

Ample Reserves for Whom?

The Role of Foreign Banks in U.S. Monetary Policy Implementation*

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Abstract

This paper studies how foreign banks shape reserve demand and the limits of balance-sheet normalization under the Federal Reserve’s ample-reserves framework. Although foreign banks account for a modest share of U.S. banking activity, they hold a disproportionate share of reserve balances. Reserve adjustment is asymmetric across policy phases: foreign banks absorb a large share of reserve inflows during quantitative easing (QE), but do not shed reserves symmetrically during quantitative tightening (QT), thereby shifting the adjustment mainly to large domestic banks. We trace this asymmetry to foreign banks’ distinctive institutional structure: they face different balance-sheet costs from domestic banks and manage global dollar liquidity through internal capital markets. Our heterogeneous reserve-demand model motivated by these empirical findings shows that foreign banks’ demand raises the minimum supply of reserves needed to maintain an ample-reserves regime, limiting how far the Federal Reserve can shrink its balance sheet.

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1 Introduction

How far can central banks shrink their balance sheets after quantitative easing (QE)? Central banks responded to the 2008 global financial crisis and the COVID-19 crisis in 2020 by purchasing large quantities of securities to support economic activity. These purchases expanded central banks’ balance sheets to unprecedented levels. In the U.S., the Federal Reserve’s assets grew from about \$870 billion, or 6 percent of GDP, in August 2007 to \$8.7 trillion, or 33 percent of GDP, in March 2023 (Figures 1 and 2). Retaining a large portfolio of long-term securities exposes the Fed to interest-rate risk (Hall and Reis, 2015). A large balance sheet may also leave the Fed with less room to respond to future recessions through QE (Anderson et al., 2026). Recent research suggests that large-scale asset purchases may also impair market functioning and make bond prices less informative about economic fundamentals (Neuhann and Sockin, 2024; Fontanier, 2026). Yet how far this expansion can be reversed through quantitative tightening (QT) remains an open policy question. New Fed Chair Kevin Warsh has advocated a smaller balance sheet and, in July 2026, announced a task force to review the Fed’s balance sheet policy.¹

The answer depends on banks’ demand for reserves. Reserves are the cash balances banks hold at the Fed to settle payments, store value, and meet regulatory liquidity requirements. The Fed primarily conducts monetary policy by setting a target range for the federal funds rate—the market interest rate banks pay on unsecured overnight borrowing of reserves. The Fed financed its QE asset purchases by creating reserve balances, which are assets for banks and liabilities for the Fed. As the Fed reduces its securities holdings through QT, the supply of reserves falls. If reserves become scarce, banks’ willingness to pay higher rates for borrowing can push the federal funds rate above the upper bound of its target range. Banks’ demand for reserves therefore constrains how far the Fed can shrink its balance sheet while keeping the federal funds rate within its target range. Yet how many reserves the Fed must supply to keep this rate within its target range remains uncertain (Powell, 2019). A growing literature studies what determines banks’ demand for reserves and how this demand shapes the scope for QT (e.g., Acharya et al., 2023; Acharya and Rajan, 2024; Afonso et al., 2023, 2025c; Copeland et al., 2025; Lopez-Salido and Vissing-Jorgensen, 2025).

This paper shows how foreign banks’ demand for reserves affects how far the Fed can shrink its balance sheet. We uncover a striking fact that has received limited attention in the literature: foreign banks operating in the U.S. hold disproportionately large reserve balances, at times exceeding the amount held by domestic banks. Foreign banks’ share of total reserves rose sharply after the Global Financial Crisis and has at times approached or exceeded 50 percent since 2008.

¹ “*Federal Reserve announces the leadership and objectives of its task forces to advance the conduct of monetary policy*”—Board of Governors of the Federal Reserve System (July 2026).

This reserve share far exceeds their share of other balance sheet components: foreign banks account for only about 10 to 25 percent of U.S. bank assets, deposits, and loans (Figure 3).

Foreign banks are not only large reserve holders; they also respond differently to changes in reserve supply during QE and QT. During QE, foreign banks absorb a large share of increases in reserve supply and exhibit the most price-elastic demand for reserves. During QT, foreign banks account for a smaller share of reserve reductions: the reductions fall more heavily on domestic banks, particularly large banks. These findings suggest that QT cannot simply reverse the pattern of reserve accumulation during QE, as foreign banks retain substantial reserve balances during QT.

Why do foreign banks hold such large reserve balances, and why do their holdings adjust differently from those of domestic banks during QE and QT? Our evidence links foreign banks' greater price responsiveness than domestic banks during QE to arbitrage incentives, and their persistent reserve holdings during QT to continuing dollar liquidity needs. Consider a European banking group whose U.S. offices hold reserves at the Fed while its offices around the world lend dollars. The group reallocates funding among these offices through its internal capital markets. Regulatory differences can make expanding its U.S. balance sheet less costly than for domestic banks. Its U.S. offices can profit from borrowing dollars and holding reserves when the interest paid by the Fed exceeds their funding and balance sheet costs, expanding these reserve holdings as this arbitrage becomes more profitable. Suppose the bank also expands its dollar lending by offering a credit line to a firm in Brazil. This creates demand for readily available dollars to meet a future drawdown. With less access to stable dollar deposits than domestic banks, the bank may hold reserves to avoid relying on wholesale borrowing or costly FX swaps at short notice (Ivashina et al., 2015; Aldasoro et al., 2022; Khetan, 2026). The credit line can remain available during QT even as arbitrage profits decline. As the bank's reserves fall relative to its outstanding dollar credit lines, further reductions leave the European bank more exposed to costly borrowing when customers draw on those lines. The bank can therefore become less willing to reduce its holdings even while retaining substantial reserves. Consistent with this precautionary liquidity channel, we find that precommitted dollar credit lines are more strongly associated with subsequent reserve accumulation at foreign banks than at domestic banks. Our findings add an international dimension to existing work on domestic liquidity claims that expand during QE and persist during QT (Acharya et al., 2023; Acharya and Rajan, 2024).

Foreign banks' persistently high demand for reserves can limit how far the Fed can shrink its balance sheet, even when aggregate reserve balances remain large. If banks had homogeneous reserve demand and reserves could be frictionlessly reallocated through money markets, the aggregate quantity would be sufficient to assess how further balance sheet reductions would affect the federal funds rate. In practice, reserve demand is heterogeneous, holdings are highly

concentrated, and money markets are segmented. When foreign banks retain reserves to support their global dollar lending, reserve reductions during QT fall more heavily on domestic banks. As domestic banks’ reserve balances decline toward the amounts needed for purposes such as payments and settlement, rising demand to borrow reserves can push the federal funds rate above the upper bound of its target range. Foreign banks’ high demand may therefore leave the Fed with a larger balance sheet and more reserves on which it pays interest, even when domestic banks’ underlying reserve demand remains unchanged. Under the Fed’s current monetary policy implementation framework, an increase in foreign banks’ reserve demand may, all else equal, require additional asset purchases to keep the federal funds rate within its target range. Foreign banks’ reserve demand can also change for reasons beyond the Fed’s direct control, including shifts in their home countries’ monetary policies, changes in home-country regulations, and changes in the dollar’s role as a global currency.²

We begin by presenting three sets of empirical results. First, we document foreign banks’ disproportionately large reserve holdings and an asymmetry in how foreign and domestic banks adjust their reserves during QE and QT. Exploiting high-frequency fluctuations in the Treasury cashflow (Treasury General Account, TGA) as plausibly exogenous supply shocks to reserves, we find that foreign banks are an especially elastic reserve-demand margin during QE. During reserves expansion, foreign banks’ reserve demand is approximately 2.3 times as elastic as that of domestic banks with respect to the spread between the federal funds rate (volume-weighted average) and interest on reserves (FFR–IOR). During QT, however, this difference disappears: the estimated elasticities of foreign and domestic banks are of the same order of magnitude, and their difference is not statistically significant at the 5 percent level. The additional evidence exhibits the same asymmetry: foreign banks absorb a large share of reserve inflows during QE, but they do not release reserves symmetrically during QT. Instead, the burden of adjustment shifts toward domestic institutions, especially large domestic banks, with the Overnight Reverse Repurchase facility (ONRRP) also explaining part of the post-2013 adjustment.

Second, we show that the majority of foreign-bank reserves are booked at U.S. branches and agencies, which face different regulatory constraints from domestic banks and are closely linked to their parent banks’ global businesses through internal capital markets. Branches and agencies are legal extensions of their foreign parents, whereas subsidiaries are stand-alone U.S. entities with their own capital. Because branches and agencies are not separately capitalized in

²For instance, European supervisors have recently asked banks to assess their reliance on short-term dollar funding and their ability to withstand disruptions in dollar markets. These requests may encourage banks to hold larger precautionary dollar liquid assets. *“European banks exposed to risk of US dollar shortfall, says EU watchdog”*—Financial Times (April 2025); *“Bank of England scrutinizes lenders for dollar risk amid Trump worries, sources say”*—Reuters (July 2025); and *“Geopolitical turbulence may test euro area banks’ forex funding, risk body warns”*—Reuters (January 2026).

the United States, they face fewer U.S.-level capital and leverage constraints. Their access to funding from the internal capital markets also distinguishes how they finance reserve holdings. We find that reserve changes at foreign branches and agencies are matched primarily by changes in funding from internal capital markets and wholesale markets, whereas reserve changes at domestic banks are matched primarily by changes in domestic deposits.

These institutional features shape foreign banks’ distinct reserve demand through two channels with different adjustment horizons: the arbitrage channel and the global dollar liquidity channel. The arbitrage channel operates when the interest rate on reserves (IOR) exceeds the combined costs of dollar funding and balance sheet costs (e.g., Bech and Klee, 2011; Keating and Macchiavelli, 2017; Banegas and Tase, 2020; Correa et al., 2025; Anderson et al., 2025; Anbil et al., 2026b). Lower regulatory balance sheet costs make foreign banks particularly well positioned to profit from this arbitrage. The global dollar liquidity channel arises because reserves held in the United States provide readily available dollars for the parent organization’s global dollar intermediation. Non-U.S. banks’ global dollar assets have grown to nearly \$18 trillion as of the first quarter of 2025. These exposures create precautionary dollar liquidity demand against funding disruptions and credit-line drawdowns. The post-crisis introduction of the Liquidity Coverage Ratio (LCR) reinforces the demand for dollar liquid assets, including reserves, by requiring buffers against stressed cash outflows (BCBS, 2013). Outstanding dollar exposures and credit lines can therefore sustain reserve demand even as arbitrage profits decline. Both channels can affect the same reserve holdings, but they imply different patterns of adjustment over time. We examine these differences using foreign banks’ temporary balance sheet reductions around quarter-end reporting dates, often called “window dressing.” The magnitude of the temporary reserve holdings reduction tracks short-run arbitrage incentives and narrows sharply during QT. Yet quarter-end reserve holdings remain high and persistent even as arbitrage spreads shrink. These patterns are consistent with an arbitrage channel that drives short-run reserve adjustments alongside a global dollar liquidity channel that sustains reserve holdings over time.

Third, we show that foreign banks with larger global dollar lending exposures accumulate more reserves at their U.S. branches and agencies. Using BIS banking statistics, we find that a 10 percent larger dollar-asset stock is associated with 1.4–2.4 percentage points higher reserve holdings. This evidence suggests that reserves held in the United States support foreign banks’ broader dollar activities. At the bank level, we find a stronger association between outstanding dollar credit lines and reserve accumulation for foreign banks than for domestic banks. Using DealScan, we reconstruct outstanding revolving credit lines for 495 domestic banking organizations and 49 foreign banking groups and match them to U.S. reserve holdings. Revolving credit lines provide a useful test of precautionary liquidity demand: borrowers choose when to draw, while lenders must stand ready to supply dollars. We measure dollar credit lines

across the global banking group; the credit lines need not be booked at the offices holding those reserves. A 10 percent larger stock of dollar credit lines is associated with 1.4–1.8 percentage points higher reserve growth at foreign banks.

Several additional tests support this precautionary liquidity interpretation. If reserves at U.S. branches help cover the parent bank’s dollar credit lines, the relationship should be weaker at subsidiaries, which have their own capital and funding. We find smaller and statistically insignificant estimates for subsidiaries. The precautionary motive also predicts a stronger relationship when lenders expect fewer deposit inflows to offset drawdowns. Consistent with this prediction, the association is stronger for nonlead lenders, which are less likely than lead arrangers to receive borrowers’ deposits when credit lines are drawn. Finally, liquidity needs should persist as long as borrowers retain the right to draw. The relationship extends to credit lines originated in earlier quarters and remains strong during QT. These findings suggest that foreign banks retain reserves against continuing dollar credit lines even as the Fed shrinks its balance sheet and reserve arbitrage becomes less profitable.

Building on our empirical findings, we develop a model of heterogeneous reserve demand based on Poole (1968). The model captures the nonlinear shape of foreign banks’ reserve demand through their arbitrage and liquidity motives. When reserves are abundant, foreign banks’ lower balance-sheet costs make reserve arbitrage attractive, and their holdings respond elastically to changes in arbitrage returns. As aggregate reserves decline, meeting global dollar liquidity needs becomes the main reason for retaining reserves. These holdings are less sensitive to interest rate changes: reducing the reserve holdings leaves foreign banks more reliant on costly wholesale funding when borrowers draw on credit lines. Reserve demand therefore becomes steeper as aggregate reserve supply falls. This mechanism explains how foreign banks can absorb substantial reserve inflows during balance-sheet expansion yet retain large balances during contraction, shifting more of the adjustment toward domestic banks.

Global dollar lending strengthens this liquidity motive and limits how far the Fed can shrink its balance sheet. Greater dollar lending increases the reserves foreign banks want to retain against potential drawdowns, raising aggregate reserve demand even when domestic banks’ liquid deposits remain unchanged. Our model suggests that the Fed needs to supply more reserves to control the monetary policy rate. With other Fed liabilities and policy arrangements fixed, this leaves less room for balance-sheet contraction.

Taken together, our findings contribute to understanding how global dollar intermediation shapes U.S. reserve demand and thereby affects how far the Fed can shrink its balance sheet. Foreign banks’ global dollar lending can sustain demand for reserves even as the Fed reduces its securities holdings. How far the Fed can shrink its balance sheet therefore depends partly on global banking conditions, even when domestic banks’ reserve demand remains unchanged.

The paper proceeds as follows. Section 2 reviews the related literature. Section 3 provides institutional background on the Fed’s balance sheet and monetary policy implementation. Section 4 documents the data. Section 5 presents differences in reserve adjustment across bank types and between QE and QT. Section 6 examines how regulation and funding shape foreign banks’ reserve demand. Section 7 investigates the connection between reserve demand and global dollar intermediation. Section 8 develops the model and assesses its policy implications. Section 9 concludes.

2 Related Literature

This paper contributes to several strands of the macro-finance literature on reserve demand, global banking, and market macrostructure.

First, this paper contributes to the literature on reserve demand and monetary policy implementation.³ Lopez-Salido and Vissing-Jorgensen (2025) and Afonso et al. (2025b) estimate aggregate reserve demand and its implications for balance sheet reduction. Estimates of aggregate reserve demand leave open how changes in reserve supply are distributed across banks. Existing work examines reserve accumulation across banks during the early rounds of QE (Ennis and Wolman, 2015) and differences in the supply of federal funds across bank and nonbank lenders (Anbil et al., 2026b). Armenter and Lester (2017) study interest-rate control with abundant reserves. Related research studies payment needs and banks’ liquidity management (Yang, 2020; Afonso et al., 2022b; Bianchi and Bigio, 2022; Goldstein et al., 2023; Copeland et al., 2025; Li et al., 2026), and uncertainty about reserve demand (Afonso et al., 2023). Our findings also complement research on liquidity creation, funding fragility, and liquidity risk associated with balance-sheet expansion (Acharya et al., 2023; Acharya and Rajan, 2024; Blickle et al., 2025; Darst et al., 2025; Dubois and Rintamäki, 2025). We contribute by showing how the distribution of reserve adjustment between foreign and domestic banks changes between QE and QT. Foreign banks absorb a large share of reserve increases during QE but account for a smaller share of reserve reductions during QT, even as their holdings remain substantial. We connect this asymmetry to foreign banks’ global dollar exposures, identifying an international source of persistent reserve demand and showing how its expansion can constrain balance-sheet reduction even when domestic banks’ reserve demand is unchanged.

Second, we contribute to research on global banks’ dollar lending and funding, and the transmission of monetary conditions across countries and within banking organizations (Cetorelli and Goldberg, 2011, 2012a,b; Schnabl, 2012; McCauley and McGuire, 2014; Bruno and Shin, 2015a,b; Kerl and Niepmann, 2015; Temesvary, 2018; Kalemli-Özcan, 2019; Bräuning and

³Appendix A4. discusses the institutional structure of the federal funds market and the related literature.

Ivashina, 2020; Doerr and Schaz, 2021; Correa et al., 2022; Eguren-Martin et al., 2024). Related research examines how regulation, bank characteristics, and financial and geopolitical risks shape cross-border banking (Berrospide et al., 2017; Morelli et al., 2022; Niepmann, 2023; Niepmann and Shen, 2025). Recent work also studies liquidity transfers and balance-sheet connections within banking organizations (Bai et al., 2026; Giannetti et al., 2026; Cetorelli and Kundu, 2026). Research on short-term dollar markets examines how regulatory and funding costs shape arbitrage incentives (Keating and Macchiavelli, 2017; Du et al., 2018; Banegas and Tase, 2020; Rime et al., 2022; Anderson et al., 2025). Correa et al. (2025) connect reserves to banks’ provision of liquidity in global dollar markets, in particular in the FX swap market. We extend this evidence by linking foreign banks’ reserve holdings to their worldwide dollar assets and precommitted credit lines. The stronger association between precommitted credit lines and subsequent reserve accumulation at foreign banks than at domestic banks is consistent with a greater precautionary role for reserves in foreign banks’ dollar lending. This connection provides an explanation for why foreign banks retain substantial reserves during QT even as arbitrage incentives weaken. Our credit-line evidence connects this international dimension to banks’ provision of liquidity insurance (Kashyap et al., 2002; Gatev and Strahan, 2009; Gatev et al., 2009; Cooperman et al., 2025) and the distribution of syndicated loans across lenders (Blickle et al., 2026). Studies of global dollar funding show how reliance on wholesale borrowing and FX swaps exposes foreign banks to funding disruptions and higher funding costs (Ivashina et al., 2015; Correa et al., 2021; Aldasoro et al., 2022; Khetan, 2026). Complementary work studies central-bank liquidity lines as a source of international liquidity insurance (Bahaj and Reis, 2022; Bahaj et al., 2026). We examine the reserves banks hold against continuing dollar credit lines.

Finally, we contribute to the literature on market macrostructure, which examines how institutions’ objectives and constraints shape asset demand and prices (Haddad and Muir, 2025).⁴ We apply this perspective to reserves, which are assets for banks and liabilities of the Fed. Foreign banks have at times been the largest investor group in these liabilities, holding more reserves than domestic banks combined. Our model shows how differences in banks’ willingness to adjust their reserve holdings affect the interest-rate consequences of balance-sheet reduction. Research on institutional demand, market segmentation, and limited arbitrage emphasizes how investor characteristics shape asset prices (Duffie, 2010; Krishnamurthy and Vissing-Jorgensen, 2012; Greenwood and Vayanos, 2014; Greenwood et al., 2018; Vayanos and Vila, 2021). Empirical studies examine portfolio rebalancing and investor demand for liquidity following asset purchases (Carpenter et al., 2015; Selgrad, 2023; Corell et al., 2025), and how investor composition affects the absorption of bond supply and the response of yields (Fang et al., 2025; Fang and Xiao,

⁴Appendix A5. discusses the broader academic and policy debate over the size and composition of the Fed’s balance sheet.

2025; Chaudhary et al., 2026; Eren et al., 2026; Jansen et al., 2026; Takahashi, 2026). Research on the pricing effects of central-bank balance-sheet policies examines how asset purchases and balance-sheet reduction affect interest rates (Krishnamurthy and Vissing-Jorgensen, 2011; D’Amico and King, 2013; Smith and Valcarcel, 2023; D’Amico and Seida, 2024; Du et al., 2026). These effects also depend on expectations of future intervention, including state-contingent asset purchases (Haddad et al., 2025a,b). Complementary work connects reserve supply to bank lending (Diamond et al., 2024) and examines how intermediation constraints shape Treasury-market functioning (Vissing-Jorgensen, 2021; He et al., 2022; d’Avernas et al., 2025). Foreign banks retain large reserve balances during QT while accounting for a smaller share of reserve adjustment than during QE. Their importance for aggregate reserve demand therefore depends on both how much they hold and how readily they adjust their holdings, with implications for how far the Fed can shrink its balance sheet.

3 Brief Overview of the Monetary Policy Implementation Framework

The surge in reserve supply since the Global Financial Crisis led to a fundamental shift in the Fed’s monetary policy framework. The Fed introduced interest on reserves (IOR) in October 2008, marking the transition to a floor system with ample supply of reserves.⁵ Under this system, IOR was intended to serve as the effective lower bound for the federal funds rate (FFR), as banks would have no incentive to lend at rates below the risk-free IOR. The mechanics of the ample-reserves system, compared to the scarce-reserves system, were expected to provide more reliable control over short-term rates (Mester, 2024). In January 2019, the Fed announced that it would continue operating under an ample-reserves regime.⁶ In March 2020, the Fed eliminated reserve requirements, setting them to zero.

Although IOR was intended to act as a floor, the FFR has persistently traded below IOR since its introduction. This deviation stems largely from Government-Sponsored Enterprises (GSEs), which may hold reserves at the Fed but are ineligible to earn interest on reserves. The Federal Home Loan Banks (FHLBs), in particular, face liquidity requirements that encourage them to lend excess balances below IOR, effectively pushing down the FFR (Gissler and Narajabad, 2025). This structural feature of the market has persistently weakened the transmission of IOR to short-term rates, keeping the FFR below IOR and creating challenges for the Fed’s monetary policy implementation.⁷ Responding to the leaky floor, the Fed implemented several

⁵For historical background, see Appendix A4.

⁶The FOMC stated that an ample supply of reserves would allow control of short-term interest rates to be exercised “primarily through the setting of the Federal Reserve’s administered rates,” with “active management of the supply of reserves” no longer required. See *Statement Regarding Monetary Policy Implementation and Balance Sheet Normalization* (January 30, 2019).

⁷For further details on the intraday federal funds dynamics, see Appendix A4. and Bech and Klee (2011);

measures to complement the floor system. First, in 2013, the Fed launched the Overnight Reverse Repurchase Agreement (ONRRP) facility, allowing non-bank entities including GSEs and money market mutual funds (MMFs) to access Fed’s liabilities. By providing an alternative investment option to a wider set of counterparties, the ONRRP helped establish a firmer lower bound on short-term rates. However, this facility alone was not sufficient to prevent rate spikes in times of stress.

In September 2019, a series of factors (e.g., corporate tax payment deadline and unusually large settlement of Treasury securities) triggered severe dislocations in the money market, exposing fragilities in the ample reserves framework (Anbil et al., 2020; Kahn et al., 2023). Reserves had been steadily declining due to the Fed’s QT, leaving banks less willing to lend in overnight markets. These pressures culminated in a sharp and unexpected spike in money market rates, with overnight borrowing costs surging well above the Fed’s target range. The episode underscored the limitations of the floor system in an environment where reserves, though still ample in aggregate, were unevenly distributed across institutions.⁸

Reserve demand, together with episodes of money market stress, has become a central consideration in determining the extent of the Federal Reserve’s balance sheet normalization. While various tools have helped limit volatility in the FFR, fragilities remain. The recurring volatilities in the short-term rate markets suggest the limits of relying solely on administered rates, highlighting the interrelationships between reserves, policy tools, and the evolving structure of funding markets (Duygan-Bump and Kahn, 2026).

Therefore, assessing reserve ampleness is an ongoing task for monetary policy implementation. In October 2024, the New York Fed began publishing the Reserve Demand Elasticity (RDE), which measures the sensitivity of the federal funds rate to changes in aggregate reserves and provides a real-time assessment of reserve ampleness (Afonso et al., 2025b). The RDE summarizes aggregate rate sensitivity without separately identifying the contributions of different types of banks. Our analysis provides a complementary perspective by examining how institutional structure and global dollar intermediation shape foreign banks’ reserve holdings. Understanding these sources of demand helps explain why reserve positions can persist during balance-sheet normalization and how the composition of reserves evolves as aggregate supply declines.

The reserve level consistent with ample conditions (the lowest comfortable level of reserves, LCLOR) can also evolve as banks’ liquidity needs, funding structures, and regulatory constraints

Gissler and Narajabad (2025).

⁸In response, the Fed introduced the Standing Repo Facility (SRF) for primary dealers in 2021, designed to stabilize short-term funding markets by offering eligible banks and primary dealers access to secured borrowing against high-quality collateral like Treasury securities. The SRF is intended to act as an automatic stabilizer, ensuring that liquidity shortages do not lead to disorderly increases in borrowing costs. By creating a mechanism through which the Fed can directly inject liquidity into the repo market, the SRF was intended to improve rate control and reduce the likelihood of extreme funding pressures disrupting monetary policy implementation.

change. For instance, these estimates have steadily increased—from \$1.5 trillion in October 2019 to approximately \$3 trillion in April 2023 (Nelson, 2024a). The LCLOR is an evolving concept, reflecting the dynamic nature of reserve demand across different types of institutions. This evolving nature complicates the Fed’s ability to forecast the effects of balance sheet normalization. QT unfolds in an environment where reserve demand is shifting in unpredictable ways. During balance-sheet normalization, the interaction between reserve supply, market structure, and institutional heterogeneity can affect both policy transmission and financial stability.

Beyond monetary policy and financial stability concerns, the presence of foreign banks in the reserve market could raise political and fiscal considerations. Interest on reserves (IOR) is paid to banks holding reserve balances at the Fed, including foreign institutions. For instance, a 2025 Senate press release introducing the FAIR Act argued that interest on reserves had generated more than \$580 billion in payments to banks since 2008, including more than \$186 billion in 2024 alone, and claimed that foreign banks received between 40 and 50 percent of total interest payments at any given time (Cruz, 2025). These concerns underscore that the distribution of reserves matters not only for rate control, but also for the perceived fiscal and political costs of the monetary policy implementation.

In the following sections, we present a series of empirical facts that characterize the reserve behavior of foreign banks, documenting how regulatory structure and global internal capital markets shape their reserve holdings.

4 Data

This section describes the data sources used throughout the paper. We draw on two main types of data for banks’ reserve holdings: (i) Weekly Bank Balance Sheet Data (H.8), which support high-frequency identification of reserve demand elasticities; and (ii) quarterly bank balance sheet data from regulatory filings, which provide detailed cross-sectional and time-series information. We supplement these sources with market and other financial data. Appendix A1. provides additional details on data construction and cleaning.

4.1 High-Frequency Data: Weekly Balance Sheets and Daily Money Market Conditions

Weekly Bank Balance Sheet Data (H.8) We use weekly balance sheet data from the Federal Reserve’s H.8 Report: Assets and Liabilities of Commercial Banks in the United States. This dataset provides a higher-frequency view of reserve dynamics than the quarterly reports, enabling us to trace behavior around key dates such as quarter-ends and in response to reserve supply shocks. Because reserves are not reported separately in the H.8 data, we use cash assets

as a proxy, which closely tracks reserve balances in the post-crisis ample-reserves regime.⁹ The H.8 data distinguish between large domestic banks, smaller domestic banks, and U.S. branches and agencies of foreign banks, allowing us to trace heterogeneous responses across bank types (Figure 4).

Other Money Market and Treasury Data We supplement the bank balance-sheet data with daily money-market rates and Treasury cash-management data. These include interest on reserves (IOR) and the federal funds target range. We also use daily federal funds rate distribution as well as borrowing data from the FR 2420 summary statistics from NY Fed. Daily Treasury General Account (TGA) balances are obtained from the U.S. Treasury’s Daily Treasury Statement. We also collect Treasury securities issuance data, including auction volumes and maturities to refine the measurement of TGA-driven reserve-supply shocks.

4.2 Quarterly Reserve Holdings and Global Dollar Exposures

Quarterly Bank Balance Sheet Data Our quarterly analysis uses bank-level reserve balances from regulatory filings. Reserve balances are reported in FFIEC 031 and 041 filings for domestic banks and foreign-owned subsidiaries, and in FFIEC 002 filings for U.S. branches and agencies of foreign banks.¹⁰ We include institutions with positive reserve balances and positive total assets. For analyses at the banking-organization level, we aggregate individual bank, branch, and agency balance sheets to the top-tier banking organization using FR Y-9C data and institution attributes from the FFIEC as well as Structure and Share Data for U.S. Banking Offices of Foreign Entities. We classify foreign banking organizations by the country of their headquarters and merge the regulatory filings with market data and policy-rate series. The full sample spans 1980Q2 to 2025Q4, the longest period over which data on U.S. branches and agencies of foreign banks are available. Most of the analysis focuses on the post-crisis period from 2009Q1 to 2025Q4, on U.S. branches and agencies of foreign banks.

Global Dollar Activity and Revolving Credit Lines. We use two complementary measures of foreign banks’ global dollar activities. At the home-country banking-system level, we combine the BIS Locational and Consolidated Banking Statistics to construct related-office-adjusted global U.S.-dollar assets by parent-bank nationality, following McGuire and Von Peter (2012);

⁹See Appendix A1. and Appendix Figure A1 for verification that cash assets are an accurate proxy for reserves and for additional data construction details.

¹⁰Reserve balances are held by depository institutions with master accounts at the Federal Reserve. These institutions include nationally chartered banks, eligible state-chartered banks, and other entities classified under Section 19(b) of the Federal Reserve Act. As of March 2020, the Federal Reserve reduced reserve requirement ratios to zero percent, effectively eliminating reserve mandates for depository institutions. While banks with master accounts continue to hold reserves, these holdings are now discretionary rather than regulatory obligations.

Aldasoro et al. (2020b). We merge the data with reserves held by the corresponding banking systems’ U.S. branches and agencies. At the individual-organization level, we use DealScan data on syndicated U.S.-dollar revolving facilities. After cleaning, we match participating lenders to 49 foreign banking organizations from 19 home countries and construct each organization’s lender-allocated stock of revolving credit lines that remain active under their stated contractual maturities. The estimation sample covers 2009Q2–2025Q3.

5 Reserve Demand Heterogeneity

In this section, we show that foreign banks play an asymmetric role in reserve adjustment over QE and QT. During QE, their reserve demand is approximately 2.3 times as elastic with respect to the FFR–IOR spread as that of domestic banks, and they absorb a large share of reserve inflows. During QT, this difference disappears: the estimated elasticities of foreign and domestic banks are of the same order of magnitude, and their difference is not statistically significant. The adjustment shifts toward large domestic banks. The distribution of reserves created during QE is therefore not simply unwound during QT. Throughout this section, the term “foreign banks” refers to U.S. branches and agencies of foreign banking organizations.

5.1 Funding Spreads and Aggregate Reserve Supply

We begin with the aggregate relationship between reserve supply and overnight funding spreads. Figure 5 plots the spread between the effective federal funds rate and interest on reserves (EFFR–IOR) against aggregate reserve balances at a weekly frequency. We define the high-frequency regimes from expansions and contractions in aggregate reserve supply: QE (January 2009–August 2014), QT (September 2014–September 2019), QE (October 2019–December 2021), and QT (January 2022–December 2025).¹¹ Across regimes, the figure shows a broadly downward-sloping relationship: as aggregate reserves decline, overnight funding spreads rise relative to IOR. For the post-2019 period, we also report SOFR–IOR as a complementary measure of overnight funding conditions.¹²

This relationship is consistent with spread-based reserve demand. Since the introduction of IOR, the federal funds rate has typically traded below the rate paid on reserves. This creates

¹¹These QE-QT labels describe the direction of reserve-supply adjustment. Both contraction episodes begin with high reserve balances, so QT does not necessarily correspond to reserve scarcity.

¹²SOFR is a broad measure of overnight Treasury repo rates. We report supplementary SOFR–IOR first-stage and reserve-demand estimates in Appendix Table A4. Although the repo market has become the largest and most active U.S. money market, with daily trading volume of roughly \$3 trillion (Copeland et al., 2025), we treat these specifications as robustness exercises. The exclusion restriction is less compelling for SOFR because changes in the TGA may coincide with Treasury issuance and settlement, affecting repo rates through collateral-supply and other secured-market channels independently of reserve supply.

an incentive for eligible banks to borrow in federal funds or related money markets and hold the proceeds as reserve balances (Bech and Klee, 2011; Keating and Macchiavelli, 2017; Anderson et al., 2025). When the EFFR–IOR spread becomes more negative, the return to this trade rises; when the spread narrows, the incentive to expand reserve holdings weakens. The relationship also appears nonlinear: at high levels of aggregate reserves, funding spreads become relatively insensitive to additional reserves, consistent with a flatter portion of the reserve-demand curve.

However, the aggregate relationship masks substantial heterogeneity across institutions. Figure 6 disaggregates the spread-reserve relationship by bank type: U.S. branches and agencies of foreign banks, large domestic banks (top 25 in asset size), and small domestic banks. Small domestic banks display little sensitivity to funding spreads or aggregate reserve supply. Large domestic banks and foreign branches respond more strongly, but their slopes differ across QE and QT episodes. These patterns motivate the causal exercises below, which use high-frequency supply shocks to identify which institutions adjust at the margin when reserve supply changes.

