A Tale of Demand and Supply for Central Bank Reserves*

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Abstract

We provide a new framework for understanding demand and supply in the interbank market for central bank reserves in the U.S., the fed funds market. Using high frequency bank-level data on reserves and deposits, we show only a subset of domestic banks meaningfully increase reserves in response to deposit inflows, highlighting the importance of bank heterogeneity. Building upon insights from the market microstructure and leveraging banks' response to deposit shocks, we find that bank lenders are price inelastic, and their lending becomes even more inelastic as the level of reserves in the banking system declines. Our results underscore the importance of unpacking micro-level data to understand how the market for central bank reserves operates, and thus, may help inform monetary policy implementation.

Keywords: monetary policy implementation, balance sheet policy, central bank reserves, fed funds market

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1 Introduction

The surge in the size of the Federal Reserve's (Fed's) balance sheet when short-term interest rates were lowered to the effective lower bound following the Global Financial Crisis (GFC) altered its monetary policy implementation framework. Large scale asset purchases (LSAPs) led to an unprecedented increase in reserves, significantly increasing the amount of liquidity in banking sector. Consequently, the Fed's monetary policy implementation transitioned from a scarce reserve regime—where interest rate control was achieved through adjustments to the supply of reserves—to an ample or abundant reserves regime—where interest rate control is achieved through adjusting administered rates on its liabilities (FOMC 2019). In this new regime, the Fed pays interest on reserve balances (IORB), and relies on banks liquidity management and arbitrage activity to steer the effective fed funds rate (EFFR)—the reference rate of overnight interbank trading in the fed funds market—within the Fed's monetary policy target range.

When operating in an ample-reserves regime, the Fed has to ensure that there are always sufficient amount of reserves in the banking system to maintain the EFFR within its policy target range without the need to manage reserves on a daily basis. Specifically, if reserves become less than ample, a temporary increase in the demand for reserves or a decline in the supply of reserves, would put upward pressure on the EFFR and other money market rates, and may even challenge rate control. This is particularly important as the Fed seeks to reduce the size of its balance sheet via quantitative tightening (QT) in order to "maintain securities holdings in amounts needed to implement monetary policy efficiently and effectively in its ample reserves regime".[1]

The Fed's decision and associated challenges to implement monetary policy in an ample-reserves regime prompted many researchers to estimate what that ample level may be. The standard approach in the recent literature has been to attempt to estimate the *demand curve for aggregate reserve balances*. Conceptually, the reserve demand curve is downward sloping when reserves are relatively scarce and flattens out as reserves become more abundant. In this environment, daily changes in the supply of reserves do not affect EFFR. However, as reserves decline, it is expected that the market rate at which banks borrow and lend reserves will start responding to daily changes in aggregate reserves. Existing studies mainly rely on the aggregate levels of deposits and central bank liabilities to estimate the point of demand curve starting to get steeper, largely inspired by a representative bank framework. Some salient examples of this approach are Lopez-Salido & Vissing-Jorgensen (2023), Afonso,

[1]See Principles of Reducing the Size of the Federal Reserve's Balance Sheet: `https://www.federalreserve.gov/newsevents/pressreleases/monetary20220126c.htm`.

La Spada, Mertens & Williams (2023), Afonso et al. (2024), Acharya et al. (2023), and Anbil et al. (2024).

The representative bank framework does not account for the evolution of trading dynamics in the fed funds market or the substantial degree of heterogeneity in the market, both of which matter for the determination of EFFR. Since banks started to earn IORB in 2008, holding reserves became more attractive relative to an environment when reserves were unremunerated. In addition, factors such as the post-crisis regulatory liquidity requirements and resulting changes in internal risk management practices made holding reserves more desirable for banks. Thus, banks' traditional incentives to borrow and lend reserves on an overnight basis to manage their liquidity declined significantly. Instead, the majority of fed funds activity is driven by non-bank counterparties that hold reserves, such as Federal Home Loan Banks (FHLBs), which are incentivized to lend because they do not earn IORB. These non-bank counterparties mainly lend to foreign banks, that are subject to less stringent regulations relative to domestic banks, and thus have a greater willingness to expand their balance sheet to earn the spread between fed funds borrowing and IORB. Therefore, trading in the fed funds market is largely driven by arbitrage activity and, to a much lesser extent, banks' desire to manage their liquidity. This raises the question: what are estimates of demand for aggregate reserve balances capturing? Understanding how the fed funds market has evolved provides clues to banks' incentives to participate in fed funds market, and their specific need to hold reserves.

In this paper, we provide a new framework built on the market micro-structure of the fed funds market to incorporate both demand and supply dynamics in interbank markets. We rely on individual bank data to relax the standard assumption of a representative bank. Our framework accounts for bank heterogeneity and the micro-structure of the fed funds market to fully understand the borrowing and lending dynamics as well as their implications for the level of reserves needed to operate in an ample reserves regime.

We first show that only a small subset of domestic banks' reserves increased meaningfully in response to deposit inflows, as opposed to what was touted by the representative bank framework. In that framework, an increase in deposits increases the representative bank's incentive to hold more reserves to hedge against deposit outflows. Given that banks' reliance on deposit funding is quite heterogeneous, it is unlikely that this incentive is salient across all banks. We find that banks with less than $10 billion in assets held less reserves and felt more compelled to increase their reserve balances when faced with shocks to their deposits. In addition, small banks are less likely to actively attract or shed deposits, consistent with the idea that deposit shocks are largely exogenous to these banks. Hence, the increase in small banks' demand for reserves affected trading volumes and rates in the fed funds market differently than other participants. This finding stands in stark difference to what was assumed in the representative bank framework.

We then estimate the *supply elasticity* in the fed funds market and find that the heterogeneity of lenders affect prices significantly. Our estimates rely on shocks to both all and small domestic bank demand deposits—which are the set of domestic banks that exhibit the strongest sensitivity of reserve balances to deposit shocks—as an instrumental variable to estimate how aggregate lending in the fed funds market responds to changes in individual banks' demand for reserves. In this analysis, we separate lending by banks who were more likely to participate to manage their liquidity, and by non-banks who had an incentive to lend their unremunerated reserves as part of their investment strategy. We find that non-bank lending is very elastic, consistent with the idea that they lend to earn the EFFR on their reserve balances that are unremunerated. In contrast, bank lending is fairly inelastic, which is consistent with the idea that their participation is to manage their liquidity position. The differential motivations to lend for these two types of lenders highlight the importance of considering the micro-structure of the fed funds market to gauge the level of aggregate central bank liquidity.

Having established that bank lending to domestic banks is fairly inelastic, we assess whether the degree of inelasticity changes with the total amount of reserves in system. This question is important because it helps determine the point at which borrowing and lending in the fed funds market is driven by incentives to manage liquidity, an indication that reserves are becoming less than ample. We indeed find that lending became more inelastic as aggregate reserve supply declined. The implication is that, as reserves decline to less ample levels, banks would become more reluctant to lend. This result suggest that frictions in the distribution of reserves in the system may lead to reserves becoming scarce locally, for example, for a subset of domestic banks that rely on the fed funds market to manage their liquidity, before reserves become scarce in the aggregate. Given the heterogeneity of the banking sector that we highlight, some institutions may find it harder to avoid liquidity shortfalls, leading to increased competition for reserves that could exert upward pressure on EFFR, while some lenders choose to hoard reserves as aggregate reserves come down.

Given the relatively low volume of fed funds trading, and various incentives for participation, a natural question that arises is: why would anyone pay attention to dynamics in the fed funds market which is quite small and seemingly idiosyncratic? While the volume in the repo market underlying the Secured Overnight Funding Rate (SOFR) is about 25 times larger than that of fed funds, the repo market may not be all that relevant to understand how central bank liquidity is distributed within the broader banking system. This is mainly because the U.S. repo market is dominated by different types of non-bank participants. In the U.S., excess reserves typically accumulate at the largest banks which are not incentivized to lend on an unsecured basis making it more difficult for smaller banks to borrow reserves in the fed funds market. As a result of such distributional frictions, even though reserves appear to be at or above ample levels in the aggregate, pressures may arise for those small banks that are unable to source the funding they need. We argue that no matter how small the fed funds market today is compared with other money markets, it still reveals important incremental information about reserve conditions that complement signals from other markets. Moreover, the fed funds market remains the market for monetary policy implementation because the Fed sets the target range for the effective fed funds rate.

Overall, our results underscore the importance of understanding dynamics in the market for central bank reserves for assessing reserve conditions. In an environment with perfect information and no market frictions, one can rely on the assumption of a representative bank and estimate aggregate reserve demand that would correspond to the sum of reserve demands by individual institutions. However, we show that the banking sector is quite heterogeneous. Potential market frictions to redistributing reserves may result in some banks persistently hoarding reserves to comply with higher scrutiny over their liquidity position. Such factors may diminish the efficiency of this market in redistributing reserves. In addition, an individual bank's demand curve may evolve over time because of idiosyncratic factors or changes in the economic and financial landscape. Therefore, insights from our analysis based on bank-level data is important in assessing reserve conditions in the presence of such market frictions and may help inform the implementation of monetary policy in an environment with ample reserves and imperfect information.

The rest of the paper is structured as follows. Section 2 provides a brief review of the existing literature and highlights the main differences with our bank-level approach. Section 3 reviews the mechanics of the fed funds market, describing the trading dynamics between the main borrowers and lenders, and the importance of this market relative to other short-term funding markets. Section 4 presents our empirical analysis, first documenting the degree of heterogeneity in how banks' demand for reserves responds to shocks to demand deposits, and then employ an instrumental variable approach to estimate the supply elasticity of bank and non-bank lenders. Finally, Section 5 summarizes our main results and provides some concluding remarks.

