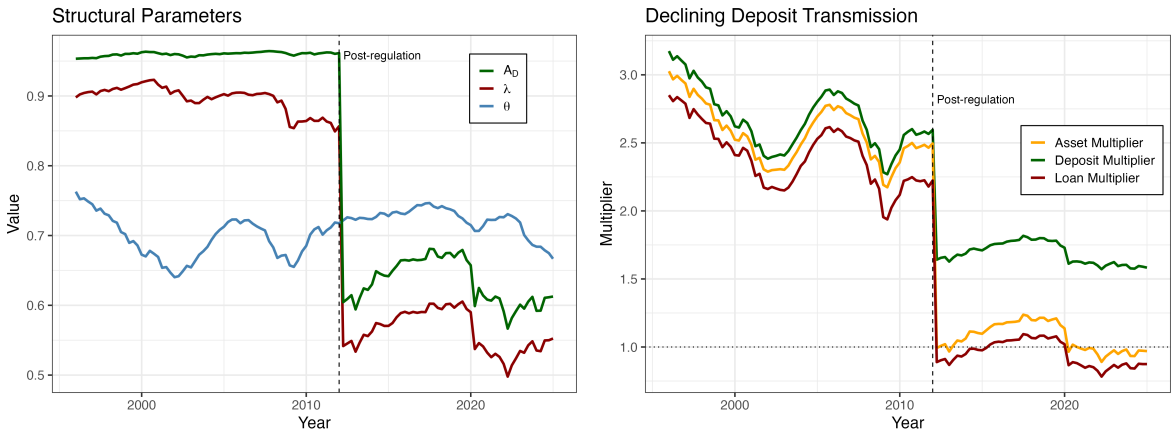


Figure 6 panel (a) plots the evolution of the three key objects that drive the deposit and asset multiplier. First, λ is displayed in red, and captures the extent to which banks expand lending in response to additional deposits. We see that λ fell from around .9 in the pre-regulation era to around .5 in the post regulation period, with movement in the intra-period being driven by regulatory slacks tightening and loosening. Thus, the passthrough of deposit shocks to lending fell by around 40% throughout the sample. Second, θ is displayed in blue, and captures the fraction of new funding that is retained in the banking system as deposits. The share of deposits held within the banking sector declined from over 75% to roughly 65% in 2009, recovered to 75% by 2016, and then fell again to about 65% by 2024. These cyclical shifts largely reflect changes in short-term interest rates (Drechsler et al., 2021a). Third, $\mathcal{A}_D$ is displayed in green,

and captures the marginal change in total bank assets per marginal dollar of deposits. We see that bank balance sheet expansion declines sharply in the post regulation period, consistent with increased costs of balance sheet expansion.

Next, Figure 6 panel (b) plots the evolution of the deposit multiplier in green and the asset multiplier in yellow. We see that the deposit multiplier in the early period is generally between 2.5 and 3, implying that an injection of one dollar of deposits into the banking system would increase its size by 2.5 to 3 dollars once we factor in the fact that lending creates additional deposits. Moreover, the deposit multiplier declines leading up the regulatory period, primarily because banks' share of the deposit market declined. Upon entrance into the constrained regulation period, we observe that the deposit multiplier falls further as both capital and liquidity regulation weigh on the degree to which banks transform deposits into loans. Moving to 2020, we observe that the deposit multiplier falls further. This is primarily a result of the influx of deposits into the banking system which tightened capital regulation (Koont and Walz, 2021).

Turning to the yellow line, we see that prior to the Basel III regulatory regime, the asset multiplier closely tracked the deposit multiplier, as wholesale funding only modestly offset deposit creation. Following the introduction of the new regulations, however, the asset multiplier declines sharply, reflecting tighter capital requirements and higher liquidity costs associated with wholesale funding, which lead banks to substitute away from wholesale liabilities when deposits expand. The multiplier falls further after 2020 as the QE-driven balance-sheet expansion tightens the capital constraint even more.

Last, in the red line, we observe the loan multiplier. This series indicates that each marginal dollar of deposits creates less than 1$ of loans by the end of the sample, down from between 2$ and 3$ in the earlier part of the sample.

6.2 What Drives the Strength of the Multiplier?

The previous section documented the historical evolution of the credit–deposit multiplier. We now turn to disentangling the underlying forces that drive this evolution in order to assess how the multiplier may evolve going forward as the structure of the financial system continues to change. In particular, we focus on the roles of the regulatory environment and competition from non-banks in both deposit and lending markets.

6.2.1 Regulatory Regime

We begin by examining the role of banks' regulatory environment. As shown in Figure 6, the stricter capital and liquidity requirements introduced under the Basel III regime sharply reduced banks' propensity to lend out new deposits (λ) and their overall balance-sheet expansion ($\mathcal{A}_D$). We now analyze the effect of each regulation in isolation to shed light on how future regulatory changes may influence the multiplier. Table 8 reports the key equilibrium objects, λ, θ, and $\mathcal{A}_D$, along with the equilibrium quantities implied by the credit–deposit multiplier. We compare three regulatory regimes: our baseline as of 2021Q4 under the Basel III regime, a regime with tighter capital requirements, and a regime with tighter liquidity requirements. We double the liquidity parameter ψ and the capital requirement κ in the tighter liquidity and tighter capital regimes, respectively.

Our tighter liquidity requirement raises the liquidity coverage ratio by increasing ψ, which governs the share of deposits that are considered runnable and therefore require backing with liquid assets. A higher ψ raises the effective liquidity cost of balance-sheet expansion, as banks must hold a larger share of low-yielding liquid assets against potential withdrawals. This reduces banks' willingness to transform new deposits into loans, lowering both λ and $\mathcal{A}_D$. As a result, equilibrium deposits are lower by 10%, loans by 26%. Economy-wide wealth falls by 10%.

Our tighter capital requirement raises κ, increasing the share of assets that must be funded with equity and sharply increasing the banking sector's cost of balance sheet expansion. This constraint dampens the multiplier by more than the heightened liquidity constraint, leading to a stronger contraction in balance-sheet amplification: both λ and $\mathcal{A}_D$ fall more severely. As a result, equilibrium deposit expansion is lower by 14%, loans by 40%, and economy-wide wealth

Table 8: Regulation Dampens Credit-Deposit Multiplier

This table compares the model-implied responses of bank balance sheet components to a tightening of liquidity and capital regulation to the baseline calibration. We double the liquidity parameter ψ and the capital requirement κ in the tighter liquidity and tighter capital regimes, respectively. We study the impact of a 1% of GDP liquidity injection in each scenario. The responses are computed using the baseline parameterization as of 2021Q4.

Scenario	θ	λ	$\mathcal{A}_D$	% of GDP: Δ D	Δ L	Δ W	Δ A	Economy: ΔW_d
$W_d \uparrow 1\%$ of GDP	0.73	0.51	0.59	1.15	0.59	-0.47	0.68	1.59
CF1: Tighter Liquidity	0.73	0.42	0.59	1.04	0.44	-0.42	0.62	1.43
CF2: Tighter Capital	0.73	0.36	0.37	0.99	0.36	-0.62	0.36	1.36

falls by 14%.