5.2 Identifying Exogenous Reserve Supply Shocks Using the TGA Shocks

The correlations above are suggestive but do not establish causality. Funding spreads and reserve holdings may be jointly determined, and both may respond to unobserved shocks to money markets or bank balance sheets. To isolate high-frequency variation in reserve supply, we use fluctuations in the Treasury General Account (TGA), the U.S. Treasury’s account at the Federal Reserve, as a source of plausibly exogenous movements in aggregate reserve supply.

TGA movements are autonomous factors on the Federal Reserve’s balance sheet and have been used extensively in prior work (e.g., Afonso et al., 2025b; Bräuning, 2017; Correa et al., 2025; Hamilton, 1997). An increase in the TGA drains reserves from the banking system, while a decrease injects reserves, unless offset by changes in overnight reverse repo (ONRRP) usage, which we control for directly. Under the current ample-reserves framework, the Federal Reserve does not routinely sterilize these day-to-day Treasury cash-management flows, allowing TGA movements to pass through to aggregate reserve balances.

Following Bräuning (2017), we construct TGA shocks by removing predictable variation in daily TGA changes. Specifically, we regress daily changes in the TGA balance on beginning-of-month, end-of-month, beginning-of-quarter, end-of-quarter, and day-of-week fixed effects, and we further control for anticipated Treasury financing flows using information on expected security issuance and redemptions. The residual from this regression, shown in Figure 7, is interpreted as the unanticipated component of TGA-driven reserve-supply variation. The shock sample spans January 2009 through December 2025. To align the shocks with the weekly reserve-holdings data, we sum the daily residuals over each Wednesday-to-Wednesday interval, excluding the preceding Wednesday and including the current Wednesday.

The identifying assumption is that, after removing predictable calendar and issuance-related components, residual TGA movements affect bank borrowing and reserve holdings through their effect on reserve supply and overnight funding conditions. Relevance follows mechanically from the Federal Reserve’s balance sheet: reserve-draining TGA shocks reduce aggregate reserves and tighten funding conditions. The main threat to exclusion is that Treasury issuance may affect repo rates directly through collateral supply.¹³ We address this concern by controlling for expected issuance and maturities in the shock construction.

Using observations from January 2009 through December 2025, we estimate the following first-stage relationship at the weekly level:

$$\Delta(i^F - i^R)_t = \beta_1 \Delta \text{TGA}_t + \beta_2 \Delta \text{ONRRP}_t + \delta_{f(t)} + \varepsilon_t, \quad (1)$$

where $\Delta(i^F - i^R)_t$ is the change in the funding spread, with i^R denoting IOR. ΔTGA_t denotes the unanticipated TGA shock, and ΔONRRP_t denotes the change in ONRRP take-up. $\delta_{f(t)}$ denotes FOMC-period fixed effects.

For the funding rate i^F , we use the daily volume-weighted average rate (FFR) across all fed funds transactions as a primary measure, following Clouse et al. (2025). The federal funds market is a decentralized over-the-counter market in which eligible financial institutions negotiate overnight unsecured loans bilaterally. Transactions therefore occur at different rates, reflecting heterogeneity in counterparties, trading relationships, and liquidity needs, rather than at a single market-wide price. We use the volume-weighted mean throughout the sample, the EFFR measure before March 2016.¹⁴ The mean can reflect movements in transaction rates and trading volumes away from the median, even when the median remains unchanged.

We also report results using two complementary spreads: $\text{FFR}_{50p} - \text{IOR}$ and $\text{FFR}_{99p} - \text{IOR}$. Here, FFR_{50p} is the volume-weighted median and FFR_{99p} is the 99th volume-weighted percentile of federal funds transaction rates. When reserves are abundant, changes in funding conditions may leave the median rate largely unchanged. Examining the mean and upper percentile therefore provides complementary evidence on the response of transaction rates. Recent research highlights differences across federal funds market segments and the limitations of EFFR as an indicator of reserve scarcity (Gissler et al., 2025; Anbil et al., 2026b). Appendix A1.1 provides

¹³Recent policy discussions have emphasized that, in principle, the Federal Reserve could actively offset fluctuations in the Treasury General Account, for example, by adjusting its asset holdings or backing the TGA with short-maturity securities, to insulate reserve balances and money market conditions from Treasury cash-management operations. See Nelson (2024b), Vissing-Jorgensen (2025), and Miran (2025). However, under the current ample-reserves operating framework, such sterilization is not implemented on a routine basis, and predictable Treasury settlements continue to generate high-frequency variation in reserve supply.

¹⁴Beginning with the March 1, 2016 rate, the New York Fed changed the published EFFR from a volume-weighted mean based on brokered transactions to a volume-weighted median based on FR 2420 transactions.

further details on their construction.

Table 1 shows that a \$100 billion TGA shock raises the FFR–IOR spread by approximately 0.49 basis points in the full sample. The estimate changes little when FOMC-period fixed effects and the ONRRP control are added, and remains statistically significant across both QE and QT periods. With both included, the estimated response is 1.02 basis points during QE and 0.20 basis points during QT; both are statistically significant. The complementary measures reveal a different pattern across the distribution. The FFR_{50p}–IOR response is significant during QE but small and statistically insignificant during QT. By contrast, the FFR_{99p}–IOR response is statistically insignificant during QE but reaches 1.50 basis points during QT. The QT pattern is consistent with funding pressures affecting upper-tail transactions while producing little movement in the median.

First-stage strength nevertheless varies across periods. For FFR–IOR, the first-stage F statistic is 18.76 in the full sample and 16.59 during QE, but falls to 5.52 during QT. During QT, FFR_{99p}–IOR has a higher first-stage F statistic than FFR–IOR, consistent with the literature’s emphasis on upper-tail rates as indicators of funding pressure. We supplement conventional inference with cluster-robust Anderson–Rubin p -values and 95 percent confidence sets (Anderson and Rubin, 1949; Andrews et al., 2019).

5.3 Reserve Demand Elasticity and QE–QT Asymmetry

We use TGA-induced variation in funding spreads to estimate reserve-demand elasticities.¹⁵ We first estimate the response of aggregate bank reserves:

$$\Delta \log(\text{Reserves}_t^{\text{All}}) = \pi_1 \Delta(\widehat{i^F - i^R})_t + \pi_2 \Delta \text{ONRRP}_t + \delta_{f(t)} + u_t, \quad (2)$$

where i^F is FFR and i^R is IOR. We estimate this equation by two-stage least squares, instrumenting the weekly spread change with ΔTGA_t . The ONRRP control is the weekly change in facility take-up, and $\delta_{f(t)}$ denotes FOMC-period fixed effects.

To examine heterogeneity, we pool the foreign and domestic reserve series and estimate:

$$\begin{aligned} \Delta \log(\text{Reserves}_{j,t}) = & \alpha + \gamma \text{Foreign}_j + \beta \Delta(\widehat{i^F - i^R})_t \\ & + \theta \left[\text{Foreign}_j \times \Delta(\widehat{i^F - i^R})_t \right] + \rho \Delta \text{ONRRP}_t + \delta_{f(t)} + u_{j,t}, \end{aligned} \quad (3)$$

where j indexes the two bank groups. Foreign_j equals one for foreign banks (U.S. branches and

¹⁵Following Anbil et al. (2026b), we refer to semi-elasticities as “elasticities” for simplicity. Multiplying the spread coefficient by 100 gives the approximate percentage change in reserves associated with a one-basis-point increase in the funding spread.

agencies) and zero for all domestic banks. The coefficient β measures the domestic response, $\beta + \theta$ measures the foreign response, and θ measures their difference. We estimate both specifications for the full sample and separately for QE and QT, using the same month-end exclusions as in the first stage.

Reserves decline when funding spreads rise. Panel A of Table 2 shows that a one-basis-point increase in FFR–IOR reduces aggregate reserves by approximately 6.3 percent in the full sample. The estimated response is larger during QT than during QE, although the QT estimate is less precise.

Reserve demand exhibits a pronounced QE–QT asymmetry across bank types: foreign banks are more elastic during QE, whereas domestic banks have the larger estimated response during QT. In Panel B, a one-basis-point increase in FFR–IOR reduces foreign-bank reserves by approximately 6.1 percent during QE, compared with 2.7 percent for domestic banks. Foreign reserve demand is therefore more than twice as responsive to funding spreads. This difference remains statistically significant under inference robust to weak instruments.

During QT, a one-basis-point increase in the instrumented FFR–IOR spread implies reserve declines of approximately 15.6 percent for domestic banks and 10.3 percent for foreign banks. Although the domestic response is larger, the foreign–domestic difference is not statistically significant at the 5 percent level. The larger QT elasticities partly reflect the limited response of the mean funding spread to reserve-supply shocks.¹⁶

Appendix Table A1 shows that large domestic banks (the top 25 by assets) exhibit reserve-demand elasticities close to those of the domestic sector as a whole. Their QT response is slightly larger: a one-basis-point increase in the instrumented FFR–IOR spread reduces their reserves by approximately 16.6 percent, compared with 15.6 percent for all domestic banks. Foreign banks remain more elastic during QE even when compared with these large domestic institutions. The similarity between the large-bank and all-domestic estimates suggests that the aggregate domestic response largely reflects adjustment by large banks. This interpretation is consistent with the concentration of domestic reserve holdings at large banks shown in Figure 4 and the limited sensitivity of small domestic banks’ reserve holdings to funding spreads in Figure 6. The distribution of reserves therefore matters within the domestic banking sector as well as between foreign and domestic banks. We also report estimates using FFR_{50p}–IOR and FFR_{99p}–IOR in Appendix Tables A2 and A3, respectively.¹⁷ Using FFR_{99p}–IOR, the estimated QT reserve declines per basis point are 2.1 percent for domestic banks and 1.3 percent for foreign banks.

¹⁶The larger QT semi-elasticities partly reflect the limited response of the mean funding spread to supply shocks. This price insensitivity is consistent with QT including periods of reserve abundance, when reserve quantities can change with little movement in funding rates. The weaker QT first stage also limits the precision of the absolute magnitudes.

¹⁷We also provide supplementary estimates using historical SOFR–IOR in Appendix Table A4.

These results show that the absolute magnitudes of estimated elasticities depend on which part of the transaction-rate distribution measures funding conditions.

5.4 TGA Shock Absorption Across Bank Types

We complement the funding-spread IV estimates with a quantity-side exercise examining which institutions absorb TGA-induced changes in reserve supply. Whereas the preceding analysis measures banks’ proportional responses to funding costs, this exercise measures their adjustment in dollar amounts. We consider foreign banks, large domestic banks, small domestic banks, and ONRRP take-up.

For each bank category j and for the ONRRP facility, we estimate

$$\begin{cases} \Delta \text{Reserves}_{j,t} = \beta_j \Delta \text{TGA}_t + \delta_{f(t)} + \varepsilon_{j,t}, \\ \Delta \text{ONRRP}_t = \beta_{\text{ONRRP}} \Delta \text{TGA}_t + \delta_{f(t)} + \varepsilon_t. \end{cases} \quad (4)$$

Here, ΔTGA_t denotes the unanticipated TGA shock aggregated over the Wednesday-to-Wednesday interval and measured in units of \$100 billion. Changes in reserves and ONRRP take-up are measured in billions of dollars. The index j denotes foreign banks, the top 25 domestic banks by asset size, and the remaining domestic banks. We estimate the regressions separately by category and QE/QT episode using weekly observations from January 2009 through December 2025. All specifications include FOMC-period fixed effects, with standard errors clustered by FOMC period.

Figure 8 summarizes $-\hat{\beta}_j$, the estimated dollar absorption associated with a \$100 billion TGA-driven reserve drain. Positive values indicate reductions in reserve holdings or ONRRP take-up. Appendix Table A5 reports the corresponding regression results.

The first cycle shows a pronounced difference in the allocation of reserve adjustment. During QE1, foreign banks absorb an estimated \$52.3 billion per \$100 billion TGA shock, compared with \$23.0 billion for large domestic banks. During QT1, large domestic banks absorb \$55.2 billion, compared with \$14.7 billion for foreign banks. The foreign–domestic differences are statistically significant in both episodes ($p = 0.045$ and $p = 0.015$, respectively).

The second cycle provides less precise evidence of differences between these bank groups. Large domestic banks have higher point estimates in both QE2 and QT2, but neither foreign–domestic difference is statistically significant. QE2 also encompasses the pandemic, when domestic banks experienced an exceptional expansion of deposits associated with fiscal transfers and higher household saving. Deposit growth substantially exceeded reserve growth, unlike earlier QE episodes, and much of the increase was uninsured (Castro et al., 2022; Acharya et al., 2023; Acharya and Rajan, 2024). These unusual funding conditions provide context for the less

pronounced foreign-bank role during QE2. ONRRP also contributes to adjustment during QE2, absorbing an estimated \$27.0 billion per \$100 billion TGA shock.

6 Institutional Drivers of Heterogeneous and Asymmetric Reserve Demand

Foreign branches and agencies absorb a large share of reserve injections during QE but play a smaller role during QT, when the adjustment shifts toward large domestic banks. This section asks whether the distinctive balance sheets of foreign branches help explain this pattern. As shown in Figure 3 Panel B, foreign branches hold the vast majority of foreign-bank reserve balances in the United States and they differ from domestic banks as well as from subsidiaries along several important dimensions. They rely less on retail deposits, maintain larger positions with related foreign offices, and are an important part of the parent bank’s internal capital market. Their reserve holdings are therefore connected to the funding costs and dollar liquidity needs of the global banking organization, rather than only to U.S. money-market conditions. We first describe these organizational and regulatory differences. We then use TGA-driven reserve variation to examine which liabilities move when each bank group absorbs a reserve change. Finally, we use quarter-end balance-sheet compression to distinguish an actively managed reserve position from a more persistent component.

6.1 Institutional Features of Foreign Branches and Agencies

Foreign banks have systematically held larger reserve balances than domestic banks since the introduction of interest on reserves (IOR) in late 2008. This gap is not fully explained by size, systemic importance, or observable balance sheet composition.¹⁸ However, a key institutional distinction is the organizational structure. Foreign banks in the United States may operate through branches and agencies, subsidiaries, or a combination of both. Branches and agencies are legal extensions of the parent bank rather than separately capitalized entities, whereas subsidiaries are stand-alone U.S. institutions.

This legal distinction is reflected in balance-sheet structure. Figure A3 shows that foreign-owned subsidiaries broadly resemble domestic banks, whereas foreign branches rely more heavily on wholesale funding, maintain larger reserve shares, and report larger positions with headquarters. Appendix Figure A4 documents heterogeneity across parent-bank jurisdictions in how foreign banks organize their U.S. operations. For instance, Canadian and UK banks have larger outstanding assets in subsidiaries, whereas Japanese banks predominantly operate through

¹⁸See Appendix Figure A10 for the evolution of foreign banks’ reserve holdings relative to domestic banks. Appendix Table A6 reports regressions of reserve holdings on foreign status, G-SIB designation, and their interaction. The foreign indicator remains large and statistically significant after controls and fixed effects.

branches and agencies. Despite this heterogeneity, Appendix Figure A5 shows that reserve balances are held predominantly at branches rather than subsidiaries across most jurisdictions.

Branches and agencies differ from subsidiaries along two dimensions central to reserve demand: the regulatory constraints on adjusting the U.S. balance sheet and the ability to obtain funding through the parent organization’s internal capital market.

Regulatory asymmetries. Branches and agencies face a lighter U.S. prudential burden than subsidiaries and domestic banks. Because they are not separately capitalized U.S. entities, they are not subject at the branch level to the same U.S. capital and leverage requirements that often constrain domestic banks. In contrast, subsidiaries must maintain capital and liquidity buffers consistent with domestic prudential standards. Unlike subsidiaries, they cannot accept FDIC-insured retail deposits, but they also avoid deposit insurance fees and certain capital surcharges.¹⁹ Branches can accept wholesale deposits broadly, while agencies face restrictions on deposits from U.S. citizens. Since July 2016, foreign banking organizations with more than \$50 billion in U.S. assets (*excluding* branch assets) have been required to form an Intermediate Holding Company (IHC) under Regulation YY, but this requirement applies to subsidiary operations rather than branches. Large FBOs’ U.S. operations can face U.S. liquidity risk-management and internal stress-testing requirements under Regulation YY.²⁰ Taken together, these regulatory asymmetries lower the marginal balance-sheet cost of holding reserves and help explain why branches and agencies can access the federal funds market more elastically than subsidiaries and domestic banks.

Access to global internal capital markets. Critically, branches and agencies can transfer liquidity between their U.S. operations and foreign headquarters (HQ) through internal capital markets, providing flexibility to reallocate dollar liquidity in response to global interest rate differentials and internal funding needs.²¹ Figure 9 shows quarterly HQ claims and liabilities by jurisdiction. Before the crisis, branches and agencies accumulated net claims on HQs; since then, they have shifted toward net borrowing from HQs, indicating that HQ funding has become an important source of dollar funding.

¹⁹Insured branches that were accepting domestic retail deposits as of December 19, 1991, were grandfathered. As of June 2025, only four such branches remain in our sample. According to Banegas and Tase (2020), only one of these participates in the federal funds market.

²⁰The rule required qualifying FBOs to consolidate their U.S. subsidiaries under a separately capitalized IHC, while leaving branches and agencies outside that structure. Consistent with the economic importance of this distinction, Paligorova and Temesvary (2022) show that FBOs newly required to form an IHC subsequently shifted assets from IHC-subject subsidiaries toward their U.S. branches and agencies.

²¹Branches and agencies are subject to Sections 23A and 23B and Regulation W, but these rules primarily govern transactions among U.S. affiliates and impose few constraints on cross-border liquidity transfers.

6.2 Divergence in marginal liquidity management.

Compared to domestic banks and subsidiaries, foreign banks' branches and agencies have different funding structures. Domestic banks and subsidiaries rely primarily on their U.S. deposit base. Foreign branches rely more heavily on wholesale funding and balances due to related foreign offices. If these differences shape reserve management, reserve changes should be accompanied by different liability adjustments across the two groups.

To examine whether these organizational differences shape balance-sheet adjustment, we use TGA-driven reserve variation to ask which liabilities move when each bank group absorbs a change in reserves. Building on the estimation (4), for bank type j and liability category l , we instrument weekly reserve changes with TGA shocks and we estimate

$$\Delta \text{Liabilities}_{j,l,t} = \beta_{j,l} \widehat{\Delta \text{Reserves}_{j,t}} + \alpha_{\tau(t)} + \varepsilon_{j,l,t}, \quad (5)$$

where the first stage follows the equation for reserve changes in (4), and $\alpha_{\tau(t)}$ denotes FOMC-period fixed effects. Standard errors are clustered by FOMC period. This exercise is diagnostic rather than fully causal. Although TGA shocks provide plausibly exogenous variation in aggregate reserves, Treasury flows may also affect deposits or wholesale funding directly. We therefore interpret $\beta_{j,l}$ as a balance-sheet matching coefficient. The comparison across bank groups is informative insofar as these direct liability-side effects do not differ systematically between foreign branches and large domestic banks. Figure 10 reports the estimates of $\beta_{j,l}$ for foreign branches and large domestic banks. Appendix Table A7 reports the corresponding full-sample estimates.

A clear contrast emerges. Large domestic banks accommodate reserve changes primarily through deposits. At foreign branches, reserve changes are instead matched by adjustments in both wholesale liabilities and funding from related foreign offices. Foreign-branch reserve adjustment therefore draws on external wholesale markets and the global banking organization's internal capital market, rather than being concentrated in a U.S.-based deposit margin.

Funding flexibility alone, however, does not explain the QE–QT asymmetry. If foreign-branch reserves consisted entirely of short-horizon carry positions financed with adjustable liabilities, the same flexibility that facilitates their expansion should also facilitate their unwinding when spreads narrow or reserves become less abundant. Yet the previous section shows that foreign branches play a substantially smaller role in releasing reserves during QT. The remaining question is therefore not how foreign branches finance reserve positions, but why some of those positions persist after the incentive to expand them weakens.

6.3 Arbitrage channel and global dollar liquidity channel.

The literature offers two complementary answers. The first, and most directly studied in the reserve-demand literature, is reserve arbitrage. The second comes from the broader literature on global banks’ management of dollar liquidity. These motives can overlap within the same reserve position, but they imply different adjustment horizons.

The first is reserve arbitrage. Foreign branches can obtain unsecured wholesale funding, including federal funds, at rates below the interest paid on reserves and invest the proceeds at the Federal Reserve (Bech and Klee, 2011; Keating and Macchiavelli, 2017; Banegas and Tase, 2020; Anderson et al., 2025). Their relatively low balance-sheet costs and access to both wholesale and internal funding make them particularly well positioned to scale this trade. This explanation is well established in the literature and provides a natural account of why foreign branches absorb reserves elastically when funding spreads are favorable.

A second motive follows from the literature on global banking and dollar liquidity. Non-U.S. banks hold large dollar assets but generally have less access than U.S. banks to stable dollar deposits. They instead rely on wholesale dollar funding, FX swaps, and intragroup transfers, so the expansion of dollar assets creates a currency-specific rollover exposure (McGuire and Von Peter, 2012; Ivashina et al., 2015; Aldasoro et al., 2022; Bruno and Shin, 2015b,a; Correa et al., 2022). Global banks manage this exposure across affiliated offices through internal capital markets (Cetorelli and Goldberg, 2012a; Eguren-Martin et al., 2024; Bräuning and Ivashina, 2020). Because a U.S. branch is integrated into its parent’s internal capital market, reserves held at the branch can provide immediately available dollar liquidity for activities booked elsewhere in the organization. They may support payment needs, provide a buffer against disruptions in wholesale dollar funding, or back contingent dollar commitments of the global bank.

These two motives differ primarily in their expected adjustment horizon. A carry position financed with short-term wholesale funding can be expanded or unwound quickly as the IOR–FFR spread, regulatory cost, or availability of funding changes. It therefore implies an actively managed and relatively reversible component of reserve holdings. By contrast, the global liquidity motive is tied to slower-moving dollar assets, contractual commitments, and internal liquidity-management policies. Although liquidity needs can change abruptly during stress, the exposures underlying this motive generally evolve over a longer horizon and need not reverse when the Federal Reserve moves from QE to QT.

The distinction is conceptual rather than mechanical. Reserves are fungible and multipurpose assets: the same dollar of reserves can earn a funding spread while also providing settlement services, regulatory liquidity, or insurance against dollar funding shocks (Goldstein et al., 2023). We therefore cannot assign individual reserve balances uniquely to one motive. However, the

different adjustment horizons nevertheless motivate a useful empirical distinction between an actively managed component and a more persistent component.

Quarter-end window dressing. We use quarter-end balance-sheet adjustment to obtain suggestive evidence on these two adjustment horizons. The components are not separately observed, but we can compare foreign-branch reserve holdings at different reporting frequencies and exploit “window dressing” behavior observed amongst foreign banks.

Window dressing refers to temporary balance-sheet adjustments around regulatory reporting dates. The practice arises when regulatory ratios are measured or disclosed using balance-sheet positions on a particular date rather than averages over the reporting period. A bank can therefore improve its reported balance-sheet by adjusting certain positions immediately before quarter-end and rebuilding them after the reporting date.

This incentive is particularly relevant for U.S. branches and agencies of foreign banks. A branch is a legal extension of its foreign parent, so its assets enter the parent’s consolidated balance sheet. In several major parent-bank jurisdictions, including the euro area and Japan, Basel III leverage-ratio measurement and disclosure have historically placed substantial weight on point-in-time quarter-end exposures.²²

These features generate two related reasons for reserves to decline at quarter-end. First, because the leverage ratio is not risk-weighted, reserves enter the exposure measure even though they carry little credit risk. Their balance-sheet cost therefore rises at reporting dates. At the same time, reserves can be reduced and rebuilt with little adjustment cost, making them a natural asset-side margin for temporary balance-sheet compression. Second, the literature documents that foreign banks curtail money-market activities around reporting dates, including repo and other short-term wholesale funding (Du et al., 2018; Correa et al., 2025; Anderson et al., 2025; Munyan, 2017). When short term liabilities run off, the asset side of the branch balance sheet must contract as well. Reserves provide a natural adjustment margin because they can be reduced without liquidating less-liquid loans or securities. Thus, both the direct balance-sheet cost of holding reserves and the quarter-end contraction in short-term funding predict a temporary decline in foreign-branch reserves.

The temporary decline in foreign-branch reserves at quarter-end therefore reveals an actively managed component of reserve holdings that can be easily compressed on reporting dates and rebuilt shortly thereafter. We measure this adjustment as the difference between reserves in the weekly H.8 observation before quarter-end and reserves reported by U.S. branches and agencies

²²An additional incentive arises at year-end from G-SIB scoring. The G-SIB assessment has historically relied largely on year-end indicators of size, interconnectedness, cross-jurisdictional activity, and other dimensions of systemic importance. Both U.S. and foreign G-SIBs may therefore reduce relevant exposures temporarily to lower their measured systemic footprint and potential capital surcharge (Bassi et al., 2024).

in the quarter-end FFIEC 002.²³

Figure 11 illustrates these two components. Panel A plots weekly reserves together with quarter-end reserves, while Panel B plots the reporting gap, defined as the last pre-quarter-end weekly observation minus the quarter-end observation. Three patterns stand out. First, the gap is generally positive: foreign-branch reserves are lower on quarter-end reporting dates than immediately beforehand, consistent with window dressing. Second, the gap varies substantially over time. It became large after the introduction of interest on reserves but narrowed as QT progressed, with particularly sharp compression near the ends of the 2017–19 and 2022–25 QT episodes. Part of foreign branches’ reserve holdings appears linked to arbitrage incentives. Within the four QE/QT episodes, a one-basis-point wider IOR–mean FFR margin is associated with a \$17 billion larger quarter-end reporting gap (Figure 12).

Third, and most importantly, the quarter-end stock remains elevated even as the conventional reserve-arbitrage margin narrows. At the end of QT in 2019Q3, foreign branches held about \$537 billion in quarter-end reserves, roughly 105 percent more than the amount held in 2009Q1. At the end of QT in 2025Q4, they still held about \$1.03 trillion, 77 percent more than the amount in 2019Q4. If the increase in foreign-branch reserves during QE reflected entirely a readily reversible arbitrage position, the quarter-end stock would be expected to return toward its level at the beginning of the corresponding QE phase as that position unwound. Instead, the evidence points to a reporting-sensitive margin layered on top of a more persistent reserve position.

For this reason, we use quarter-end reserve balances as a proxy for the slower-moving component of reserve demand that remains after reporting-sensitive positions are unwound.

7 Reserves as Liquidity for Global Dollar Intermediation

We now ask whether the persistent component is connected to the parent organization’s global dollar activities. Because reserves at U.S. branches provide immediately available dollar liquidity, they can support exposures booked elsewhere in the global banking organization. We begin with suggestive evidence across national banking systems and then turn to our main FBO-level test using outstanding revolving credit lines.

7.1 Global Dollar Positions and Reserve Adjustment

The U.S. dollar is the dominant global currency in international trade and finance, generating substantial demand for dollar credit outside the United States (Gopinath et al., 2020; Gopinath

²³Using internal daily data, Afonso et al. (2025a) report that on average, foreign branches reduce reserves by approximately 20 percent on quarter-end days compared to their average level on all other days.

and Stein, 2021). Dollar-denominated loans and securities have also at times offered higher gross yields than comparable assets denominated in lower-rate currencies, further encouraging non-U.S. banks to expand their dollar balance sheets (Liao, 2020). In 2025Q1, non-U.S. banks collectively held approximately \$17.8 trillion in dollar-denominated assets, much of it booked outside the United States (Figure 13, Panel A). The balance sheet of a U.S. branch therefore captures only one part of the dollar exposures managed by its parent organization. This geographic separation motivates relating U.S.-branch reserves to the parent banking system’s global dollar position rather than only to activities booked in the United States.

These global dollar positions create currency-specific liquidity needs. Non-U.S. banks generally have more limited access than U.S. banks to a stable dollar deposit base and rely more heavily on wholesale dollar funding and FX swaps. Hedging the currency mismatch does not eliminate the need to roll over this funding, particularly when the underlying dollar assets have longer maturities (McGuire and Von Peter, 2012; Ivashina et al., 2015; Aldasoro et al., 2022).²⁴ Reserves at branches and agencies are well suited to buffer this exposure because they provide immediately available dollar liquidity and can support liquidity management through the organization’s internal capital market.

Post-crisis liquidity regulation reinforces this liquidity-management motive. Although the Basel III Liquidity Coverage Ratio (LCR) is met on a consolidated basis and reported in a single currency, banks are expected to monitor liquidity separately in significant currencies and to maintain high-quality liquid assets (HQLA) consistent with the currency composition of their liquidity needs. The reserves qualify as Level 1 HQLA and provide directly usable dollar liquidity. Global dollar exposures may therefore increase the value of reserve balances at U.S. branches insofar as they generate dollar-specific funding needs under stress (BCBS, 2013).²⁵

Two aggregate facts provide suggestive evidence that foreign banks manage reserves at their U.S. branches alongside their broader global dollar positions. First, QT does not unwind QE

²⁴Central bank swap lines provide an important backstop to global dollar funding markets, but they do not eliminate this precautionary motive. Individual foreign banks that face an idiosyncratic liquidity shock do not have direct access to the Federal Reserve’s swap lines; dollar liquidity is provided through their home central bank and depends on the availability and terms of the home central bank’s dollar operations. Moreover, the mechanics of the swap lines themselves illustrate the special role of U.S. affiliates’ reserve accounts in the global dollar system. Because banks located outside the U.S. cannot hold reserve accounts at the Federal Reserve, dollar liquidity obtained through a foreign central bank swap line is ultimately transferred through a U.S. affiliate or correspondent bank. During the 2020 swap line operations, increases in foreign banks’ intragroup positions were accompanied by increases in reserves at their U.S. affiliates (Aldasoro et al., 2020a, 2021).

²⁵National supervisors further supplement Basel with currency-specific assessments. For instance, Japan’s Financial Services Agency (FSA) and Bank of Japan jointly review major banks’ foreign-currency liquidity stress tests (Bank of Japan and Financial Services Agency, 2024). In Europe, the EBA announced that 60 of 267 banks reporting the dollar as significant had dollar Net Stable Funding Ratios (NSFRs) below 100 percent despite aggregate compliance, while U.K. and euro-area supervisors have examined disruptions to dollar and FX-swap funding (European Banking Authority, 2025; Spezzati et al., 2025; European Central Bank and European Systemic Risk Board, 2026).

along the same path. Figure 14, Panel A, traces the two series over time. During the 2009–14 QE period, branch reserves rose sharply while global dollar assets excluding reserves were broadly flat. During the 2017–19 QT episode, reserves declined but remained well above their 2009 level, even as dollar assets continued to expand. Both series jumped during the pandemic; since 2022, dollar assets have continued to grow while branch reserves have remained near \$1 trillion.

Panel B shows corresponding comovement in changes. Quarterly changes in nonreserve dollar assets and branch reserves have a Pearson correlation of 0.454. This correlation is descriptive, but the non-retracing path and positive comovement are consistent with foreign banks adjusting U.S. reserves as part of their broader dollar balance-sheet management. This channel offers a potential explanation for the QE–QT asymmetry documented in Section 5.

Second, the relationship differs sharply across parent banking systems. Figure A7 shows positive level associations for Japan, Canada, the United Kingdom, Australia, and Sweden, but weak or negative associations for France, Germany, and Switzerland. This heterogeneity is economically informative. Several European banking systems retrenched from dollar intermediation after the global financial crisis, whereas Japanese and Canadian banks expanded their dollar balance sheets (IMF, 2019). Funding structures also differ. Euro-area banks can be net dollar lenders through FX derivatives, while Japanese banks remain persistent net dollar borrowers (Aldasoro et al., 2022; Becker et al., 2024; Klocks et al., 2023). Gross dollar assets therefore measure the scale of dollar activity, but are not a sufficient statistic for the dollar funding gap—or reserve demand—generated by that activity.²⁶

These facts motivate a within-banking-system test. We ask whether a larger beginning-of-quarter global dollar position predicts faster reserve growth over the following quarter, conditional on inherited reserve holdings, persistent differences across banking systems, and shocks common to all systems in a given quarter. We estimate

$$\begin{aligned} \Delta \log(\text{Reserves})_{i,t} = & \beta_1 \log(\text{USD Assets})_{i,t-1} + \beta_2 \log(\text{Reserves})_{i,t-1} \\ & + \beta_3 \text{HedgedMargin}_{c(i),t}^{3M} + \alpha_i + \lambda_t + \varepsilon_{i,t}. \end{aligned} \quad (6)$$

In the country-level specifications, i indexes the parent-country banking system and $c(i)$ its currency area. In the currency-area specifications, we first aggregate reserves and dollar assets across banking systems sharing a currency. $\text{USD Assets}_{i,t-1}$ is the lagged stock of global dollar assets *excluding* reserves held at U.S. branches and agencies. The three-month FX-hedged reserve margin is defined as $\text{HedgedMargin}_{c,t}^{3M} = \text{IOR}_t^{\text{US}} - \text{IOR}_{c,t}^{\text{home}} + \rho_{c,t}^{3M}$, where $\rho_{c,t}^{3M}$ is the annualized FX-hedging adjustment. A higher margin makes Federal Reserve balances more attractive relative to balances at the parent bank’s home central bank (Bräuning and Ivashina,

²⁶The persistent cross-country differences in reserve intensity in Figure A6, Panel B, reinforce this point.

2020).

Table 3 shows a positive and statistically significant association in all four specifications. In the controlled country specification, a 10 percent larger lagged dollar-asset stock is associated with approximately 1.4 percentage points higher reserve growth in the following quarter. The corresponding currency-area estimate is 2.4 percentage points.

These estimates strengthen the macro evidence, but remain suggestive. Gross dollar assets capture the scale of global dollar intermediation, not the particular positions that generate liquidity needs. For instance, the outstanding dollar assets could contain non-reserve liquid assets. We therefore turn to a directly observable contractual exposure: outstanding revolving credit lines.