2 Related Literature

Our paper is closely related to the literature aimed at measuring the slope of the aggregate demand curve for central bank reserves. The seminal work that attempts to measure the sensitivity of fed funds rates to changes in reserves in an environment of scarce reserves dates back to Hamilton (1997). Using changes in Treasury General Account balances as exogenous shocks to changes in reserves balances, that paper provided an estimate of the so-called liquidity effect. By relying on the Fed's forecast errors for open market operations, Carpenter & Demiralp (2006) also identified a liquidity effect at a daily frequency which they documented to be nonlinear.

More recently, Lopez-Salido & Vissing-Jorgensen (2023), Acharya & Rajan (2024), Anbil et al. (2024), and Yang (2020) aim to estimate the demand for reserves using aggregate data. Lopez-Salido & Vissing-Jorgensen (2023) rely on a representative framework to argue that the level of demand deposits in the banking sector affects the overall demand for reserves. Their analysis provides an estimate of the level of reserves in which the reserve demand curve starts to be downward sloping. Acharya et al. (2023) argue that changes in aggregate bank reserves affect the supply of deposits, and highlight the asymmetry between periods of QE—in which deposits rise mechanically as the central bank buys assets from primary dealers, and periods of QT—in which banks may find it harder to shed deposits as the central bank rolls off its assets. They find a positive relationship between bank reserves and demand deposits, and also show how they affect the spread between EFFR and IOR. Anbil et al. (2024) structurally estimates the demand for reserves taking into account the capacity of the repo market. They argue that non-bank reserve demand, that is the demand for cash by non-banks, will determine the optimal size of the Fed's balance sheet. Finally, while Afonso et al. (2024) also estimates the slope of the aggregate demand curve with a structural time-varying econometric model over a longer period, their high-frequency data is still at the aggregate level and does not incorporate how the heterogeneity of banks in the fed funds market might affect the aggregate demand curve.

Our paper is also related to another strand of the literature that uses payment data to detect the point of reserves becoming less ample. Afonso, La Spada, Mertens & Williams (2023) document significant strategic complementarities in payments—that is, banks' reliance on incoming payments to make outgoing ones— and how these complementarities increase as reserves become scarce. Lagos & Navarro (2023) provide a structural model to estimate payment flows between different types of banks, providing a measure of the demand for aggregate reserves as a function of reserve balances.

Finally, our paper is related to the theoretical literature on bank liquidity management in interbank markets that dates back to Poole (1968) who shows that banks' individual demand for reserves depends on their risk of having a liquidity shortfall late in the day. In the context of the Fed funds market, Bech & Klee (2011) document how monetary policy implementation changed after the GCF and the high degree of market segmentation. Armenter & Lester

(2017) study how the Fed's post-GFC monetary policy implementation framework interacts with other short-term funding markets and Afonso et al. (2019) provide a unified framework to study the evolution of the fed funds market. More recently, d'Avernas et al. (2023) show the effect of limits on central bank intraday credit on banks' precautionary motive to hoard reserves and d'Avernas et al. (2024) shows how these incentives affect banks' willingness to participate in other funding markets, such as Treasury repo, and can contribute to disruptions in the Treasury market. Kim et al. (2020) models the revival of an interbank market as the central bank reduces its balance sheet incentivizing banks to trade within the fed funds market as reserves become more scarce. Our paper utilizes fed funds transaction data to show that banks pay higher prices from bank lenders as aggregate reserves decrease.

3 Overview of the Fed Funds Market

In this section, we provide an overview of the fed funds market, describing the main participants and their incentives. We then present summary statistics of our dataset that include borrowing and lending volumes, associated rates and spreads, and reserve balances and demand deposits.

3.1 Institutional Background

The fed funds market is where banks borrow unsecured funds typically on an overnight basis. Since the GFC, most trading is between foreign banks and FHLBs (Banegas & Tase 2020). The EFFR is calculated as a volume-weighted median of overnight fed funds transactions reported in the FR 2420 Report of Selected Money Market Rates.[2]

Prior to the LSAPs conducted by the Fed in response to GFC, the amount of reserves in the banking system was around $40 billion. Banks' trading was largely driven by their motivation to avoid holding excess balances in their accounts at the Fed above their target holdings at the end of each day. When LSAPs were ended, the amount of reserves held in the banking sector was increased to almost $3 trillion. Such a substantial increase in the level of reserves prompted a change in Fed's framework for implementing monetary policy (Ihrig et al. 2020).

To maintain rate control in this environment of abundant reserves, the Fed relied on two key administered rates—the interest rate on reserve balances (IORB) and the offered rate on overnight reverse repurchase agreement operations (ON RRP). This new framework worked remarkably well in providing interest rate control even with very large quantities of

[2]More information about the FR 2420 Report of Selected Money Market Rates can be found here.

reserves in the banking system (Clouse et al. 2025). On January 2019, the Fed announced its intention to implement monetary policy in a regime with an "ample" level of reserves. As a result, the need to actively borrow in the fed funds market has largely waned and led to significant changes in the structure of the market (FOMC 2019).[3]

In this environment of abundant reserves, most transactions in the fed funds market reflect arbitrage activity between banks that earn IOR and FHLBs, which we label as non-banks, that do not. Since the GFC, FHLBs became the primary lenders of fed funds, accounting for more than 90 percent of total lending volume. The amount FHLBs' depends on their desired liquidity buffers, which are affected by their regulatory environment, and the relative attractiveness of alternative investments. Unlike banks, FHLBs are not eligible to earn IORB on their cash held at the Fed. Therefore, they have an incentive to lend in the fed funds market at rates below IORB to earn a return on their cash balances. Moreover, FHLBs value investing overnight in the fed funds market since it provides them with the benefit of getting their funds back early the next day, as opposed to other investments.

There are two types of borrowers in the fed funds market: i) U.S. branches of foreign banks, that have fewer regulatory restrictions to increase their balance sheet size and are willing to borrow from FHLBs at rates below IORB to earn the spread between fed funds and IORB (Anderson et al. 2021) and ii) domestic banks that borrow to meet liquidity needs typically at rates near IORB. Borrowing volumes of these two types of participants and their associated rates reflect their different motivations to borrow fed funds, and may be informative about conditions suggesting that reserves are becoming less ample. Currently, foreign banks account for about 90 percent of borrowing in the fed funds market.

Liquidity Coverage Ratio (LCR) regulations incentivize larger domestic banks to borrow in fed funds on occasion. These banks are required to hold a certain amount of high-quality liquid assets relative to their expected cash outflows according to these regulations. When calculating the LCR, borrowings are assigned depending on their characteristics and lender identity. Non-bank lenders, such as FHLBs, result in a lower LCR for the bank borrower because they enjoy a lower assumed run-off rate. Anderson et al. (2024) show that banks that report their LCR daily are willing to pay higher rates to borrow in the fed funds market relative to other banks.

Finally, those smaller domestic banks that account for the rest of the borrowing in the fed funds market trade to manage their liquidity. The amount of borrowing is affected by the supply of aggregate reserves provided by the Fed to the financial system. As aggregate

[3] Afonso, Cisternas, Gowen, Miu & Younger (2023) estimate that daily trading volume declined from above \$150, or around 2 percent of commercial bank assets, prior to 2008 to around \$60 to \$80 per day in 2010s, and then increased to an average of \$110 billion, or about 0.5 percent of bank assets, per day in 2023.

reserves decline and liquidity is redistributed across the financial system, competition by these banks to borrow the funds they need is expected to increase, which should be reflected in higher rates and increased activity in the fed funds market (Kim et al. 2020).

3.2 Borrower-Lender Activity in the Fed Funds Market

We now turn to our micro-level dataset to show how differential incentives of market participants leave an imprint on trading volumes and associated rates in the fed funds market. We focus on two types of transactions in the fed funds market: (i) domestic banks borrowing from banks and non-banks; and (ii) foreign banks borrowing from banks and non-banks.

The top and bottom panels of Figure 1 show the total borrowing volume and associated volume-weighted average spreads to IORB in the fed funds market, respectively, for four different types of trades between 2016 and 2024. As indicated in Section 3.1, Figure 1 shows that the majority of volume is driven by foreign banks borrowing from non-bank lenders at relatively low spreads. Moreover, foreign bank borrowing from other banks is almost negligible. This configuration of volumes and spreads suggest that foreign banks are willing to borrow large volumes at relatively low rates from FHLBs. That is, foreign banks primary motivation to borrow from FHLBs is to earn the spread between the rate on fed funds and IORB, a trade commonly referred to as "fed arb" (Anderson et al. 2021).

In contrast, domestic banks borrow both from both non-banks and other banks, but do so at relatively higher spreads. Their willingness to borrow at higher rates is indicative of their motivation to acquire the funds they need rather than profiting from fed arb. Consistent with the idea that their borrowing is more likely motivated by their need to manage their liquidity buffers, and in line with the observations in Anderson & Na (2024), we see that at the end of the last quantitative tightening (QT) period that ended in 2019, domestic bank borrowing volumes increased, as did the rates these banks paid. Intuitively, as aggregate reserves declined and eventually became less ample, domestic banks relied more heavily on the fed funds market to manage their liquidity. The bottom panel of Figure 1 also shows that the share of domestic bank borrowing from non-banks increased.