6.2.2 Non-bank Disintermediation in Deposit and Loan Markets

Table 9: Non-Bank Disintermediation Dampens Credit-Deposit Multiplier

This table compares the model-implied responses of bank balance sheet components in counterfactuals with greater presence of non-banks on either side of the bank balance sheet, relative to the baseline calibration. We study the impact of a 1% of GDP liquidity injection in each scenario. The responses are computed using the baseline parameterization as of 2021Q4.

Scenario	θ	λ	$\mathcal{A}_D$	% of GDP: Δ D	Δ L	Δ W	Δ A	Economy: ΔW_d
$W_d \uparrow 1\%$ of GDP	0.73	0.51	0.59	1.15	0.59	-0.47	0.68	1.59
CF1: Deposits -20% of GDP	0.54	0.61	0.75	0.81	0.50	-0.20	0.61	1.50
CF2: Loans -20% of GDP	0.73	0.41	0.58	1.03	0.42	-0.42	0.61	1.42

We next examine how the growing presence of non-bank intermediaries on both sides of banks' balance sheets affects the credit–deposit multiplier. Because the propagation of deposits and credit through the banking system relies on banks retaining deposits within the sector and transforming them into loans, it is natural to consider how changes in competition in deposit and lending markets alter this mechanism. Moreover, as banks lose market share to non-banks, a smaller fraction of funding circulates through the banking system's amplification process, which may have affects on the economy-wide multiplier of funding and credit.

We consider three scenarios: the baseline as of 2021Q4, greater non-bank competition in deposit markets, and greater non-bank competition in loan markets. Table 9 reports the key equilibrium objects, λ, θ, and $\mathcal{A}_D$, and the corresponding equilibrium quantities implied by the credit–deposit multiplier under each scenario. In addition, it reports the change in the market size of deposits, ΔW_d, which captures the change in the total supply of depositor wealth flowing through the banking system and therefore the extent to which banks remain central to economy-wide balance-sheet creation.

In our first counterfactual, we reallocate 20 percentage points of GDP in funding from bank deposits to money market funds, which lowers the bank deposit share from 0.73 to 0.54.[15] As a result, deposits recycle back into the banking system to a lesser extent, and equilibrium deposits are lower by 29.6% and loans by 15.2%. Moreover, the market-size of deposits is

[15]This translates into a reduction of 0.19 in θ due to the difference between the market size of deposits W_d relative to GDP.

lower by 5.6%, capturing that a smaller share of funding is being amplified through the banking system's multiplier, reducing the overall growth of money in the economy.

In our second counterfactual, we decrease the loans of the banking sector by 20 percentage points of GDP, increasing corporate bonds by that same amount. As a result, banks face more elastic loan demand and a different balance-sheet mix, and optimally choose a lower lending response to deposits. This lower pass-through from deposits to loans weakens the credit–deposit multiplier and reduces the impact of a given funding shock on bank lending and assets. As a result, deposits are lower by -10.4%, loans by 28.8%, and the economy-wide market-size of deposits by 10.7%.

7 Implications for Credit Cyclicality and Policy Transmission

7.1 Deposit Flows and Balance-Sheet Amplification

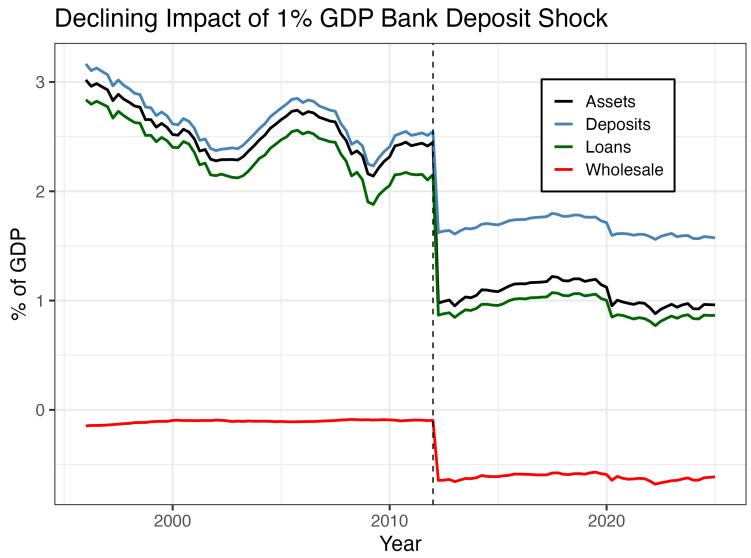
We next use the model to study how deposit flows shape bank balance sheets over time, which has implications for the cyclicality of credit expansion and safe asset creation. Deposit inflows arise naturally as the economy grows, with higher income, savings, and financial activity expanding the deposit base. They can also result from specific policy shocks. For instance, during the 2020 COVID crisis, the federal government distributed around $800B in stimulus checks to boost demand and help consumers. These payments were routed directly to the bank accounts of taxpayers, providing a real-world policy experiment for the deposit multiplier.

To illustrate how a deposit inflow propagates through the credit-deposit multiplier and affects equilibrium quantities, we study the impact of a sudden increase in deposits of 1% of GDP in the time series of our sample from 1995 to 2024. At each date, we evaluate the model at the realized quantities and interest rates, using these to recover the implied value of λ, θ, and $\mathcal{A}_D$, which jointly determine the equilibrium degree of balance-sheet amplification across loans, deposit, and wholesale funding. We display the model implied multipliers in Figure 7.

In the earlier part of the sample, a 1% deposit inflow would have increased total deposits by roughly 2–3%, with bank assets and loans expanding by slightly less. During this period, banks faced limited frictions in expanding their balance sheets, and liquidity costs remained modest, allowing deposit inflows to translate efficiently into both credit provision and deposit creation. In

Figure 7: Declining Impact of a 1% of GDP Depositor Wealth Injection

This figure shows the model-implied response of bank balance sheet components to a one-time 1% of GDP increase in depositor wealth. The figure reports the decomposition of the credit-deposit multiplier across loans, securities, and wholesale funding, using annual parameters estimated from 1995 to 2024.



the post-regulation period, however, the same 1% deposit inflow would have produced a smaller expansion: deposits would have risen by about 1.5%, and assets and loan growth by only around 1%, respectively, as banks substituted aggressively away from wholesale funding.

This shift implies that deposit inflows have become much less expansionary through the banking system, as tighter constraints and higher liquidity costs have weakened the feedback loop between funding, lending, and deposit creation. Consequently, both the cyclicality of credit and deposit expansion and the effectiveness of fiscal policy in stimulating aggregate demand are reduced when deposits no longer amplify as strongly through bank balance sheets. For instance, when the federal government injected roughly 4% of GDP into household bank accounts during the 2020 COVID stimulus, the transmission through the banking sector was substantially dampened. In earlier periods, such a large deposit inflow would have generated a much stronger credit expansion and likely greater inflationary pressure through the banking system's amplification mechanism.