7.2 Revolving credit lines and reserve demand

A revolving credit line gives a borrower the right to draw, repay, and redraw funds up to an agreed limit before maturity, at specified pricing terms and subject to contractual conditions. The undrawn portion creates a contingent claim on the lender’s liquidity because the borrower may request funds on short notice. Unlike gross dollar assets, outstanding credit lines identify a specific, slow-moving source of dollar-liquidity demand. This mechanism builds on the view of credit lines as on-demand liquidity claims supported by banks’ liquid-asset capacity (Kashyap et al., 2002; Gatev et al., 2009). It may be especially relevant for foreign banks, which are major participants in dollar syndicated lending and manage dollar funding across affiliates and jurisdictions (Ivashina et al., 2015; Acharya et al., 2017; Bräuning and Ivashina, 2020).

Direct evidence for this channel comes from the Federal Reserve’s September 2020 Senior Financial Officer Survey. The contrast is striking: 92 percent of foreign-bank respondents cited preparation for potential credit-line drawdowns as a leading reason for holding more reserves, compared with 63 percent of domestic banks (Board of Governors of the Federal Reserve System, 2020). The survey covers an exceptional stress episode. It therefore establishes that drawdown risk can affect reserve demand, but not whether credit lines shape reserve adjustment in normal times. Combining DealScan data with regulatory balance-sheet data for domestic banks and foreign banks, we test whether outstanding dollar credit lines are more strongly associated with subsequent reserve growth at foreign banks than at domestic banks.²⁷

Measuring outstanding revolving credit lines. We turn to syndicated-loan data, DealScan, for the revolving credit line data. A single syndicated deal often combines a revolving facility

²⁷Aldasoro et al. (2021) provide complementary evidence from the pandemic stress episode. Using call-report data for U.S. affiliates of non-U.S. banks, they show that net credit-line drawdowns at U.S. offices are correlated with increases in affiliate loans in 2020Q1.

with one or more term facilities. Credit lines expose lenders to future drawdown risk and are disproportionately provided by commercial banks, whereas nonbanks participate more heavily in fully funded term lending (Gatev and Strahan, 2009). Within leveraged-loan packages, revolving facilities and Term Loan A facilities generally constitute the bank, or “pro rata,” portion of the deal, whereas Term Loan B facilities are directed primarily toward institutional investors such as CLOs (Ivashina and Sun, 2011; Fleckenstein et al., 2026).²⁸ Consistent with this segmentation, credit lines are substantially less likely than term loans to enter the secondary market, in part because their holders must remain able to fund future draws (Drucker and Puri, 2009). Post-origination lender composition also remains substantially more stable for credit lines than for institutional term loans (Blickle et al., 2026). Origination allocations are therefore a more informative proxy for a banking organization’s continuing contractual exposure in revolvers than in term-loan participations.

We reconstruct each bank’s lender-allocated stock of U.S.-dollar revolving credit lines scheduled to remain active under their stated maturities and match it to reserves held in the U.S. Our measure captures outstanding contractual credit lines rather than the undrawn amount at each date, since DealScan does not observe facility utilization. The match is at the banking organization level; for foreign banks, the facilities need not be booked at those U.S. offices. Our measure carries original lender allocations from origination through stated maturity. The sample includes 495 domestic banking organizations and 49 foreign banking groups from 19 home countries, covering 2009Q2–2025Q3 (Appendix Table A8).

Both domestic and foreign banks maintain substantial revolving-credit portfolios. In the regression sample, average quarterly outstanding commitments are approximately \$1 trillion for domestic banks and \$856 billion for foreign banks (Table 4). U.S. borrowers dominate, although foreign borrowers account for 19.5 percent of borrowers served by foreign banks, compared with 7.3 percent for domestic banks. The median original contractual maturity is five years in both groups.²⁹ These multiyear commitments create substantial overlap across reserve-supply

²⁸Meanwhile, the literature suggests that the bank-versus-institutional classification is not absolute. Using both Dealscan and Shared National Credit Registry (SNC) data, Blickle et al. (2026) show that some Term Loan A shares are sold after origination, although their ownership remains considerably more bank-centered than that of Term Loan B facilities. Conversely, institutional term loans may temporarily remain with arranging banks when unexpectedly weak investor demand creates pipeline risk (Malherbe et al., 2020).

²⁹Appendix Figure A13 reports quarterly originations of revolving credit lines by original contractual maturity. Under the Basel II standardized approach (finalized in June 2004 and followed by 2006 Comprehensive Version), the unused portion of a credit line with an original maturity of up to one year received a 20 percent credit-conversion factor (CCF), compared with 50 percent for credit lines over one year (BCBS, 2006); see also Xu (2026). The final post-crisis Basel III reforms, released in December 2017, instead set a 40 percent CCF regardless of maturity (BCBS, 2017). Implementation of that reform has, however, occurred at different dates across jurisdictions. In the United States, the standardized approach treatment was 0 percent for credit lines of one year or less and 50 percent for longer credit lines through 2014; beginning January 1, 2015, the schedule became 20 percent and 50 percent.

regimes: credit lines originated during QE can remain contractually active during subsequent QT, so their runoff need not coincide with the Federal Reserve’s balance-sheet contraction.

Baseline specification and results. We test whether banks’ global dollar credit lines are associated with higher subsequent reserve growth in the United States, and whether this association is stronger for foreign banks compared to domestic banks. We estimate the following pooled specification:

$$\begin{aligned} \Delta \log(\text{Reserves})_{i,t} = & \beta_1 \log(\text{Active Credit Lines})_{i,t-1} \\ & + \beta_2 [F_i \times \log(\text{Active Credit Lines})_{i,t-1}] + \gamma' X_{i,t-1} \\ & + \theta [F_i \times \text{HedgedMargin}_{c(i),t}^{3M}] + \alpha_i + \lambda_{g(i),t} + \varepsilon_{i,t}. \end{aligned} \quad (7)$$

Here, i indexes banking organizations, and F_i equals one for foreign banks. $\text{Active Credit Lines}_{i,t-1}$ is the lender-allocated stock of outstanding U.S.-dollar revolving credit lines at the end of the preceding quarter. The control vector $X_{i,t-1}$ includes bank balance sheet controls, including lagged log reserves and assets. All three specifications include bank fixed effects, α_i . For the time fixed effects, we explore three specifications. First we include bank-type-by-quarter fixed effects, $\lambda_{g(i),t}$. Second, we replace these effects with home-country-by-quarter fixed effects, absorbing quarterly shocks shared by banks headquartered in the same country. In the third specification, we return to the bank-type-by-quarter fixed effects and add the three-month hedged margin component, set to zero for domestic banks. This specification is estimated on observations with available FX data, excluding banks headquartered in Taiwan, Israel, and the United Arab Emirates.

Table 5 shows that dollar credit lines are more strongly associated with higher subsequent reserve growth at foreign banks than at domestic banks. Across the three specifications, a 10 percent larger stock of active dollar credit lines is associated with approximately 1.4–1.8 percentage points higher reserve growth at foreign banks. The foreign-bank relationship is statistically significant at the 5 percent level in every specification, while the domestic-bank coefficient is small and statistically indistinguishable from zero.³⁰ The foreign–domestic difference is significant at the 5 percent level in column (1) and at the 10 percent level in columns (2) and

³⁰The insignificant coefficient does not rule out that domestic banks use reserve holdings for precautionary liquidity. Appendix Table A9 shows that, within domestic banks, the association between credit lines and subsequent reserve growth strengthens with uninsured deposits. The result supports the funding-stability interpretation: banks with greater exposure to potential deposit outflows have a stronger incentive to maintain liquidity against credit-line drawdowns, consistent with the role of funding fragility emphasized by Acharya et al. (2023); Darst et al. (2025). We examine this variation within domestic banks because their deposit composition is not directly comparable to the funding structure of foreign banks’ U.S. branches and agencies (Appendix Figure A3).

(3). These findings are consistent with reserves held at U.S. branches and agencies providing liquidity against the foreign banking organization’s global dollar credit lines. Foreign banks’ more limited access to stable dollar deposits may strengthen their incentive to maintain readily available dollars against potential drawdowns. Continuing commitments can therefore sustain the liquidity value of reserves even as the profitability of reserve arbitrage declines.

Reserve adjustment during QE and QT. We next examine whether the relationship between outstanding dollar credit lines and reserve adjustment remains present during QT. Table 6 estimates the baseline specifications separately during QE and QT. During QT, a 10 percent larger stock of dollar credit lines is associated with approximately 2.4–2.7 percentage points higher subsequent quarterly reserve growth at foreign banks. The foreign-bank slope is statistically significant at the 1 percent level in all three specifications. Domestic banks also exhibit a positive relationship during QT, but their coefficient is considerably smaller; the foreign–domestic difference is significant at the 5 percent level throughout.

The QT results suggest that foreign banks retain reserves against dollar commitments that remain available to borrowers as the Fed shrinks its balance sheet. During this contraction, higher conditional reserve growth can mean a smaller decline in holdings. Continuing commitments therefore provide a reason to retain reserves even when arbitrage becomes less profitable. This interpretation helps explain why large domestic banks bear more of the aggregate reserve reduction. During QE, the quarterly relationship is less clear. Arbitrage opportunities may drive more of reserve accumulation, making the role of continuing liquidity needs harder to detect.

Preexisting versus new origination. To distinguish continuing contractual obligations from recent lending activity, we decompose the active stock into preexisting and newly originated credit lines. Table A10 shows that preexisting credit lines are positively and significantly associated with subsequent reserve growth at foreign banks. Across the three specifications, a 10 percent larger stock is associated with approximately 1.6–2.0 percentage points higher reserve growth in the following quarter. The domestic-bank coefficient is statistically indistinguishable from zero, and the foreign–domestic difference is significant at the 5 percent level throughout. Newly originated credit lines have no statistically significant association with subsequent reserve growth at foreign banks.³¹ The association with preexisting commitments is consistent with foreign banks maintaining dollar liquidity against obligations that persist beyond the origination quarter. These commitments can remain available for borrowers to draw as the Fed moves from QE to QT, so the associated liquidity needs need not decline with reserve supply. Continuing

³¹At the foreign-bank median exposures, the equal-dollar contrasts do not reject equal reserve responses to preexisting and new credit lines.

dollar exposures can therefore give foreign banks a reason to retain reserves even as arbitrage incentives weaken.

Branches versus subsidiaries. The credit-line relationship is substantially smaller when foreign banks’ reserves are measured at their U.S. subsidiaries. We repeat the pooled baseline specification, replacing foreign banks’ reserve outcomes and lagged reserve and asset controls with subsidiary balances, while retaining the domestic observations and parent-level credit lines. Subsidiary data are available for 22 foreign banking groups (Appendix Table A11). Appendix Table A12 reports implied foreign-bank slopes of -0.168 to -0.047, all statistically indistinguishable from zero. The foreign–domestic differences are also insignificant.

Unlike branches and agencies, subsidiaries are separately incorporated and manage their own liquidity, not much exposed to the internal capital markets. The smaller estimates are consistent with branches and agencies playing a greater role in the parent’s global dollar liquidity management.

Lead versus nonlead lenders. Within foreign banks, the positive reserve relationship is concentrated in nonlead credit lines. This distinction matters because a lender’s funding need depends on whether drawdowns generate offsetting deposits. Borrowers may deposit the proceeds with their main relationship bank rather than distribute them across the lending syndicate (Cooperman et al., 2025). To the extent that these deposits accrue mainly to lead lenders, nonlead lenders face larger net funding needs when borrowers draw and therefore have a stronger incentive to hold precautionary dollar liquidity.

We divide each foreign banking organization’s active credit lines into lead and nonlead stocks using DealScan’s syndicate roles at origination and enter both stocks jointly in the reserve-adjustment regression. We use asinh of amounts measured in U.S.-dollar billions to retain zero stocks. Appendix Table A13 shows positive nonlead coefficients of 0.245–0.262, significant at the 5 percent level or better in all three specifications. Lead coefficients are negative and statistically indistinguishable from zero. Tests reject equality of the lead and nonlead coefficients at the 5 percent level in columns (1) and (3), and at the 10 percent level in column (2). This pattern is consistent with nonlead lenders maintaining dollar reserves against drawdowns for which they expect fewer offsetting deposit inflows.

Term Loan A. We compare revolving credit lines with Term Loan A to examine whether the reserve relationship also appears for funded term lending. We re-estimate equation (7), replacing lagged log active credit lines with lagged $\text{asinh}(\text{Term Loan A})$ in both the main term and its foreign interaction. Term Loan A is measured in U.S.-dollar billions; the transformation

retains zero exposures.

Table A14 shows a positive association between Term Loan A exposures and subsequent reserve growth at domestic banks, significant at the 1 percent level throughout. The foreign-bank estimates are small and statistically indistinguishable from zero. Unlike revolving commitments, funded term loans do not give borrowers a continuing right to draw and redraw funds (Ivashina and Sun, 2011). Revolving lenders must stand ready to provide additional dollars at uncertain times, including when their own funding becomes more expensive (Cooperman et al., 2025). The foreign-bank revolving-credit association is consistent with reserves providing insurance against these future funding requests.

This interpretation complements Darst et al. (2025), who show that banks more exposed to uninsured nonbank deposits reduce credit-line commitments relative to less-exposed banks, primarily through the undrawn component, with no corresponding significant difference in term lending. Their analysis examines how funding fragility affects the commitments banks provide. Ours examines reserve adjustment associated with continuing exposures. Banks can manage drawdown risk both by limiting undrawn commitments and by maintaining liquidity against commitments that remain outstanding. The two studies thus connect the provision of liquidity insurance to borrowers with banks’ own liquidity management.

DealScan does not separate drawn from undrawn commitments. Our Term Loan A measure does not adjust for repayments or subsequent loan sales. Some recorded loan shares may therefore no longer be on the originating banks’ balance sheets (Blickle et al., 2026). The comparison remains thus suggestive: the Term Loan A foreign–domestic differences are insignificant, and the separate regressions do not establish different responses across loan types.

8 Reserve Demand Model with Foreign Banks

Our evidence points to arbitrage and global dollar liquidity channels for reserve holdings by foreign banks. Balance-sheet costs help explain their large reserve positions, while growing dollar credit-line commitments incentivize banks to hold reserves as precautionary liquidity. We provide a tractable framework showing how foreign banks could limit how far the Federal Reserve can shrink its balance sheet.³²

8.1 Model Setup

Demand. We build on the bank reserve-management problem in Poole (1968) and the ample-reserves framework in Afonso et al. (2025c). We extend the model by incorporating heterogeneity. Two bank types hold reserves: domestic banks (D) and foreign branches and agencies (F).

³²Appendix A6. provides the derivations and proofs of the propositions.

Reserves earn i^{IOR} , and i denotes the federal funds rate. Bank j takes the difference $i - i^{\text{IOR}}$ and its liquidity exposure as given and chooses reserves Q_j before a dollar liquidity need $\tilde{Q}_j$ is realized:

$$\max_{Q_j \geq 0} \left\{ (i^{\text{IOR}} - i)Q_j - \left(\kappa_j Q_j + \frac{\phi_j}{2} Q_j^2 \right) + \chi_j \mathbb{E}[\min\{Q_j, \tilde{Q}_j\}] \right\}, \quad (8)$$

where $\phi_j, \chi_j > 0$ and $\kappa_j \geq 0$. The first term is arbitrage income at the IOR–federal funds margin; the second is the balance-sheet cost of holding reserves. The last term is the liquidity and regulatory value of reserve holdings: reserves cover $\min\{Q_j, \tilde{Q}_j\}$ of the realized need and save χ_j per dollar in costs of obtaining liquidity or adjusting other positions. We assume $\chi_j > \kappa_j$, so that both bank types choose positive reserve holdings when the federal funds rate equals IOR.

We impose two additional restrictions across bank types. First, we assume $\kappa_F \leq \kappa_D$ to capture foreign branches' balance-sheet cost advantage on non-quarter-end dates. Second, we assume $\chi_F > \chi_D$, reflecting a higher per-dollar value of liquidity coverage. Their reliance on wholesale dollar funding can make replacement liquidity more costly during stress.

For tractability, let $\tilde{Q}_j \sim U[0, q_j]$, where $q_j > 0$ is the upper bound on liquidity needs for bank type j . For domestic banks, this bound depends on liquid deposits L , with $q_D = q_D(L)$ differentiable and $q'_D(L) > 0$: greater liquid deposits raise potential liquidity needs (Acharya and Rajan, 2024; Lopez-Salido and Vissing-Jorgensen, 2025; Darst et al., 2025). For foreign branches, let $q_F(G) = mG$, with $G > 0$ and a fixed $m > 0$ that scales global dollar exposure into the upper bound on liquidity needs. Banks take current exposures as given when choosing reserves. The model abstracts from deposit creation and the origination of foreign banks' dollar credit.

Below q_j , expected liquidity coverage is $Q_j - Q_j^2/(2q_j)$; above it, coverage is $q_j/2$. Strict concavity gives a unique reserve choice. For positive holdings, the first-order condition shows the rate difference as the marginal liquidity benefit minus the marginal holding cost. The resulting inverse demand is

$$i - i^{\text{IOR}} = \begin{cases} -\kappa_j - \phi_j Q_j, & Q_j \geq q_j \quad (\text{arbitrage carry region}), \\ \chi_j - \kappa_j - \left(\phi_j + \frac{\chi_j}{q_j} \right) Q_j, & 0 < Q_j < q_j \quad (\text{liquidity region}). \end{cases} \quad (9)$$

Thus, reserve demand is piecewise linear. Within each positive-holdings region, we write $Q_j = a_j - b_j(i - i^{\text{IOR}})$, where a_j is the region-specific intercept and $-b_j$ is the slope. At the zero-reserve corner, $Q_j = 0$ if and only if $i - i^{\text{IOR}} \geq \chi_j - \kappa_j$. In the arbitrage carry region, reserves cover all modeled liquidity needs, so marginal holdings earn carry. In the liquidity region, reserve withdrawals also increase expected shortfall costs. Demand is continuous at

$Q_j = q_j$, but dollar responsiveness falls below this threshold:

$$b_j \equiv -\frac{\partial Q_j}{\partial(i - i^{\text{IOR}})} = \begin{cases} 1/\phi_j, & Q_j > q_j, \\ 1/(\phi_j + \chi_j/q_j), & 0 < Q_j < q_j. \end{cases} \quad (10)$$

Supply and market clearing. The Federal Reserve supplies an aggregate stock of reserves $S > 0$ and sets i^{IOR} . Banks choose their individual reserve holdings but cannot change the aggregate stock. We take these policy settings, liquidity exposures L and G , and cost parameters as given in each equilibrium. We study the interior-corridor case with no contemporaneous facility take-up and abstract from trading frictions.

An equilibrium consists of a federal funds rate $i(S)$ and nonnegative reserve holdings $Q_D(S)$ and $Q_F(S)$ such that each bank type's holdings solve equation (8) and the aggregate reserve market clears:

$$Q_D(i(S) - i^{\text{IOR}}, L) + Q_F(i(S) - i^{\text{IOR}}, G) = S. \quad (11)$$

Thus banks take the rate as given when choosing reserves, while market clearing determines the rate and the allocation of the fixed aggregate stock. Aggregate demand is continuous and strictly decreasing whenever positive, so the equilibrium is unique for $S > 0$. Within each positive-holdings region, reserve demand takes the form $Q_j = a_j - b_j(i - i^{\text{IOR}})$, giving

$$i(S) - i^{\text{IOR}} = \frac{a_D + a_F - S}{b_D + b_F}, \quad Q_j(S) = a_j - b_j[i(S) - i^{\text{IOR}}], \quad (12)$$

retaining the combination that satisfies its region inequalities.

8.2 Asymmetric Reserve Adjustment and the Limits to the Fed's Balance-Sheet Contraction

We use the model to examine two aspects of foreign banks' role in reserve contraction (QT). We first distinguish reserve holdings from marginal adjustment and show how relative reserve responsiveness changes across demand regions. We then examine how foreign banks' global dollar lending affects the reserve supply required for rate control.

Margin of adjustment. The model shows that foreign banks' large reserve holdings need not imply that they absorb a correspondingly large share of reserve contraction. The allocation of a marginal supply change depends on each bank type's dollar responsiveness.

Proposition 8.1 (Margin of Adjustment). *At an equilibrium with both bank types holding positive reserves, away from region boundaries and holding exposures and costs fixed,*

$$\frac{dQ_F}{dS} = \underbrace{\frac{\partial Q_F}{\partial(i - i^{\text{IOR}})}}_{-b_F} \underbrace{\frac{d(i - i^{\text{IOR}})}{dS}}_{-1/(b_F + b_D)} = \frac{b_F}{b_F + b_D} \underset{\text{in general}}{\neq} \frac{Q_F}{S}. \quad (13)$$

Large holdings do not imply a large share of marginal adjustment.

Foreign banks' lower balance-sheet costs lead to larger reserve positions. When further reserve reductions begin to compromise liquidity coverage, their dollar responsiveness falls. If domestic banks remain in the same active region, the foreign share of marginal adjustment falls as well. A substantial foreign reserve stock can therefore coexist with the margin of adjustment shifting toward domestic banks.

From arbitrage to liquidity. Next, we examine how the motive for marginal foreign reserve holdings shapes asymmetric reserve responses. We compare equilibria in which domestic banks hold reserves for liquidity, while foreign banks' marginal holdings serve different purposes: arbitrage in one equilibrium and liquidity in the other. Domestic banks' holding cost κ_D exceeds the IOR–FFR arbitrage margin in both equilibria.³³ We measure local proportional responsiveness by the semi-elasticity magnitude $\mathcal{E}_j \equiv -\partial \log Q_j / \partial(i - i^{\text{IOR}}) = b_j / Q_j$.³⁴

Proposition 8.2 (Relative responsiveness across demand regions). *Suppose domestic banks hold positive reserves in the liquidity region. Under the maintained parameter assumptions,*

$$\begin{aligned} \mathcal{E}_F &> \mathcal{E}_D \quad \text{if } Q_F > q_F, \\ \mathcal{E}_F &< \mathcal{E}_D \quad \text{if } 0 < Q_F < q_F. \end{aligned} \quad (14)$$

This reversal provides a mechanism for the asymmetry between QE, when reserve supply expands, and QT, when it contracts. During reserve expansion, foreign banks can absorb additional reserves for arbitrage. During reserve contraction, their marginal holdings can instead provide liquidity. When both types hold reserves for liquidity, foreign banks' higher liquidity value net of holding costs makes their proportional response smaller, even while they retain large reserve positions.

³³We find little evidence of IOR–FFR arbitrage by domestic banks in our sample. Keating and Macchiavelli (2017); Banegas and Tase (2020) document that this activity is concentrated among foreign banks.

³⁴The period-specific IV estimates pool weekly variation, potentially across demand regions, whereas $\mathcal{E}_j$ describes the local semi-elasticity at a given equilibrium.

Foreign banks and the limits to Fed’s balance-sheet contraction. Foreign banks’ global dollar liquidity needs can limit how far the Fed can shrink its balance sheet. When foreign banks hold reserves for liquidity, greater global dollar lending raises their reserve demand at a given federal funds rate. With domestic banks’ liquid deposits and model parameters fixed, aggregate reserve demand shifts to the right. If reserve supply is unchanged, the equilibrium rate rises. The Fed therefore needs a higher minimum reserve supply to maintain the same rate ceiling, leaving less room for balance-sheet contraction.

We represent the Fed’s rate-control objective in an ample-reserves system by an upper bound $i^{\text{IOR}} + \tau$ on the federal funds rate, where $\tau \geq 0$ is the allowed spread above IOR.³⁵ Let $S^*(L, G; \tau)$ denote the minimum aggregate reserve supply for which $i - i^{\text{IOR}} \leq \tau$. We characterize this threshold for a given rate ceiling, domestic liquid deposits, and global dollar lending.³⁶

Proposition 8.3 (Global dollar lending limits the Fed’s balance-sheet contraction). *Suppose $0 \leq \tau < \chi_D - \kappa_D$, and hold i^{IOR} , domestic banks’ liquid deposits L , and model parameters fixed. Greater global dollar lending raises foreign reserve demand at the rate ceiling:*

$$\frac{\partial Q_F(\tau, G)}{\partial G} = \frac{(\chi_F - \kappa_F - \tau)\chi_F m}{(\phi_F m G + \chi_F)^2} > 0. \quad (15)$$

With domestic demand unchanged, aggregate reserve demand rises by the same amount. The Fed therefore needs to supply at least $S^(L, G; \tau)$ reserves to keep the federal funds rate at or below $i^{\text{IOR}} + \tau$, where*

$$S^*(L, G; \tau) = Q_D(\tau, L) + Q_F(\tau, G), \quad \frac{\partial S^*}{\partial G} = \frac{\partial Q_F(\tau, G)}{\partial G} > 0. \quad (16)$$

³⁵The literature assesses reserve adequacy using several approaches. Afonso et al. (2025b) estimate the slope of the reserve-demand curve, assessing reserve conditions through the sensitivity of interest rates to changes in reserve supply. Afonso et al. (2022b) examine banks’ reliance on incoming payments to fund outgoing payments as an indicator of liquidity constraints and Ferris et al. (2025) estimate based on the publicly available Fedwire data. Using the Senior Financial Officer Survey, Keating et al. (2019); Andros et al. (2019) extrapolate banks’ reported lowest comfortable reserve balances to the banking system, conditional on prevailing interest rates. These estimates do not incorporate additional reserves that may be needed to overcome frictions in reserve redistribution. Waller (2025) uses the experience of 2019, supplemented by a buffer reflecting bank size and reserve distribution, to suggest an ample-reserves benchmark of roughly 9 percent of GDP, or \$2.7 trillion in July 2025. The institutional environment also matters: Anderson et al. (2026) examine how regulatory and operational changes could reduce reserve demand while retaining an ample-reserves framework. This last approach considers changes to the conditions determining reserve demand.

³⁶In this paper, we do not model the optimal choice of reserve supply or the tolerance. We analyze the Fed’s optimal reserve supply with heterogeneous banks in Oguri and Pizzimenti (forthcoming). Related analyses of reserve supply and monetary policy implementation include Afonso et al. (2023). Ismail and Zúñiga (2026); Pagel (2026) study the welfare implications of the size of the central bank balance sheet.

The elasticity of the minimum reserve supply with respect to global dollar lending is

$$\frac{\partial \log S^*}{\partial \log G} = \frac{Q_F(\tau, G)}{S^*(L, G; \tau)} \frac{\chi_F}{\chi_F + \phi_F m G}. \quad (17)$$

It equals foreign banks' reserve share multiplied by the elasticity of their reserve demand with respect to global dollar lending.

Suppose global dollar lending has grown between a balance-sheet expansion and the subsequent contraction, so $G^{QT} > G^{QE}$. Long-lived dollar commitments can sustain foreign reserve demand as the Fed shrinks its balance sheet. Our empirical evidence suggests that this channel may be substantial.

To isolate the contribution of this lending growth, hold domestic banks' liquid deposits fixed at L^{QT} and compare the reserves needed under current lending with those needed if lending had stayed at its earlier level:

$$S^*(L^{QT}, G^{QT}; \tau) - S^*(L^{QT}, G^{QE}; \tau) = Q_F(\tau, G^{QT}) - Q_F(\tau, G^{QE}) > 0. \quad (18)$$

Starting from the same reserve stock above both thresholds, this gap measures how much less the Fed can withdraw while keeping the federal funds rate at or below $i^{\text{IOR}} + \tau$. With other liabilities and policy arrangements fixed, it also measures how much less the Fed can shrink its balance sheet.

9 Conclusion

We find that foreign banks hold a disproportionate share of U.S. reserve balances, but their role in reserve adjustment differs between balance-sheet expansion and contraction. They absorb a large share of reserve increases during expansion, whereas reserve reductions during contraction fall more heavily on large domestic banks.

Our evidence links foreign banks' persistent reserve demand to their global dollar lending. Reserve growth at U.S. branches is positively associated with their parent banking systems' global dollar assets and, at the banking-group level, with preexisting dollar revolving commitments. The relationship is weaker and statistically insignificant at subsidiaries. These findings point to branches' role in their parent organizations' global dollar liquidity management.

The model connects global dollar liquidity needs to the limits on the Fed's balance-sheet contraction. Greater global dollar lending raises the minimum reserves the Fed needs to supply to maintain a given interest-rate ceiling, even when domestic banks' liquid deposits remain unchanged. Long-lived dollar commitments can sustain this demand as aggregate reserve supply

declines. With other Fed liabilities and policy arrangements fixed, this leaves less room for the Fed to shrink its balance sheet.

Our analysis focuses on monetary policy implementation and leaves the welfare implications of foreign banks' reserve demand open. Diamond et al. (2024) show that reserve injections can crowd out private lending by increasing banks' balance-sheet costs. By absorbing reserves during balance-sheet expansion, foreign branches may ease this burden on domestic banks. These potential benefits suggest that a fuller assessment is needed to establish the net welfare implications of foreign banks' reserve demand.

This paper shows that the dollar's role as a global currency connects U.S. monetary policy implementation to foreign banks' liquidity needs. These banks hold reserves at the Fed to support dollar lending commitments across countries. The global banking system's demand for dollar liquidity therefore constrains how far the Fed can shrink its balance sheet.

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Figures

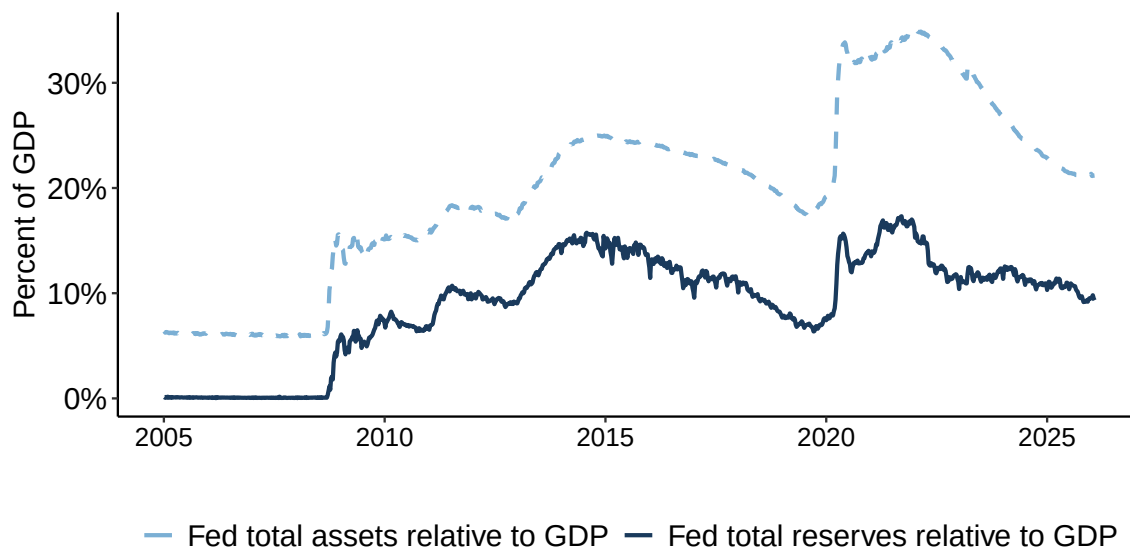


Figure 1: Federal Reserve Balance Sheet Relative to GDP. Weekly ratios of total Federal Reserve assets (WALCL) and reserve balances (WRESBAL) to U.S. GDP. GDP is quarterly and linearly interpolated to weekly frequency. Source: Federal Reserve Board H.4.1 Factors Affecting Reserve Balances and FRED.

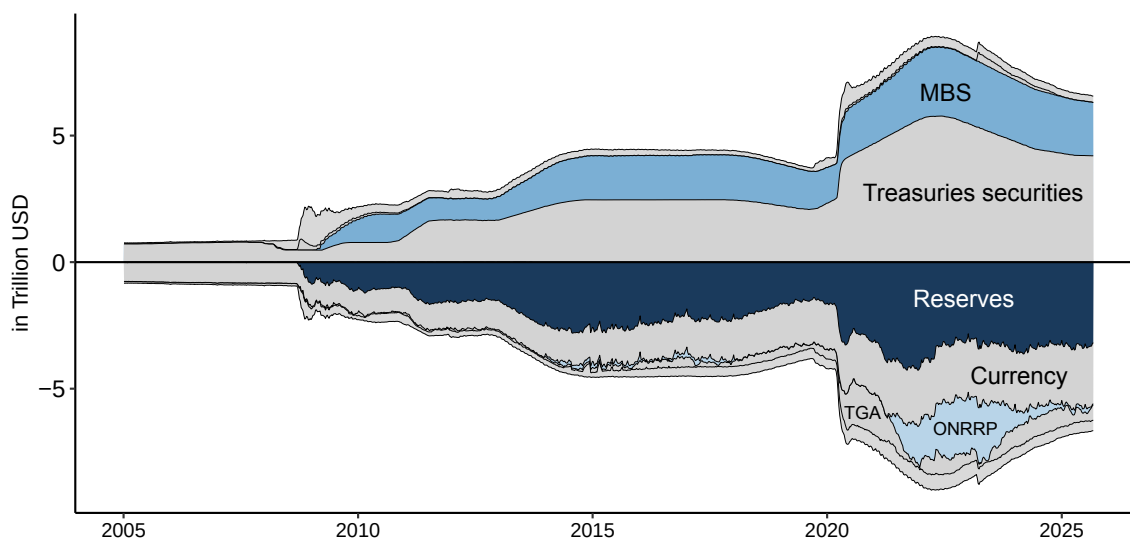


Figure 2: Federal Reserve Balance Sheet Breakdown. Composition of the Federal Reserve's balance sheet from 2005 to the present, highlighting the key components used in this paper. Source: Federal Reserve Board H.4.1 Factors Affecting Reserve Balances.