This configuration of higher volumes at lower spreads for foreign banks and lower volumes at higher spreads for domestic ones underscores the differential motives for these banks to participate in the fed funds market. Foreign banks tend to borrow from non-banks at low rates to earn the spread between IORB and fed funds. Moreover, these differential motivations are more evident outside the zero lower bound period (shaded grey area), in which money market spreads are wider. Taken together, these observations suggest that domestic banks are more likely to rely on the fed funds market to manage liquidity risk in interbank markets than foreign banks. Thus, changes in their need to manage liquidity could affect overall trading conditions in the fed funds market.

Focusing on trading activity of domestic banks, Figure 2 shows the cumulative spread and quantity of domestic banks that are active in the fed funds market.[4] There, we confirm that borrowing from non-banks is associated with relatively low spreads and that these spreads do not increase with volumes (the red dots); while, borrowing from other banks are typically at larger spreads and, importantly, are sensitive to trading volumes (the blue dots). These observations suggest that non-bank (bank) lenders are fairly elastic (inelastic) in their supply of reserves in the fed funds market, and that supply elasticity depends on the type of lender. Indeed, Figure 2 provides evidence that bank lending supply is much more price sensitive, indicating that banks' participation in the market depends on the marginal spread, and potentially, on aggregate liquidity conditions.

4 Empirical Analysis

The evidence discussed in section 3.2 indicates that domestic bank borrowers, and not foreign banks, are more likely to rely on the fed funds market to manage their liquidity, and that supply elasticity depends on the type of the lender. Thus, our analysis will focus on domestic banks' incentives to borrow, which are more likely to be driven by their liquidity management strategies. In this section, we describe our main empirical framework, which examines domestic banks trading activity and their associated spreads in the fed funds market.

To measure the supply elasticity in the fed funds market for domestic banks, we must first solve the endogeneity problem that banks' volume borrowed in the fed funds market is likely affected by the price of borrowing, and vice versa. To address this problem, we use plausiblly exogenous changes to banks' demand deposits as an instrumental variable for the amount borrowed in the fed funds market.[5] Because domestic banks are more likely to rely on the fed funds market to manage their liquidity risk, plausibly exogenous changes, that is shocks, to their demand deposits should affect the demand for reserves. Furthermore, we focus on shocks to demand deposits for smaller domestic banks, which are typically borrowers in the fed funds market and may have less scope to actively attract or shed deposits [need cite here].

Consistent with this idea, in subsection 4.2 we first document how changes in domestic banks' total deposits lead to an increase in reserves at the bank level. We show that

[4]For completeness, Figure A.1 in the appendix also shows the cumulative trading volume and associated spread of foreign banks.

[5]Our results are robust to using total deposits instead of demand deposits. Total deposits are defined as the sum of demand deposits, other deposits, and small-time deposits.

this sensitivity depends on the relative importance of banks deposit base, which is higher for small-sized banks, underscoring the importance of understanding bank heterogeneity. This finding lends support to the interpretation that, a positive shock to all deposits, but specifically to deposits of small domestic banks, increases their demand for reserves.

Then, we use these shocks to measure how they affect domestic banks' aggregate trading volume and spreads, separated by bank and non-bank lending, to measure their supply elasticity to domestic banks in the fed funds market. We find strong evidence that non-bank lending elastic while bank lending is inelastic. We then measure how supply elasticity changes with the aggregate level of reserves to total bank assets and find that bank lending become more inelastic as aggregate reserve balances decline, while non bank lending is fairly elastic regardless of the level of reserves to total bank assets.

4.1 Data

We use the FR 2900: Savings and Loans data and FR 2420 Report of Selected Money Market Rates for our analysis. The FR 2900 collects daily data on selected deposits, vault cash, and reserve balances from banks. Banks submit data once a week reflecting daily data, and provide their reserve balances, demand deposits, other liquid deposits, cash, and small-time deposits (time deposits with balances less than $100,000). The FR2420 report collects transactions in the fed funds market to properly monitor the EFFR. The limitation of these data is that while it includes the identity of the bank borrower, it does not include the identity of the lender. We only observe the lender type, that is, bank or non-bank.[6] From these data we calculate the total trading volume and associated spread to IORB for domestic and foreign banks that borrow from banks and non-banks, separately.

Because the FR 2900 is used to construct U.S. monetary aggregates as required by Section 19(b) of the Federal Reserve Act, the Board of Governors created a robust internal roadmap of RSSD IDs to merge with the FFIEC Call Reports. We use this roadmap to merge the FR 2900 banks to the Call Report data to arrive with 1,983 banks between October 27, 2015 and January 16, 2024.[7]

Of these 1,983 banks, 1,822 are classified as domestic banks according to their Call Report. We separate domestic banks into three cohorts depending on bank size. Specifically, we classify small banks as those with less than $10 billion in total assets during that quarter (resulting in 1,294 small banks), medium banks as those with greater than $10 billion and less than $100 billion in total assets during that quarter (resulting in 156 medium banks),

[6] The vast majority of non-bank lending comes from Federal Home Loan Banks.

[7] Our data start in October 2015 because that is the first month of clean data from the FR 2420 for our purposes. Banks began reporting the FR 2420 form in April 2014.

and large banks as those with assets greater than $100 billion during that quarter (resulting in 31 large banks).[8]

Table 1 displays summary statistics of all 1,983 banks in our sample. On average, any bank has $1.3 billion in reserves and $1.6 billion in demand deposits ($2.1 billion in total deposits) during our time period. Conditioning on the 1,822 domestic banks, on average, they hold about $700 million in reserves. In addition, Table 1 shows that 78 domestic banks traded in the fed funds market during our time period. On average, each bank borrows nearly $9 billion over the week and pays 3.4 basis points below IOR. When borrowing from banks, domestic banks borrow, on average, $2.6 billion over the week and pay 2.3 basis points above IOR.

4.2 Bank-level Sensitivity of Reserves to Deposits

We start by documenting the positive relationship between reserves and demand deposits for certain types of domestic banks. Our interpretation of this relationship is similar to the representative bank framework in Lopez-Salido & Vissing-Jorgensen (2023) where plausibly exogenous changes in demand deposits affects the bank's reserves.[9] Specifically, in that framework, as demand deposits increase a representative bank is more likely to hold reserves to mitigate the risks of deposit outflows.

However, by assumption, this representative bank framework ignores the different motivations across banks to manage their reserves based on their size. The urgency to increase reserves in response to shocks to deposits is likely to be different for banks with distinct levels of deposit leverage. For example, banks with a lower reserves-to-deposits ratio might weight liquidity risk more than a bank with a higher reserves-to-deposits ratio as they experience deposit shocks.

Figure 3 shows the histogram of reserves to total bank deposits for all banks, small banks, and medium & large banks together.[10] While the histogram for all banks is positively skewed, much of this skewness seems to be driven by smaller banks. Specifically, the histogram of medium- and large-sized banks looks more uniform, with appreciable mass for relatively higher ratios. The higher level of reserve-to-deposit ratios makes it unlikely that their holdings of reserves would respond to changes in their deposits. Thus, it is more likely that smaller sized banks' reserve management would be more reactive to deposits.

[8]The sum of small, medium, and large banks is larger at 1,481 banks than the total number of domestic banks with Call Report data at 1,379 banks because banks can move between classifications over time.

[9]Acharya et al. (2023) also documents a positive relationship between demand deposits and reserves but arrives at a different interpretation. See the discussion in Section [insert label here].

[10]We do not plot the histograms for medium and large banks separately to protect their identities.

To more robustly test this hypothesis, we estimate the following specification in equation (1) for bank i during week t between October 2015 and January 2024:

$$\begin{aligned}\Delta Reserves_{i,t} &= \alpha + \beta_1 \Delta DemandDeposits_{i,t} + \beta_2 \Delta Reserves_{i,t-1} \\ &\quad + \theta_i + \phi_{month} + \epsilon_{i,t}.\end{aligned} \tag{1}$$

In this regression, we estimate the sensitivity of weekly average changes to bank i's individual reserves to weekly average changes in bank i's demand deposits. We include changes in lagged reserves $\Delta Reserves_{i,t-1}$, bank fixed effects θ_i, and month fixed effects ϕ_{month} as control variables. Standard errors are clustered at the bank level. Table 2 shows the estimation results from equation (1).

Table 2 shows that shocks to domestic banks' demand depositsincreased their reserves. This sensitivity is strongest among small banks, and is consistent with the idea that banks with relatively low reserve-to-deposit ratios reacted to increasing their reserve balances when faced with shocks to their demand deposits. Overall, we interpret these findings as strong evidence that changes in deposits drove individual banks' demand for reserves. In terms of economic magnitude, a \$100 increase in small bank demand deposits is associated with a \$16 dollar increase in their reserves. Positive shocks to small banks' demand deposit were more likely to increase their demand for reserves, and consequently, increase their trading activity in the fed funds market.

Our results also suggest that the positive relationship between demand deposits and reserves is likely not driven by payment effects. If the effect of a decrease (increase) in demand deposits on reserves stemmed from an outgoing (incoming) payment between banks, then we would expect the coefficients to be close to one. Table 2 shows that this sensitivity is much smaller for small banks, and even smaller for large- and medium-sized banks, making it unlikely that payments are driving the sensitivity. The more plausible explanation stems from the representative bank framework: an increase in the bank's balance sheet (e.g., from extending loans) that increased its demand deposits, prompted banks to seek more reserves to manage their outflow risk. Moreover, as we discuss in the next section, the sparse activity of banks in the fed funds market—especially by smaller banks—also suggests that payment effects have little effect on how banks manage their reserves.