7.1.1 Asymmetric Transmission of Funding Shocks

Next we study how the banking system responds asymmetrically to increases and decreases in deposit funding. In the model, these shocks correspond to changes in depositor wealth that shift funding between the banking and non-bank sectors. In practice, such deposit inflows can arise from fiscal stimulus, large-scale asset purchases (quantitative easing, QE), or a general expansion in economic activity. Conversely, outflows may reflect fiscal austerity, balance-sheet runoff (quantitative tightening, QT), or the contraction phase of a business cycle.

The connection to QE and QT arises because central bank balance-sheet policies alter the quantity of deposits and reserves in the financial system: QE injects deposits and reserves through asset purchases, while QT withdraws them. The model abstracts from price effects on securities and from differences in the stability of QE-related deposits, focusing instead on the deposit-creation channel and how such liquidity shocks affect bank lending capacity. More broadly, this exercise can be viewed as a stylized representation of the business cycle. During expansions, deposit inflows ease liquidity constraints and support credit growth, whereas during contractions, outflows tighten these constraints and amplify credit retrenchment. Examining the asymmetric responses to inflows and outflows therefore sheds light on why credit expansion in booms tends to be gradual, while contractions are often sharper and more destabilizing.

To illustrate how positive and negative funding shocks propagate through the credit-deposit multiplier and reshape equilibrium balance sheets, in Table 10 we simulate a 1% of GDP deposit inflow and outflow, and report the key equilibrium objects λ, θ, and $\mathcal{A}_D$, and the corresponding equilibrium quantities implied by the credit-deposit multiplier in the two scenarios. We conduct the experiment as of 2021Q4 to capture the influence of policy measures in a time characterized by large fiscal and monetary policy packages and high subsequent inflation.

Table 10: Negative Shocks Transmit More Than Positive Shocks

This table compares the model-implied responses of bank balance sheet components to a 1% of GDP liquidity injection and an equivalent liquidity withdrawal. The responses are computed using the baseline parameterization as of 2021Q4.

Scenario	θ	λ	$\mathcal{A}_D$	% of GDP: Δ D	Δ L	Δ W	Δ A	Economy: ΔW_d
$W_d \uparrow 1\%$ of GDP	0.73	0.51	0.59	1.15	0.59	-0.47	0.68	1.59
$W_d \downarrow 1\%$ of GDP	0.73	0.52	0.60	-1.16	-0.60	0.47	-0.69	-1.60

First, we observe that the share of bank deposits in both scenarios is the same at 73 percent, as it scales with the total supply of depositor wealth. Next, we observe in the second column that the propensity to lend out a marginal deposit, λ, is higher in absolute value in the austerity scenario. In the stimulus case, when deposits flow into the system, banks have ample funding and the marginal value of deposits is low, limiting the pass-through of new deposits into loans. In contrast, during an outflow, deposits become scarce and their marginal value rises, leading banks to contract lending more sharply. The response of the liquidity constraint depends on how the balance sheet adjusts: deposit inflows that are primarily transformed into new loans tighten liquidity slacks, whereas those absorbed as liquid assets loosen them.

Turning to balance-sheet quantities, the initial deposit injection creates a 1.59 percent of GDP increase in deposits and a .8 percent increase in loans, with wholesale funding falling. These effects are smaller in absolute value than under the austerity scenario, where the deposit outflow raises the shadow value of liquidity and produces a larger contraction in lending. We also observe in the final column that the total impact on economy-wide money supply is greater with the austerity policy as deposits become more scarce and constraints bind more tightly.

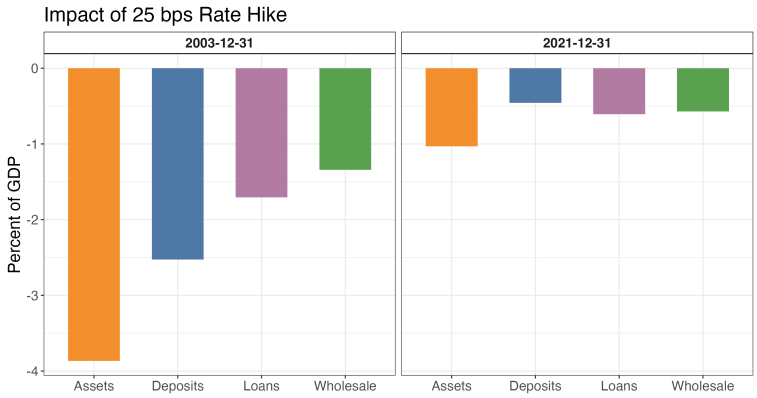
The asymmetry arises because both the capital and liquidity constraints are nonlinear in the relevant balance-sheet ratios. In the model, the regulatory costs of expansion increase steeply as capital or liquidity buffers shrink, but fall only gradually as they expand, generating asymmetric marginal responses to inflows and outflows. This curvature captures an important real-world feature of banking: balance-sheet expansion is tightly constrained by capital and liquidity requirements, while contraction is far less limited. In practice, when banks expand during booms, their assets grow faster than their equity and liquid reserves, causing capital and liquidity ratios to deteriorate and limiting further credit growth. During contractions, these ratios improve mechanically as balance sheets shrink, but funding becomes scarce and banks reduce lending to preserve liquidity, amplifying the downturn. Together, these dynamics imply weaker credit creation in booms and sharper deleveraging in recessions.

7.2 Monetary Policy Passthrough

Finaly, we use the model to quantify how changes in the policy rate affect bank balance sheets and credit. A change in the short-term interest rate r^S simultaneously shifts all three first-order conditions for deposits, loans, and wholesale funding. We study the impact of a 25 basis point

Figure 8: Impact of Monetary Policy Has Declined

The figure reports model-implied changes in deposits, loans, wholesale funding, and total assets following a 25 basis point policy rate increase, comparing pre-GFC (2003Q4) and post-GFC (2021Q4) banking sectors. The shock is introduced contemporaneously, with balance sheet quantities re-evaluated at the updated slacks in the second step of the simulation.



increase in the policy rate, implemented at time t, for two representative banking sectors: one calibrated to 2003Q4 (pre-GFC) and one to 2021Q4 (post-GFC). In the first step of the exercise, we evaluate the immediate change in balance sheet quantities using the system of first-order responses derived in Appendix A.2. Economically, this corresponds to the contemporaneous adjustment of deposit, loan, and wholesale funding rates to the policy shock. In the second step, we recompute the implied liquidity and capital slacks at the updated balance sheet position, capturing how constraints tighten as funding costs rise and balance sheet composition adjusts.

The pre-GFC banking sector is characterized by a lower liquidity requirement and an inactive capital constraint, while in the post-GFC period both wedges are present and more binding. As a result, banks in 2021Q4 face tighter limits on balance-sheet expansion and weaker passthrough of funding shocks. The same 25 basis point increase in the policy rate therefore produces a much smaller contraction in bank balance sheets than before the crisis. As shown in Figure 8, total assets fall by roughly 3–4 percent of GDP in 2003Q4 but by only around 1 percent in 2021Q4. Similarly, deposits and loans decline by more than 2 percent and 1.75 percent of GDP in 2003Q4, compared with less than 0.5 percent and 0.6 percent, respectively, in 2021Q4.[16] The decline in the responsiveness of deposits and loans mirrors the fall in the credit–deposit multi-

[16]We hold fixed the degree of passthrough from the policy rate to corporate bond yields, denoted by $\phi_{CB} = 0.09$. This assumption implies that approximately 9 percent of policy rate changes transmit to corporate borrowing costs, consistent with limited short-run passthrough in credit markets. Loan demand therefore shifts modestly relative to deposit and wholesale adjustments.

plier: with banks now more constrained by liquidity and capital requirements, policy-induced changes in funding conditions translate less into new lending and deposit creation. This muted balance-sheet response implies that monetary policy transmission through the banking system has become substantially weaker in the post-GFC period due to a decline in the credit-deposit multiplier.