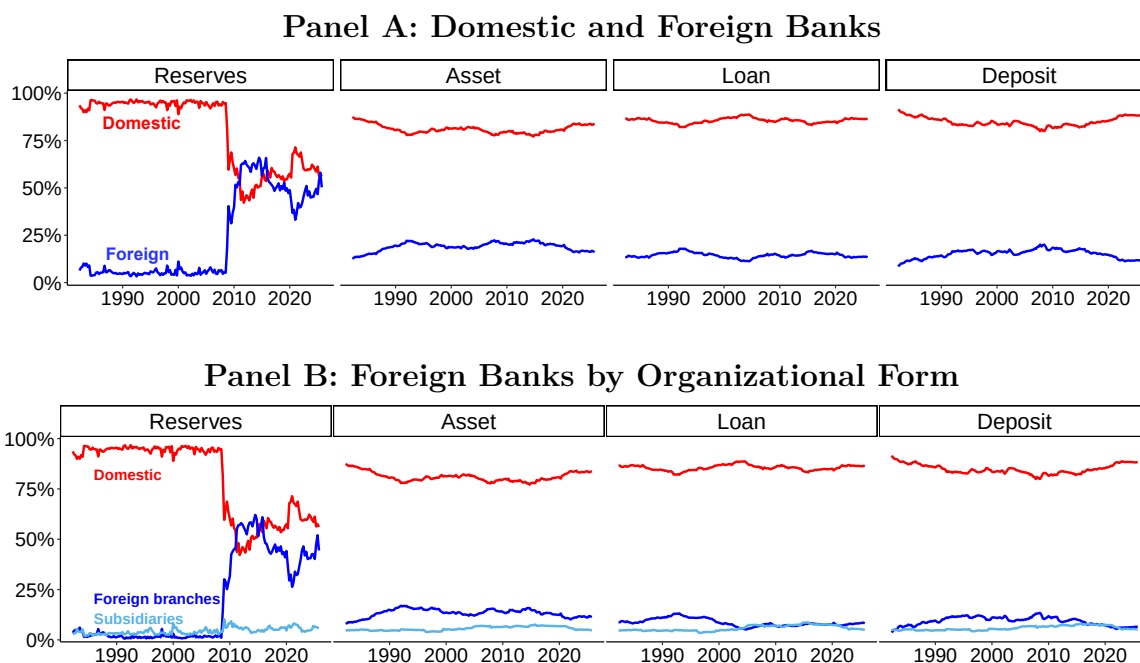
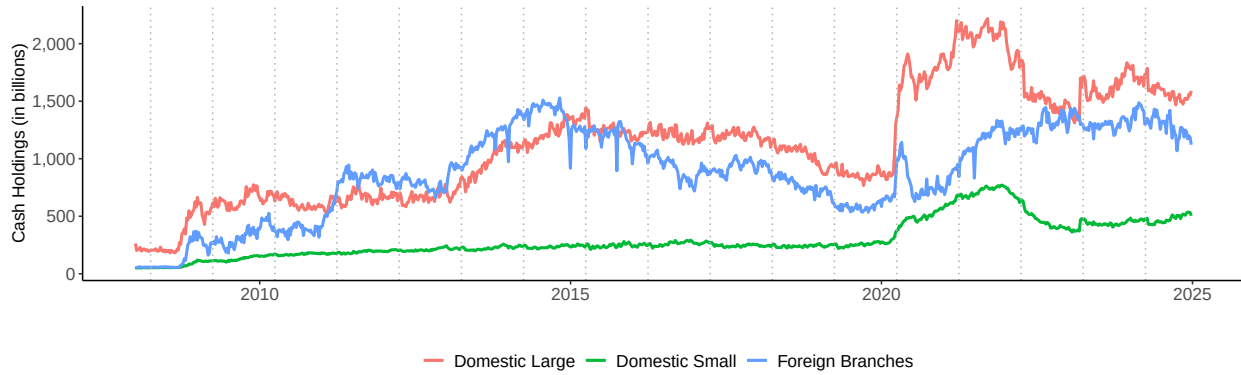
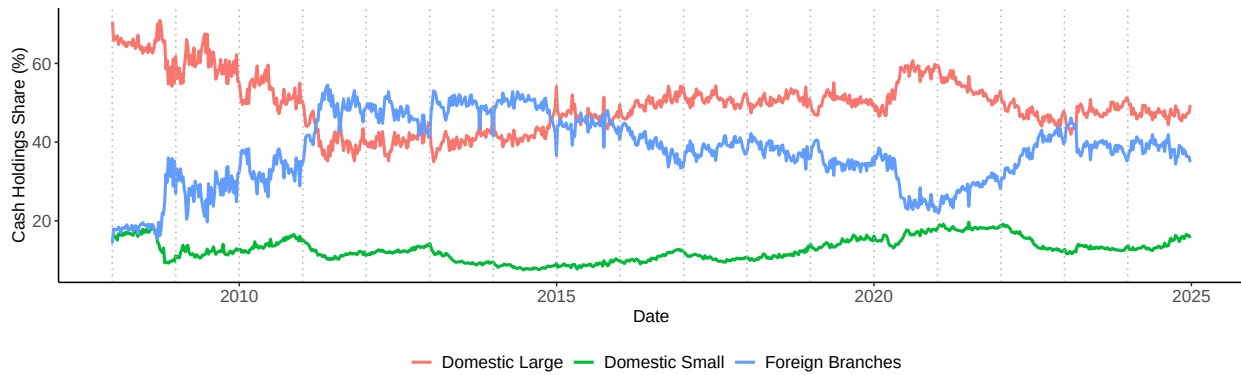


Figure 3: Share of Balance Sheet Components by Bank Type. Panel A shows the shares of assets, loans, deposits, and reserves held by domestic banks and foreign banks, where foreign banks aggregate subsidiaries with branches and agencies. Panel B decomposes the foreign-bank share into branches and agencies and subsidiaries, with domestic banks shown for comparison. The sample runs from 1980Q2 to 2025Q4 and is based on Call Report filings. Both panels adjust foreign-branch reserve holdings for quarter-end window dressing. Source: FFIEC 002, 031, and 041 reports and Federal Reserve H.8 release.

Panel A: Reserve Holding (in billions USD)



Panel B: Share of Reserve Holding



Panel C: Reserve-to-Assets Ratio

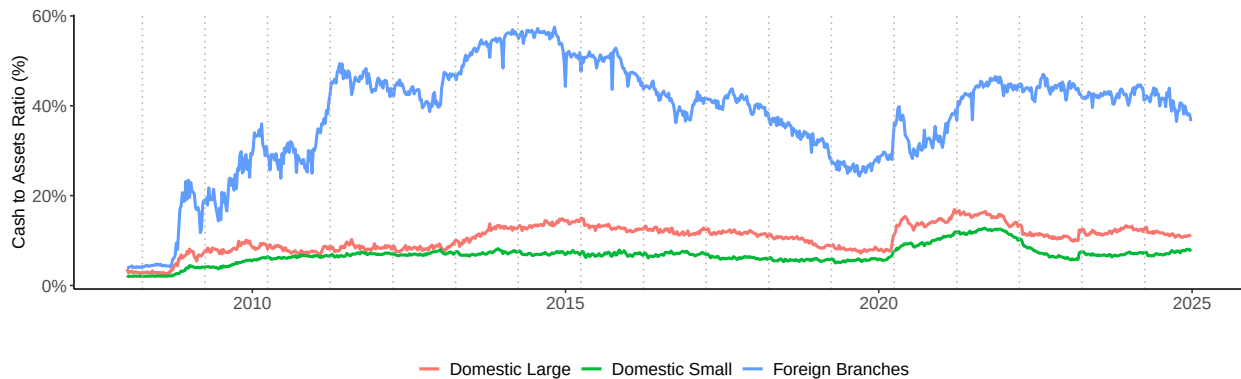


Figure 4: Reserve Holdings by Bank Type This figure plots the evolution of reserve balances (proxied by cash holdings) among banks from 2008 to 2025, distinguishing between domestic large banks (Top 25 banks by asset size), domestic small banks, and U.S. branches of foreign banks. Panel A shows the total level of reserve holdings (in billions of dollars). Panel B displays the share of total U.S. banking system reserve held by each bank type. Panel C presents the ratio of reserve to total assets. Vertical dotted lines indicate calendar year-ends. Source: Federal Reserve's H.8 release.

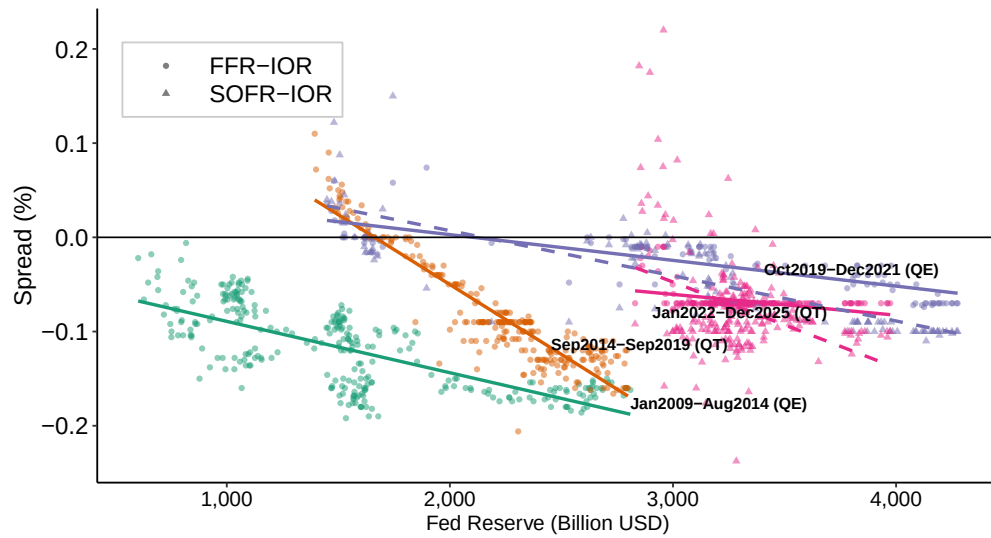


Figure 5: Funding Spreads and Aggregate Reserve Balances This figure plots the spread between the Federal Funds Rate (FFR) and interest on reserves (IOR) against aggregate reserve balances at the Federal Reserve, measured at weekly frequency. Regimes are defined by expansions and contractions in aggregate reserve supply: QE (January 2009 to August 2014), QT (September 2014 to September 2019), QE (October 2019 to December 2021), and QT (January 2022 to December 2025). Solid lines show FFR-IOR spreads; dashed lines show SOFR-IOR spreads for periods beginning in October 2019. Each point represents a weekly level observation; fitted lines are estimated by OLS within each regime. Source: FRED

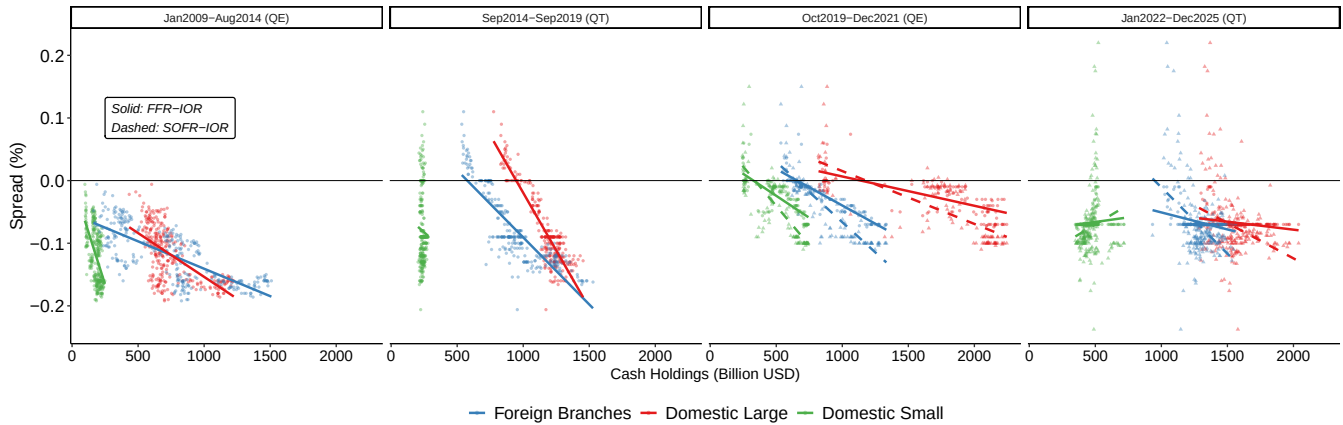


Figure 6: Reserve Holdings and Funding Spreads by Bank Type This figure plots reserve holdings against the FFR-IOR spread for three bank types: foreign branches (blue), large domestic banks (red), and small domestic banks (green). Each panel corresponds to a monetary policy regime. Solid lines represent FFR-IOR relationships; dashed lines represent SOFR-IOR relationships (available for post-2019 periods only). Reserve holdings are measured weekly from the Federal Reserve H.8 release. Source: FRED .

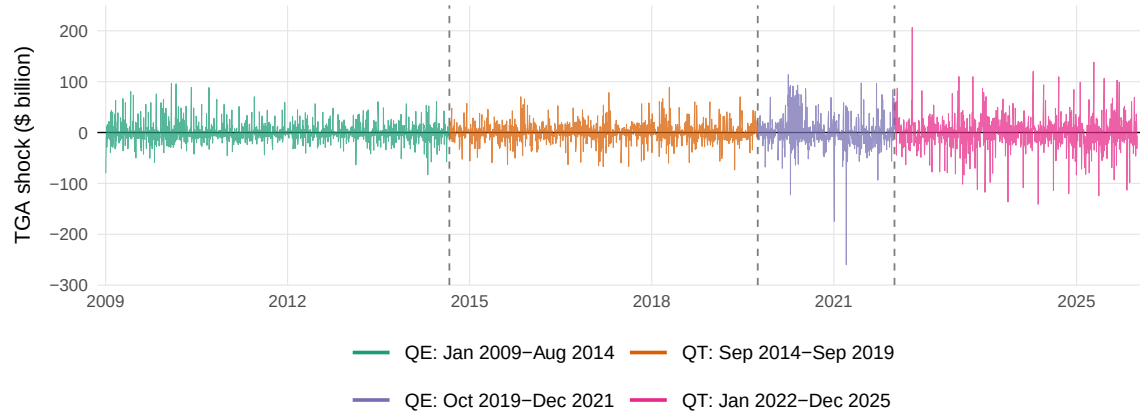


Figure 7: Daily Treasury General Account (TGA) Shocks. This figure plots daily unanticipated TGA changes over 2009–2025, in billions of dollars. Shocks are residuals from regressing TGA changes on issuance and redemptions of bonds and calendar fixed effects. TGA changes and bond issuance and redemption flows use the same consecutive federal funds trading-date intervals. Positive values represent reserve drains; negative values represent reserve injections. Dashed lines mark regime transitions. The series is unsmoothed; intervals crossing regime transitions are excluded. Source: U.S. Treasury Daily Treasury Statement; authors’ calculations.

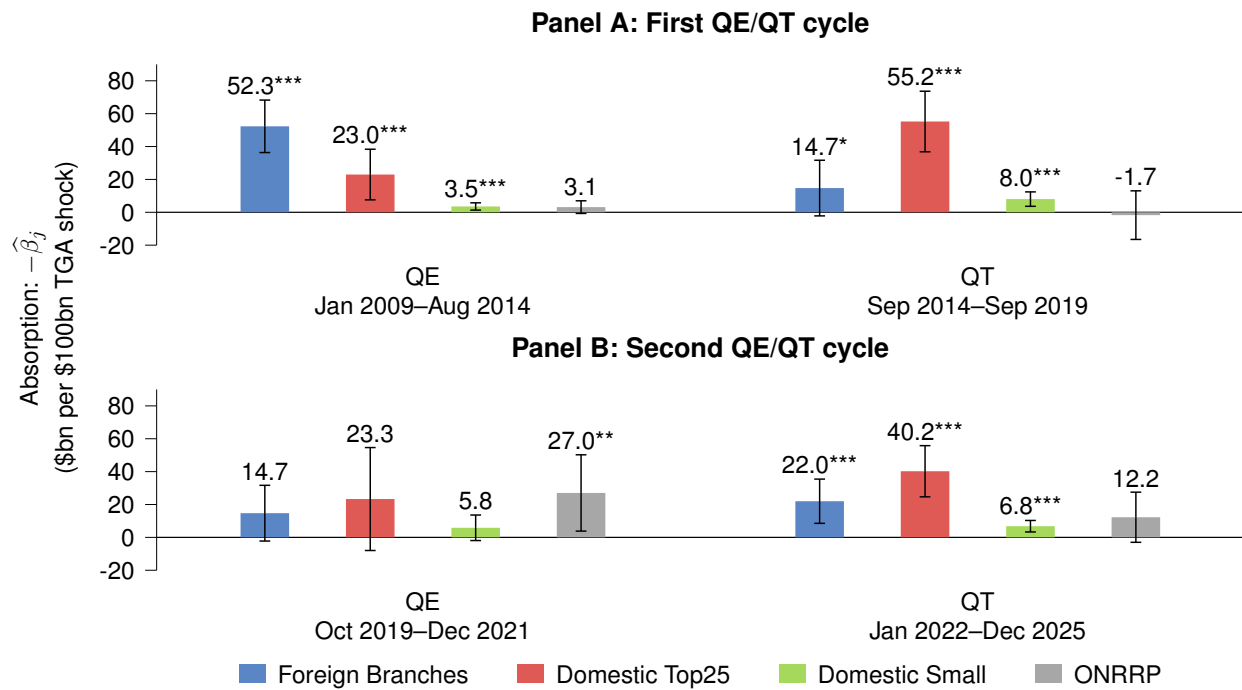


Figure 8: TGA Shock Absorption by Bank Type and Monetary Policy Regime.

This figure plots $-\hat{\beta}_j$, the estimated dollar absorption by each category for a \$100 billion TGA-driven reserve drain, separately by QE and QT episode over 2009–2025. Positive values indicate reductions in reserves holdings or ONRRP take-up. Weekly TGA shocks sum daily unanticipated TGA changes over Wednesday-to-Wednesday intervals. Weeks with either Wednesday endpoint within one calendar day of month-end, and weeks spanning a regime transition, are excluded. All specifications include FOMC-period fixed effects. Vertical lines show 95% confidence intervals based on standard errors clustered by FOMC period. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The corresponding regression results are reported in Appendix Table A5.

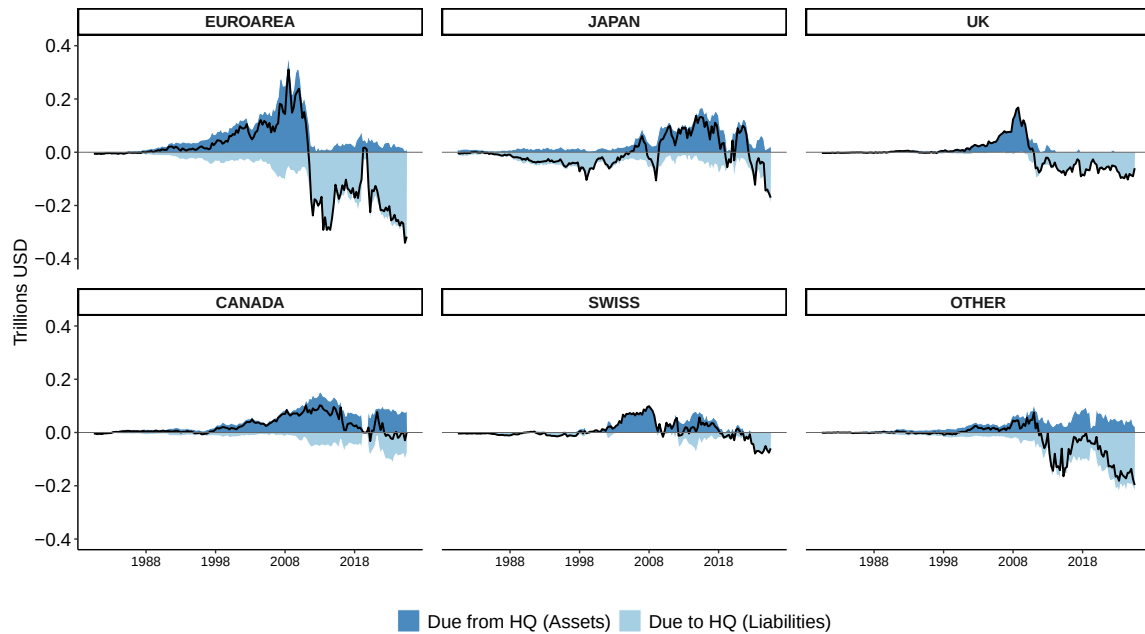


Figure 9: Headquarters (HQ) Funding Flows of Foreign Bank Branches This figure illustrates the intra-group funding flows between U.S. branches of foreign banks and their headquarters (HQ), disaggregated by jurisdiction. Positive values indicate lending from branches to HQ, while negative values represent borrowing from HQ to fund branch operations. The black solid line indicates the net balances. Source: FFIEC 002 reports

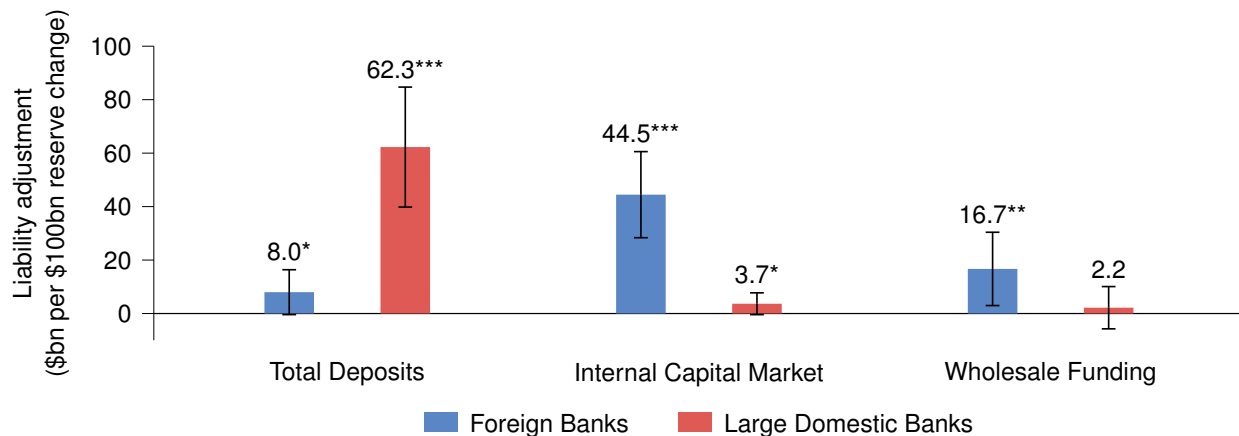


Figure 10: Liability Adjustment Associated with Reserve Changes: Foreign and Large Domestic Banks. Bars report $100\hat{\beta}_{j,l}$ from the weekly two-stage least-squares specification in equation (5) over 2009–2025: the change in the relevant liability category, in billions of dollars, associated with a \$100 billion instrumented reserve change. Weekly reserve changes are instrumented with unanticipated TGA changes aggregated over Wednesday-to-Wednesday intervals. “Internal Capital Market” denotes headquarters funding for foreign banks and internal funding for large domestic banks. All specifications include FOMC-period fixed effects. Weeks with either Wednesday endpoint within one calendar day of month-end, and weeks spanning a regime transition, are excluded. Vertical lines show 95% confidence intervals based on standard errors clustered by FOMC period. The estimates are diagnostic balance-sheet matching coefficients rather than causal effects, and the categories do not form an exhaustive accounting decomposition. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. Source: Federal Reserve H.8 release and U.S. Treasury Daily Treasury Statement; authors’ calculations.

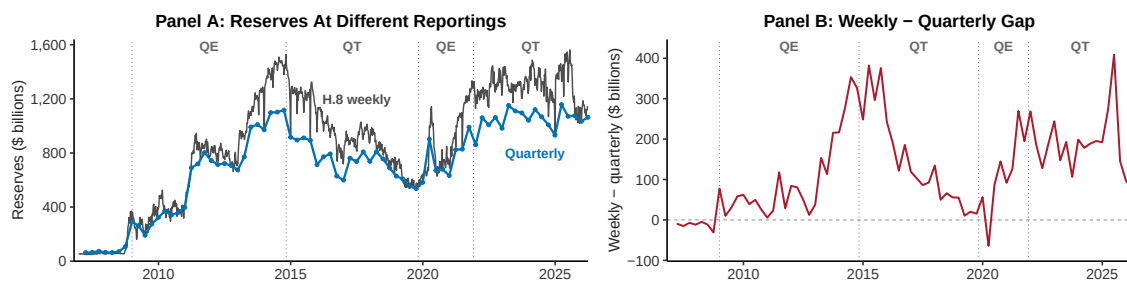


Figure 11: Foreign-Bank Reserves and the Quarter-End Reporting Gap. Panel A compares non-seasonally adjusted Wednesday reserves of foreign-related institutions from the Federal Reserve H.8 release, which we use as a proxy for reserves, with aggregate cash reported by U.S. branches and agencies of foreign banks in the quarter-end FFIEC 002. Panel B plots the window-dressing gap, defined as the latest weekly reserves observation strictly before each quarter-end minus the corresponding quarter-end reserves balance. The matched H.8 observation falls one to seven days before quarter-end, and values are in billions of dollars. Dotted vertical lines mark QE and QT reserve-supply regimes. The sample runs from 2007Q1 through 2026Q1. Source: Federal Reserve H.8 release and FFIEC 002 reports; authors’ calculations.

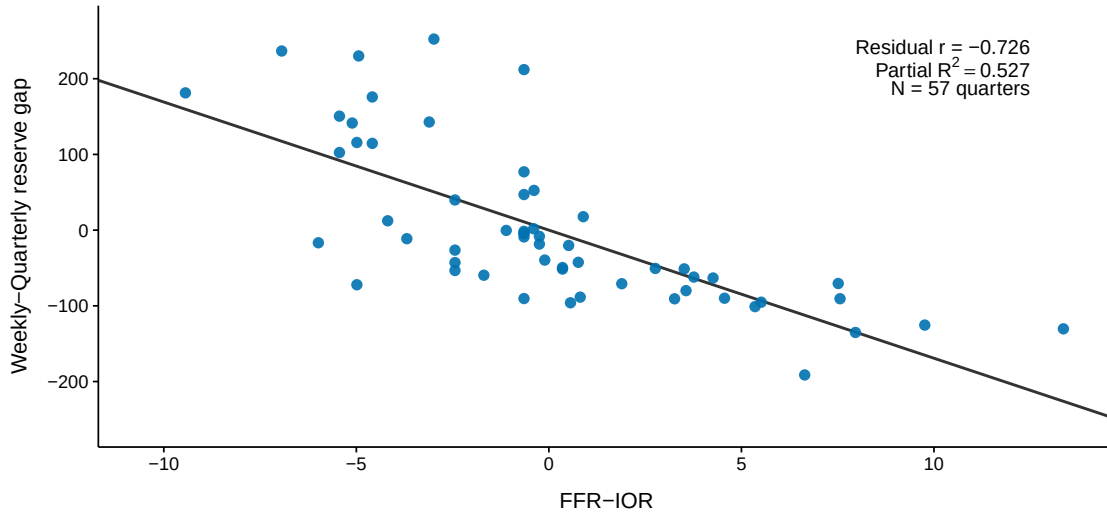


Figure 12: Quarter-End Reserve Gap and Funding Spreads. This figure plots the weekly–quarterly reserve gap against the volume-weighted mean FFR–IOR spread for U.S. branches and agencies of foreign banks. The gap is the latest H.8 reserve balance before quarter-end minus the reserve balance reported in the quarter-end FFIEC 002, measured in billions of dollars. Both reserve series are proxied by cash holdings. The spread is measured in basis points and averaged over eligible observations in the seven calendar days before quarter-end. Both variables are demeaned within each of the four QE/QT episodes defined in Section 5. Each dot represents a quarter, and the solid line corresponds to an OLS regression with episode fixed effects. The reported partial R^2 measures the share of gap variation remaining after episode means are removed that is explained by the spread. The sample contains 57 quarters during 2009–2025, after applying the month-end exclusions to daily rates and matched H.8 dates. Sources: Federal Reserve H.8 release, FFIEC 002 reports, and Federal Reserve Bank of New York; authors’ calculations.

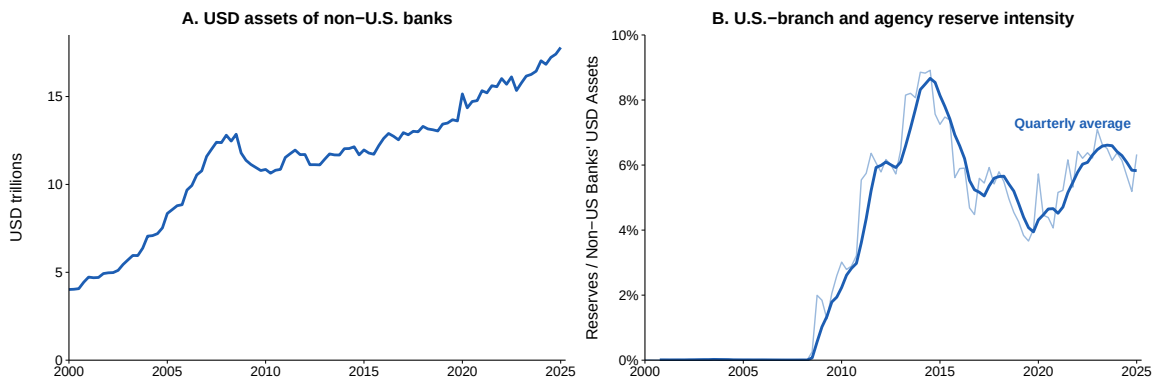


Figure 13: Global Dollar Assets of Non-U.S. Banks and U.S.-Branch Reserve Intensity Panel A plots dollar assets of non-U.S.-parent banks. Panel B plots the percentage of reserve holdings that are the balances summed across all foreign branches and agencies filing FFIEC 002, relative to the aggregate dollar assets of non-U.S.-parent banks. The sample covers 2000Q1–2025Q1. Sources: BIS, FFIEC 002, and authors’ calculations.

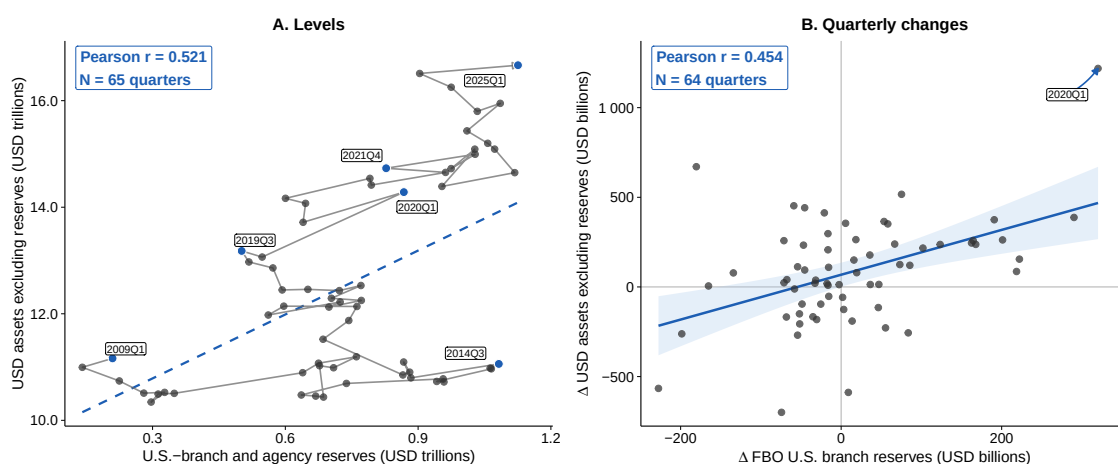


Figure 14: Global Dollar Assets of Non-U.S. Banks and U.S.-Branch Reserve Holdings The figure plots dollar assets of non-U.S.-parent banks excluding reserves holdings, and reserve holdings that are the balances summed across all foreign branches and agencies filing FFIEC 002. The common sample covers 2009Q1–2025Q1. Panel A plots quarter-end levels, with line connecting successive quarters to trace their evolution over time. Panel B plots quarter-to-quarter changes. The blue lines show fitted linear relationships; the shaded region in Panel B is the conventional 95 percent confidence band. The Pearson correlations are 0.521 in levels (65 quarters) and 0.454 in quarterly changes (64 quarters). Sources: BIS, FFIEC 002, and authors' calculations.