4.2.1 Alternative Interpretations

Our empirical results establishes a positive relationship between changes in demand deposits and changes in reserves for individual domestic banks. While this result is also consistent with Acharya et al. (2023), they arrive at a different interpretation. They argue that the growth of the Fed's balance sheet—which increases the aggregate amount of reserves in the system—-*drives* banks' willingness to increase their deposits, especially uninsured ones. This interpretation is supported by the observation that the amount of deposits *mechanically* increased when the Fed purchased securities from primary dealers. Thus, an increase in aggregate reserves led to an increase in aggregate bank deposits.

However, while this observation is true in the aggregate, the distribution of deposits across banks is not uniform. Figure 4 shows the aggregate level of reserves provided by the Fed plotted with the total amount of deposits (demand plus other deposits plus small-time), separated by large, medium, and small bank size, as a ratio of GDP. The figure shows that as aggregate reserves increased as a consequence of Fed asset purchases, only large, and to a much lesser extent, medium banks increased their deposits. Moreover, small banks did not increase their total deposits as the Fed increased the supply of reserves through asset purchases. Given that we can estimate the sensitivity of reserves to demand deposits by bank at a weekly level, we can observe how small changes in aggregate reserves can affect individual bank behavior. Indeed, because small banks are arguably limited in their ability to attract deposits, Table 2 provides evidence that demand deposit shocks drove small banks' demand for reserves.

Finally, one may be concerned that changes in deposits mechanically increases reserves, as banks with deposit outflows make payments to banks with deposit inflows. However, given that our analysis uses weekly data—which mitigates the effect of high frequency changes coming from payments—and the relative sparseness of bank participation in the fed funds market (see Table 1), the mechanical effect of payment flows is likely to be small. Moreover, we focus on shocks to small banks' demand deposits. Afonso et al. (2022) show that the vast majority of payments in Fedwire are attributable to the largest banks mitigating concerns that the positive sensitivity of reserves to demand deposits among small banks are driven by payment obligations.[11]

4.3 Supply Elasticity in the Fed Funds Market

Having documented the differential motivations of bank and non-bank lenders in the fed funds market, and that shocks to individual domestic bank demand deposits, especially among small banks, affects their holdings of reserves, we now turn to the question of how these shocks affect trading in the fed funds market. We exploit shocks to individual domestic banks' demand deposits to understand *aggregate domestic bank borrowing demand* in the fed

[11] Afonso et al. (2022) find that, in dollar amounts, the top 15 banks are responsible for 76% of all payments sent by the top 100 entities.

funds market so we can measure the elasticity of supply. Domestic bank borrowing demand is more likely to be driven by liquidity management rather than fed arb.

Figure 5 shows a stylistic representation of our empirical strategy. The figure depicts domestic banks' demand, and bank and non-banks' supply, in the fed funds market. The horizontal axis represents the quantity traded in the fed funds market and the vertical axis represents the spread between fed funds trading rates to IORB. The stylized supply curve differentiates between two types of lenders: non-banks and banks. Non-banks supply funds elastically at a relatively low spread (solid red line). Beyond a certain trading volume, banks supply funds into the market represented by an upward sloping supply curve (solid blue line). Both of these supply curves together represent the aggregate supply curve. The curve representing the demand for bank reserves is downward-sloping given the opportunity cost of holding reserves (solid black line). Our empirical framework assumes that positive shocks to domestic bank deposits increases demand for reserves, shifting up the demand curve (dashed black line). By exploiting deposit shocks, we aim to measure changes in fed fund borrowing volumes (ΔQ) and changes in fed funds spreads to IORB ($\Delta FF - IORB$).

The ideal specification would use shocks to an individual bank's demand deposits and test whether that bank borrows in the fed funds market. Unfortunately, trading in the fed funds market is sparse as a feature of the ample reserves framework. Most borrowers rarely borrow in the fed funds market, which makes it infeasible to rely on changes in trading volumes and rates of individual banks. Then, for domestic bank i during week t, we estimate the effect of changes in their demand deposits on changes in aggregate total log trading volume $\Delta ln(Volume_{L,t})$ and associated changes in volume-weighted average spreads $\Delta(FF_{L,t} - IOR_t)$ for all domestic banks that borrowed in the fed funds market during week t. That is, we estimate:

$$
\begin{aligned}
\Delta ln(Volume_{L,t}) &= \alpha + \gamma_1 \Delta DemandDeposits_{i,t} + \gamma_2 \Delta ln(Volume_{L,t-1}) \\
&\quad + \gamma_3 \Delta(FF_{L,t-1} - IOR_{t-1}) + \theta_i + \phi_{month} + \epsilon_{i,t}, \qquad (2) \\
\Delta(FF_{L,t} - IOR_t) &= \alpha + \gamma_1' \Delta DemandDeposits_{i,t} + \gamma_2' \Delta(FF_{L,t-1} - IOR_{t-1}) \\
&\quad + \gamma_3' \Delta ln(Volume_{L,t-1}) + \theta_i' + \phi_{month}' + \epsilon_{i,t} \qquad (3)
\end{aligned}
$$

where $\Delta DemandDeposits_{i,t}$ is expressed in trillions and L refers to the type of lender where $L \in \{all, banks, non\text{-}banks\}$ over week t. We control for lagged variables of each dependent variable to account for autocorrelation. Furthermore, we include bank fixed effects θ_i and weekly time fixed effects ϕ_{month}. Standard errors are clustered at the bank level.

We estimate Equations 2 and 3 in two ways using changes in demand deposits for all and then only small domestic banks. Table 3 shows the estimation results. Changes in demand deposits for the top panel is for all domestic banks, while changes in demand deposits for the bottom panel is for all small domestic banks. The first observation is that the sensitivity of shocks to bank deposits on aggregate domestic trading volume is larger for non-bank lenders relative to bank lenders. This finding suggests that the quantity of non-bank lending supply is particularly sensitive to deposits shocks. However, the results are quite different when looking at changes in spreads. We find that bank lending spreads are positive, large, and statistically significant; consistent with inelastic supply. In contrast, non-bank lending is economically small, even marginally negative, consistent with the idea that their lending is fairly elastic. These observations support the idea that lending activity in the fed funds market depends whether lending comes from a bank or non-bank.

4.3.1 Instrumental Variable Approach

Next, we employ an instrumental variable approach to directly measure supply elasticity. Because estimating Equations 2 and 3 measure the effect of demand deposits on fed funds trading volume and prices separately, the instrumental variable approach allows us to measure the effect of fed funds trading on prices in that market directly. We rely on the identifying assumption that *weekly shocks to deposits only affect the demand for reserves and not supply.* As argued in section 4.2.1 this identifying assumption is more likely to hold for small banks.

Then, for domestic bank i during week t, we estimate the effect of changes in fed funds borrowing $\Delta ln(Volume_{L,t})$ on associated changes in volume-weighted average spreads $\Delta(FF_{L,t} - IOR_t)$ for all domestic banks that borrowed in the fed funds market during week t. We instrument for $\Delta ln(Volume_{L,t})$ with $\Delta DemandDeposits_{i,t}$. That is, we estimate:

$$\begin{aligned}
\Delta ln(V\hat{olume}_{L,t}) &= \alpha + \gamma_1 \Delta DemandDeposits_{i,t} \\
&\quad + \gamma_2 \Delta ln(Volume_{L,t-1}) + \theta_i + \phi_{month} + \epsilon_{i,t} \\
\Delta(FF_{L,t} - IOR_t) &= \alpha + \gamma_1' \Delta ln(V\hat{olume}_{L,t}) + \gamma_2' \Delta(FF_{L,t-1} - IOR_{t-1}) \\
&\quad + \gamma_3' \Delta ln(Volume_{L,t-1}) + \theta_i' + \phi_{month}' + \epsilon_{i,t} \qquad (4)
\end{aligned}$$

where $\Delta DemandDeposits_{i,t}$ is expressed in trillions and L refers to the type of lender where $L \in \{all, banks, non\text{-}banks\}$ over week t. We control for lagged variables of each dependent variable to account for autocorrelation. Furthermore, we include bank fixed effects θ_i and weekly time fixed effects ϕ_{month}. Standard errors are clustered at the bank level.

Table 4 shows the results of our instrumental variable approach in equation 4 and directly measures supply elasticity. The top panel displays the results for all domestic banks while the bottom panel displays the results conditioning on demand deposit shocks for only small banks. In the top panel, consistent with Table 3, a one-unit increase in borrowing from banks yields a positive, statistically significant, and economically meaningful with an elasticity measure of approximately 0.18 (shown in column 4). In contrast, a one-unit increase in borrowing from non-banks yields a *negative* and statistically insignificant coefficient. These results corroborate that bank lending in the fed funds market is inelastic while non-bank landing is inelastic. Turning to the bottom panel, we observe the same relationship of borrowing from banks and non-banks hold and yield larger coefficients when conditioning on demand deposit shocks at small banks. A one-unit increase in borrowing from banks yields a positive and statistically significant coefficient of 0.2. Moreover, the F-statistic, indicating the power of our instrumental variable, is much higher. Changes in demand deposits among small domestic banks is a more appropriate instrument to capture changes in the demand for reserves.[12]

4.3.2 Instrumental Variable Approach as a Function of Aggregate Reserves

Finally, we explore whether our measures of bank and non-bank supply elasticity change with the total amount of bank reserves relative to the size of the banking sector. Specifically, we augment equation (4) by interacting $\Delta ln(V\hat{olume}_{L,t})$ with the ratio of total aggregate reserves divided by total bank assets $\frac{Reserves}{BankAssets}_t$.