8 Conclusion

This paper quantifies how bank deposit creation has changed over time and what that implies for macro transmission. Using plausibly exogenous shocks to depositor wealth, we document a pronounced decline in the credit–deposit feedback: before the financial crisis, each dollar of external deposits ultimately generated more than three dollars of total deposits; by the 2020s, the multiplier is close to one.

We interpret these facts using a structural model in which deposit creation arises from the joint determination of deposits and loans under capital and liquidity requirements. The model attributes the decline in the multiplier to tighter balance-sheet constraints and to a shrinking share of deposits intermediated by banks, rather than to changes in any exogenous market size. In our framework, three sufficient statistics summarize this amplification channel: the bank share on the funding side, the responsiveness of lending to marginal deposits, and the extent to which new deposits expand bank assets rather than substituting for other funding sources. All three emerge endogenously from regulatory slacks and portfolio composition. Counterfactuals that relax capital or liquidity wedges or increase banks' funding share materially strengthen the multiplier, while policies that reduce banks' footprint weaken it. The model also delivers asymmetric responses: equal-sized inflows and outflows of deposits generate different lending effects because the shadow value of funding is state dependent.

The continued growth of non-bank intermediation, such as the rise of stablecoins, would further attenuate both the banking multiplier and the economy-wide multiplier, since a smaller share of funding would pass through the banking sector's amplification mechanism. This highlights that reallocating money from banks to non-banks is not neutral: as banks become a smaller part of the financial system, deposit and credit creation become less responsive to underlying shocks. Conversely, easing regulatory constraints would increase the degree of amplification.

Taken together, our results show that the behavior of the credit–deposit multiplier, and therefore the transmission of both monetary and fiscal policy, depends critically on the competitive and regulatory structure of the banking sector and on banks' role in creating deposits.

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Appendix A.1 Model Derivation

A.1.1 Simple Version of Multiplier Example

Table A.1: Successive Rounds of Deposit Creation: Bank Balance Sheets

Bank 1: After Initial Deposit

Assets		Liabilities	
Cash	\$100	Deposits	\$100
Securities	\$100	Wholesale	\$100
	\$200		\$200

Bank 1: After Loan Origination

Assets		Liabilities	
Cash	\$20	Deposits	\$100
Securities	\$100	Wholesale	\$90
Loans	\$70		
	\$190		\$190

Bank 2: After Loan is Deposited

Assets		Liabilities	
Cash	\$80	Deposits	\$80
	\$80		\$80

Bank 2: After Loan Origination

Assets		Liabilities	
Cash	\$16	Deposits	\$80
Loans	\$64		
	\$80		\$80

Bank 3: After Loan is Deposited

Assets		Liabilities	
Cash	\$64	Deposits	\$64
	\$64		\$64

Bank 3: After Loan Origination

Assets		Liabilities	
Cash	\$12.8	Deposits	\$64
Loans	\$51.2		
	\$64		\$64

Table A.2: Banking Sector Totals After Each Step ($\lambda = 0.8,\ \theta = 1$)

Step	New Deposits	Total Deposits	New Loans	Total Loans
After Initial Deposit (Bank 1)	\$100	\$100	\$0	\$0
After Loan Origination (Bank 1)	\$0	\$100	\$80	\$80
After Loan Deposited (Bank 2)	\$80	\$180	\$0	\$80
After Loan Origination (Bank 2)	\$0	\$180	\$64	\$144
After Loan Deposited (Bank 3)	\$64	\$244	\$0	\$144

Next rounds continue with factors $\times\lambda = 0.8$ for loans and $\times\theta = 1$ for redeposits.

A.1.2 Bank First Order Conditions

$$\Pi = (r^{\ell} - r^{S})L \; + \; (r^{S} - r^{d})D \; - \; \frac{\kappa_W}{2}W^2 \; + \; \xi \ln\big(K\big) \; + \; \tau \ln\big(\Lambda\big) \tag{1}$$

Re-writing the capital and liquidity slack in terms of choice variables of the bank:

$$K \; = \; (1-\kappa)E \; - \; \kappa(D+W) \tag{2}$$

$$\Lambda = S - \chi(\psi D + W) = E - L + (1-\chi\psi)D + (1-\chi)W \tag{3}$$

A.1.2.1 Loan Rate r^{ℓ}

The total derivative of profits along bank's optimal responses:

$$\frac{d\Pi}{dr^{\ell}} = \frac{d\Pi}{dr^{\ell}} + \underbrace{\frac{d\Pi}{dW}}_{=0}\frac{dW}{dr^{\ell}} + \underbrace{\frac{d\Pi}{dr^{d}}}_{=0}\frac{dr^{d}}{dr^{\ell}} \tag{4}$$

Via the envelope theorem, the cross terms drop. Thus,

$$\begin{aligned}\frac{d\Pi}{dr^{\ell}} &= (r^{\ell} - r^{s})\frac{dL}{dr^{\ell}} + L + \tau\frac{1}{\Lambda}\frac{d\Lambda}{dL}\frac{dL}{dr^{\ell}} \\ &= (r^{\ell} - r^{s})\frac{dL}{dr^{\ell}} + L - \tau\frac{1}{\Lambda}\frac{dL}{dr^{\ell}}\end{aligned} \tag{5}$$

The first order condition sets this equal to zero, and we then solve for r^{ℓ}:

$$\begin{aligned}0 &= (r^{\ell} - r^{s})\frac{dL}{dr^{\ell}} + L - \tau\frac{1}{\Lambda}\frac{dL}{dr^{\ell}} \\ r^{\ell} &= r^{s} - \frac{L}{\dfrac{dL}{dr^{\ell}}} + \tau\frac{1}{\Lambda}\end{aligned} \tag{6}$$

We can then solve for $\dfrac{dL}{dr^{\ell}}$. First,

$$L(r^{\ell}) = s^{\ell}(r^{\ell})W^{\ell}, \tag{7}$$

where s^ℓ is the banking sector's loan share. Then,

$$\frac{dL}{dr^\ell} = W^\ell \frac{ds^\ell}{dr^\ell} \tag{8}$$

Where $s_\ell(r^\ell) = \frac{e^{\xi_\ell - \alpha_\ell r^\ell}}{1+e^{\xi_\ell - \alpha_\ell r^\ell}+e^{\xi_{nb} - \alpha_\ell r^{nb}}}$, let $\xi_\ell - \alpha_\ell r^\ell = v^\ell$

$$\frac{dL}{dr^\ell} = W^\ell \frac{ds^\ell}{dr^\ell} = W^\ell \frac{ds^\ell}{dv^\ell}\frac{dv^\ell}{dr^\ell} = \underbrace{W^\ell s^\ell}_{=L}(1-s^\ell)\frac{dv^\ell}{dr^\ell} = -\alpha^\ell(1-s^\ell)L \tag{9}$$