Tables

Table 1
First Stage: TGA Shock and Overnight Spreads

This table reports weekly first-stage regressions of changes in federal funds spreads on TGA shocks over 2009–2025. Spread changes are Wednesday-to-Wednesday, and ΔTGA is the sum of daily TGA residuals over the same interval. Weeks with either Wednesday endpoint within one calendar day of month-end are excluded. Panel A uses the volume-weighted mean (FFR); Panel B uses the volume-weighted median (FFR_{50p}) and the 99th volume-weighted percentile (FFR_{99p}). IOR denotes IOER through July 28, 2021 and IORB thereafter. Coefficients measure the basis point change in the spread per \$100 billion TGA shock. Standard errors clustered by FOMC period are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: FFR – IOR

	$\Delta(\text{FFR} - \text{IOR})$ (bps)				
	(1)	(2)	(3)	(4)	(5)
ΔTGA (\$100bn)	0.4980*** (0.1086)	0.4869*** (0.1120)	0.4896*** (0.1130)	1.0183*** (0.2500)	0.1983** (0.0844)
FOMC Period FE		✓	✓	✓	✓
ΔONRRP Control			✓	✓	✓
Sample	All	All	All	QE	QT
Observations	693	693	693	323	370
R^2	0.031	0.521	0.521	0.581	0.230
First-stage F	21.02	18.90	18.76	16.59	5.52

Panel B: FFR_{50p} – IOR and FFR_{99p} – IOR

	$\Delta(\text{FFR}_{50p} - \text{IOR})$ (bps)			$\Delta(\text{FFR}_{99p} - \text{IOR})$ (bps)		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔTGA (\$100bn)	0.4573*** (0.1191)	1.0095*** (0.2466)	0.1446 (0.1032)	1.1276*** (0.4265)	0.4276 (0.5996)	1.4954*** (0.5620)
FOMC Period FE	✓	✓	✓	✓	✓	✓
ΔONRRP Control	✓	✓	✓	✓	✓	✓
Sample	All	QE	QT	All	QE	QT
Observations	693	323	370	693	323	370
R^2	0.479	0.561	0.154	0.216	0.395	0.104
First-stage F	14.75	16.76	1.96	6.99	0.51	7.08

Table 2
Second Stage: Reserve Demand Elasticity
Full Sample, QE and QT Periods

This table reports weekly IV estimates using FFR–IOR over 2009–2025, with the funding-rate definition, weekly timing and exclusions in Table 1. Reserves are proxied by H.8 cash assets. The dependent variable is $\Delta \log(\text{Reserves})$; spread changes are in basis points. Panel A uses all banks; Panel B pools foreign and all domestic banks. Foreign equals one for U.S. branches and agencies of foreign banks. The instruments are ΔTGA and, in Panel B, $\text{Foreign} \times \Delta \text{TGA}$. All specifications include FOMC-period fixed effects and a weekly ΔONRRP control. In Panel B, β is the domestic response, θ the foreign–domestic difference, and $\beta + \theta$ the foreign response; observations count the two series separately each week. First-stage F refers to the funding-spread first stage. In Panel B, Wald and Anderson–Rubin (AR) tests assess $\theta = 0$; AR inference accommodates weak instruments. Standard errors clustered by FOMC period are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: All Banks			
	$\Delta \log(\text{Reserves})$		
	(1)	(2)	(3)
$\Delta(\text{FFR} - \text{IOR}) (\pi_1)$	-0.0626*** (0.0131)	-0.0363*** (0.0076)	-0.1356** (0.0567)
FOMC Period FE	✓	✓	✓
ΔONRRP Control	✓	✓	✓
Sample	All	QE	QT
Observations	693	323	370
First-stage F	18.76	16.59	5.52
Panel B: Foreign versus Domestic Banks			
	$\Delta \log(\text{Reserves})$		
	(1)	(2)	(3)
$\Delta(\text{FFR} - \text{IOR}) (\beta)$	-0.0616*** (0.0150)	-0.0266*** (0.0078)	-0.1555** (0.0658)
$\text{Foreign} \times \Delta(\text{FFR} - \text{IOR}) (\theta)$	-0.0104 (0.0123)	-0.0345*** (0.0119)	0.0530 (0.0354)
Foreign	0.0046** (0.0023)	0.0062 (0.0046)	-0.0030 (0.0045)
Foreign response ($\beta + \theta$)	-0.0719*** (0.0139)	-0.0611*** (0.0123)	-0.1025** (0.0460)
FOMC Period FE	✓	✓	✓
ΔONRRP Control	✓	✓	✓
Sample	All	QE	QT
Observations	1,386	646	740
First-stage F	18.76	16.59	5.52
Wald p -value: $\theta = 0$	0.3999	0.0051	0.1387
AR p -value: $\theta = 0$	0.4253	0.0124	0.0627
AR 95% set for θ	[-0.0345, 0.0195]	[-0.0641, -0.0096]	[-0.0029, 0.3011]

Table 3
Global Dollar Claims and Foreign-Branch Reserve Adjustment

This table reports quarterly regressions of reserve growth on the lagged scale of worldwide dollar activity. The dependent variable is $\Delta \log(\text{Reserves})_{i,t}$. $\text{USD Assets}_{i,t-1}$ denotes lagged worldwide U.S.-dollar claims excluding reserve balances held at the banking system's U.S. branches and agencies. $\text{HedgedMargin}_{c(i),t}^{3M}$ is the contemporaneous three-month FX-hedged reserve margin for the currency area associated with banking system i , measured in annualized percentage points. Columns (1)–(2) use 14 home-country banking systems. Columns (3)–(4) first aggregate reserves and dollar assets to seven currency areas—Australia, Canada, the euro area, Japan, Sweden, Switzerland, and the United Kingdom—before taking logs. Columns (2) and (4) include the hedged-margin control; columns (1) and (3) omit it while retaining the corresponding estimation samples. The sample runs from 2009Q2 through 2025Q1 and is unbalanced. All specifications include country or currency-area fixed effects and time fixed effects. Standard errors are two-way clustered by currency area and calendar quarter and are reported in parentheses. Reported p -values use the small-cluster t reference with six degrees of freedom. Because the hedged margin varies across only seven currency areas, inference for that coefficient should be interpreted cautiously. The claims-minus-reserves variable is a descriptive scale proxy rather than an accounting net-claims measure. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	$\Delta \log(\text{Reserves})_{i,t}$			
	Country		Currency area	
	(1)	(2)	(3)	(4)
$\log(\text{USD Assets})_{i,t-1}$	0.157** (0.052)	0.143** (0.048)	0.261** (0.081)	0.253*** (0.067)
$\log(\text{Reserves})_{i,t-1}$	−0.364*** (0.025)	−0.365*** (0.026)	−0.494*** (0.114)	−0.502*** (0.119)
$\text{HedgedMargin}_{c(i),t}^{3M}$		0.147 (0.086)		0.091 (0.065)
Hedged-margin control		✓		✓
Country / currency-area FE	✓	✓	✓	✓
Time FE	✓	✓	✓	✓
Observations	850	850	425	425
Within R^2	0.180	0.181	0.244	0.250

Table 4
USD Syndicated-Loan Facilities in the
Matched DealScan Sample

This table summarizes U.S.-dollar syndicated revolving facilities, covering 2009Q2–2025Q3. In Panel A, subpanels (i)–(iii) report all banks, domestic banks, and foreign banks, respectively. Deal and tranche counts describe distinct identifiers among originations allocated to sample banks in the origination quarter. Average active stock is the average quarterly aggregate lender-allocated commitment, including earlier originations still active. Panel B reports bank and borrower characteristics for domestic and foreign banks.

Panel A: USD syndicated-loan facilities					
Tranche type	# Deals	# Tranches	Average active stock (\$bn)	Maturity (years)	
				Median	Average
<i>(i) All banks</i>					
Revolver	26,229	28,007	1,860.528	5.00	3.91
<i>of which:</i> < 1 year	1,932	2,033	73.577	1.00	0.90
≥ 1 year	23,862	25,304	1,786.951	5.00	4.15
<i>(ii) Domestic banks</i>					
Revolver	22,279	23,611	1,004.439	5.00	3.94
<i>of which:</i> < 1 year	1,672	1,744	34.047	1.00	0.89
≥ 1 year	20,368	21,438	970.392	5.00	4.19
<i>(iii) Foreign banks</i>					
Revolver	16,456	17,932	856.088	5.00	3.92
<i>of which:</i> < 1 year	1,324	1,396	39.529	1.00	0.93
≥ 1 year	14,935	16,127	816.559	5.00	4.18
Panel B: Bank and borrower characteristics					
	Domestic		Foreign		
Number of highest-level bank parents	495		49		
Average quarterly active commitments (\$bn)	1,004.4		856.1		
Average quarterly origination amount (\$bn)	62.0		59.9		
US borrowers (%)	91.46		79.03		
Foreign borrowers (%)	7.34		19.53		
Foreign borrower in the US (%)	0.62		0.79		
Lead-arranger share of outstanding credit lines (%)	30.91		27.88		

Table 5
Contractual Dollar Commitments and Reserve Adjustment

The dependent variable is the quarterly change in log U.S. reserves, $\Delta \log(\text{Reserves})_{i,t}$. Active credit lines are lender-allocated U.S.-dollar syndicated revolving commitments treated as active from origination through contractual maturity, including drawn and undrawn amounts. F_i equals one for foreign banks. Reserves and assets cover domestic bank charters for domestic organizations and U.S. branches and agencies for foreign banking groups. Credit lines, reserves, and assets are lagged one quarter. All columns include bank fixed effects, lagged log reserves and assets as controls. Columns (1) and (3) include bank-type-by-quarter fixed effects. Column (2) replaces these with home-country-by-quarter fixed effects on the same sample. Column (3) adds the three-month FX-swap control, $\text{HedgedMargin}_{c(i),t}^{3M}$, measured in annualized percentage points and set to zero for domestic banks. The sample spans 2009Q2–2025Q3 and includes 495 domestic organizations and 49 foreign groups in columns (1)–(2). Column (3) excludes banks headquartered in Taiwan, Israel, and the United Arab Emirates because FX data are unavailable. The foreign-bank slope is $\beta_1 + \beta_2$, where β_1 is the domestic credit-line coefficient and β_2 is the foreign interaction coefficient; its standard error and test use the full coefficient covariance matrix. Standard errors in parentheses are two-way clustered by bank and calendar quarter. ***, **, and * denote significance at the 1, 5, and 10 percent levels.

	$\Delta \log(\text{Reserves})_{i,t}$		
	(1)	(2)	(3)
$\log(\text{Active Credit Lines})_{i,t-1}$	0.0220 (0.0150)	0.0201 (0.0148)	0.0219 (0.0150)
$F_i \times \log(\text{Active Credit Lines})_{i,t-1}$	0.1669** (0.0745)	0.1264* (0.0701)	0.1642* (0.0828)
$\log(\text{Reserves})_{i,t-1}$	−0.4738*** (0.0265)	−0.4897*** (0.0259)	−0.4748*** (0.0266)
$F_i \times \text{HedgedMargin}_{c(i),t}^{3M}$			0.0561** (0.0224)
Foreign slope: $\beta_1 + \beta_2$	0.1889** (0.0725)	0.1465** (0.0681)	0.1861** (0.0812)
p -value: $H_0 : \beta_1 + \beta_2 = 0$	0.0113	0.0352	0.0251
Bank FE	✓	✓	✓
Bank-type $\times$ quarter FE	✓		✓
Home-country $\times$ quarter FE		✓	
Bank balance-sheet controls	✓	✓	✓
Observations	15,079	15,079	14,815
R^2	0.267	0.377	0.270
Within R^2	0.222	0.226	0.224

Table 6
Outstanding Dollar Credit Lines and Reserve Adjustment:
QE and QT

The dependent variable is the quarterly change in log U.S. reserves, $\Delta \log(\text{Reserves})_{i,t}$. Panels A and B estimate the total active-credit-line specifications in Table 5 separately during QE and QT. Under the paper's phase classification, QE covers 2009Q1–2014Q3 and 2019Q4–2021Q4; QT covers 2014Q4–2019Q3 and 2022Q1–2025Q4, with data ending in 2025Q3. Requiring $t-1$ and t to belong to the same phase excludes 2014Q4, 2019Q4, and 2022Q1, leaving 30 QE and 33 QT quarters. F_i indicates foreign banks. All columns include bank fixed effects and lagged log U.S. reserves and assets. Columns (1) and (3) include bank-type-by-quarter fixed effects; column (2) replaces these with home-country-by-quarter fixed effects. Column (3) adds contemporaneous $F_i \times \text{HedgedMargin}_{c(i),t}^{3M}$, set to zero for domestic banks; missing FX data exclude banks headquartered in Taiwan, Israel, and the United Arab Emirates. The foreign-bank slope is $\beta_1 + \beta_2$. Standard errors in parentheses are two-way clustered by bank and calendar quarter. ***, **, and * denote significance at the 1, 5, and 10 percent levels.

Dependent variable: $\Delta \log(\text{Reserves})_{i,t}$			
	(1)	(2)	(3)
<i>Panel A: QE periods</i>			
$\log(\text{Active Credit Lines})_{i,t-1}$	0.0122 (0.0318)	0.0124 (0.0314)	0.0122 (0.0318)
$F_i \times \log(\text{Active Credit Lines})_{i,t-1}$	0.1641 (0.1768)	0.0568 (0.1751)	0.1418 (0.1988)
$\log(\text{Reserves})_{i,t-1}$	-0.5478*** (0.0361)	-0.5594*** (0.0349)	-0.5475*** (0.0360)
$F_i \times \text{HedgedMargin}_{c(i),t}^{3M}$			0.0557 (0.0521)
Foreign slope: $\beta_1 + \beta_2$	0.1763 (0.1745)	0.0691 (0.1713)	0.1540 (0.1968)
Observations	6,293	6,293	6,173
R^2	0.293	0.413	0.296
Within R^2	0.244	0.252	0.246
<i>Panel B: QT periods</i>			
$\log(\text{Active Credit Lines})_{i,t-1}$	0.0412** (0.0202)	0.0398* (0.0199)	0.0410* (0.0202)
$F_i \times \log(\text{Active Credit Lines})_{i,t-1}$	0.2142** (0.0933)	0.2445*** (0.0726)	0.2351** (0.0863)
$\log(\text{Reserves})_{i,t-1}$	-0.5592*** (0.0474)	-0.5694*** (0.0436)	-0.5608*** (0.0472)
$F_i \times \text{HedgedMargin}_{c(i),t}^{3M}$			0.0602** (0.0275)
Foreign slope: $\beta_1 + \beta_2$	0.2555*** (0.0881)	0.2843*** (0.0698)	0.2761*** (0.0814)
Observations	8,084	8,084	7,952
R^2	0.315	0.398	0.319
Within R^2	0.268	0.263	0.270
Bank FE	✓	✓	✓
Bank-type $\times$ quarter FE	✓		✓
Country $\times$ quarter FE		✓	
Bank balance-sheet controls	✓	✓	✓

Appendix

A1. Data Details

For our analysis of supply shocks on short-term interest rates, we construct key variables from multiple sources. Daily Treasury General Account (TGA) balances are obtained from the Treasury website and Haver Analytics. Policy rates, including interest on reserves (IOR), are obtained from FRED. Federal funds rate measures are constructed from historical brokered transaction data and FR 2420 summary statistics, as described below. The general collateral (GC) repo rate and LIBOR rate come from Bloomberg.

Although Treasury cash balances have always affected reserve supply, their quantitative importance increased substantially after the Global Financial Crisis. Prior to 2008, the Treasury managed most of its cash through the Treasury Tax and Loan (TT&L) program, which placed funds with private depository institutions. Following the introduction of interest on reserves in late 2008, this arrangement became less efficient, and the Treasury gradually shifted cash management to the TGA, effectively ending the TT&L program by 2012 (Santoro, 2012). As a result, post-crisis fluctuations in the TGA are large and frequent, making the TGA the dominant autonomous driver of reserve supply over our sample period.

We construct TGA shocks as residuals from a regression of changes in TGA balances on beginning-of-month, end-of-month, beginning-of-quarter, end-of-quarter, and day-of-week indicators, QE–QT episode fixed effects, and net issuance of marketable Treasury bonds. Net issuance is measured as reported issues minus redemptions. TGA changes are calculated across consecutive observed federal funds trading days, with issuance accumulated over the same intervals.

For the weekly analysis, we sum the daily TGA residuals between consecutive Wednesdays, excluding the preceding Wednesday and including the current Wednesday. Changes in H.8 balance-sheet variables and ONRRP take-up are measured using Wednesday levels. We exclude weeks with either Wednesday endpoint within one calendar day of month-end and weeks spanning a QE–QT episode transition.

We rely on the FR 2420 for daily transaction data on federal funds purchased, Eurodollar transactions, and certificates of deposit. The breakdown of bank type in these data is available only from March 1, 2016. Our primary data source for weekly bank balance sheet information is the H.8 Report, Assets and Liabilities of Commercial Banks in the United States, published by the Federal Reserve Board. The H.8 data, compiled from FR 2644 weekly reporting banks, provide an aggregate view of commercial bank assets and liabilities, allowing us to track trends in bank reserves. We use non-seasonally adjusted Wednesday values. The weekly reserve-demand, reserve-absorption, and liability-adjustment analyses cover January 2009

through December 2025.

The classification of foreign banks in this section differs from our bank panel analysis. In the H.8 report, foreign-related institutions refer specifically to branches and agencies of foreign banks, as well as Edge Act and agreement corporations, but exclude foreign subsidiaries as well as International Banking Facilities (IBFs). As a result, the foreign banks examined in the supply shock section primarily capture the reserve holdings of foreign branches, not subsidiaries.³⁷

Since reserves are not directly reported in the H.8 data, we use cash assets as a proxy variable. The H.8 cash holding category includes vault cash, cash items in process of collection, balances due from depository institutions, and reserves. While this measure closely tracks reserves, it differs from the Call Report definition, which also includes balances due from foreign central banks and foreign financial institutions.³⁸

We verify that the deviation between H.8 cash assets and actual reserve balances is minimal following the introduction of Interest on Reserves (IOR). Figure A1 left panel compares Call Report aggregate cash balances, Call Report aggregate reserves, H.4.1 reported Fed reserves, and H.8 bank cash holdings. Before the Global Financial Crisis in 2008, the discrepancy between cash assets reported in H.8 (purple line) and reserves at the Fed (light blue line) was substantial, but post-GFC, the two measures converge. Notably, weekly cash and reserve balances dip around quarter-ends, consistent with window-dressing, where banks adjust their balance sheets for regulatory reporting purposes. This suggests that weekly data are better suited to capture banks' reserve management behavior and arbitrage sensitivity. Similarly, Figure A1 right panel shows that foreign-related banks' cash holdings in the H.8 data closely align with the reserve holdings of foreign branches reported in Call Report FFIEC 002 at quarter-end, while diverging at non-quarter-end periods, where H.8 cash holdings appear larger.

The H.8 dataset further classifies domestic banks into large domestically chartered banks, and small domestically chartered banks. Large domestically chartered banks refer to the top 25 banks ranked by domestic assets as of the most recent Call Report. These institutions include all U.S. Global Systemically Important Banks (G-SIBs) as well as most Category II to IV banks, which are subject to heightened prudential standards. For instance, in 2019Q1, the top 25 banks by total assets included all Category II to IV banks, making them a distinct regulatory group. Small domestically chartered banks consist of all other

³⁷Edge Act and agreement corporations hold a negligible share of reserves.

³⁸The Call Report (FFIEC 031, 041, 002) defines cash to include balances due from foreign financial institutions (RCON0070). While a more precise measure of Call Report cash (excluding foreign balances) can be constructed, this breakdown is only reported by banks with total assets exceeding \$300 million, limiting full comparability.

domestic banks reporting FR 2644 data. Since FR 2644 reporting is voluntary, the H.8 sample—approximately 850 institutions—is smaller than the full Call Report sample.

A1.1 Construction of Federal Funds Rate Measures

We construct the volume-weighted average federal funds rate (FFR), the volume-weighted median (FFR_{50p}), and the 99th volume-weighted percentile (FFR_{99p}) from January 2009 through December 2025. Through February 2016, these measures use historical brokered federal funds data. From March 2016 onward, they use FR 2420 summary statistics.

Before March 2016, the published effective federal funds rate (EFFR) was a volume-weighted average; thereafter, it became a volume-weighted median. We therefore use the separately reported volume-weighted average after this change to preserve the same statistical measure throughout the sample. Transaction coverage nevertheless changes with the transition to FR 2420.

The three measures are aligned to a common federal funds trading-day calendar. Funding spreads subtract IOR, defined as IOER through July 28, 2021 and IORB thereafter. For the weekly regressions, spread changes are calculated using consecutive Wednesday endpoints.

Figure A2 provides additional evidence on the information content of the upper tail of the federal funds rate distribution. Panel A plots unsmoothed daily observations of the volume-weighted average federal funds rate on the left and the 50th and 99th percentiles on the right, each relative to IOR, from January 2009 through March 2026. The two plots use separate vertical scales. Panel B is from the lower panel of Figure 1 in Anbil et al. (2026b), which decomposes federal funds borrowing spreads to IORB by borrower and lender type. Panel C is from Figure 2(b) of Gissler and Narajabad (2025), which reports federal funds spreads to IORB across lender–borrower segments. Panels B and C show that rates in liquidity-sensitive interbank segments are higher and more variable than rates in the dominant FHLB–foreign-bank segment. The 99th-percentile series in Panel A exhibits pronounced variation during many of the same episodes, suggesting that upper-tail rates contain information about marginal funding pressure that is less evident in the median and volume-weighted average. This interpretation is consistent with Gissler et al. (2025), who identify rates and volumes in the domestic interbank federal funds market as early indicators of reserve scarcity. Motivated by this evidence, we use FFR_{99p} as an observable indicator of liquidity pressure at the margin, rather than as a sufficient statistic for systemwide reserve scarcity.

The empirical analysis constructs weekly spread changes from unsmoothed daily rates. Panel A of Figure A2 also uses unsmoothed daily observations, with spreads above 30 basis points capped at 30 basis points for display only.

A1.2 Construction of Historical SOFR series

We construct a historical repo-rate series using the New York Fed’s primary dealer Treasury general collateral repo survey rate before August 22, 2014, indicative SOFR from August 22, 2014 through March 29, 2018, and published SOFR from April 3, 2018. The survey rate is a volume-weighted mean based on a narrower set of transactions, whereas SOFR is a volume-weighted median based on broader transaction-level data. We use the survey rate as a proxy for repo market conditions before SOFR data are available (Bowman, 2019).

A1.3 Quarterly Bank-BHC Panel Data

To construct the quarterly panel dataset, we obtain Call Report data and Y-9C Reports from the National Information Center (NIC) and the Federal Reserve Bank of Chicago. FFIEC 031 and 041, the Call Report data for U.S. commercial banks and foreign bank subsidiaries, provide detailed balance sheet and income statement information.³⁹ FFIEC 002, ‘Report of Assets and Liabilities of U.S. Branches and Agencies of Foreign Banks,’ provides balance sheet data for foreign branches and agencies. The Y-9C reports contain similar data at the bank holding company (BHC) level. The Call Report data are available from 1976Q1 for domestic banks and foreign bank subsidiaries, while data on foreign bank branches begin in 1980Q2. While balance sheet variables on foreign branches and agencies are similar to those for domestic banks, there are differences in RSSD variables and some contents. For instance, they do not contain income statement and capital accounts, although they provide information on flows with their headquarters.⁴⁰ Y-9C reports are available starting in 1986Q2. To maintain consistency in our sample, we exclude reporters of FR 2886a (New York Investment Companies) and FR 2886b (Edge Act and Agreement Corporations) from our foreign samples and concentrate on branches and agencies and subsidiaries.

We link bank-level data to their respective BHCs using the following approach. When available, we rely on RSSD9347 and RSSD9348 to match RSSD9001 (individual bank IDs) to their parent holding companies. In cases where these identifiers are missing or inconsistent over time, we supplement the linkage using the Relationship Data provided by the NIC. We also refer to ‘Events & Changes’ on the FDIC website to account for some large mergers

³⁹Typical economic analyses of Call Report data primarily use FFIEC 031, 041, and 051 reports. We exclude FFIEC 051 due to its focus on small banks. Designed for institutions with total assets under \$5 billion, the FFIEC 051 report does not separately report reserve holdings, instead aggregating them with other cash assets, preventing us from observing reserve holdings. Additionally, smaller banks are less likely to engage in active reserve management, making them less relevant for studying reserve dynamics. To ensure accurate measurement of reserves and focus on institutions with significant reserve activity, we restrict our sample to FFIEC 031 and 041 filers.

⁴⁰Previous literature that has used FFIEC 002 includes Aldasoro et al. (2022); Cetorelli and Goldberg (2011); Fillat et al. (2018).

and liquidations. For foreign banking organization (FBO) samples after December 2008, we also rely on the Federal Reserve’s Structure and Share Data for mapping. For banks headquartered in Australia, Canada, the Eurozone, Japan, Sweden, Switzerland, and the U.K., we manually check and refine these assignments to ensure accurate representation at the top-tier level.

To classify foreign banking organizations by country and type, we follow Aldasoro et al. (2022), using RSSD9331 and RSSD9209.⁴¹ When these variables are missing, we impute the country classification based on the bank’s most recent filings or refer to the Federal Reserve’s Structure and Share Data for verification. If a bank is headquartered in Austria, Belgium, Croatia, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Portugal, Slovakia, Slovenia, or Spain, we classify it as ‘Euroarea’. To identify G-SIBs and domestic U.S. banks subject to relevant regulations, we refer to data from the Financial Stability Board (FSB), the Federal Reserve Board, and other regulatory agencies. We then compile regulatory ratios from manually collected Basel III Pillar 3 Disclosure Reports and supplement this information with Bloomberg data before merging it into our dataset.

We construct our key variables—including reserves, assets, and balance sheet components—from Call Report data while ensuring consistency over time. For domestic banks and foreign subsidiaries, we adopt methodologies outlined in Kashyap and Stein (2000); Drechsler et al. (2017, 2021); Correia et al. (2024). Where applicable, we adhere to definitions used in these sources to maintain continuity. However, for foreign banks and more recent data, we develop new variable definitions to account for changes in FFIEC 002 reports. In our main analysis, we compute variables at both the BHC-merged level and the standalone bank level, ensuring robustness in our empirical results. We omit samples that report non-positive reserves or assets. When calculating the shares of reserve holdings in Figure 3, we compare the holdings of domestic and foreign banks, aggregating subsidiaries and branches and agencies, and exclude reserve holdings of other entities. In other words, we do not include deposit categories such as ‘Term deposits held by depository institutions,’ ‘U.S. Treasury, General Account,’ ‘U.S. Treasury, Supplementary Financing Account,’ ‘Foreign official accounts,’ and ‘Other deposits’ in the H.4.1 report for our share analysis.

Our primary outcome is reserve holdings, which are held by depository institutions with a master account at the Federal Reserve. These institutions include nationally chartered banks, eligible state-chartered banks, and other entities classified under Section 19(b) of the Federal Reserve Act. In March 2020, reserve requirement ratios were reduced to zero, so

⁴¹We are deeply grateful to the authors for their invaluable guidance on classification methodologies and assistance.

reserve holdings in the post-2020 period reflect banks' discretionary liquidity management rather than statutory reserve mandates.

In analyses involving cross-jurisdiction reserve-remuneration spreads, we focus on foreign banks headquartered in jurisdictions for which we can construct a consistent home-country central-bank remuneration rate: the euro area, Japan, the United Kingdom, Canada, Sweden, Switzerland, and Australia. These rate-matched jurisdictions account for 81.8% of total foreign-bank reserve holdings over 2009Q1–2025Q4 on a pooled reserve-dollar basis, and the matched share averages 82.4% across quarters.

For each jurisdiction, we collect the relevant home-country reserve-remuneration or central-bank deposit rate and define the international reserve-rate spread as $IOR_t^{US} - IOR_{c,t}^{home}$. Figure A8 plots this spread across countries and shows substantial variation over the sample period. The home-country benchmark $IOR_{c,t}^{home}$ is intended to capture the marginal administered return that a bank can earn on balances held at its home central bank. For tiered remuneration systems, we use the marginal or non-exempt rate rather than a bank-specific average rate across tiers. Thus, for the euro area we use the ECB deposit facility rate, including the non-exempt tier during the two-tier period; for Japan we use the Bank of Japan policy-rate balance rate; and for Switzerland we use the SNB sight-deposit remuneration rate applicable above the exemption threshold. For the United Kingdom we use Bank Rate, for Canada the Bank of Canada deposit or settlement-balance remuneration benchmark, for Sweden the Riksbank standing deposit facility rate, and for Australia the RBA Exchange Settlement balance remuneration rate.

We also construct the three-month FX hedge component, $\rho_{c,t}^{3m}$, from spot exchange rates and three-month FX forward/swap quotes. The object captures the annualized exchange-rate cost or benefit of synthetically converting a home-currency position into a hedged U.S. dollar position over a three-month horizon. Let $S_{c,t}$ denote the spot exchange rate and $F_{c,t}^{3m}$ the outright three-month forward rate, expressed in a consistent foreign-currency-per-U.S.-dollar convention. We compute

$$\rho_{c,t}^{3m} = 100 \times \frac{A_c}{D_{c,t}^{3m}} \left[\log F_{c,t}^{3m} - \log S_{c,t} \right],$$

where $D_{c,t}^{3m}$ is the number of days to maturity of the forward contract and A_c is the relevant annualization convention. We use actual days to maturity when available; otherwise we use a standard 90-day three-month maturity. The annualization convention is 365 days for Canada, the United Kingdom, Australia, and Sweden, and 360 days for the euro area, Japan, and Switzerland.⁴²

⁴²We are deeply grateful to Chase Ross and Sharon Ross for sharing their insights in variable construction.

For currencies quoted in U.S. dollars per foreign currency, such as the euro, pound sterling, and Australian dollar, we invert the quote convention before applying the formula, equivalently using $\log S_{c,t} - \log F_{c,t}^{3m}$. The resulting $\rho_{c,t}^{3m}$ is measured in annualized percentage points. Under our sign convention, a positive value raises the FX-hedged return on U.S. reserves relative to the unhedged spread $\text{IOR}_t^{\text{US}} - \text{IOR}_{c,t}^{\text{home}}$, while a negative value lowers it. The three-month FX-hedged reserve spread is therefore

$$\text{HedgedMargin}_{c,t}^{3m} = \text{IOR}_t^{\text{US}} - \text{IOR}_{c,t}^{\text{home}} + \rho_{c,t}^{3m}.$$

A1.4 USD assets of non-US banks

We estimate the currency composition of consolidated foreign claims by combining the BIS Locational Banking Statistics (LBS) and Consolidated Banking Statistics (CBS), following McGuire and Von Peter (2012) and Aldasoro et al. (2020b).⁴³ We consider additional treatment for Japanese banks. Japan’s international banking statistics include both banks’ own-account positions and positions held in trust accounts, whereas most reporting jurisdictions cover only banks’ own-account positions. Following Saito et al. (2018), we use Bank of Japan data to construct an approximate alternative series for Japanese banks that excludes trust-account assets. Figure A6 plots the resulting estimates of global U.S.-dollar assets held by non-U.S. banking systems.

A1.5 Syndicated Dollar Credit Facilities and FBO Matching

We use lender-level records from LPC DealScan and construct a bank-quarter panel covering 2009Q1–2025Q3. The original unit of observation in the data is a lender’s participation in a particular deal–tranche–origination event. Because a syndicated deal can contain multiple tranches with different contractual terms, we retain separate tranches rather than collapsing the data to the deal level. We restrict the sample to original, U.S.-dollar-denominated tranches whose distribution method is recorded as syndication, with an identified bank lender and a positive lender allocation of at least \$10,000. We exclude amendment records. We classify facilities using DealScan’s tranche-type field. We classify the tranche as commitment if the category is labeled as 364-Day Facility, Revolver/Line < 1 Yr., Revolver/Line ≥ 1 Yr., Limited Line, or Revolver/Term Loan. We define Term Loan A strictly as tranches for which DealScan’s tranche type is Term Loan A. We do not include generic term loans, delayed-draw term loans, or Term Loan B and later institutional tranches in this category. DealScan

⁴³For the BIS statistics as well as Dealscan data construction, we are especially grateful to Iñaki Aldasoro, Sebastian Doerr, Patrick McGuire, Goetz von Peter, and International Banking and Financial Statistics at BIS for their generous advice and helpful discussions on the construction of these measures.

generally reports the total contractual amount of each tranche and the identities of its participating lenders, but lender-specific allocation shares are frequently missing. Assigning the full tranche amount to every lender would multiply the same credit facility by the size of the syndicate. We therefore allocate each tranche across all observed syndicate members before restricting the data to our matched foreign banking organizations. We first collapse repeated records to a unique deal–tranche–origination–lender observation. For each lender, we use its row-level DealScan share when reported. If that field is missing, we divide the tranche equally across all observed lenders. When shares are available for only part of the syndicate, we preserve those shares and divide the remaining unassigned share equally among lenders with missing shares. If known shares sum to more than 110 percent, indicating internally inconsistent reporting, we instead divide the tranche equally across all observed lenders. When every observed lender has a reported share, we retain those shares without rescaling them. The allocation uses the observed lender records for the complete syndicate, not only the foreign banks ultimately included in our estimation sample and not DealScan’s separately reported number-of-lenders field. We acknowledge that Mueller et al. (2025) emphasize that estimates can depend on whether the researcher retains the full syndicate or only lead arrangers, requires lender shares to be reported, and restricts the sample to particular facility types. Our procedure follows the same reported-share-first principle but additionally accommodates partially reported syndicates by allocating only the residual share. Given this potential measurement problem, we check the cleaned origination data against summary statistics shown in Fleckenstein et al. (2026).