Table 5 shows the results when we condition on demand deposit shocks for small banks only (like the bottom panel of Table 4. Our results are consistent with those in Table 4: the supply elasticity provided by bank lenders measured in column 6 is positive and statistically significant at 0.37 while the supply elasticity provided by non-bank lenders measured in column 9 at -0.02, and not statistically significant, suggests that non-bank lending is elastic. The coefficient on the interaction term $\Delta ln(V\hat{olume}_{L,t}) \times \frac{Agg.Reserves}{BankAssets}_t$ in column 6 is -1.25 and highly statistically significant. The supply elasticity provided by bank lenders eases as aggregate reserves increase. Banks are not as price sensitive if the supply of reserves is abundant. However, the coefficient on the interaction term in column 9 suggests that the supply elasticity curve of non-bank lenders is not affected by aggregate reserves. In the Appendix, we use changes in total deposits, rather than demand deposits, as our instrumental variable for $\Delta ln(Volume_{L,t})$. The results are quantitatively similar and shown in Tables A.1 and A.2.

Figure 6 gives a graphical representation of how supply elasticity changes with the level of reserves in the system relative to total bank assets. The horizontal axis displays the level of reserves to assets during our sample period, which fluctuates between 8 and 19 percent.

[12] An alternative specification that uses log changes in individual bank deposits rater than first differences gives quantitatively similar estimates of supply elasticities but with much larger F-statistics.

Each line shows bank and non-bank supply elasticity, with the shaded area representing the 95th percentile confidence interval. The figures hows that when reserves become more scarce—that is, when the ratio of reserves to bank assets is relatively low—both bank and non-bank lending become more inelastic. However, the estimate for non-bank lending is mostly statistically insignificant, while bank elasticity peaks at around 27 percent. Both Table 5 and Figure 6 corroborate the different level of supply elasticity between bank and non-banks, and that bank lending become significantly more elastic as the amount of central bank liquidity declines.

5 Concluding Remarks

We provide a new framework to shed light on demand and supply dynamics in the fed funds market which underwent significant changes in the aftermath of the GFC. Leveraging changes in bank deposits as a proxy for exogenous changes in the demand for fed funds borrowing—especially from changes in deposits of small banks whose demand for reserves is particularly sensitive to deposit shocks—we show that bank lending is more inelastic while non-bank lending is fairly elastic. This finding is consistent with the observation that these two lender cohorts have different motives to participate in the fed funds market: non-bank lenders participate to monetize their unremunerated reserves while bank lenders participate to manage their liquidity positions. Moreover, we find that bank lenders become quite inelastic as the level of aggregate reserves in the system declines, suggesting that their incentives to *lend* are reduced as the amount of liquidity provided by the central bank declines.

Our results highlight the importance of considering the differential incentives of fed funds market participants in understanding market dynamics. In particular, as aggregate reserves in the system declines, bank heterogeneity matters for the incentives of borrowers and lenders that are shaped by differential liquidity management strategies and alternative investment opportunities. Our paper differs from the existing literature that focuses on aggregate demand for reserves and relies on a representative bank framework. Our analysis reveals that when thinking about interbank trading dynamics, it is important to account for bank heterogeneity. These findings underscore the importance of banks' incentives to participate in both sides of interbank markets, which are important to understand as central banks implement monetary policy with ample reserves.

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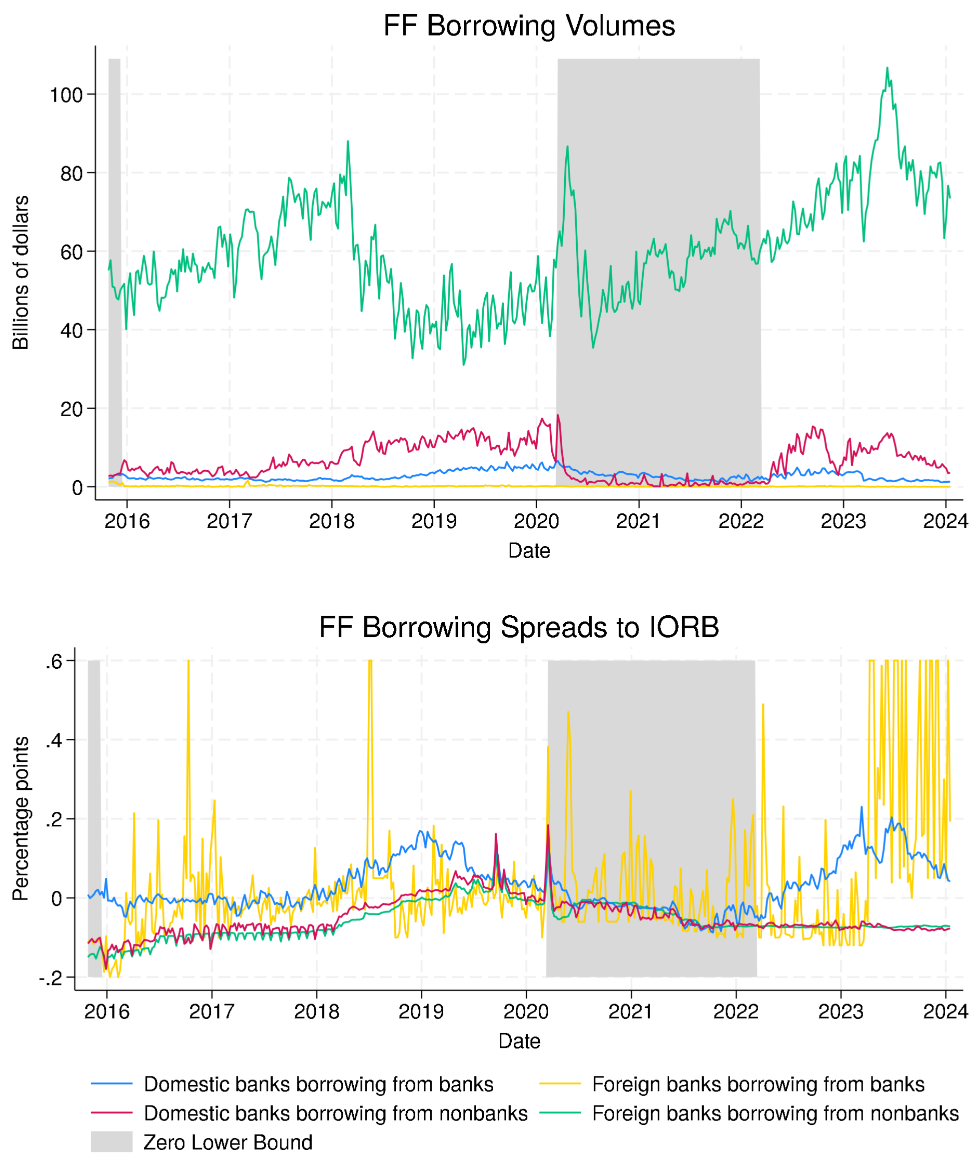
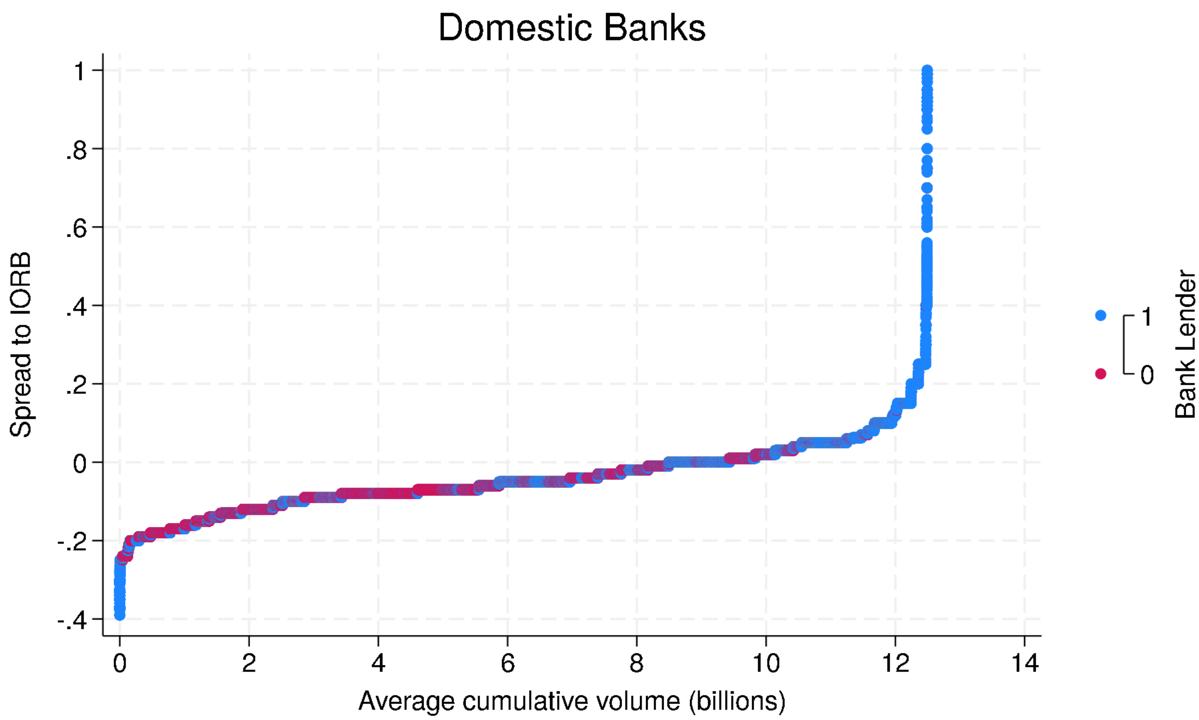
Figures and Tables