Substituting back in to the first order condition we recover the expression in the main text:

$$\begin{aligned} 0 &= (r^\ell - r^s)\frac{dL}{dr^\ell} + L - \tau\frac{1}{\Lambda}\frac{dL}{dr^\ell} \\ r^\ell &= r^s + \frac{1}{\alpha^\ell(1-s^\ell)} + \tau\frac{1}{\Lambda} \end{aligned} \tag{10}$$

A.1.2.2 Deposit Rate r^d

The total derivative of profits along bank's optimal responses:

$$\frac{d\Pi}{dr^d} = \frac{d\Pi}{dr^d} + \underbrace{\frac{d\Pi}{dW}}_{=0}\frac{dW}{dr^d} + \underbrace{\frac{d\Pi}{dr^\ell}}_{=0}\frac{dr^\ell}{dr^d} \tag{11}$$

Via the envelope theorem, the cross terms drop. Thus,

$$\begin{aligned} \frac{d\Pi}{dr^d} &= (r^s - r^d)\frac{dD}{dr^d} - D + \xi\frac{1}{K}\frac{dK}{dr^d} + \tau\frac{1}{\Lambda}\frac{d\Lambda}{dr^d} \\ &= (r^s - r^d)\frac{dD}{dr^d} - D + \xi\frac{1}{K}\frac{dK}{dD}\frac{dD}{dr^d} + \tau\frac{1}{\Lambda}\frac{d\Lambda}{dD}\frac{dD}{dr^d} \\ &= (r^s - r^d)\frac{dD}{dr^d} - D - \kappa\xi\frac{1}{K}\frac{dD}{dr^d} + \tau(1-\chi\psi)\frac{1}{\Lambda}\frac{dD}{dr^d} \end{aligned} \tag{12}$$

The first order condition sets this equal to zero, and we then solve for r^d:

$$\begin{aligned} 0 &= (r^s - r^d)\frac{dD}{dr^d} - D - \kappa\xi\frac{1}{K}\frac{dD}{dr^d} + \tau(1-\chi\psi)\frac{1}{\Lambda}\frac{dD}{dr^d} \\ r^d &= r^s - \frac{D}{\frac{dD}{dr^d}} - \kappa\xi\frac{1}{K} + \tau(1-\chi\psi)\frac{1}{\Lambda} \end{aligned} \tag{13}$$

Similarly to $\frac{dL}{dr^\ell}$ derived above, we have that $\frac{dD}{dr^d} = \alpha^d(1-s^d)D$ where there is now no negative sign due to depositor utility increasing in deposit rates. Thus, we recover the expression in the main text,

$$r^d = r^s - \frac{1}{\alpha^d(1-s^d)} - \kappa\xi\frac{1}{K} + \tau(1-\chi\psi)\frac{1}{\Lambda} \tag{14}$$

A.1.2.3 Wholesale Funding W

The total derivative of profits along bank's optimal responses:

$$\frac{d\Pi}{dW} = \frac{d\Pi}{dW} + \underbrace{\frac{d\Pi}{dr^d}}_{=0}\frac{dr^d}{dW} + \underbrace{\frac{d\Pi}{dr^\ell}}_{=0}\frac{dr^\ell}{dW} \tag{15}$$

Via the envelope theorem, the cross terms drop. Thus,

$$\frac{d\Pi}{dW} = -\kappa_W W - \kappa\xi\frac{1}{K} + \tau(1-\chi)\frac{1}{\Lambda} \tag{16}$$

The first order condition sets this equal to zero, and then we solve for W, recovering the expression in the main text:

$$\begin{aligned} 0 &= -\kappa_W W - \kappa\xi\frac{1}{K} + \tau(1-\chi)\frac{1}{\Lambda} \\ W &= \frac{\tau(1-\chi)}{\kappa_W\Lambda} - \frac{\xi\kappa}{\kappa_W K} \end{aligned} \tag{17}$$

A.1.3 Derivation of $\lambda = \frac{dL}{dD}$

In this section we derive the pass-through $\lambda = \frac{dL}{dD}$, the change in loans L generated by a marginal change in deposits D, evaluated at the bank's optimum. Three ingredients determine λ: the liquidity identity, the wholesale FOC, and the loan FOC.

We study small shocks around an interior optimum $x^* = (r_d^*, r_\ell^*, W^*, D^*, L^*)$. Given our functional forms, the objective and demand maps are C^1 on the domain $\{K > 0, \Lambda > 0\}$. We assume two regularity conditions at the evaluated point:

(i) **Interiority:** the optimum lies in the smooth region, with $K > 0$, $\Lambda > 0$, $W > 0$, and shares strictly in $(0, 1)$

(ii) **Nonsingular Jacobian:** the Jacobian of the stacked equilibrium system with respect to x is invertible.

Under (i)–(ii) the Implicit Function Theorem ensures a unique, differentiable local equilibrium map $x(z)$, so it is valid to take total differentials of the equilibrium system and solve for the local co-movements dx for any small driver z.[17] Thus, we take total differentials in turn of each of the model's key balance-sheet definitions and optimality conditions below to obtain the linearized relations among $(d\Lambda, dL, dD, dW)$.

$$\Lambda = E - L + (1 - \chi\psi)\, D + (1 - \chi)\, W, \qquad \text{(liquidity identity)} \tag{18}$$

$$K = (1 - \kappa)E - \kappa(D + W), \qquad \text{(capital identity)} \tag{19}$$

$$\kappa_W W = \frac{\tau(1 - \chi)}{\Lambda} - \frac{\xi\kappa}{K}, \qquad \text{(wholesale FOC)} \tag{20}$$

$$0 = \Big(r_\ell - r_S - \frac{\tau}{\Lambda}\Big)\frac{\partial L}{\partial r_\ell} + L, \qquad \text{(loan FOC)} \tag{21}$$

(a) Liquidity identity. Differentiating (18) gives,

$$d\Lambda = -\, dL + (1 - \chi\psi)\, dD + (1 - \chi)\, dW. \tag{22}$$

Intuitively, more loans tighten liquidity one-for-one, while deposits and wholesale funding relax it in proportion to their liquidity weights.

(b) Capital identity. Differentiating (19) gives,

$$dK = -\kappa(dD + dW). \tag{23}$$

Intuitively, each additional unit of funding that comes from deposits or wholesale liabilities must be supported by capital in proportion to the regulatory requirement κ. Hence, higher deposits or wholesale borrowing reduce available capital one-for-one (scaled by κ), while reductions in these liabilities free up capital capacity.

[17] For instance, a change in the policy r_S or a non-price deposit shifter Z that enters only the deposit demand identity $D = D^d(r_d, r_S; \theta_D, Z)$.