We next aggregate all affiliated lender records assigned to the same FBO analysis group within each deal–tranche–origination event. We define newly originated commitments as stock-eligible facilities originated during quarter t . Inherited commitments are facilities originated before quarter t that remain contractually active. We treat each originated facility as active through the facility’s stated maturity.⁴⁴ For Term Loan A, we construct an analogous measure by retaining the allocated original notional through stated maturity. Because DealScan does not continuously observe amortization, prepayment, or lender sell-down, we refer to this variable as a Term Loan A notional proxy rather than outstanding principal. Finally, we manually construct a crosswalk between DealScan parent identifiers and FFIEC operating-FBO identifiers, assigning affiliated entities to a common FBO analysis group. We verify the crosswalk against institution names, ownership histories, and merger records. To maintain a consistent organizational perimeter over time, we combine UBS and Credit Suisse on a pro

⁴⁴DealScan does not observe subsequent utilization, amendment, early cancellation, refinancing, or secondary-market transfers. However, we consider these events are rare for revolving commitment line issuance, while acknowledging these might affect the term loan A.

forma basis throughout the sample, including before their 2023 merger. The foreign-bank estimation sample contains 49 foreign banking organizations from 19 home countries over 2009Q2–2025Q3, after requiring the prior-quarter observations needed to construct reserve growth and lagged explanatory variables. Table 4 summarizes the facilities and allocation methods, while Table A8 reports reserve and commitment coverage for each FBO.

A2. Additional Evidence on Reserve-Adjustment Shares

We provide descriptive evidence on how the composition of reserve adjustment evolves within and across policy regimes. While the baseline coefficients in Section 5 summarize average pass-through over each sample period, reserve demand need not be stable over time: shifts in market structure, regulation, and balance-sheet constraints can alter banks’ capacity and willingness to absorb reserve shocks (Afonso et al., 2025b). Accordingly, we estimate 52-week rolling coefficients, $\hat{\beta}_{j,t}^{(52)}$, from the baseline reserve-absorption specification and use them to construct time-varying adjustment shares,

$$\theta_{j,t} = 100 \times \frac{-\hat{\beta}_{j,t}^{(52)}}{\sum_{k \in \{\text{Foreign branches, Large domestic, Small domestic, ONRRP}\}} \left(-\hat{\beta}_{k,t}^{(52)}\right)}. \quad (\text{A1})$$

The negative sign ensures that institutions absorbing reserve drains receive positive shares. These objects are not elasticities. They are normalized shares of contemporaneous TGA-induced dollar adjustment. Because one category may move opposite to aggregate adjustment, or offset movements in other categories, an individual share can be negative and the set of shares can temporarily exceed 100% in absolute value.

Appendix Figure A11 plots the time-varying composition of reserve absorption shares, with vertical dashed lines indicating major reserve-supply regime changes. The figure is broadly consistent with three patterns. First, during the January 2009–August 2014 expansionary period, foreign branches absorb the majority of TGA-induced reserve fluctuations, consistent with their high reserve-demand elasticity and active cross-border liquidity management. Second, following the introduction and subsequent expansion of the ONRRP facility after 2014, reserve absorption becomes more distributed across bank types and the ONRRP facility. Third, during tightening periods, the composition shifts toward large domestic institutions and, in parts of the contraction beginning in January 2022, ONRRP, while foreign branches no longer dominate the marginal adjustment. Small domestic banks play a limited but generally positive role throughout the sample.

Appendix Figure A12 provides a complementary stock-level perspective. It plots cumulative balance changes across the two expansion–tightening cycles. Domestic and foreign-bank

reserves both rise substantially during QE, but the subsequent QT declines are incomplete, especially in the post-2019 cycle. Foreign-bank reserves rise by about \$551 billion during the second expansion but fall by only about \$96 billion during the subsequent tightening. By contrast, ONRRP behaves more like a reversible policy margin, rising by about \$1.64 trillion during the second expansion and falling by about \$1.49 trillion during QT. These stock patterns are descriptive, but they point in the same direction as the TGA-shock evidence: reserve buildups are not unwound one-for-one during normalization, and the persistence of reserves depends on which institutions absorb them during expansions.

A3. Relevant Regulations: Leverage Ratio and Liquidity Coverage Ratio

A3.1 Basel III standards

Basel III is a global regulatory framework developed by the Basel Committee on Banking Supervision (BCBS) to strengthen the resilience of internationally active banks. Introduced in response to the 2008 financial crisis, Basel III enhances capital adequacy, introduces stricter liquidity requirements, and limits excessive leverage to reduce systemic risk. The framework builds on Basel I and Basel II by raising minimum capital requirements, implementing the Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR), and incorporating a non-risk-based leverage ratio to serve as a backstop to risk-weighted capital measures. Basel III applies to banks operating across jurisdictions, with national regulators responsible for its phased implementation and enforcement.

Leverage Ratio: The Basel III leverage ratio framework has evolved over time to strengthen the resilience of the global banking system by constraining excessive leverage. Before its introduction, there was no globally standardized leverage ratio, as bank capital regulation primarily relied on risk-weighted capital requirements. However, the Global Financial Crisis (GFC) exposed weaknesses in this approach, revealing that risk-weighted asset (RWA) calculations often understated actual risk exposures. The leverage ratio was introduced as a supplementary, non-risk-based measure to serve as a backstop against potentially miscalculated RWAs. Between 2009 and 2013, no formal requirements were in place as discussions around the framework were still ongoing. In January 2014, the Basel Committee on Banking Supervision (BCBS) introduced the Basel III leverage ratio framework and disclosure requirements, setting a minimum Tier 1 leverage ratio of 3% and mandating public disclosure to enhance market discipline. This marked the beginning of a parallel run period, allowing banks to report their leverage ratios without mandatory compliance (Basel Committee on Banking Supervision, 2014). In 2017, the BCBS refined the leverage ratio by revising the definition of exposure, incorporating insights from the parallel run to ensure the

leverage ratio functioned as an effective backstop to risk-based capital requirements (Basel Committee on Banking Supervision, 2017a).

By January 2018, the leverage ratio transitioned from a reporting requirement to a binding Pillar 1 capital standard, requiring banks to maintain a minimum leverage ratio of 3% (Basel Committee on Banking Supervision, 2014). This transition was based on the original 2014 framework but incorporated the revised exposure definitions introduced in 2017. The 2017 revisions also introduced a leverage ratio buffer for Global Systemically Important Banks (G-SIBs), requiring them to hold an additional leverage ratio buffer equal to 50% of their risk-weighted higher loss absorbency requirement. Originally scheduled for implementation in January 2022, the redefinition of the exposure and the G-SIB leverage ratio buffer were postponed to January 2024 to provide banks with additional time to adapt to the new requirements (Basel Committee on Banking Supervision, 2017b).

Liquidity Coverage Ratio: Prior to the Global Financial Crisis (GFC), there was no globally standardized liquidity requirement. While the importance of liquidity risk was recognized, its measurement and regulation remained fragmented across jurisdictions, reflecting the structural differences in national financial markets. Basel II largely overlooked liquidity risk, focusing instead on capital adequacy. However, the crisis exposed significant weaknesses in banks' liquidity positions, highlighting the need for an internationally coordinated approach.

In December 2010, the Basel Committee on Banking Supervision (BCBS) introduced the Liquidity Coverage Ratio (LCR) as part of Basel III, requiring banks to hold sufficient high-quality liquid assets (HQLA) to withstand a 30-day period of severe liquidity stress. The LCR was initially scheduled for full implementation by January 1, 2015, but following concerns over its impact on financial markets and credit supply, the BCBS revised the framework in January 2013. The revisions adjusted the definitions of HQLA and net cash outflows while introducing a phase-in schedule, starting at 60% in 2015 and increasing annually to reach 100% by 2019 (BCBS, 2013).

With the full implementation of the LCR in 2019, banks are required to maintain a minimum 100% LCR under normal conditions, ensuring that short-term liquidity risk is adequately managed. During stress periods, banks are permitted to draw down their liquidity buffers, recognizing the role of HQLA in mitigating shocks rather than serving as a static regulatory minimum. This evolution marks a shift in Basel regulation, expanding its scope beyond capital adequacy to explicitly incorporate liquidity as a pillar of financial stability.

A3.2 US

The Basel III framework allows member countries a degree of national discretion in its implementation, enabling jurisdictions to tailor standards to their domestic banking systems.

For this reason, the implementation schedule and the scope differ between the Basel III and the US standards.

Leverage Ratio: Leverage ratio requirements have long been integral to US banking regulation, predating international standards such as Basel III. While the definition of the numerator differs (Basel III being stricter), US banks have been historically subject to a minimum Tier 1 leverage ratio of 4%, with a 5% threshold for well-capitalized status since 1985.

In 2014, US regulators introduced the Supplementary Leverage Ratio (SLR) as part of the Basel III reforms, a year ahead of the Basel Committee's 2015 timeline. The SLR requires large, internationally active banks to maintain a minimum Tier 1 capital of 3% of their total leverage exposure, which includes both on-balance-sheet assets and certain off-balance-sheet exposures, which is consistent with Basel III definition. The US implementation did not include a phase-in period; banks were expected to comply with the SLR requirements upon the rule's effective date.

To further enhance the resilience of systemically important banks, US regulators implemented the Enhanced Supplementary Leverage Ratio (eSLR) in 2014. This rule mandates US G-SIBs to maintain an additional buffer of 2% at the BHC level, raising the minimum SLR requirement to 5%. At the depository institution level, these banks are required to maintain a 6% SLR to be considered "well-capitalized."

In 2018, the Economic Growth, Regulatory Relief, and Consumer Protection Act (EGRRCPA) was enacted, mandating adjustments to the SLR for specific banking organizations.⁴⁵ This led banks under \$250 billion total assets to be excluded from the SLR requirement. The final rule implementing this change became effective on April 1, 2020, aiming to more accurately reflect the leverage exposure of these specialized institutions.

In April 2020, responding to the outbreak of COVID-19, the Federal Reserve announced a temporary change to the Supplementary Leverage Ratio (SLR) requirements for large banks, intending to ease strains in the Treasury market and promote lending to households and businesses. This modification allowed banks to exclude U.S. Treasury securities and reserves at the Fed from the SLR calculation. This relief measure expired on March 31, 2021, at which point the previous SLR requirements were reinstated.⁴⁶

⁴⁵Furthermore, Section 402 of the EGRRCPA requires federal banking agencies to amend their capital regulations to allow custodial banks to exclude certain central bank deposits from the SLR calculation. This provision primarily benefits institutions predominantly engaged in custody, safekeeping, and asset servicing activities, such as The Bank of New York Mellon, Northern Trust Corporation, and State Street Corporation.

⁴⁶Jurisdictions varied in their treatment of reserve exemptions in leverage ratio calculations. For instance, the ECB and Japan temporarily excluded reserves, while the UK had already permanently excluded them since 2016. Canada and Switzerland also implemented temporary exemptions, whereas the US reinstated its

Liquidity Coverage Ratio: In September 2014, US federal banking agencies finalized a rule implementing the Liquidity Coverage Ratio (LCR) for large and internationally active banking organizations. This rule established a standardized minimum liquidity requirement, mandating that these institutions hold sufficient high-quality liquid assets (HQLA) to cover projected net cash outflows over a 30-day stress period. The US LCR rule closely aligns with the Basel Committee on Banking Supervision’s LCR standard but incorporates certain adjustments to address the specific characteristics of the US financial system.

A notable distinction between the US and Basel III LCR implementation lies in the phase-in schedules. The Basel III framework introduced the LCR starting at 60% on January 1, 2015, with annual increments of 10 percentage points, reaching 100% by January 1, 2019. In contrast, the US adopted a more accelerated timeline: institutions were required to maintain an LCR of 80% by January 1, 2015, increasing to 90% by January 1, 2016, and achieving full compliance at 100% by January 1, 2017.

A4. Institutional Structure and Rate Formation in the Federal Funds Market

This section describes the institutional structure of the post-crisis federal funds market and its implications for rate formation and the information contained in EFFR.

In the post-crisis ample-reserves regime, the federal funds market has become highly segmented and institutionally constrained.⁴⁷ Although the federal funds rate remains the Federal Reserve’s primary operating target, it is no longer determined through broad-based trading among a wide range of depository institutions. Instead, as shown in Figure A9, trading is concentrated between a narrow set of participants: the Federal Home Loan Banks (FHLBs) on the lending side and branches of foreign banking organizations on the borrowing side. Transactions between FHLBs and foreign bank branches account for roughly 90 percent of federal funds trading volume. The resulting oligopoly–oligopsony structure reflects two sets of institutional forces: the regulatory and intraday liquidity needs of the FHLBs and the relatively low balance-sheet costs and funding flexibility of foreign branches.

These trading frictions are part of a broader set of constraints on short-term funding markets. Related work studies trading relationships in the U.S. repo market (Anbil and Senyuz, 2022) and monetary policy transmission in the segmented European repo market

original SLR framework after March 2021.

⁴⁷For analyses of segmentation, bargaining, and trading frictions in the federal funds market, see Bech and Klee (2011); Afonso and Lagos (2015); Schulhofer-Wohl and Clouse (2018); Afonso et al. (2019); Lagos and Navarro (2023). For a broader discussion of monetary policy implementation with ample reserves, see Afonso et al. (2025c).

(Eisenschmidt et al., 2024). Anbil et al. (2026a) identify repo-market intermediation capacity as a distinct constraint on balance-sheet reduction. Separately, payment-system demands can impose a lower bound on reserve supply (Duffie, 2026).

From scarce reserves to interest on reserves. Before 2008, the Fed operated under a scarce reserves system, adjusting reserve supply through open market operations to steer the Federal Funds Rate (FFR). Banks, constrained by reserve requirements and liquidity needs, actively managed their balances by borrowing and lending in the federal funds market and using intraday credit at the Fed. Small changes in reserve supply had large effects on interbank rates, placing the supply curve on the sloped part of the reserve demand curve. This operating environment changed in late 2008 as reserves flooded the banking system, rendering reserve requirements non-binding; fluctuations in reserve supply no longer moved the FFR, as liquidity had become abundant and supply now intersected the flat part of the demand curve. For further details and historical background, see Ihrig and Wolla (2020); Hughes and Younger (2026).

In 2006, Congress passed a series of regulatory relief measures for banks and other financial institutions. This package, known as the Financial Services Regulatory Relief Act of 2006, included the authorization for the Fed to pay interest on bank reserves. Although this was intended to take effect in 2011, the Fed’s response to the GFC expedited the implementation of IOR. The idea of paying interest on reserve holdings had been proposed by economists including Friedman (1959), and the implementation concept was further developed by Goodfriend (2002). For further historical background, see Wall (2017); Borio (2023).

A4.1 FHLBs as the Dominant Lenders

On the lending side, the FHLBs have emerged as the dominant suppliers of federal funds (Gissler et al., 2025, 2023). Like other government-sponsored enterprises (GSEs), the FHLBs hold accounts at the Federal Reserve but are ineligible to earn interest on reserve balances, which gives them a strong incentive to lend cash at rates below IOR. Other GSEs largely withdrew from unsecured lending after the Global Financial Crisis. In particular, Fannie Mae and Freddie Mac curtailed and ultimately ceased their participation in unsecured lending markets after entering conservatorship in September 2008 and receiving supervisory guidance in the early 2010s.⁴⁸ As a result, the FHLBs are now the sole GSEs supplying liquidity to the federal funds market.

The FHLBs’ participation in the federal funds market is shaped by both regulatory

⁴⁸Fannie Mae and Freddie Mac are permitted to place overnight cash in the Federal Reserve’s ONRRP facility, which is a secured transaction.

requirements and operational needs.⁴⁹ Each of the 11 regional FHLBs manages its own investment portfolio and liquidity position (Gissler and Narajabad, 2017a,b,c). To fund their activities, FHLBs issue debt through the Office of Finance and extend advances to member institutions. Critically, they must maintain sufficient intraday liquidity to meet debt-service obligations, which are typically due around 12:00 p.m. ET. Among the available short-term instruments, overnight federal funds lending is uniquely well suited to this requirement. These transactions operate through the Fedwire Funds Service, which opens at 9:00 p.m. ET on the prior business day ($T - 1$) and closes at 7:00 p.m. ET on the settlement day (T), offering a wide window for access.⁵⁰ More importantly, overnight federal funds loans are typically repaid by 9:00 a.m. on $T + 1$, allowing the FHLBs to redeploy cash ahead of their midday funding obligations on the following day.

Federal funds also receive favorable regulatory treatment. Under contingent liquidity requirements, FHLBs must hold a minimum stock of liquid assets. Interest-bearing deposits at commercial banks are subject to unsecured credit-exposure limits, whereas placements in the federal funds market are exempt from these constraints.⁵¹ These features make federal funds lending not only operationally flexible but also regulatory-efficient, reinforcing its role as the FHLBs' preferred short-term investment vehicle.

Other short-term investment options available to the FHLBs are operationally or institutionally constrained in ways that limit their usefulness for intraday liquidity management. Interest-bearing bank deposits, for example, are subject to strict internal single-name counterparty limits, which restrict unsecured exposure to individual institutions and make it difficult to deploy large volumes of cash. Although these placements may offer returns comparable to federal funds, they are typically less scalable under current regulatory risk frameworks. The ONRRP facility offers a risk-free overnight investment option, but its timing is misaligned with FHLBs' operational requirements. The ONRRP auction window opens only between 12:45 p.m. and 1:15 p.m. ET, and the transaction settles on a $T + 1$ basis at 3:30 p.m. ET. Cash placed in the facility is therefore unavailable on the same day, limiting its usefulness for midday liquidity obligations. Similarly, tri-party repo transactions unwind late, at around 3:30 p.m. ET. Although these instruments may serve a role in broader liquidity management, they are not viable substitutes for federal funds in meeting the FHLBs' intraday needs.

⁴⁹Related research examines the FHLBs' role in funding markets and financial stability (Gissler et al., 2023), intraday liquidity management (Gissler and Narajabad, 2025), and the information that nonbank cash lenders provide about reserve conditions (Gissler et al., 2025).

⁵⁰The Fedwire Funds Service closing time was extended from 6:30 p.m. to 7:00 p.m. ET on March 8, 2021.

⁵¹This treatment was updated in January 2025, when the FHFA revised the liquidity framework for FHLBs: <https://www.fhfa.gov/news/news-release/fhfa-announces-final-rule-expanding-access-to-liquidity-for-the-federal-home-loan-bank-system>.

A4.2 Foreign Branches as the Dominant Borrowers

On the borrowing side, foreign bank branches account for the majority of activity in the federal funds market (Bech and Klee, 2011; Banegas and Tase, 2020; Anbil et al., 2026b). Several regulatory and structural features contribute to this oligopsonistic outcome. First, foreign bank branches are exempt from paying the FDIC deposit-insurance assessment, which domestic banks must pay on their total liabilities, including federal funds borrowed. This exemption makes overnight borrowing less costly for foreign branches than for their domestic counterparts.⁵²

Second, many large domestic banks face binding constraints under the Supplementary Leverage Ratio (SLR) or enhanced SLR (eSLR), which raise the marginal cost of balance-sheet expansion, especially when borrowing reserves. In contrast, branches of foreign banks are not subject to these leverage requirements at the branch level, allowing them to expand their U.S. balance sheets without facing the same regulatory balance-sheet costs.⁵³ Balance-sheet expansion at branches is therefore less directly constrained by U.S. capital and leverage requirements than expansion at domestic banks or separately capitalized foreign-owned subsidiaries. This differential treatment creates a structural asymmetry in reserve demand, with foreign branches acting as more elastic borrowers in the overnight unsecured market. Because branches are legal extensions of their foreign parents, they can also access headquarters funding directly and adjust their liability composition when spreads are favorable.

Foreign branches are also more likely to meet the credit standards required to borrow from the FHLBs. The FHLBs impose internal counterparty-rating requirements for federal funds lending, typically at or above investment grade. In practice, many smaller domestic banks lack formal credit ratings or prefer to borrow term advances rather than participate in the overnight market.⁵⁴ By contrast, foreign banks operating branches in the United States are generally large global institutions with strong credit ratings, making them natural and eligible counterparties for FHLB transactions. Together, lower marginal U.S. balance-sheet costs, access to internal capital markets, and counterparty eligibility make foreign branches the natural marginal borrowers in the post-IOR federal funds market.

⁵²For evidence on regulatory differences, balance-sheet costs, and reserve and repo-market arbitrage, see Keating and Macchiavelli (2017); Munyan (2017); Banegas and Tase (2020); Anderson et al. (2025). Related work examines how bank balance-sheet costs affect the allocation of funds to the overnight reverse repurchase facility (Afonso et al., 2022a). Related theoretical work studies foreign banks' role in interbank markets and monetary policy implementation (Kim, 2026).

⁵³These exemptions apply to branches of foreign banking organizations. The consolidated parent may still be subject to leverage constraints, but these are often less strict than those imposed under the Dodd–Frank framework in the United States.

⁵⁴Foreign banks are not members of the FHLBs and therefore do not have access to secured advances from them.

A5. Policy Background: Balance-Sheet Size and Composition

Wallace (1981) provides a neutrality benchmark in which open-market operations leave equilibrium allocations unchanged. The economic effects of central-bank balance-sheet policy therefore depend on the frictions that distinguish public and private financial claims.

The appropriate size of the Fed’s balance sheet depends on the benefits of supplying public liquidity and the costs associated with its asset holdings. A larger supply of safe, liquid central-bank liabilities can reduce reliance on runnable private short-term debt (Greenwood et al., 2016). Maintaining substantial reserve balances can also facilitate monetary policy implementation through administered interest rates (Gagnon and Sack, 2014; Reis, 2016). Related models connect reserve supply and remuneration to bank lending, financial stability, and monetary policy transmission (Kashyap and Stein, 2012; Bigio and Sannikov, 2021). These benefits must be weighed against the liquidity services of securities removed from private portfolios when reserves are created (Vissing-Jorgensen, 2023). The optimal size and composition of the balance sheet consequently depend on financial frictions, bank regulation, and the maturity structure of government debt (Eren et al., 2025). In a welfare analysis, Pagel (2026) weighs the reduction in bank-run risk from reserve provision against the crowding out of private investment associated with restrictions on central-bank asset holdings. Ismail and Zúñiga (2026) examine how reserve remuneration and interbank-market frictions affect the welfare implications of alternative reserve regimes.

These benefits must also be considered alongside the financial risks associated with the assets held against central-bank liabilities. Financing long-term securities with interest-bearing reserves exposes the Fed’s income and remittances to changes in short-term interest rates (Hall and Reis, 2015; d’Avernas et al., 2026). The implications for monetary policy depend on fiscal backing and the institutional arrangements governing central-bank finances (Sims, 2013). Research also examines the design, implementation, and effectiveness of balance-sheet policies (Carlson et al., 2020; Anderson et al., 2026) and uncertainty about future balance-sheet policies (D’Amico and Feldman, 2024). These considerations distinguish the quantity of reserves supplied from the maturity and composition of the securities held against them.

Policy discussions place different weights on these considerations.⁵⁵ Logan (2019) emphasizes reliable interest-rate control and reduced reliance on frequent reserve-management operations, while Barr (2026) cautions that pursuing balance-sheet reduction as an objective can undermine bank resilience and market functioning. Waller (2025) supports further

⁵⁵The FOMC’s 2014 normalization principles envisaged holding only the securities needed for effective policy implementation, primarily Treasuries (Federal Open Market Committee, 2014). Subsequent changes in the normalization plans are summarized by Board of Governors of the Federal Reserve System (2025).

reduction while emphasizing the importance of asset composition and maturity mismatch. Bowman (2025) and Miran (2026) emphasize a smaller market footprint and preserving room for future intervention, although they differ in their preferred monetary policy implementation arrangements.

Our analysis informs this debate by identifying how foreign banks' global dollar lending affects the reserve demand that constrains balance-sheet reduction. We map this constraint conditional on a given interest rate and domestic reserve demand. Assessing the socially optimal size and composition of the Fed's balance sheet requires weighing the broader benefits and costs described above.

A6. Model Derivations

Reserve choice. Expected liquidity coverage is $Q_j - Q_j^2/(2q_j)$ for $0 \leq Q_j \leq q_j$ and $q_j/2$ for $Q_j \geq q_j$. The derivative of the strictly concave objective is

$$-(i - i^{\text{IOR}}) - \kappa_j - \phi_j Q_j + \chi_j \Pr(\tilde{Q}_j > Q_j). \quad (\text{A2})$$

Solving the first-order condition and imposing nonnegativity gives

$$Q_j(i - i^{\text{IOR}}) = \begin{cases} \frac{-\kappa_j - (i - i^{\text{IOR}})}{\phi_j}, & i - i^{\text{IOR}} \leq -\kappa_j - \phi_j q_j, \\ \frac{\chi_j - \kappa_j - (i - i^{\text{IOR}})}{\phi_j + \chi_j/q_j}, & -\kappa_j - \phi_j q_j < i - i^{\text{IOR}} < \chi_j - \kappa_j, \\ 0, & i - i^{\text{IOR}} \geq \chi_j - \kappa_j. \end{cases} \quad (\text{A3})$$

The two positive formulas coincide at $Q_j = q_j$. The intercepts in equation (12) are $a_j = -\kappa_j/\phi_j$ in carry and $a_j = (\chi_j - \kappa_j)/(\phi_j + \chi_j/q_j)$ in liquidity.

Proof of Proposition 8.1. Differentiating market clearing holding domestic banks' liquid deposits, global dollar lending, and costs fixed gives $-(b_D + b_F)d(i - i^{\text{IOR}}) = dS$. Combining this derivative with $\partial Q_F/\partial(i - i^{\text{IOR}}) = -b_F$ gives equation (13). The adjustment and stock shares coincide precisely when $b_F Q_D = b_D Q_F$, or equivalently $\mathcal{E}_F = \mathcal{E}_D$. Thus the inequality in the proposition describes the general case rather than excluding equality.

Within fixed positive-holdings regions, a lower balance sheet cost raises foreign holdings without changing b_D or b_F . In particular,

$$\left. \frac{\partial Q_F}{\partial \kappa_F} \right|_{S,L,G} = -\frac{b_D b_F}{b_D + b_F} < 0, \quad \left. \frac{\partial Q_F}{\partial \kappa_D} \right|_{S,L,G} = \frac{b_D b_F}{b_D + b_F} > 0. \quad (\text{A4})$$

At the foreign liquidity transition, b_F falls from $1/\phi_F$ to $1/(\phi_F + \chi_F/q_F)$ while holdings

remain continuous. If domestic banks do not simultaneously change regions, their dollar responsiveness is unchanged and the foreign marginal adjustment share falls.

Proof of Proposition 8.2. Consider an equilibrium with $0 < Q_D < q_D$ and positive foreign reserve holdings, away from region boundaries. The domestic cost condition $i^{\text{IOR}} - i < \kappa_D$ is sufficient to place positive domestic holdings in the liquidity region: carry holdings would require $i^{\text{IOR}} - i = \kappa_D + \phi_D Q_D > \kappa_D$. Dividing dollar responsiveness by holdings yields

$$\mathcal{E}_j = \frac{b_j}{Q_j} = \begin{cases} \frac{1}{-\kappa_j - (i - i^{\text{IOR}})}, & Q_j > q_j, \\ \frac{1}{\chi_j - \kappa_j - (i - i^{\text{IOR}})}, & 0 < Q_j < q_j. \end{cases} \quad (\text{A5})$$

All denominators are positive under the stated region conditions. When foreign banks are in the arbitrage carry region, the domestic denominator exceeds the foreign denominator by $\chi_D - \kappa_D + \kappa_F > 0$, since $\chi_D > \kappa_D$ and $\kappa_F \geq 0$. Hence $\mathcal{E}_F > \mathcal{E}_D$.

When foreign banks are in the liquidity region, the maintained assumptions $\chi_F > \chi_D$ and $\kappa_F \leq \kappa_D$ imply

$$(\chi_F - \kappa_F) - (\chi_D - \kappa_D) = (\chi_F - \chi_D) + (\kappa_D - \kappa_F) > 0.$$

The foreign denominator is therefore strictly larger, giving $\mathcal{E}_F < \mathcal{E}_D$.

Global dollar lending and the foreign transition. At the foreign transition, $i - i^{\text{IOR}} = -\kappa_F - \phi_F q_F(G)$. The corresponding aggregate reserve stock is

$$S_F(L, G) = q_F(G) + Q_D(-\kappa_F - \phi_F q_F(G), L). \quad (\text{A6})$$

With domestic banks active and away from a region boundary,

$$\frac{\partial S_F}{\partial G} = m(1 + \phi_F b_D) > 0. \quad (\text{A7})$$

Greater global dollar lending therefore moves the transition to a higher aggregate reserve stock. Within the liquidity region, increasing q_F raises both Q_F and b_F at a fixed spread; its effect on the comparison in Proposition 8.2 operates through the region conditions, while the relative-response ranking when both types hold reserves for liquidity follows from the maintained parameter assumptions.

Proof of Proposition 8.3. Monotonicity of aggregate demand implies that the equilibrium rate spread is at most τ exactly when supply is at least demand evaluated at τ . Under the

proposition's conditions, both types have positive liquidity-region holdings at that spread. Foreign holdings satisfy

$$Q_F(\tau, G) = \frac{(\chi_F - \kappa_F - \tau)q_F(G)}{\phi_F q_F(G) + \chi_F}, \quad (\text{A8})$$

and hence

$$\frac{\partial S^*}{\partial G} = \frac{\partial Q_F(\tau, G)}{\partial G} = \frac{(\chi_F - \kappa_F - \tau)\chi_F m}{[\phi_F q_F(G) + \chi_F]^2} > 0. \quad (\text{A9})$$

Since $q_F(G) = mG$, we have $Gq'_F(G) = q_F(G)$. Multiplying the foreign demand derivative by G/Q_F gives $\eta_G = \chi_F/(\chi_F + \phi_F q_F)$. Since domestic banks' liquid deposits and reserve demand are fixed, multiplying instead by G/S^* gives the threshold elasticity in equation (17). Applying strict monotonicity between G^{QE} and G^{QT} establishes equation (18).

The foreign liquidity transition and the policy threshold answer different questions. The transition occurs at a negative spread, $-\kappa_F - \phi_F q_F$. At the criterion $\tau \geq 0$, both types are already in liquidity under the proposition's assumptions. The threshold calculation applies independently of the demand-region comparison in Proposition 8.2.

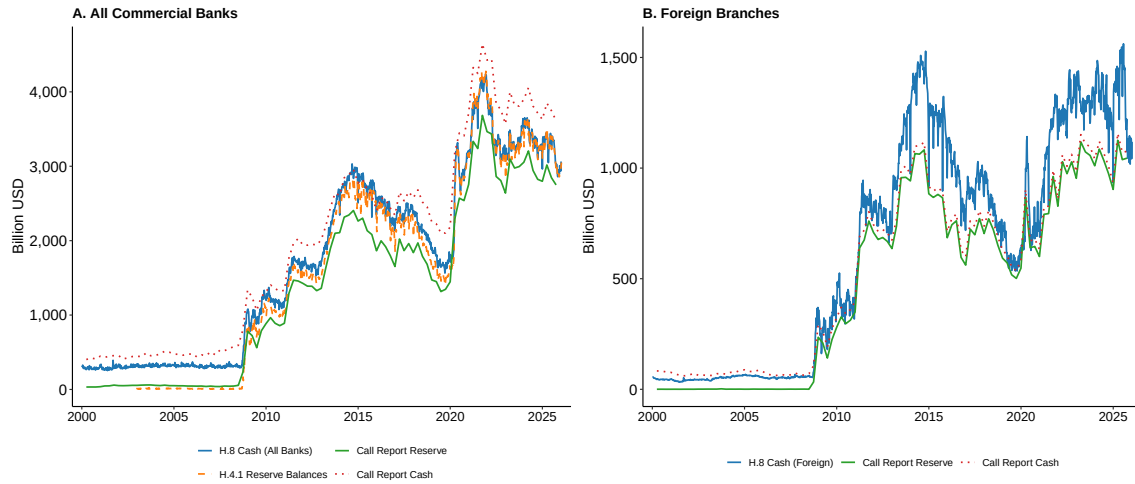
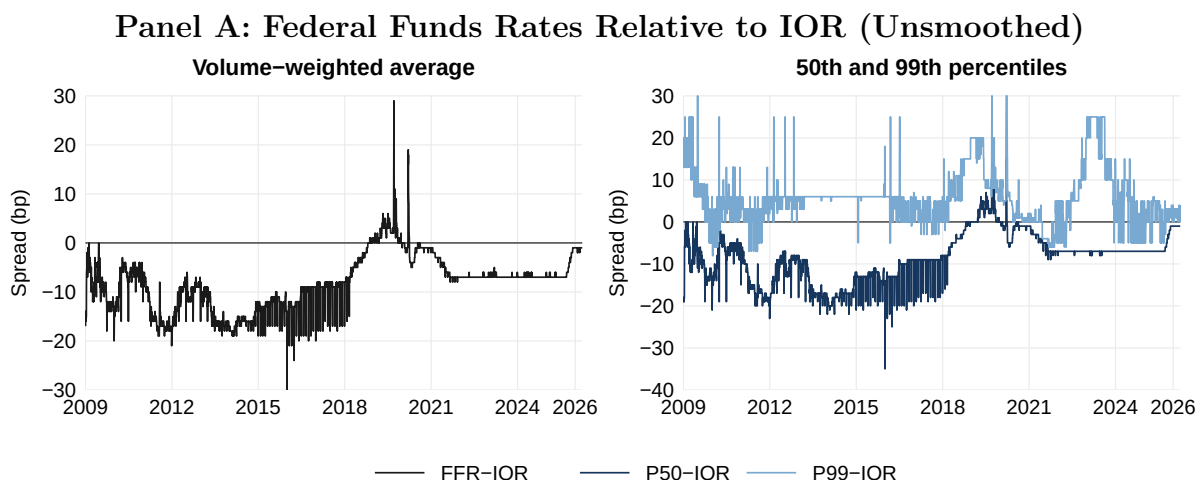
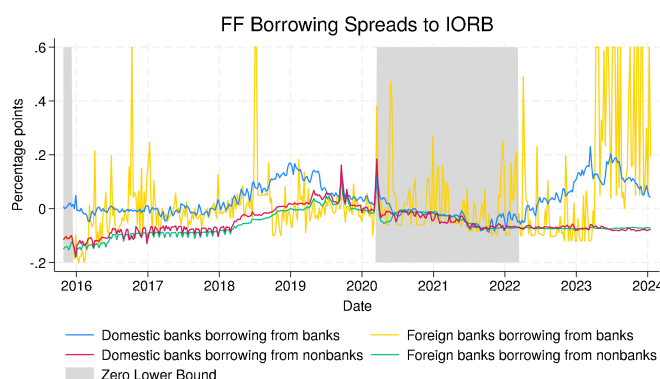


Figure A1: Cash and reserve data source and frequency comparison Source: FFIEC 002, 031, 041 reports, Assets and Liabilities of Commercial Banks in the United States (H.8), Federal Reserve Balance Sheet: Factors Affecting Reserve Balances (H.4.1)



Panel B: Borrowing Spreads by Borrower and Lender Type



Panel C: Federal Funds Spreads by Counterparty Type

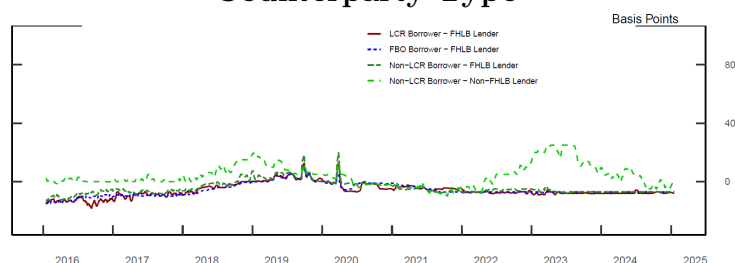


Figure A2: Federal Funds Rate Measures. Panel A plots unsmoothed daily observations of the volume-weighted average federal funds rate (left) and the 50th and 99th percentiles (right), relative to IOR in basis points, from January 2009 through March 2026. Spreads above 30 basis points are capped at 30 basis points for display. Panel B is from the lower panel of Figure 1 in Anbil et al. (2026b), which decomposes federal funds borrowing spreads to IORB by borrower and lender type. Panel C is from Figure 2(b) of Gissler and Narajabad (2025), which reports federal funds spreads to IORB across lender–borrower segments. Sources: brokered federal funds data, FR 2420, FRED, Anbil et al. (2026b), and Gissler and Narajabad (2025).