Figure 1: Time Series of Aggregate Trading Volumes in Fed Funds Market



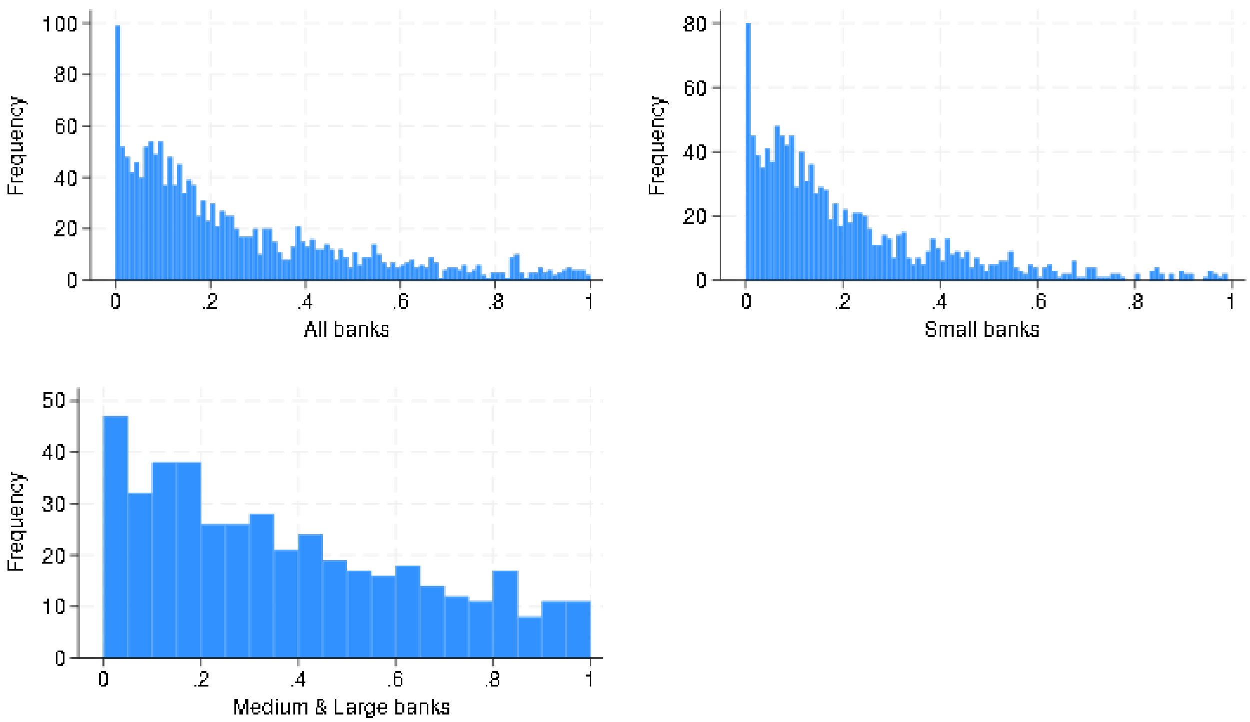
This figure displays borrowing dynamics in the fed funds market for domestic and foreign banks. Source: FR 2420

Figure 2: Cumulative Price and Quantities of Domestic Bank Borrowing in the Fed Funds Market



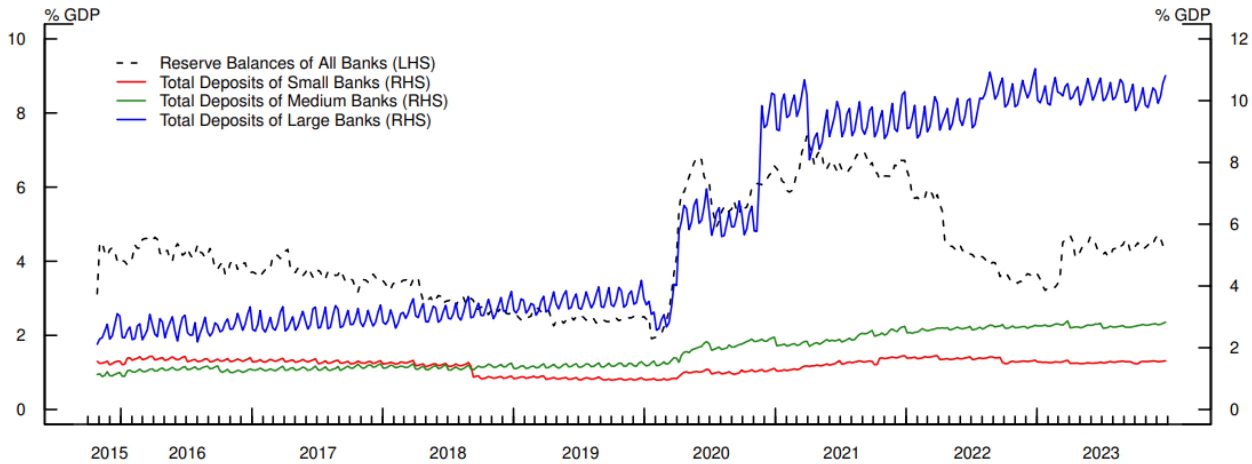
This figure displays cumulative average trading quantities and spreads in the fed funds market of domestic bank borrowing by lender (bank lenders are blue dots and non-bank lenders are red dots. Source: FR 2420

Figure 3: Reserves to Deposits across Domestic Banks



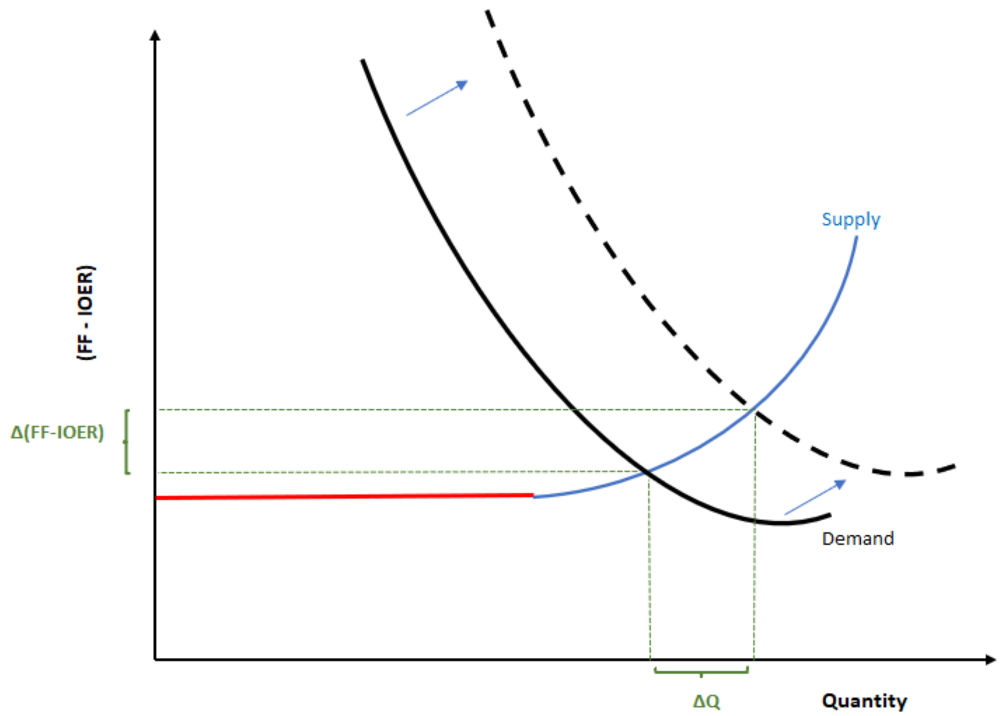
Histograms of domestic banks' reserves to deposit ratios, separated by small sized banks (less than \$10 billion in assets), and medium and large sized banks (greater than \$10 billion). Source: FR 2900 Savings and Loan