(c) Wholesale FOC. Differentiating (20) yields,

$$\kappa_W \, dW = -\frac{\tau(1-\chi)}{\Lambda^2} \, d\Lambda + \frac{\xi\kappa}{K^2} \, dK. \tag{24}$$

Substituting in dK from (23) and collecting terms,

$$\begin{aligned}
\kappa_W \, dW &= -\frac{\tau(1-\chi)}{\Lambda^2} \, d\Lambda + \frac{\xi\kappa}{K^2} \left(-\kappa dD - \kappa dW\right) \\
\kappa_W \, dW &= -\frac{\tau(1-\chi)}{\Lambda^2} \, d\Lambda - \frac{\xi\kappa^2}{K^2} dD - \frac{\xi\kappa^2}{K^2} dW \\
\left(\kappa_W + \frac{\xi\kappa^2}{K^2}\right) dW &= -\frac{\tau(1-\chi)}{\Lambda^2} \, d\Lambda - \frac{\xi\kappa^2}{K^2} \, dD. \\
dW &= -\frac{\tau(1-\chi)}{\Lambda^2} \, \frac{1}{\kappa_W + \xi\kappa^2/K^2} \, d\Lambda \; - \; \frac{\xi\kappa^2/K^2}{\kappa_W + \xi\kappa^2/K^2} \, dD,
\end{aligned} \tag{25}$$

Equation (25) shows how wholesale funding responds to shifts in liquidity and deposits. The denominators $\kappa_W + \xi\kappa^2/K^2$ represent the total marginal cost of raising wholesale funds, combining both the direct funding cost κ_W and the tightening of the capital constraint ($\xi\kappa^2/K^2$). A fall in liquidity slack Λ raises the shadow value of liquidity, captured by $-\frac{\tau(1-\chi)}{\Lambda^2} d\Lambda$, prompting the bank to increase W to its restore liquidity position. Conversely, when deposits expand, capital slack K shrinks, represented by $-\frac{\xi\kappa^2}{K^2} dD$, which reduces the incentive to borrow wholesale funding. Because both effects are scaled by the inverse of the total marginal cost, adjustments in W are more muted when wholesale funding is expensive or capital constraints are tight, and more elastic when these frictions are small. In equilibrium, the bank chooses dW so that the liquidity gains from higher funding exactly offset its marginal liquidity and capital costs.

(d) Loan FOC. We now differentiate (21). Define

$$\begin{aligned}
F(r_\ell, \Lambda) &\equiv \left(r_\ell - r_S - \frac{\tau}{\Lambda}\right) \frac{\partial L}{\partial r_\ell} + L = 0 \\
dF &= \frac{\partial F}{\partial r_\ell} dr_\ell + \frac{\partial F}{\partial \Lambda} d\Lambda = 0
\end{aligned} \tag{26}$$

Then we can compute each partial derivative that appears in (26).

$$\frac{\partial F}{\partial r_\ell} = \frac{\partial L}{\partial r_\ell} + \Big(r_\ell - r_S - \frac{\tau}{\Lambda}\Big)\frac{\partial^2 L}{\partial r_\ell^2} + \frac{\partial L}{\partial r_\ell}$$
$$\frac{\partial F}{\partial r_\ell} = 2\frac{\partial L}{\partial r_\ell} + \Big(r_\ell - r_S - \frac{\tau}{\Lambda}\Big)\frac{\partial^2 L}{\partial r_\ell^2} \tag{27}$$

And,

$$\frac{\partial F}{\partial \Lambda} = \frac{\tau}{\Lambda^2}\frac{\partial L}{\partial r_\ell}. \tag{28}$$

Substituting in these expressions into (26),

$$\Big[2\frac{\partial L}{\partial r_\ell} + \Big(r_\ell - r_S - \frac{\tau}{\Lambda}\Big)\frac{\partial^2 L}{\partial r_\ell^2}\Big]dr_\ell + \Big[\frac{\tau}{\Lambda^2}\frac{\partial L}{\partial r_\ell}\Big]d\Lambda = 0 \tag{29}$$

Substituting in the loan FOC (21), we arrive at,

$$\Big[2\frac{\partial L}{\partial r_\ell} - \frac{L}{\partial L/\partial r_\ell}\frac{\partial^2 L}{\partial r_\ell^2}\Big]dr_\ell + \Big[\frac{\tau}{\Lambda^2}\frac{\partial L}{\partial r_\ell}\Big]d\Lambda = 0 \tag{30}$$

We now use the fact that $L = L(r_\ell)$ and so $dL = \dfrac{\partial L}{\partial r_\ell}dr_\ell$ or equivalently, $dr_\ell = dL \cdot \Big(\dfrac{\partial L}{\partial r_\ell}\Big)^{-1}$, and plug this in to recover,

$$\Big[2\frac{\partial L}{\partial r_\ell} - \frac{L}{\partial L/\partial r_\ell}\frac{\partial^2 L}{\partial r_\ell^2}\Big]dL \cdot \Big(\frac{\partial L}{\partial r_\ell}\Big)^{-1} + \Big[\frac{\tau}{\Lambda^2}\frac{\partial L}{\partial r_\ell}\Big]d\Lambda = 0$$
$$\Big[2 - \frac{L}{(\partial L/\partial r_\ell)^2}\frac{\partial^2 L}{\partial r_\ell^2}\Big]dL + \Big[\frac{\tau}{\Lambda^2}\frac{\partial L}{\partial r_\ell}\Big]d\Lambda = 0 \tag{31}$$

Now we derive the partial derivatives that appear in equation (31). With $L = s_\ell(r_\ell)\, W_\ell$ and $ds_\ell/dr_\ell = -\alpha^\ell s_\ell(1 - s_\ell)$, the first derivative is

$$\frac{\partial L}{\partial r_\ell} = W_\ell \frac{ds_\ell}{dr_\ell} = -\,\alpha^\ell s_\ell(1 - s_\ell)\, W_\ell = -\,\alpha^\ell(1 - s_\ell)\, L. \tag{32}$$

And the second derivative is,

$$\begin{aligned}\frac{\partial^2 L}{\partial r_\ell^2} &= \frac{d}{dr_\ell}\Big[-\alpha^\ell(1-s_\ell)L\Big] = \alpha^\ell \frac{ds_\ell}{dr_\ell}L - \alpha(1-s_\ell)\frac{dL}{dr_\ell} \\ &= -(\alpha^\ell)^2 s_\ell(1-s_\ell)L + (\alpha^\ell)^2(1-s_\ell)^2 L \\ &= (1-2s_\ell)(1-s_\ell)(\alpha^\ell)^2 L \end{aligned} \tag{33}$$

We can use these to solve out for the following term that appears in the differential loan FOC (31),

$$\begin{aligned}2 - \frac{L}{(\partial L/\partial r_\ell)^2}\frac{\partial^2 L}{\partial r_\ell^2} &= 2 - \frac{(1-2s_\ell)(1-s_\ell)(\alpha^\ell)^2 L^2}{(\alpha^\ell)^2\,(1-s_\ell)^2\,L^2} \\ &= 2 - \frac{1-2s_\ell}{1-s_\ell} \\ &= \frac{2-2s_\ell-1+2s_\ell}{1-s_\ell} \\ &= \frac{1}{1-s_\ell} \end{aligned} \tag{34}$$