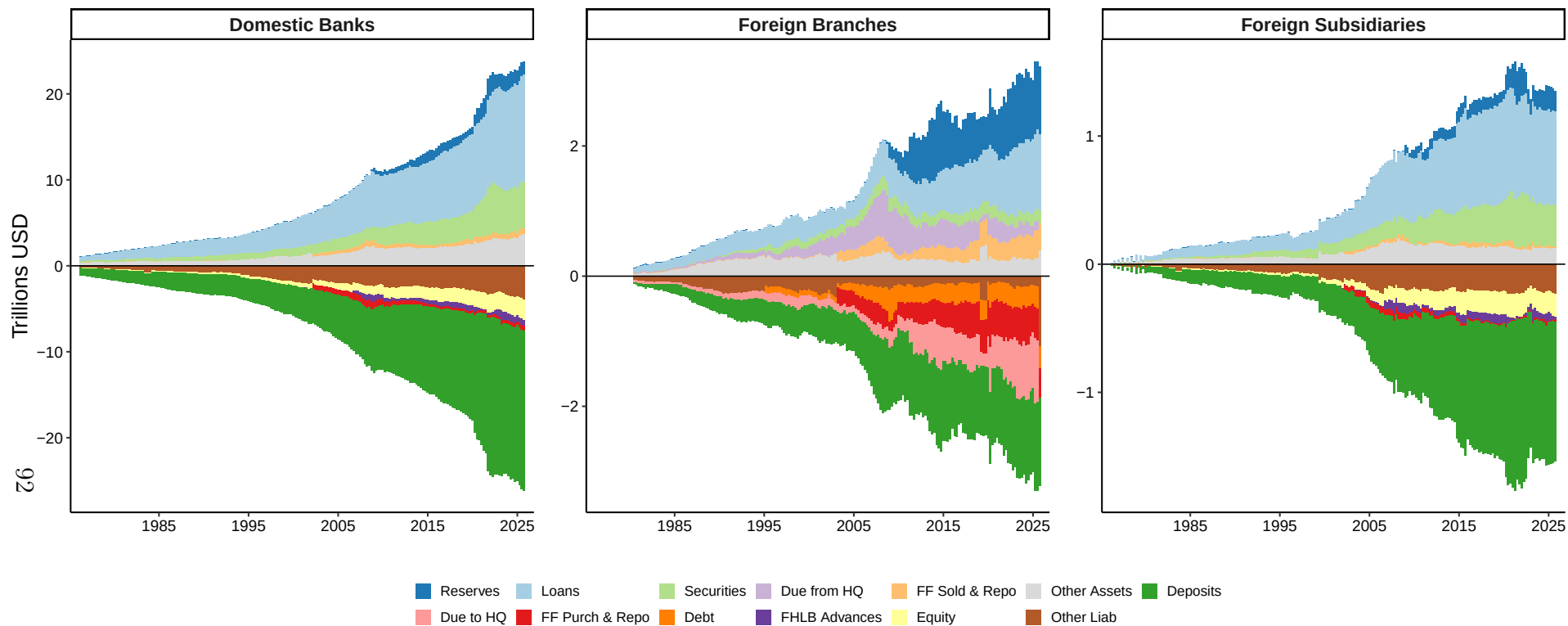


Figure A3: Balance Sheet Breakdown Source: FFIEC 002, 031, 041 reports, FR Y-9C reports

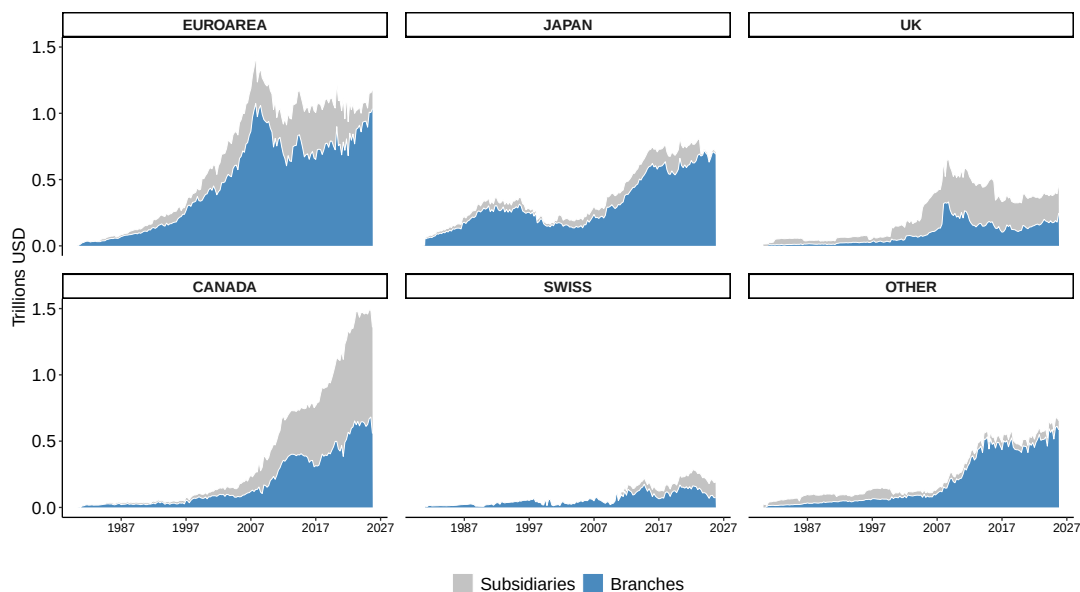


Figure A4: Asset Composition of Foreign Banks by Jurisdiction This figure displays the total assets of foreign banks in the U.S., disaggregated by jurisdiction and organizational structure. Each panel shows the time series of total assets for banks headquartered in a given jurisdiction, broken down into branches (gray) and subsidiaries (blue). Source: FFIEC 002, 031, 041 reports

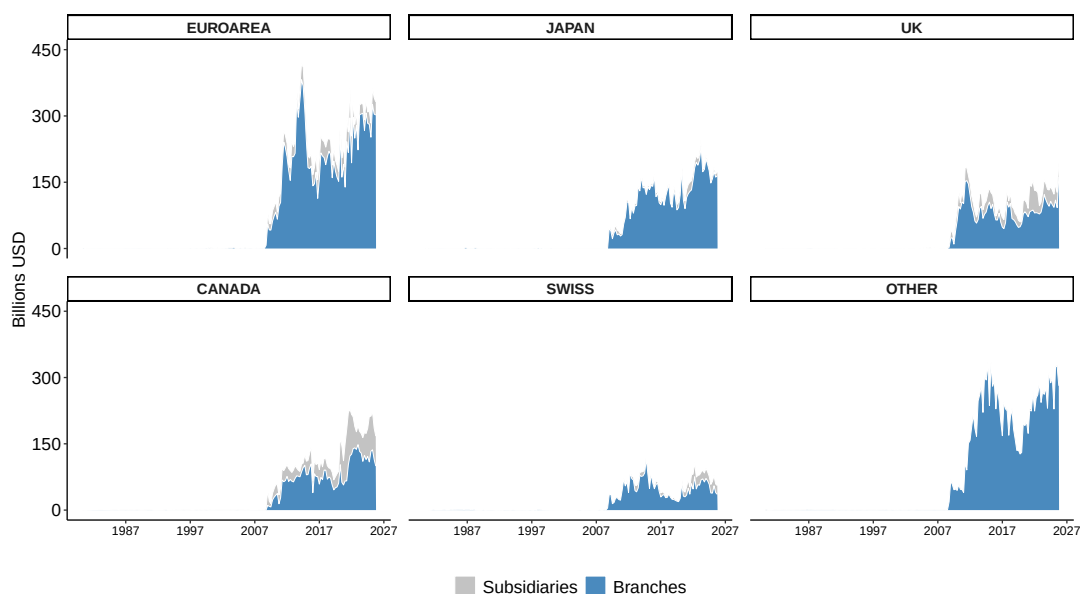


Figure A5: Reserves Composition of Foreign Banks by Jurisdiction This figure displays the total reserves of foreign banks in the U.S., disaggregated by jurisdiction and organizational structure. Each panel shows the time series of total reserves for banks headquartered in a given jurisdiction, broken down into branches (gray) and subsidiaries (blue). Source: FFIEC 002, 031, 041 reports

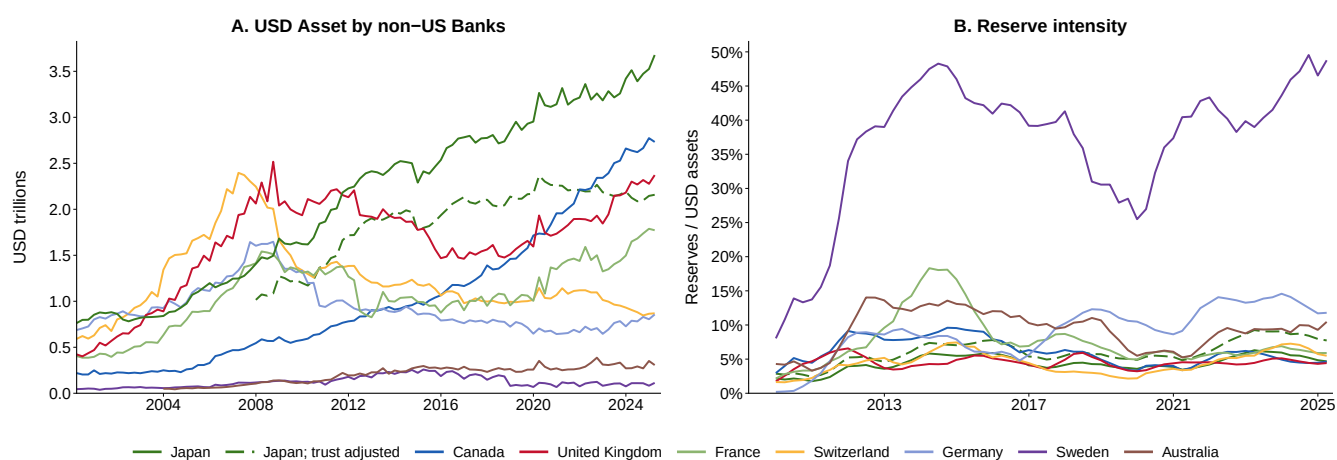


Figure A6: USD Assets and Relative Reserve Intensity of Non-US Banks Panel A reports quarter-end stocks of worldwide external U.S. dollar assets, classified by the nationality of the parent banking system and expressed in trillions of dollars. Panel B reports the four-quarter average of reserve balances held by each banking system's U.S. branches and agencies, divided by its corresponding dollar assets from 2009 Q1. We construct global dollar assets by combining the BIS locational banking statistics by nationality with the consolidated banking statistics. See Appendix A1.4 for details. For Japan, the dashed line applies the approximate trust adjustment motivated by Saito et al. (2018). Sources: BIS, BOJ, FFIEC 002, and authors' calculations.

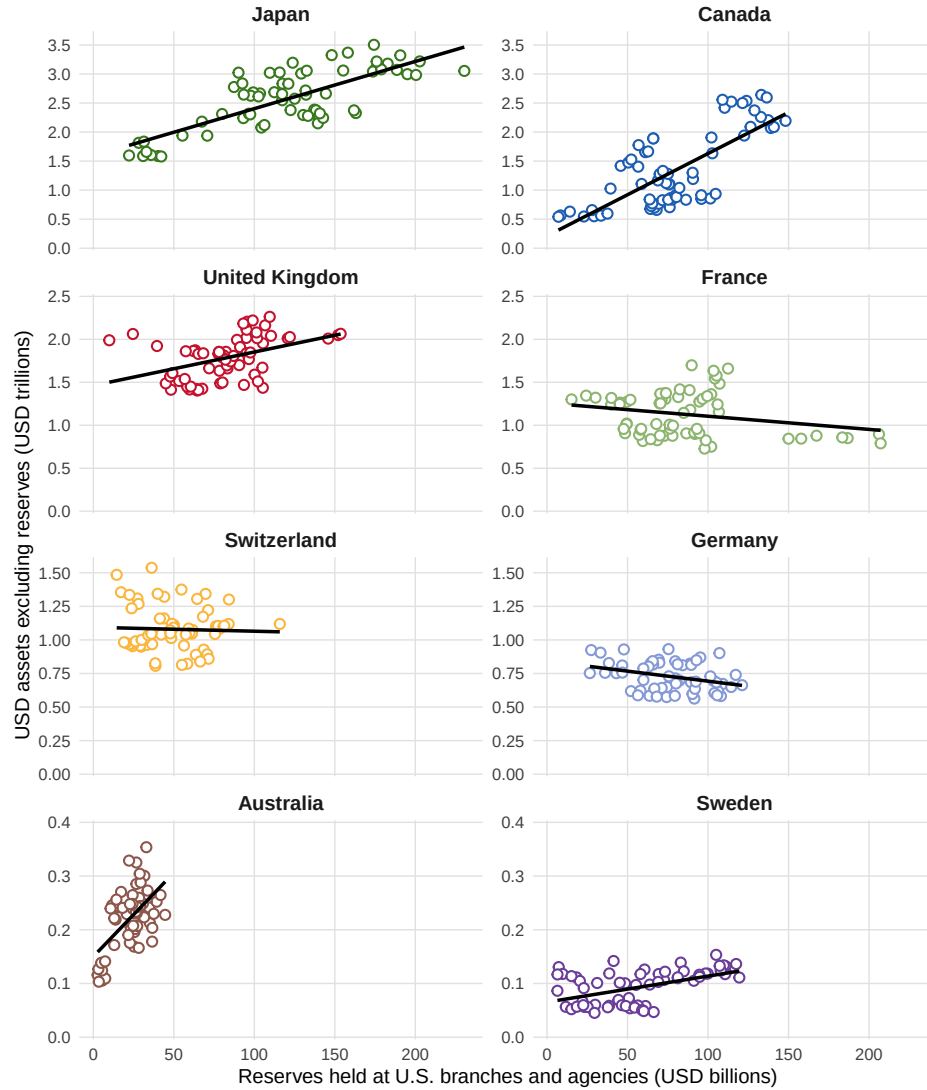


Figure A7: U.S.-Branch Reserves and USD Assets of Non-U.S. Banks Each panel plots quarterly reserve balances held at Federal Reserve Banks by the U.S. branches and agencies of banks headquartered in the indicated country against the corresponding parent banking system's worldwide external U.S. dollar assets excluding those reserves. Dollar assets are classified by parent-bank nationality and combine BIS statistics. Hollow circles denote quarterly observations, and solid black lines are country-specific linear fits. The sample covers 2009Q1–2025Q1. The y-axis scale varies across rows to display within-country variation. Sources: BIS, FFIEC 002, and authors' calculations.

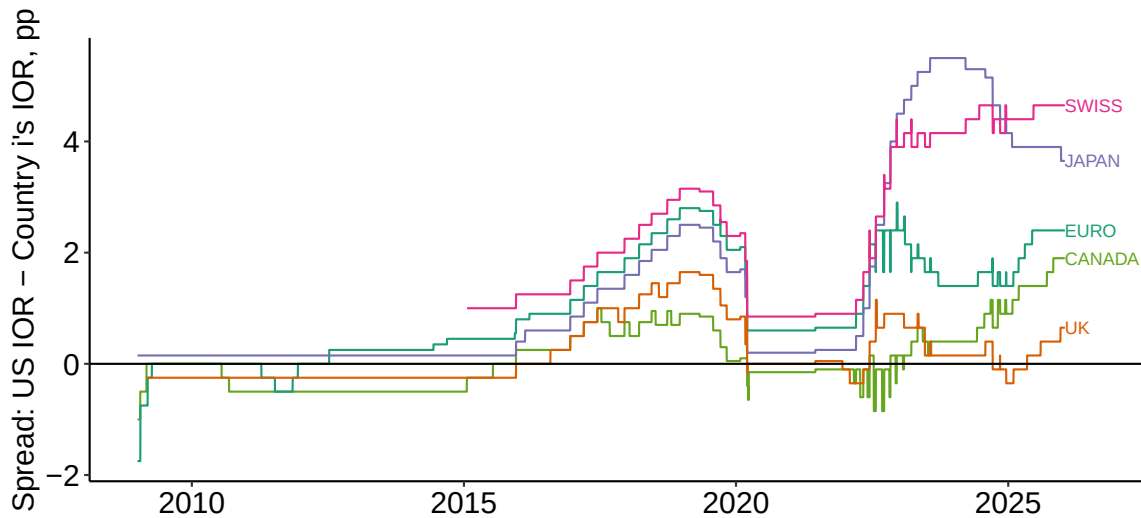


Figure A8: International Reserves Rate Spreads for Foreign Banks This figure displays the daily interest rate spread between the US interest on reserves (IOR) and the corresponding reserve interest rates in selected foreign jurisdictions. For the US, we use the interest rate on excess reserves (IOER) until July 28, 2021, after which we use the interest rate on reserve balances (IORB). For Japan, following the introduction of the three-tier reserve system in January 2016, we use the allocation to the policy rate balance as the relevant rate, representing the lowest interest rate applied to reserves held at the Bank of Japan. This rate was -0.1% through March 2024 and was raised to 0.1% thereafter. For the Euro area, we use the deposit facility rate, while for the UK, we use the Bank Rate. For Switzerland, we use the interest rate on sight deposits above the policy threshold, starting from January 22, 2015. Data sources: Bank of Canada, Bank of England, Bank of Japan, European Central Bank, Federal Reserve Board, and Swiss National Bank.

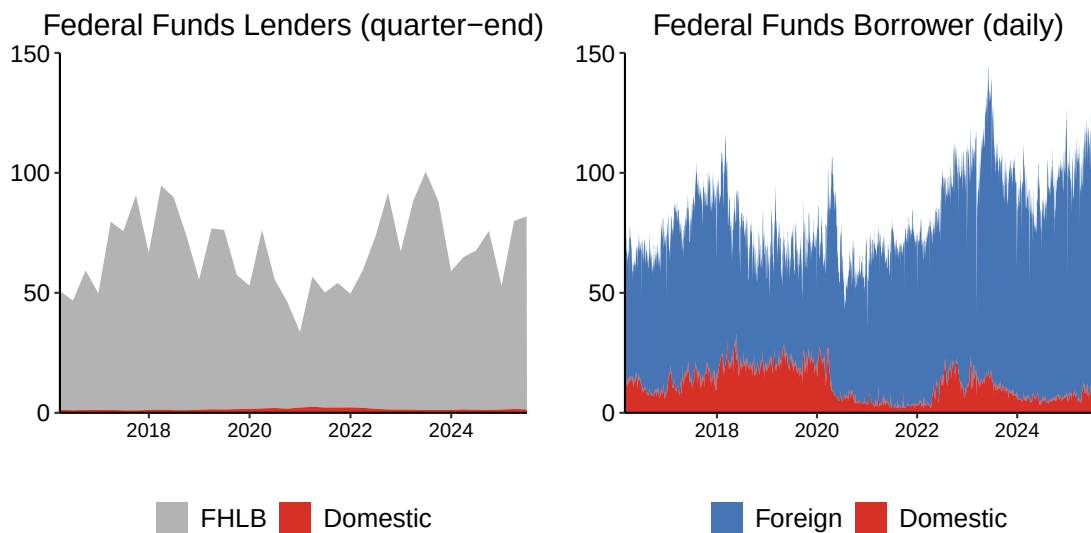


Figure A9: Federal Funds Market Dynamics. This figure shows the institutional composition of the post-2016 federal funds market. The left panel plots federal funds lending volumes by lender type at quarter-end, distinguishing Federal Home Loan Banks (FHLBs) from domestic banks. The right panel plots daily federal funds borrowing volumes by borrower type, distinguishing U.S. branches and agencies of foreign banks from domestic banks. Volumes are measured in billions of dollars. The figure illustrates the concentration of federal funds activity in an FHLB-to-foreign-branch segment: FHLBs are the dominant lenders, while foreign branches account for most borrowing. Source: FFIEC 002 reports, Federal Reserve Bank of New York, and FHLB data.

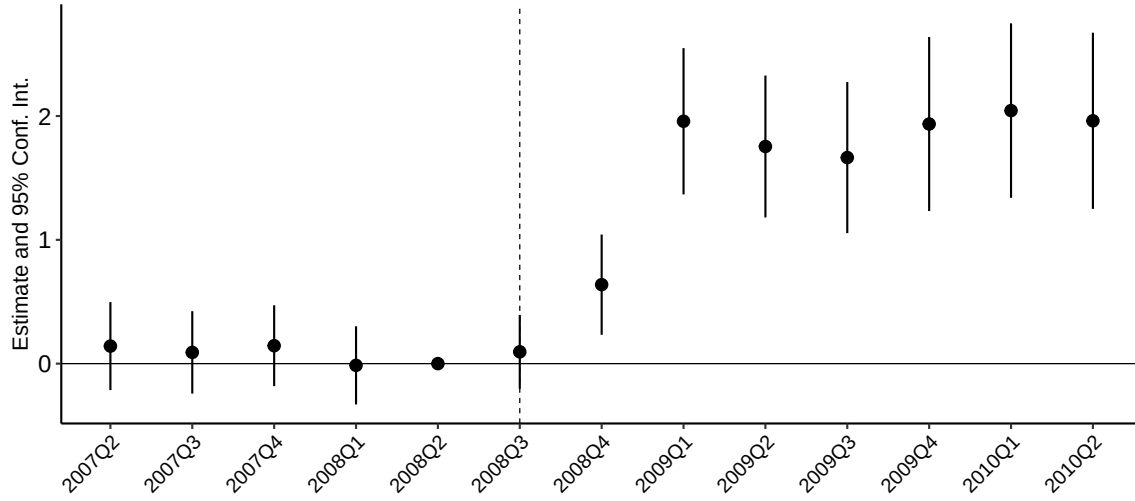


Figure A10: Event study around 2008Q3 This figure presents an event study analysis of the reserve holdings of bank holding companies (BHCs) around 2008Q3 of equation $Y_{it} = \sum_{k \neq 0} \gamma_k \cdot \mathbb{1}\{T_i = k\} + \beta X_{it} + \alpha_i + \delta_t + \epsilon_{it}$, where Y_{it} denotes the log of reserves held by bank holding company i at time t . The event, which corresponds to the third quarter of 2008, is normalized to $k = 0$, and $\mathbb{1}\{T_i = k\}$ is an indicator for periods k relative to this event. The coefficients γ_k capture the differential reserve accumulation of foreign banks relative to domestic banks before and after the event. The model includes BHC fixed effects (α_i), and time fixed effects (δ_t), which control for macroeconomic shocks common to all banks. Additionally, we control for bank-specific characteristics (X_{it}), such as the lagged value of total assets, which account for differences in bank size and balance sheet structure. The horizontal axis represents time in quarters relative to this event, while the vertical axis shows the estimated effect on log reserve holdings. Confidence intervals at the 95% level are shown for each estimate. Source: FFIEC 002, 031, 041 reports, FR Y-9C reports

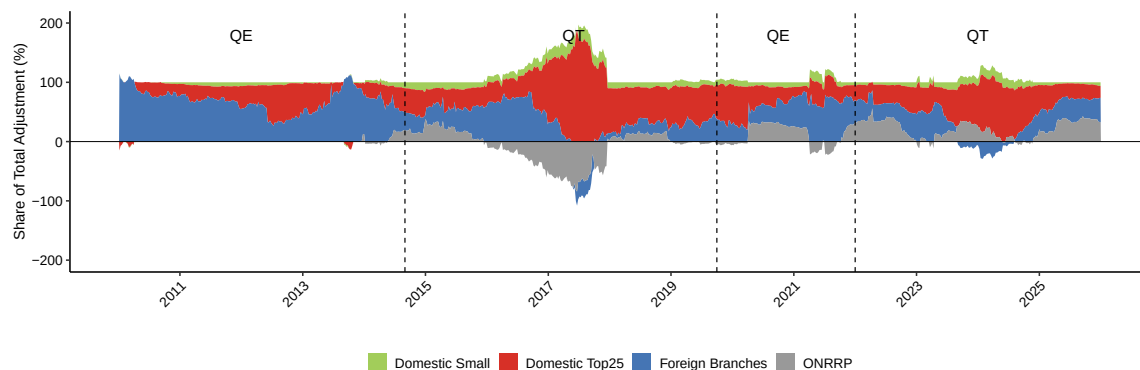


Figure A11: Composition of Reserve Adjustment to TGA Shocks over Time. This figure plots rolling adjustment shares, not elasticities, based on 52-week rolling regressions of changes in banks' reserve holdings (proxied by cash assets) on TGA shocks. Each share is constructed from the corresponding rolling coefficient and normalized by the sum across categories, so it describes the composition of contemporaneous TGA-induced dollar adjustment. Shares can be negative or exceed 100% when one category offsets the response of others. Vertical dashed lines mark the reserve-supply transitions in September 2014 (expansion to contraction), October 2019 (contraction to expansion), and January 2022 (expansion to contraction). Values that exceed 200% or -200% are trimmed for readability. The underlying regression specification follows Table A5.

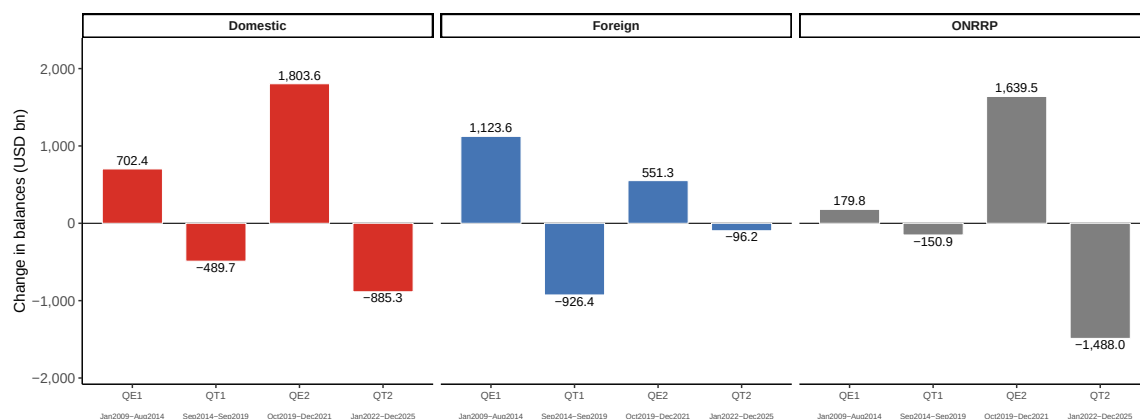


Figure A12: Changes in reserve holdings and ONRRP across QE and QT episodes. This figure plots the change in weekly Wednesday observations between the first and last available week in each reserve-supply episode. Domestic is the sum of H.8 Domestic Large (Top25) and Domestic Small; Foreign is H.8 Foreign-related institutions; ONRRP is aggregate overnight reverse repo take-up aligned to the same weekly Wednesday dates. To remove spurious early observations unrelated to the standing ONRRP facility, ONRRP is set to zero before 2013-02-13. Episode coverage is QE1 (2009-01-01 to 2014-08-31; actual weekly observations 2009-01-07 to 2014-08-27), QT1 (2014-09-01 to 2019-09-30; actual 2014-09-03 to 2019-09-25), QE2 (2019-10-01 to 2021-12-31; actual 2019-10-02 to 2021-12-29), and QT2 (2022-01-01 to 2025-12-24; actual 2022-01-05 to 2025-12-24). QT2 ends on 2025-12-24 rather than 2025-12-31 to avoid quarter-end and year-end window-dressing effects: foreign H.8 cash is USD 1129.7 bn on 2025-12-24, falls to USD 1040.9 bn on 2025-12-31, and rebounds to USD 1118.9 bn on 2026-01-07.

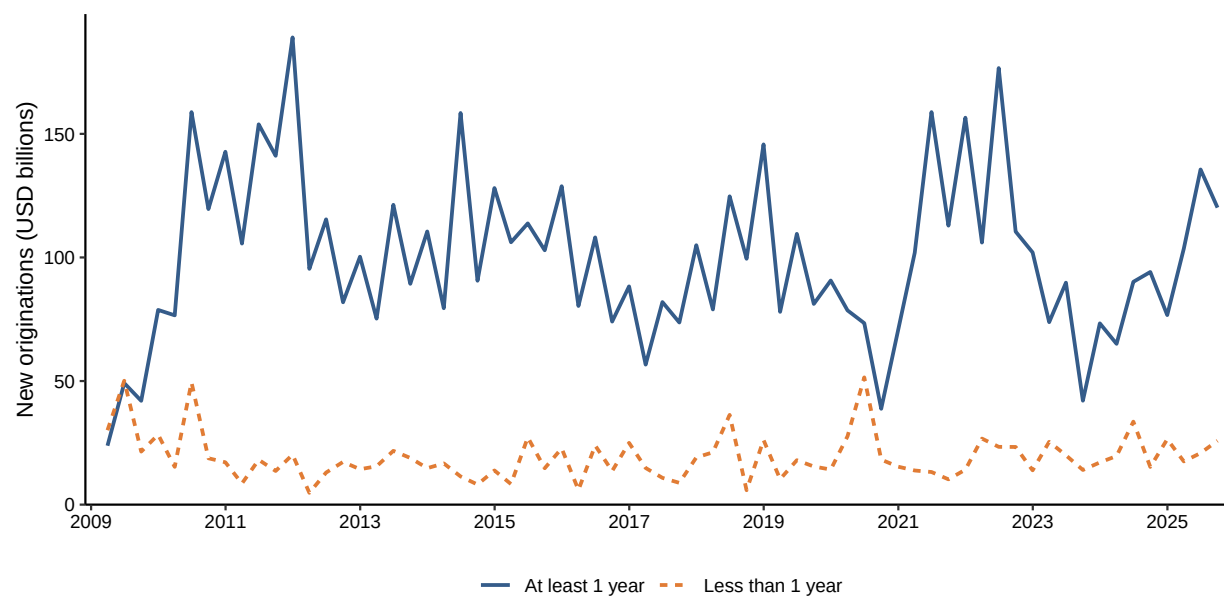


Figure A13: U.S.-Dollar Revolving-Credit Originations by Contractual Maturity.

This figure reports quarterly lender-allocated amounts of newly originated U.S.-dollar syndicated revolving credit lines, summed across 495 domestic banking organizations and 49 foreign banking groups, from 2009Q1 through 2025Q3. Facilities are grouped by original contractual maturity: at least one year or less than one year. Amounts are in billions of U.S. dollars. Facilities without usable maturity information, representing 1.71 percent of origination dollars, are excluded.