Figure 4: Aggregate Reserves and Deposits per Bank Size to GDP



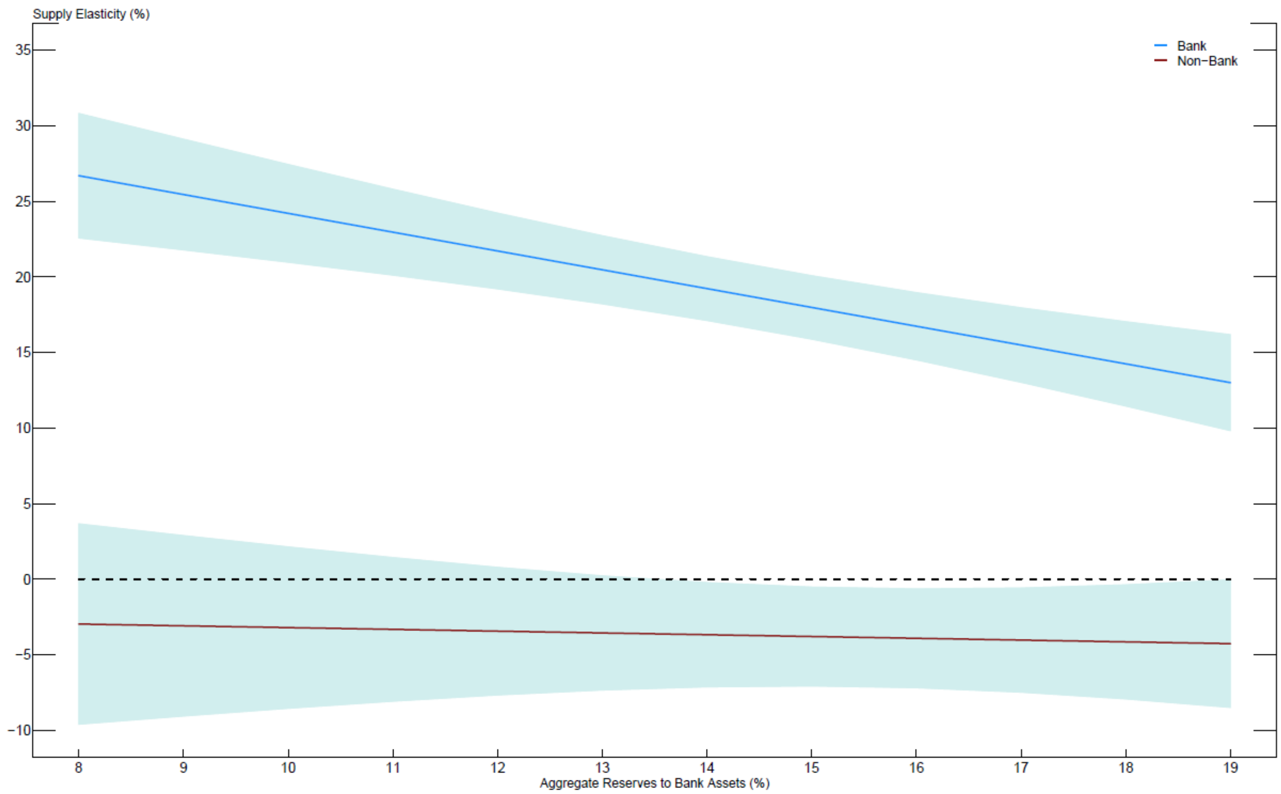
This figure displays aggregate reserves balances as a fraction of GDP and aggregate deposits of banks by bank size to GDP. Small banks are banks with less than \$10 billion in assets. Large banks have assets greater than \$100 billion in assets. Source: FR 2900, FFIEC Call Reports, FRED.

Figure 5: Theoretical Demand and Supply Curves in the Fed Funds Market



Vertical axis is spread of fed funds rate to IORB, horizontal line is trading volumes in the fed funds market. Red and blue lines depict supply in the fed funds market by non-bank and banks, respectively. Black solid line depicts demand in the fed funds market, dashed black lines depicts demand after a deposit shock.

Figure 6: Estimate of Supply Elasticity for Small Domestic Banks as a Function of Total Reserves to Bank Assets



This figure displays our estimate of supply elasticity as a function of the ratio of total reserve balances to total bank assets estimated via a 2-stage regression as in equation 4, including the interaction term of aggregate reserves to total bank assets, that is, $\Delta ln(V\hat{olume}_{L,t}) \times \frac{Reserves}{BankAssets}_t$, conditioning on changes to demand deposits at small banks for our instrumental variable. The figure shows the estimate of the total effect, that is, $\Delta ln(V\hat{olume}_{L,t})$ and $\Delta ln(V\hat{olume}_{L,t}) \times \frac{Reserves}{BanksAssets}_t$, separated by bank and non-bank lending, using the estimates of Table 5. The shaded area illustrates the confidence intervals of our elasticity measure at the 95th percentile. Source: FR 2420, FR 2900, FFIEC Call Reports.

Variable	No. of Banks	Mean	Median	Std. Dev.
All Banks				
Reserves (in billions)	1,983	1.3	0.06	8.4
Demand Deposits (in billions)	1,983	1.6	0.07	19.0
Total Deposits (in billions)	1,983	2.1	0.26	20.4
Assets (in billions)	1,543	14.4	2.0	90.6
Domestic Banks				
Reserves (in billions)	1,822	0.7	0.04	7.1
Demand Deposits (in billions)	1,822	1.9	0.25	18.6
Assets (in billions)	1,379	13.0	1.8	91.4
$FF_{all} - IOR_t$ (in bps)	78	-3.4	-4.6	4.0
$FF_{bank} - IOR_t$ (in bps)	78	2.3	0.4	5.7
$FF_{non-bank} - IOR_t$ (in bps)	78	-5.7	-6.9	4.6
$Volume_{all}$ (in billions)	78	8.7	7.3	4.7
$Volume_{bank}$ (in billions)	78	2.6	2.2	1.1
$Volume_{non-bank}$ (in billions)	78	6.1	5.2	4.1
Small Banks				
Reserves (in millions)	1,294	105.2	32.7	212.4
Demand Deposits (in millions)	1,294	288.1	110.4	523.5
Assets (in billions)	1,294	2.4	1.7	2.2
$FF_{all} - IOR_t$ (in bps)	21	-3.5	-4.7	4.1
$FF_{bank} - IOR_t$ (in bps)	21	2.1	0.2	5.5
$FF_{non-bank} - IOR_t$ (in bps)	21	-5.8	-6.9	4.7
$Volume_{all}$ (in billions)	21	8.7	7.3	4.6
$Volume_{bank}$ (in billions)	21	2.6	2.2	1.1
$Volume_{non-bank}$ (in billions)	21	6.1	5.1	4.1

Table 1: Summary Statistics.

This table presents summary statistics about the independent and dependent variables in our analysis between October 27, 2015 and January 26, 2024. $FF_L - IOR_t$ where L refers to the type of lender and $L \in \{all, banks, non\text{-}banks\}$ is the volume-weighted average rate in the fed funds market across for lender type L. $Volume_L$ is the summed borrowed volume in the fed funds market from lender type L. Total deposits are equal to the sum of demand deposits, other liquid deposits, and small-time deposits. Small banks are banks with assets less than $10 billion during their last Call Report quarter. Source: (1) FR 2900 Savings and Loans; (2) FFIEC Call Reports; (3) FR 2420

	(1) All Domestic	(2) Large	(3) Medium	(4) Small
$\Delta(DemandDeposits_{i,t})$	0.031***	0.029***	0.072***	0.16***
	(3.00)	(2.80)	(2.63)	(4.95)
$\Delta Reserves_{i,t-1}$	0.15	0.14	0.017	-0.024
	(1.31)	(1.21)	(0.46)	(-0.37)
Observations	455287	8496	38356	291010
Adjusted R^2	0.0270	0.0386	0.0143	0.0347
Month FE?	Yes	Yes	Yes	Yes

Table 2: The Effect of Deposits on Reserves for Domestic Banks.
This table shows the results of equation (1). All columns show the estimates from a weekly panel regression between October 27, 2015 and January 26, 2024 examining the effects of the change in deposits on the change in reserves. Column 1 shows the results for 1,822 domestic banks, Column 2 shows for small banks, Column 3 shows for medium banks, and Column 4 shows for large banks. We include bank and month fixed effects. Standard errors are clustered at the bank level. t statistics are shown in parentheses. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10. Source: (1) FR 2900 Savings and Loans; (2) FFIEC Call Reports

	(1) $\Delta ln(Volume_{all,t}$	(2) $\Delta(FF_{all,t} - IOR\_t)$	(3) $\Delta ln(Volume_{banks,t})$	(4) $\Delta(FF_{banks,t} - IOR_t)$	(5) $\Delta ln(Volume_{non\text{-}banks,t})$	(6) $\Delta(FF_{non\text{-}banks,t} - IOR_t)$
$\Delta(DemandDeposits_{i,t})$	1.11***	0.039***	0.62***	0.11***	2.00***	-0.0043
	(3.69)	(3.42)	(3.76)	(4.01)	(3.57)	(-0.39)
Observations	455287	455287	453900	453900	453900	453900
Adjusted R^2	0.1496	0.1052	0.1417	0.1733	0.1769	0.0990
Month FE?	Yes	Yes	Yes	Yes	Yes	Yes
Lagged LHS?	Yes	Yes	Yes	Yes	Yes	Yes

	(1) $\Delta ln(Volume_{all,t}$	(2) $\Delta(FF_{all,t} - IOR_t)$	(3) $\Delta ln(Volume_{banks,t})$	(4) $\Delta(FF_{banks,t} - IOR_t)$	(5) $\Delta ln(Volume_{non\text{-}banks,t})$	(6) $\Delta(FF_{non\text{-}banks,t} - IOR_t)$
$\Delta(DemandDeposits_{i,t})$	107.7***	2.29***	76.6***	16.2***	140.5***	-4.27***
	(4.87)	(2.75)	(6.97)	(7.53)	(3.25)	(-4.76)
Observations	291010	291010	291010	289980	291010	289980
Adjusted R^2	0.1381	0.1057	0.1388	0.1516	0.1743	0.0952
Month FE?	Yes	Yes	Yes	Yes	Yes	Yes
Lagged LHS?	Yes	Yes	Yes	Yes	Yes	Yes

Table 3: The Effect of Deposit Shocks on Fed Funds Trading.