Plugging back in to the differential loan FOC (31),

$$\begin{aligned}\frac{1}{1-s_\ell}dL &= -\alpha^\ell(1-s_\ell)L\frac{\tau}{\Lambda^2}d\Lambda \\ dL &= \frac{\tau\alpha^\ell L}{\Lambda^2}(1-s_\ell)^2 d\Lambda \end{aligned} \tag{35}$$

This equation describes how lending L adjusts to small changes in liquidity slack Λ. When liquidity increases ($d\Lambda > 0$), the shadow cost of liquidity τ/Λ falls, lowering the effective cost of extending loans and inducing the bank to lend more. The Λ^2 term reflects the nonlinearity of the liquidity constraint: as liquidity tightens, its marginal value rises disproportionately, making loan supply highly sensitive to small changes in Λ. Economically, τ measures how binding the liquidity constraint is, while $1/\Lambda^2$ reflects its curvature. The responsiveness of lending also scales with $\alpha^\ell L(1-s)^2$: lending reacts more when loan demand is rate-sensitive (high α^ℓ), the bank's loan share s_ℓ is small (more market room to expand), or the loan book L is large.

(e) Combine to solve for λ. We now substitute dW from the differential of the wholesale funding FOC (25), into the differential of the liquidity identity (22).

$$\begin{aligned} d\Lambda &= -\,dL + (1-\chi\psi)\,dD + (1-\chi)\,dW \\ &= -\,dL + \Big[(1-\chi\psi) - (1-\chi)\frac{\frac{\xi\kappa^2}{K^2}}{\kappa_W + \frac{\xi\kappa^2}{K^2}}\Big]\,dD \;-\; (1-\chi)\frac{\tau(1-\chi)}{\Lambda^2}\,\frac{1}{\kappa_W + \xi\kappa^2/K^2}\,d\Lambda \end{aligned} \tag{36}$$

Isolating for $d\Lambda$,

$$\Big(1 + \frac{\tau(1-\chi)^2}{\Lambda^2}\frac{1}{\kappa_W + \xi\kappa^2/K^2}\Big)d\Lambda = -\,dL + \Big[(1-\chi\psi) - (1-\chi)\frac{\frac{\xi\kappa^2}{K^2}}{\kappa_W + \frac{\xi\kappa^2}{K^2}}\Big]\,dD$$

$$d\Lambda = \frac{-\,dL + \Big[(1-\chi\psi) - (1-\chi)\frac{\frac{\xi\kappa^2}{K^2}}{\kappa_W + \frac{\xi\kappa^2}{K^2}}\Big]\,dD}{\Big(1 + \frac{\tau(1-\chi)^2}{\Lambda^2}\frac{1}{\kappa_W + \xi\kappa^2/K^2}\Big)} \tag{37}$$

Then, we plug (37) into the differential loan FOC (35),

$$dL = \frac{\tau\alpha^\ell L}{\Lambda^2}(1-s_\ell)^2 \cdot \frac{-\,dL + \Big[(1-\chi\psi) - (1-\chi)\frac{\frac{\xi\kappa^2}{K^2}}{\kappa_W + \frac{\xi\kappa^2}{K^2}}\Big]\,dD}{\Big(1 + \frac{\tau(1-\chi)^2}{\Lambda^2}\frac{1}{\kappa_W + \xi\kappa^2/K^2}\Big)}$$

We simplify and re-arrange,

$$\Big(1 + \frac{\tau(1-\chi)^2}{\Lambda^2}\frac{1}{\kappa_W + \xi\kappa^2/K^2} + \frac{\tau\alpha^\ell L}{\Lambda^2}(1-s_\ell)^2\Big)dL = \frac{\tau\alpha^\ell L}{\Lambda^2}(1-s_\ell)^2\Big[(1-\chi\psi) - (1-\chi)\frac{\frac{\xi\kappa^2}{K^2}}{\kappa_W + \frac{\xi\kappa^2}{K^2}}\Big]\,dD$$

And simplify to arrive at the expression for λ in the main text,

$$\lambda = \frac{dL}{dD} = \frac{(1-\chi\psi) - (1-\chi)\frac{\xi\kappa^2/K^2}{\kappa_W + \xi\kappa^2/K^2}}{1 + \frac{1}{\alpha^\ell L(1-s_\ell)^2}\Big(\frac{\Lambda^2}{\tau} + \frac{(1-\chi)^2}{(\kappa_W + \xi\kappa^2/K^2)}\Big)} \tag{38}$$

A.1.4 Derivation of $\mathcal{W}_D = \frac{dW}{dD}$

We again study small shocks along an interior optimum x^*. We begin from (25), the differential form of the wholesale funding FOC, with the differential form of the capital identity substituted in. We then substitute in $d\Lambda$ from (37),

$$\begin{aligned}
\frac{dW}{dD} &= -\frac{\tau(1-\chi)}{\Lambda^2}\frac{1}{\kappa_W+\xi\kappa^2/K^2}\frac{d\Lambda}{dD} - \frac{\xi\kappa^2/K^2}{\kappa_W+\xi\kappa^2/K^2} \\
&= -\frac{\tau(1-\chi)}{\Lambda^2}\frac{1}{\kappa_W+\xi\kappa^2/K^2}\frac{\left[(1-\chi\psi)-(1-\chi)\frac{\frac{\xi\kappa^2}{K^2}}{\kappa_W+\frac{\xi\kappa^2}{K^2}}\right]-\lambda}{\left(1+\frac{\tau(1-\chi)^2}{\Lambda^2}\frac{1}{\kappa_W+\xi\kappa^2/K^2}\right)} - \frac{\xi\kappa^2/K^2}{\kappa_W+\xi\kappa^2/K^2} \\
&= \frac{-1}{\kappa_W+\xi\kappa^2/K^2}\Big(\frac{\tau(1-\chi)}{\Lambda^2}\frac{\left[(1-\chi\psi)-(1-\chi)\frac{\frac{\xi\kappa^2}{K^2}}{\kappa_W+\frac{\xi\kappa^2}{K^2}}\right]-\lambda}{\left(1+\frac{\tau(1-\chi)^2}{\Lambda^2}\frac{1}{\kappa_W+\xi\kappa^2/K^2}\right)} + \xi\kappa^2/K^2\Big)
\end{aligned}$$

To simplify the expression, we define several shorthands,

$$R \equiv \frac{\xi\kappa^2}{K^2}, \quad \Phi \equiv \kappa_W + R, \quad A \equiv \frac{\tau(1-\chi)}{\Lambda^2}, \quad a \equiv \frac{\tau(1-\chi)^2}{\Lambda^2}. \tag{39}$$