Table A1
Second Stage: Reserve Demand Elasticity
Foreign versus Large Banks

This table reports weekly IV estimates using FFR–IOR over 2009–2025, with the funding-rate definition, weekly timing and exclusions in Table 1. Reserves are proxied by H.8 cash assets. The dependent variable is $\Delta \log(\text{Reserves})$; spread changes are in basis points. The specification follows Panel B of Table 2, pooling foreign banks and large domestic banks. Large banks (Top 25 in assets) are the 25 largest domestically chartered banks by domestic assets at the most recent H.8 benchmark. Foreign equals one for U.S. branches and agencies of foreign banks and zero for large domestic banks. The instruments are ΔTGA and $\text{Foreign} \times \Delta \text{TGA}$. All specifications include FOMC-period fixed effects and a weekly ΔONRRP control. β is the response of large domestic banks, θ the foreign–domestic difference, and $\beta + \theta$ the foreign response; observations count the two series separately each week. First-stage F refers to the funding-spread first stage. Wald and Anderson–Rubin (AR) tests assess $\theta = 0$; AR inference accommodates weak instruments. Standard errors clustered by FOMC period are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Foreign versus Large banks (Top 25 in assets)

	$\Delta \log(\text{Reserves})$		
	(1)	(2)	(3)
$\Delta(\text{FFR} - \text{IOR}) (\beta)$	-0.0656*** (0.0161)	-0.0282*** (0.0083)	-0.1662** (0.0709)
$\text{Foreign} \times \Delta(\text{FFR} - \text{IOR}) (\theta)$	-0.0072 (0.0128)	-0.0333*** (0.0122)	0.0613 (0.0387)
Foreign	0.0046* (0.0024)	0.0065 (0.0047)	-0.0038 (0.0048)
Foreign response ($\beta + \theta$)	-0.0728*** (0.0141)	-0.0615*** (0.0124)	-0.1049** (0.0470)
FOMC Period FE	✓	✓	✓
ΔONRRP Control	✓	✓	✓
Sample	All	QE	QT
Observations	1,386	646	740
First-stage F	18.76	16.59	5.52
Wald p -value: $\theta = 0$	0.5760	0.0080	0.1175
AR p -value: $\theta = 0$	0.5905	0.0171	0.0391
AR 95% set for θ	$[-0.0318, 0.0248]$	$[-0.0633, -0.0076]$	$[0.0030, 0.3461]$

Table A2
Second Stage: Reserve Demand Elasticity
FFR_{50p}–IOR

This table reports weekly IV estimates using FFR_{50p} – IOR over 2009–2025. FFR_{50p} is the volume-weighted median of federal funds transaction rates. Funding-rate definitions, weekly timing and exclusions follow Table 1. Reserves are proxied by H.8 cash assets; spread changes are in basis points. Panel A uses all banks; Panel B pools foreign and all domestic banks. Foreign equals one for U.S. branches and agencies of foreign banks. The instruments are ΔTGA and, in Panel B, $\text{Foreign} \times \Delta\text{TGA}$. All specifications include FOMC-period fixed effects and a weekly ΔONRRP control. In Panel B, β is the domestic response, θ the foreign–domestic difference, and $\beta + \theta$ the foreign response. F reports the funding-spread first stage. In Panel B, Wald and Anderson–Rubin (AR) tests assess $\theta = 0$; AR inference accommodates weak instruments. Standard errors clustered by FOMC period are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: All Banks			
	$\Delta \log(\text{Reserves})$		
	(1)	(2)	(3)
$\Delta(\text{FFR}_{50p} - \text{IOR}) (\pi_1)$	-0.0671*** (0.0161)	-0.0366*** (0.0075)	-0.1859 (0.1312)
FOMC Period FE	✓	✓	✓
ΔONRRP Control	✓	✓	✓
Sample	All	QE	QT
Observations	693	323	370
First-stage F	14.75	16.76	1.96

Panel B: Foreign versus Domestic Banks			
	$\Delta \log(\text{Reserves})$		
	(1)	(2)	(3)
$\Delta(\text{FFR}_{50p} - \text{IOR}) (\beta)$	-0.0658*** (0.0180)	-0.0263*** (0.0079)	-0.2117 (0.1471)
$\text{Foreign} \times \Delta(\text{FFR}_{50p} - \text{IOR}) (\theta)$	-0.0114 (0.0135)	-0.0358*** (0.0122)	0.0696 (0.0565)
Foreign	0.0047* (0.0024)	0.0069 (0.0049)	-0.0036 (0.0054)
Foreign response ($\beta + \theta$)	-0.0772*** (0.0170)	-0.0621*** (0.0122)	-0.1421 (0.1053)
FOMC Period FE	✓	✓	✓
ΔONRRP Control	✓	✓	✓
Sample	All	QE	QT
Observations	1,386	646	740
First-stage F	14.75	16.76	1.96
Wald p -value: $\theta = 0$	0.3982	0.0046	0.2223
AR p -value: $\theta = 0$	0.4253	0.0124	0.0627
AR 95% set for θ	$[-0.0389, 0.0227]$	$[-0.0660, -0.0100]$	$(-\infty, -0.2643] \cup [-0.0040, \infty)$

Table A3
Second Stage: Reserve Demand Elasticity
FFR_{99p}–IOR

This table reports weekly IV estimates using FFR_{99p} – IOR over 2009–2025. FFR_{99p} is the 99th volume-weighted percentile of federal funds transaction rates. Funding-rate definitions, weekly timing and exclusions follow Table 1. Reserves are proxied by H.8 cash assets; spread changes are in basis points. Panel A uses all banks; Panel B pools foreign and all domestic banks. Foreign equals one for U.S. branches and agencies of foreign banks. The instruments are ΔTGA and, in Panel B, $\text{Foreign} \times \Delta\text{TGA}$. All specifications include FOMC-period fixed effects and a weekly ΔONRRP control. In Panel B, β is the domestic response, θ the foreign–domestic difference, and $\beta + \theta$ the foreign response. F reports the funding-spread first stage. In Panel B, Wald and Anderson–Rubin (AR) tests assess $\theta = 0$; AR inference accommodates weak instruments. Standard errors clustered by FOMC period are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: All Banks			
	$\Delta \log(\text{Reserves})$		
	(1)	(2)	(3)
$\Delta(\text{FFR}_{99p} - \text{IOR}) (\pi_1)$	-0.0272*** (0.0099)	-0.0864 (0.1194)	-0.0180*** (0.0062)
FOMC Period FE	✓	✓	✓
ΔONRRP Control	✓	✓	✓
Sample	All	QE	QT
Observations	693	323	370
First-stage F	6.99	0.51	7.08

Panel B: Foreign versus Domestic Banks			
	$\Delta \log(\text{Reserves})$		
	(1)	(2)	(3)
$\Delta(\text{FFR}_{99p} - \text{IOR}) (\beta)$	-0.0265*** (0.0097)	-0.0566 (0.0935)	-0.0211*** (0.0070)
$\text{Foreign} \times \Delta(\text{FFR}_{99p} - \text{IOR}) (\theta)$	-0.0050 (0.0066)	-0.0956 (0.1194)	0.0080* (0.0044)
Foreign	0.0045* (0.0024)	0.0156 (0.0185)	0.0015 (0.0027)
Foreign response ($\beta + \theta$)	-0.0315** (0.0127)	-0.1522 (0.2007)	-0.0131** (0.0059)
FOMC Period FE	✓	✓	✓
ΔONRRP Control	✓	✓	✓
Sample	All	QE	QT
Observations	1,386	646	740
First-stage F	6.99	0.51	7.08
Wald p -value: $\theta = 0$	0.4518	0.4259	0.0754
AR p -value: $\theta = 0$	0.4253	0.0124	0.0627
AR 95% set for θ	$[-0.0273, 0.0078]$	$(-\infty, -0.0173]$ $\cup [0.0389, \infty)$	$[-0.0005, 0.0224]$

Table A4
First and Second Stages: SOFR–IOR

This table reports weekly first-stage and IV estimates using historical SOFR–IOR over 2009–2025. The historical rate combines the Treasury GC repo survey rate before August 22, 2014, indicative SOFR through March 2018, and published SOFR from April 2018. The IOR definition, weekly timing and month-end exclusions follow Table 1; weeks crossing rate-source transitions are also excluded. Panel A reports first-stage spread changes in basis points per \$100 billion TGA shock. Panel B follows the pooled specification in Table 2 for foreign and all domestic banks. Reserves are proxied by H.8 cash assets. The spread change and its interaction with Foreign are instrumented by ΔTGA and $\text{Foreign} \times \Delta\text{TGA}$. F reports the funding-spread first stage. Wald and Anderson–Rubin (AR) tests assess $\theta = 0$; AR inference accommodates weak instruments. Standard errors clustered by FOMC period are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

Panel A: First Stage, SOFR – IOR

	$\Delta(\text{SOFR} - \text{IOR})$ (bps)				
	(1)	(2)	(3)	(4)	(5)
ΔTGA (\$100bn)	0.9033** (0.4044)	1.0234** (0.5023)	1.0077* (0.5184)	1.7174*** (0.5408)	0.5999 (0.7276)
FOMC Period FE		✓	✓	✓	✓
ΔONRRP Control			✓	✓	✓
Sample	All	All	All	QE	QT
Observations	689	689	689	322	367
R^2	0.006	0.051	0.051	0.165	0.024
First-stage F	4.99	4.15	3.78	10.09	0.68

Panel B: Second Stage, Foreign versus Domestic Banks

	$\Delta \log(\text{Reserves})$		
	(1)	(2)	(3)
$\Delta(\text{SOFR} - \text{IOR})$ (β)	-0.0296* (0.0164)	-0.0145** (0.0062)	-0.0526 (0.0630)
$\text{Foreign} \times \Delta(\text{SOFR} - \text{IOR})$ (θ)	-0.0058 (0.0063)	-0.0231*** (0.0074)	0.0195 (0.0253)
Foreign	0.0036 (0.0023)	0.0040 (0.0042)	0.0032 (0.0039)
Foreign response ($\beta + \theta$)	-0.0355** (0.0159)	-0.0376*** (0.0088)	-0.0331 (0.0399)
FOMC Period FE	✓	✓	✓
ΔONRRP Control	✓	✓	✓
Sample	All	QE	QT
Observations	1,378	644	734
First-stage F	3.78	10.09	0.68
Wald p -value: $\theta = 0$	0.3534	0.0024	0.4435
AR p -value: $\theta = 0$	0.4154	0.0124	0.0676
AR 95% set for θ	$[-0.0258, 0.0295]$	$[-0.0449, -0.0075]$	$(-\infty, -0.0251] \cup [-0.0008, \infty)$

Table A5
Weekly TGA Shock Absorption by Bank Type and Monetary Policy Regime

This table reports coefficient estimates from weekly regressions estimated separately by bank type and QE/QT episode over 2009–2025. The dependent variables are changes in H.8 cash holdings or ONRRP take-up, measured in billions of dollars. Large domestic banks are the top 25 by asset size; small domestic banks are the remaining domestic institutions. Weekly TGA shocks sum daily unanticipated TGA changes over Wednesday-to-Wednesday intervals and are measured in units of \$100 billion. Weeks with either Wednesday endpoint within one calendar day of month-end, and weeks spanning a regime transition, are excluded. ONRRP observations require data at both Wednesday endpoints; take-up before September 23, 2013 is set to zero. All specifications include FOMC-period fixed effects. Standard errors clustered by FOMC period are in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	QE Periods				QT Periods			
	(1) Foreign	(2) Large Domestic	(3) Small Domestic	(4) ONRRP	(5) Foreign	(6) Large Domestic	(7) Small Domestic	(8) ONRRP
<i>Panel A: First QE/QT Cycle</i>								
	QE1: Jan 2009 – Aug 2014				QT1: Sep 2014 – Sep 2019			
Δ TGA (\$100bn)	-52.3059*** (8.1454)	-22.9679*** (7.8566)	-3.5386*** (1.1320)	-3.1406 (1.9626)	-14.7383* (8.6349)	-55.2339*** (9.4008)	-8.0229*** (2.2374)	1.7307 (7.5434)
Observations	238	238	238	237	210	210	210	204
R ²	0.29	0.16	0.18	0.23	0.13	0.29	0.27	0.07
<i>Panel B: Second QE/QT Cycle</i>								
	QE2: Oct 2019 – Dec 2021				QT2: Jan 2022 – Dec 2025			
Δ TGA (\$100bn)	-14.7217 (8.6473)	-23.3275 (15.9770)	-5.8347 (3.9588)	-27.0259** (11.8433)	-21.9923*** (6.8648)	-40.2392*** (7.9410)	-6.7960*** (1.7857)	-12.2496 (7.7802)
Observations	93	93	93	90	167	167	167	164
R ²	0.39	0.46	0.28	0.35	0.15	0.35	0.38	0.29

Table A6
Bank Characteristics and Reserve Holdings

Notes: This table presents the results of estimating: $Y_{it} = \beta_1 F_i + \beta_2 G_i + \beta_3 (F_i \times G_i) + \Gamma X_{it} + \epsilon_{it}$, using quarterly data for U.S. bank holding companies (BHCs), 2009:Q1–2024:Q4. Here Y_{it} is the log of reserves held by BHC i at time t . The vector X_{it} includes lagged bank size, the aggregate supply of reserves, and other balance-sheet controls. Standard errors are clustered at the BHC level. Columns (1)–(3) relate reserve holdings to (i) a foreign-bank indicator F_i , (ii) a G-SIB indicator G_i , and (iii) their interaction. Columns (4)–(6) add controls for log assets and log deposits; column (5) restricts the sample to foreign banks, and column (6) excludes G-SIBs. G-SIBs face stricter post-GFC liquidity and capital rules—most notably the Liquidity Coverage Ratio (LCR) and CCAR stress tests—which raise their demand for high-quality liquid assets such as reserves. Moreover, their central role in wholesale funding and payment systems necessitates larger settlement balances. ***, **, and * denote significance at the 1 %, 5 %, and 10 % levels, respectively.

	log(Reserves)					
	(1)	(2)	(3)	(4)	(5)	(6)
F	3.361*** (0.2209)		2.763*** (0.2127)	1.661*** (0.1513)		1.665*** (0.1516)
G		7.382*** (0.2182)	8.555*** (0.2338)	3.316*** (0.1344)	0.5838** (0.2363)	
F × G			-4.299*** (0.3891)	-1.508*** (0.2224)		
Balance Sheet Control				✓	✓	✓
Reserve Supply Control	✓	✓	✓	✓	✓	✓
Sample	All	All	All	All	Foreign	Non-GSIBs
Observations	305,310	305,310	305,310	295,643	7,873	294,034
R ²	0.15	0.15	0.20	0.46	0.58	0.40

Table A7
Liability Adjustment Associated with Reserve Changes

This table reports weekly two-stage least-squares estimates of equation (5) over 2009–2025. Coefficients give the liability change, in billions of dollars, per \$1 billion instrumented reserve change. Weekly reserve changes are instrumented with unanticipated TGA changes aggregated over Wednesday-to-Wednesday intervals. Weeks with either Wednesday endpoint within one calendar day of month-end, and weeks spanning a regime transition, are excluded. All specifications include FOMC-period fixed effects; standard errors clustered by FOMC period are in parentheses. Total deposits sum large time and other deposits. HQ and internal funding measure positive net funding from related foreign offices. First-stage F is the squared clustered t statistic for TGA. ***, **, and * denote significance at the 1%, 5%, and 10% levels, respectively.

	Foreign Banks			Large Domestic Banks (Top 25)		
	Δ total deposits (1)	Δ HQ funding (2)	Δ wholesale funding (3)	Δ total deposits (4)	Δ internal funding (5)	Δ wholesale funding (6)
$\widehat{\Delta \text{Reserves}}$	0.0799* (0.0428)	0.4447*** (0.0822)	0.1670** (0.0699)	0.6227*** (0.1145)	0.0366* (0.0208)	0.0218 (0.0403)
Observations	708	708	708	708	708	708
First-stage F	31.66	31.66	31.66	47.18	47.18	47.18

Table A8
Foreign Banking Organizations in the DealScan Sample

This table reports bank-level time-series averages for 49 foreign banking organizations from 19 home countries, covering 2009Q2–2025Q3. Reserves aggregate each group’s U.S. branches and agencies. Revolving credit lines are lender-allocated U.S.-dollar contractual commitments active at quarter-end, including drawn and undrawn amounts, and need not be booked at those U.S. offices. UBS and Credit Suisse are combined pro forma throughout; Nordea is classified as Finnish throughout.

Bank name	Country	Average reserves (\$bn)	Average revolving credit lines (\$bn)	Quarters
ANZ	Australia	10.456	9.810	66
Commonwealth Bank of Australia	Australia	2.688	4.755	66
National Australia Bank	Australia	4.696	4.104	66
Westpac	Australia	6.177	5.485	66
KBC Group	Belgium	3.317	3.165	66
Bank of Montreal	Canada	12.776	14.352	65
CIBC	Canada	9.551	13.002	66
National Bank of Canada	Canada	5.128	3.033	66
Royal Bank of Canada	Canada	17.476	52.424	66
Scotiabank	Canada	26.135	34.687	66
Toronto-Dominion	Canada	10.809	38.147	66
Agricultural Bank of China	China	3.067	3.510	49
Bank of China	China	25.025	16.244	66
China Construction Bank	China	9.983	2.652	62
Industrial and Commercial Bank of China	China	7.207	8.372	64
Nordea	Finland	17.828	5.380	66
BNP Paribas	France	26.000	72.746	66
Credit Agricole CIB	France	13.278	10.053	66
Credit Mutuel Alliance Federale / CIC	France	3.709	1.486	66
Natixis	France	15.990	9.536	66
Societe Generale	France	28.618	28.847	66
BayernLB	Germany	1.922	2.970	66
Commerzbank	Germany	7.361	13.780	66
DZ Bank	Germany	4.344	2.710	66
Deutsche Bank	Germany	48.346	62.575	66
LBBW	Germany	7.679	0.871	66
Bank Hapoalim	Israel	3.064	1.406	66
Intesa Sanpaolo	Italy	3.536	9.006	66
UniCredit	Italy	2.677	5.336	66
MUFG	Japan	35.936	75.310	66
Mizuho	Japan	38.385	49.789	66
Norinchukin	Japan	6.637	0.693	66
Sumitomo Mitsui Financial Group	Japan	31.732	41.187	66
Sumitomo Mitsui Trust	Japan	9.210	1.548	66
Rabobank	Netherlands	13.428	12.329	66
DNB	Norway	14.139	10.227	66
Woori Bank	South Korea	1.617	0.268	66
BBVA	Spain	6.172	24.826	66
Santander	Spain	15.358	19.486	66
SEB	Sweden	15.354	4.086	66
Svenska Handelsbanken	Sweden	22.067	1.158	66
Swedbank	Sweden	8.737	1.500	66
UBS-Credit Suisse pro forma	Switzerland	48.868	61.887	66
CTBC Financial Holding	Taiwan	1.142	1.564	66
Mega Financial Holding	Taiwan	5.670	2.457	66
First Abu Dhabi Bank	United Arab Emirates	15.955	3.372	66
Barclays	United Kingdom	42.450	68.346	66
Lloyds Banking Group	United Kingdom	9.033	14.743	66
Standard Chartered	United Kingdom	20.846	22.403	66

Table A9
Uninsured Deposits, Dollar Credit Lines, and Domestic Reserve Adjustment

The dependent variable is the quarterly change in log U.S. reserves, $\Delta \log(\text{Reserves})_{i,t}$. The sample covers domestic banking organizations over 2009Q2–2025Q3. Column (1) uses the full domestic sample and baseline specification in Table 5. Column (2) adds $u_{i,t-1}$, uninsured deposits divided by assets of the same domestic-charter group, and its interaction with lagged log credit lines. Column (3) adds $\text{asinh}(\text{Uninsured Deposits}_{i,t-1})$, measured in U.S.-dollar billions before transformation. The inverse-hyperbolic-sine transformation retains observations for banks with zero uninsured deposits. All financial regressors are lagged one quarter; all columns include bank and quarter fixed effects and lagged log reserves and assets. Standard errors in parentheses are two-way clustered by bank and calendar quarter. ***, **, and * denote significance at the 1, 5, and 10 percent levels.

	$\Delta \log(\text{Reserves})_{i,t}$		
	(1)	(2)	(3)
$\log(\text{Active Credit Lines})_{i,t-1}$	0.0222 (0.0150)	−0.0237 (0.0212)	−0.0146 (0.0210)
$\log(\text{Active Credit Lines})_{i,t-1} \times u_{i,t-1}$		0.1978*** (0.0574)	0.1456** (0.0604)
$\text{asinh}(\text{Uninsured Deposits}_{i,t-1})$			0.1658** (0.0693)
$u_{i,t-1}$: uninsured deposits/assets		−0.2408 (0.2070)	−0.7302** (0.3014)
$\log(\text{Reserves})_{i,t-1}$	−0.4724*** (0.0255)	−0.4751*** (0.0256)	−0.4782*** (0.0254)
$\log(\text{Assets})_{i,t-1}$	0.2989*** (0.0661)	0.3122*** (0.0572)	0.2427*** (0.0508)
Bank FE	✓	✓	✓
Quarter FE	✓	✓	✓
Domestic banking organizations	495	492	492
Observations	11,869	11,792	11,792
R^2	0.287	0.289	0.290
Within R^2	0.240	0.243	0.244

Table A10
Preexisting and New Dollar Credit Lines and Reserve Adjustment

The dependent variable is the quarterly change in log U.S. reserves, $\Delta \log(\text{Reserves})_{i,t}$. This table decomposes the active contractual dollar credit lines in Table 5 into preexisting and new credit lines. At the end of $t - 1$, preexisting credit lines were originated before that quarter and remain active; new credit lines were originated during that quarter and remain active. Their dollar levels sum to the total active stock. New credit lines enter as $\text{asinh}(\text{New Credit Lines}_{i,t-1})$, measured in U.S.-dollar billions before transformation, retaining quarters with zero new credit lines. F_i indicates foreign banks. All columns include bank fixed effects, lagged log U.S. reserves and assets. Columns (1) and (3) include bank-type-by-quarter fixed effects; column (2) replaces these with home-country-by-quarter fixed effects. Column (3) adds contemporaneous $F_i \times \text{HedgedMargin}_{c(i),t}^{3M}$, set to zero for domestic banks. Samples and balance-sheet coverage match the corresponding columns of Table 5, spanning 2009Q2–2025Q3. β_P and β_N are the domestic slopes; δ_P and δ_N are the corresponding foreign–domestic differences. Standard errors in parentheses are two-way clustered by bank and calendar quarter. ***, **, and * denote significance at the 1, 5, and 10 percent levels.

	$\Delta \log(\text{Reserves})_{i,t}$		
	(1)	(2)	(3)
$\log(\text{Preexisting Credit Lines})_{i,t-1}$	0.0176 (0.0150)	0.0158 (0.0147)	0.0175 (0.0149)
$F_i \times \log(\text{Preexisting Credit Lines})_{i,t-1}$	0.1889** (0.0716)	0.1517** (0.0653)	0.1936** (0.0793)
$\text{asinh}(\text{New Credit Lines}_{i,t-1})$	0.0389 (0.0687)	0.0363 (0.0688)	0.0387 (0.0687)
$F_i \times \text{asinh}(\text{New Credit Lines}_{i,t-1})$	−0.0988 (0.1072)	−0.0628 (0.1175)	−0.1186 (0.1115)
$\log(\text{Reserves})_{i,t-1}$	−0.4737*** (0.0265)	−0.4898*** (0.0258)	−0.4746*** (0.0266)
$F_i \times \text{HedgedMargin}_{c(i),t}^{3M}$			0.0568** (0.0218)
Foreign preexisting slope: $\beta_P + \delta_P$	0.2065*** (0.0692)	0.1675*** (0.0624)	0.2111*** (0.0772)
Foreign new slope: $\beta_N + \delta_N$	−0.0599 (0.0681)	−0.0266 (0.0795)	−0.0798 (0.0725)
Joint test: $\delta_P = \delta_N = 0$ (p -value)	0.0285**	0.0725*	0.0425**
Bank FE	✓	✓	✓
Bank-type $\times$ quarter FE	✓		✓
Country $\times$ quarter FE		✓	
Bank balance-sheet controls	✓	✓	✓
Observations	15,079	15,079	14,815
R^2	0.267	0.377	0.270
Within R^2	0.222	0.226	0.224

Table A11
Foreign Banking Organizations in the U.S. Subsidiary Sample

This table reports unweighted bank-level time-series averages for 22 foreign banking organizations from 12 home countries, covering 2009Q1–2025Q3. Reserves aggregate each group’s U.S. bank and trust subsidiaries, using a broader cash proxy when direct reserve reports are unavailable. The sample includes 48 distinct subsidiary charters under dated ownership. Both averages use the same 1,291 complete subsidiary group-quarters, including reported zero reserves; this descriptive sample is broader than the reserve-growth regression sample. Revolving credit lines are lender-allocated U.S.-dollar contractual commitments active at quarter-end, including drawn and undrawn amounts, and need not be booked at those subsidiaries. UBS and Credit Suisse are combined pro forma throughout.

Bank name	Country	Average subsidiary reserves (\$bn)	Average revolving credit lines (\$bn)	Subsidiary charters	Observed subsidiary quarters
ANZ	Australia	0.170	9.310	2	60
National Australia Bank	Australia	0.108	4.628	1	26
Bank of Montreal	Canada	13.390	14.204	5	67
CIBC	Canada	4.153	14.706	2	48
National Bank of Canada	Canada	0.024	3.046	1	67
Royal Bank of Canada	Canada	2.312	52.262	4	67
Scotiabank	Canada	0.183	36.918	1	43
Toronto-Dominion	Canada	21.655	37.988	2	67
Industrial and Commercial Bank of China	China	0.178	9.727	1	53
BNP Paribas	France	4.772	76.161	2	56
Deutsche Bank	Germany	17.574	63.116	4	67
MUFG	Japan	5.695	80.445	3	55
Mizuho	Japan	1.253	49.835	3	67
Sumitomo Mitsui Financial Group	Japan	0.411	41.215	1	67
Sumitomo Mitsui Trust	Japan	1.812	1.531	1	67
Rabobank	Netherlands	0.314	14.011	1	42
Woori Bank	South Korea	0.196	0.267	1	67
BBVA	Spain	3.597	28.697	4	49
Santander	Spain	6.934	19.805	3	55
UBS-Credit Suisse pro forma	Switzerland	9.641	62.506	2	67
CTBC Financial Holding	Taiwan	0.283	1.552	1	67
Barclays	United Kingdom	3.889	68.678	3	67

Table A12
Contractual Dollar Commitments and U.S. Subsidiary Reserve Adjustment

The dependent variable is the quarterly change in log U.S. reserves, $\Delta \log(\text{Reserves})_{i,t}$. Active credit lines are lender-allocated U.S.-dollar syndicated revolving commitments treated as active from origination through contractual maturity, including drawn and undrawn amounts. F_i equals one for foreign banks. Reserves and assets cover domestic bank charters for domestic organizations and U.S. bank and trust subsidiaries for foreign banking groups. Relative to Table 5, foreign banks' reserve outcomes and lagged reserve and asset controls use subsidiary balances; domestic observations and parent-level credit lines are unchanged. Credit lines, reserves, and assets enter as regressors lagged one quarter. All columns include bank fixed effects and lagged log reserves and assets as controls. Columns (1) and (3) include bank-type-by-quarter fixed effects. Column (2) replaces these with home-country-by-quarter fixed effects on the same sample. Column (3) adds the contemporaneous three-month FX-swap control, $\text{HedgedMargin}_{c(i),t}^{3M}$, measured in annualized percentage points and set to zero for domestic banks. The sample spans 2009Q2–2025Q3 and includes 495 domestic organizations and 22 foreign groups in columns (1)–(2). Column (3) excludes banks headquartered in Taiwan because FX data are unavailable, leaving 21 foreign groups. Subsidiary reserves use direct reserve reports where available and an existing broader cash proxy otherwise; 28.8 percent of foreign observations use this proxy at the current or lagged endpoint. The foreign-bank slope is $\beta_1 + \beta_2$, where β_1 is the domestic credit-line coefficient and β_2 is the foreign interaction coefficient; its standard error and test use the full coefficient covariance matrix. Standard errors in parentheses are two-way clustered by bank and calendar quarter. ***, **, and * denote significance at the 1, 5, and 10 percent levels.

	$\Delta \log(\text{Reserves})_{i,t}$		
	(1)	(2)	(3)
$\log(\text{Active Credit Lines})_{i,t-1}$	0.0162 (0.0142)	0.0150 (0.0141)	0.0161 (0.0142)
$F_i \times \log(\text{Active Credit Lines})_{i,t-1}$	−0.0720 (0.0647)	−0.1826 (0.1135)	−0.0630 (0.0720)
$\log(\text{Reserves})_{i,t-1}$	−0.5224*** (0.0286)	−0.5327*** (0.0284)	−0.5232*** (0.0287)
$F_i \times \text{HedgedMargin}_{c(i),t}^{3M}$			0.0311 (0.0212)
Foreign slope: $\beta_1 + \beta_2$	−0.0558 (0.0635)	−0.1676 (0.1134)	−0.0469 (0.0710)
$p\text{-value: } H_0 : \beta_1 + \beta_2 = 0$	0.3828	0.1441	0.5114
Bank FE	✓	✓	✓
Bank-type $\times$ quarter FE	✓		✓
Home-country $\times$ quarter FE		✓	
Bank balance-sheet controls	✓	✓	✓
Observations	13,132	13,132	13,066
R^2	0.295	0.319	0.295
Within R^2	0.247	0.249	0.247

Table A13
Lead and Nonlead Dollar Credit Lines and Reserve Adjustment

The dependent variable is the quarterly change in log reserves held at foreign banks' U.S. branches and agencies, $\Delta \log(\text{Reserves})_{i,t}$. The sample contains 49 foreign banking groups from 19 home countries over 2009Q2–2025Q3. Lead and nonlead stocks are lender-allocated U.S.-dollar revolving credit lines that remain active under their stated maturities. Roles follow DealScan's primary designation at origination: lead includes administrative agents, lenders designated as *Agent*, arrangers, bookrunners, and designated lead or senior arranging and management roles; nonlead includes the remaining classified roles. Both stocks enter jointly, lagged one quarter, using asinh of U.S.-dollar billions to retain zero stocks. All columns include bank fixed effects and lagged log reserves and assets of U.S. branches and agencies. Columns (1) and (3) include quarter fixed effects; column (2) replaces these with home-country-by-quarter fixed effects. Column (3) adds contemporaneous HedgedMargin^{3M}_{c(i),t} and excludes banks headquartered in Taiwan, Israel, and the United Arab Emirates because FX data are unavailable. β_L and β_N denote the lead and nonlead slopes. Standard errors in parentheses are two-way clustered by bank and calendar quarter. ***, **, and * denote significance at the 1, 5, and 10 percent levels.

	$\Delta \log(\text{Reserves})_{i,t}$		
	(1)	(2)	(3)
asinh(Lead Active Credit Lines _{i,t-1})	-0.0961 (0.1084)	-0.1262 (0.1138)	-0.1387 (0.1277)
asinh(Nonlead Active Credit Lines _{i,t-1})	0.2449*** (0.0816)	0.2489** (0.1090)	0.2624*** (0.0932)
log(Reserves) _{i,t-1}	-0.3378*** (0.0653)	-0.3162*** (0.0543)	-0.3398*** (0.0663)
HedgedMargin ^{3M} _{c(i),t}			0.0430 (0.0258)
Nonlead minus lead: $\beta_N - \beta_L$	0.3410** (0.1608)	0.3750* (0.1981)	0.4012** (0.1914)
<i>p</i> -value: $\beta_N = \beta_L$	0.0392	0.0644	0.0419
Bank FE	✓	✓	✓
Quarter FE	✓		✓
Country × quarter FE		✓	
Bank balance-sheet controls	✓	✓	✓
Foreign banking groups	49	49	45
Observations	3,210	3,210	2,946
R^2	0.225	0.553	0.234
Within R^2	0.186	0.170	0.190

Table A14
Term Loan A and Reserve Adjustment

The dependent variable is the quarterly change in log U.S. reserves, $\Delta \log(\text{Reserves})_{i,t}$. Each column replaces lagged log active credit lines and their foreign interaction in Table 5 with $\text{asinh}(\text{Term Loan } A_{i,t-1})$ and its foreign interaction. F_i equals one for foreign banks. Term Loan A is measured in U.S.-dollar billions before transformation; the inverse-hyperbolic-sine transformation retains zero exposures. The measure carries original lender-allocated dollar notionals through observed contractual maturity without adjusting for amortization, prepayments, or subsequent loan sales. Each column retains the corresponding baseline sample, balance-sheet controls, and bank fixed effects over 2009Q2–2025Q3. Columns (1) and (3) include bank-type-by-quarter fixed effects; column (2) replaces these with home-country-by-quarter fixed effects. Column (3) adds contemporaneous $F_i \times \text{HedgedMargin}_{c(i),t}^{3M}$, set to zero for domestic banks, and excludes banks headquartered in Taiwan, Israel, and the United Arab Emirates because FX data are unavailable. All columns include lagged log U.S. reserves and assets. The foreign-bank slope is $\beta_1 + \beta_2$. Standard errors in parentheses are two-way clustered by bank and calendar quarter. ***, **, and * denote significance at the 1, 5, and 10 percent levels.

	$\Delta \log(\text{Reserves})_{i,t}$		
	(1)	(2)	(3)
$\text{asinh}(\text{Term Loan } A_{i,t-1})$	0.2167*** (0.0767)	0.2148*** (0.0750)	0.2166*** (0.0767)
$F_i \times \text{asinh}(\text{Term Loan } A_{i,t-1})$	−0.1767 (0.1546)	−0.1790 (0.1653)	−0.1661 (0.1582)
$\log(\text{Reserves})_{i,t-1}$	−0.4767*** (0.0265)	−0.4923*** (0.0257)	−0.4774*** (0.0265)
$F_i \times \text{HedgedMargin}_{c(i),t}^{3M}$			0.0485** (0.0236)
Foreign slope: $\beta_1 + \beta_2$	0.0400 (0.1267)	0.0358 (0.1433)	0.0505 (0.1311)
p -value: $H_0 : \beta_1 + \beta_2 = 0$	0.7529	0.8033	0.7015
Bank FE	✓	✓	✓
Bank-type $\times$ quarter FE	✓		✓
Home-country $\times$ quarter FE		✓	
Bank balance-sheet controls	✓	✓	✓
Observations	15,079	15,079	14,815
R^2	0.266	0.378	0.269
Within R^2	0.222	0.226	0.223