Then,

$$\begin{aligned}
\frac{dW}{dD} &= -\frac{1}{\Phi}\left(A\frac{\left[(1-\chi\psi)-(1-\chi)\frac{R}{\Phi}\right]-\lambda}{1+\frac{a}{\Phi}}+R\right) \\
&= -\frac{1}{\Phi}\left(A\left[(1-\chi\psi)-(1-\chi)\tfrac{R}{\Phi}-\lambda\right]\frac{\Phi}{\Phi+a}+R\right) \\
&= -\frac{1}{\Phi(\Phi+a)}\left(A\Phi\left[(1-\chi\psi)-(1-\chi)\tfrac{R}{\Phi}-\lambda\right]+R(\Phi+a)\right) \\
&= -\frac{1}{\Phi(\Phi+a)}\left(A\Phi(1-\chi\psi)-(1-\chi)AR-A\Phi\lambda+R\Phi+aR\right) \\
&= -\frac{1}{\Phi(\Phi+a)}\left(A\Phi(1-\chi\psi)-(1-\chi)AR-A\Phi\lambda+R\Phi+(1-\chi)AR\right) \\
&= -\frac{A(1-\chi\psi-\lambda)+R}{\Phi+a}
\end{aligned} \tag{40}$$

Thus we arrive at the expression for $\mathcal{W}_D$ in the main text,

$$\frac{dW}{dD} = -\frac{\frac{\tau(1-\chi)}{\Lambda^2}(1-\chi\psi-\lambda)+\frac{\xi\kappa^2}{K^2}}{\kappa_W+\frac{\xi\kappa^2}{K^2}+\frac{\tau(1-\chi)^2}{\Lambda^2}} \tag{41}$$

Appendix A.2 Derivation of Monetary Policy Passthrough

We now derive the local general equilibrium response of deposit quantities to a change in the policy rate r_S. First we start with the depositor demand function where r_S shows up in two places.

$$s_D(r_D, r_S) = \frac{e^{\xi_d+\alpha_d r_D}}{e^{\xi_d+\alpha_d r_D}+e^{\alpha_d r_S}+e^{\xi_C}}, \qquad s_M(r_S) = \frac{e^{\alpha_d r_S}}{e^{\xi_d+\alpha_d r_D}+e^{\alpha_d r_S}+e^{\xi_C}},$$

Differentiating produces the following

$$\frac{\partial D}{\partial r_D} = W^d \frac{\partial s_D}{\partial r_D} = \alpha_d W^d\, s_D(1-s_D) = \alpha_d D(1-s_D) \equiv a_D,$$

$$-\frac{\partial D}{\partial r_S} = -W^d \frac{\partial s_D}{\partial r_S} = \alpha_d W^d\, s_D s_M = \alpha_d D\, s_M \equiv b_D.$$

Hence the linearization of deposit demand around the equilibrium is

$$dD = a_D\, dr_D - b_D\, dr_S,$$

with elasticity form

$$\frac{a_D}{D} = \alpha_d(1-s_D), \qquad \frac{b_D}{D} = \alpha_d s_M.$$

Substituting into the GE pass-through system then delivers the deposit quantity response $\frac{dD}{dr_S} = a_D\,\beta - b_D$, where $\beta \equiv dr_D/dr_S$ is solved from the FOC-based Jacobian. Now, to pin down the β term, we move to the system of first-order conditions for deposits, loans, and wholesale funding:

$$F_1: \quad (r_S - r_D) - \frac{1}{\alpha_d(1-s_D)} + \tau(1-\chi\psi)\Lambda^{-1} - \xi\kappa K^{-1} = 0, \tag{42}$$

$$F_2: \quad (r_L - r_S) - \frac{1}{\alpha_l(1-s_{BL})} - \tau\Lambda^{-1} = 0, \tag{43}$$

$$F_3: \quad \kappa_W W - \tau(1-\chi)\Lambda^{-1} + \xi\kappa K^{-1} = 0, \tag{44}$$

where Λ and K denote the liquidity and capital slacks, respectively.

Taking total differentials around a steady-state interior optimum gives

$$d\Lambda = (1 - \chi\psi)dD + (1 - \chi)dW - dL, \tag{45}$$

$$dK = -\kappa(dD + dW), \tag{46}$$

and each FOC can be linearized in response to a small change in r_S.

Differentiating F_1 yields

$$dF_1 = (1 - \beta) - m_D\, dD - c_L(1 - \chi\psi)\, d\Lambda + g_K\, dK = 0, \tag{47}$$

where $m_D \equiv \partial[1/\{\alpha_d(1 - s_D)\}]/\partial D$, $c_L \equiv \tau/\Lambda^2$, and $g_K \equiv \xi\kappa/K^2$. Substituting for $d\Lambda$ and dK gives the partial coefficients on (dD, dL, dW) that enter the local Jacobian.

Analogously, linearizing F_2 and F_3 gives

$$dF_2 = (\ell - 1) - m_L\, dL + c_L\, d\Lambda = 0, \tag{48}$$

$$dF_3 = \kappa_W\, dW + c_L(1 - \chi)\, d\Lambda - g_K\, dK = 0, \tag{49}$$

where $m_L = \partial[1/\{\alpha_l(1 - s_{BL})\}]/\partial L$ and $\ell \equiv dr_L/dr_S$.

Collecting terms, the system can be written compactly as

$$J \begin{bmatrix} dr_D/dr_S \\ dr_L/dr_S \\ dW/dr_S \end{bmatrix} = -\,\mathbf{b}, \qquad J = \begin{bmatrix} F_{1,r_D} & F_{1,r_L} & F_{1,W} \\ F_{2,r_D} & F_{2,r_L} & F_{2,W} \\ F_{3,r_D} & F_{3,r_L} & F_{3,W} \end{bmatrix}, \tag{50}$$

which defines the local general equilibrium Jacobian. Solving for the vector of total derivatives yields the endogenous pass-through coefficients

$$\beta = \frac{dr_D}{dr_S}, \qquad \ell = \frac{dr_L}{dr_S}, \qquad \omega = \frac{dW}{dr_S}.$$

Given the local linearized demand $dD = a_D\, dr_D - b_D\, dr_S$, the total deposit response to a

one percentage point change in the policy rate is

$$\frac{dD}{dr_S} = a_D\,\beta - b_D. \tag{51}$$

In contrast a simpler multiplier formulation, this local-GE system allows r_S to affect deposits both directly (via b_D) and indirectly through the endogenous adjustments of loans and wholesale funding that enter Λ and K. This feedback term ensures that a rise in r_S tightens the funding constraint, reduces the shadow value of deposits, and generates a decline in deposit quantities.

Alternatively, a simpler multiplier model substitutes $d\Lambda = [(1-\chi\psi)+(1-\chi)w_D]\,dD$ and $dK = -\kappa(1+w_D)\,dD$, treating slack variables as functions of deposits alone. This collapses the general equilibrium system to a single deposit equation and replaces the full Jacobian with a scalar feedback coefficient Q. While analytically convenient, that approximation omits $\partial\Lambda/\partial r_S$ and $\partial K/\partial r_S$ terms coming from dW and dL, overstating pass-through and attenuating the negative response of deposits to r_S. The local-GE Jacobian therefore provides the correct first-order equilibrium mapping between the policy rate and funding quantities.

Appendix A.3 Figures and Tables

Figure A.1: Model Implied Structural Parameters

The figure plots the implied slacks (K_t, Λ_t). The vertical line at 2012Q1 marks the start of the post-reform regime. Lower values indicate tighter constraints (larger wedges/slacks), conditional on the level of the capital and liquidity constraint severity parameters ξ, τ.