This table shows the results from estimating equation (2) and (3), separately, using demand deposit shocks to all and small domestic banks. The results of a panel regression between October 27, 2015 and January 26, 2024, with Panel A using deposit shocks to all 1,822 domestic banks and Panel B using shocks to 1,294 small domestic banks (banks with total assets last quarter less than $10 billion USD). The dependent variables are $\Delta ln(Volume_{L,t})$, the total trading volume in the fed funds market, and $\Delta(FF_{L,t} - IOR_t)$, the aggregate volume-weighted average borrowing rate in the fed funds market minus IORB, where L refers to the type of lender and $L \in \{all, banks, non\text{-}banks\}$. The independent variable is $\Delta DemandDeposits_{i,t}$, weekly changes in individual bank demand deposits, expressed in trillions. We include bank and month fixed effects. Standard errors are clustered at the bank level. t statistics are shown in parentheses. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10. Source: (1) FR 2900 Savings and Loans; (2) FFIEC Call Reports; (3) FR 2420

	$\Delta(FF_{all,t} - IOR_t)$		$\Delta(FF_{banks,t} - IOR_t)$		$\Delta(FF_{non\text{-}banks,t} - IOR_t)$	
	(1) First Stage	(2) Second Stage	(3) First Stage	(4) Second Stage	(5) First Stage	(6) Second Stage
$\Delta ln(Volume_{all,t})$		0.035***				
		(6.20)				
$\Delta ln(Volume_{banks,t})$				0.18***		
				(6.00)		
$\Delta ln(Volume_{non\text{-}banks,t})$						-0.0022
						(-0.37)
$\Delta DemandDeposits_{i,t}$	1.11***		0.62***		2.00***	
	(3.69)		(3.76)		(3.57)	
Observations	455287	455287	453900	453900	453900	453900
First-Stage F statistic		13.7		14.1		12.7
Month FE?		Yes		Yes		Yes
Lagged LHS?		Yes		Yes		Yes

	$\Delta(FF_{all,t} - IOR_t)$		$\Delta(FF_{banks,t} - IOR_t)$		$\Delta(FF_{non\text{-}banks,t} - IOR_t)$	
	(1) First Stage	(2) Second Stage	(3) First Stage	(4) Second Stage	(5) First Stage	(6) Second Stage
$\Delta ln(Volume_{all,t})$		0.026***				
		(4.61)				
$\Delta ln(Volume_{banks,t})$				0.20***		
				(17.06)		
$\Delta ln(Volume_{non\text{-}banks,t})$						-0.035**
						(-2.27)
$\Delta DemandDeposits_{i,t}$	93.0***		76.4***		122.7***	
	(4.42)		(6.94)		(2.92)	
Observations	291010	291010	289980	289980	289980	289980
First-Stage F statistic		19.5		48.1		8.50
Month FE?		Yes		Yes		Yes
Lagged LHS?		Yes		Yes		Yes

Table 4: Elasticity of Supply in the Fed Funds Market for Banks and Non-Banks.
This table shows our instrumental variable approach estimate supply elasticity using equation 4, using demand deposit shocks to all (top panel) and small domestic banks (bottom panel). The results of a weekly IV panel regression between October 27, 2015 and January 26, 2024, with Panel A using shocks to 1,822 all domestic banks in our sample and Panel B using shocks to 1,294 small domestic banks in our sample (banks with total assets last quarter less than \$10 billion USD), to examine the elasticity of supply in the fed funds market. Columns 1, 3, and 5 show the results of the first stage regression where we regress $\Delta ln(Volume_{L,t})$ where L refers to the type of lender and $L \in \{all, banks, non\text{-}banks\}$ on $\Delta DemandDeposits_{i,t}$, expressed in trillions. The dependent variable, $\Delta(FF_{L,t} - IOR_t)$ is the aggregate volume-weighted average borrowing rate to lender type L in the fed funds market on day t minus IORB. We include bank and month fixed effects. Standard errors are clustered at the bank level. t statistics are shown in parentheses. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10. Source: (1) FR 2900 Savings and Loans; (2) FFIEC Call Reports; (3) FR 2420

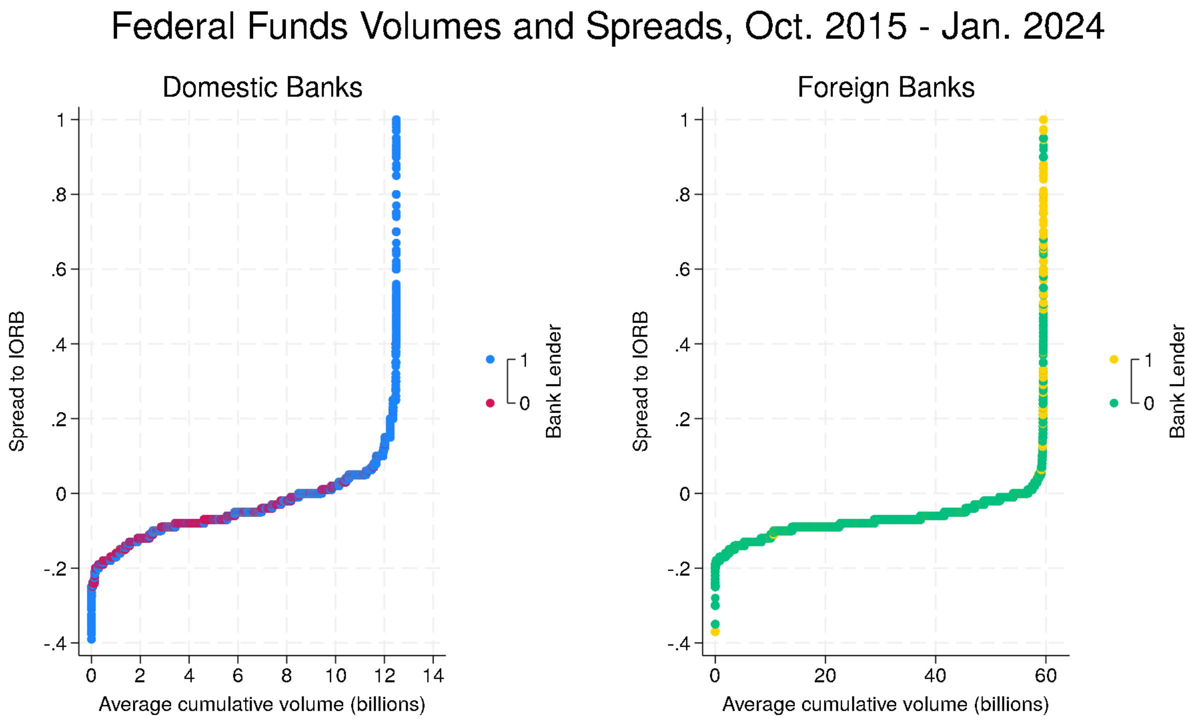
	$\Delta(FF_{all,t} - IOR_t)$			$\Delta(FF_{banks,t} - IOR_t)$			$\Delta(FF_{non\text{-}banks,t} - IOR_t)$		
	(1) First Stage	(2) First Stage	(3) Second Stage	(4) First Stage	(5) First Stage	(6) Second Stage	(7) First Stage	(8) First Stage	(9) Second Stage
$\Delta ln(Volume_{all,t})$			0.32***						
			(7.13)						
$\Delta ln(Volume_{banks,t})$						0.37***			
						(8.82)			
$\Delta ln(Volume_{non\text{-}banks,t})$									-0.020
									(-0.32)
$\Delta ln(Volume_{all,t}) \times \frac{Reserves}{BankAssets\,t}$			-1.93***						
			(-6.24)						
$\Delta \ln(Volume_{banks,t}) \times \frac{Reserves}{BankAssets\,t}$						-1.25***			
						(-4.52)			
$\Delta ln(Volume_{non\text{-}banks,t}) \times \frac{Reserves}{BankAssets\,t}$									-0.12
									(-0.30)
$\frac{Reserves}{BankAssets\,t}$	-3.73***	-0.58***	-0.22***	-2.51***	-0.33***	-0.53***	-5.37***	-0.90***	0.11
	(-60.21)	(-55.13)	(-5.57)	(-32.42)	(-27.40)	(-16.86)	(-49.85)	(-51.21)	(1.14)
$\Delta DemandDeposits_{i,t}$	20.0	-10.4		189.4***	12.1***		-251.9	-55.3	
	(0.29)	(-0.81)		(4.99)	(2.60)		(-1.29)	(-1.52)	
$\Delta(DemandDeposits_{i,t}) \times \frac{Reserves}{BankAssets\,t}$	485.7	165.2		-784.4***	-9.99		2527.7	511.0*	
	(0.85)	(1.52)		(-3.32)	(-0.29)		(1.57)	(1.71)	
Observations	291010	291010	291010	289980	289980	289980	289980	289980	289980
First-Stage F statistic			18.6			26.8			9.43
Month FE?			Yes			Yes			Yes
Lagged LHS?			Yes			Yes			Yes

Table 5: Elasticity of Supply in the Fed Funds Market of Banks and Non-Banks Interacted with Aggregate Reserves to Total Bank Assets.

This table shows our instrumental variable approach estimate supply elasticity using equation 4, using demand deposit shocks to small domestic banks augmented by including an interaction term of the level of aggregate reserves to total bank assets in the banking sector. This table shows the results of a weekly IV panel regression between October 27, 2015 and January 26, 2024 for 1,294 small domestic banks (banks with total assets last quarter less than $10 billion USD). Columns 1, 3, and 5 show the results of the first stage regression where we regress $\Delta ln(Volume_{L,t})$ where L refers to the type of lender and $L \in \{all, banks, non\text{-}banks\}$ on $\Delta(DemandDeposits)_{i,t}$, expressed in trillions. The dependent variable, $\Delta(FF_{L,t} - IOR_t)$ is the aggregate volume-weighted average borrowing rate to lender type L in the fed funds market on day t minus IORB. $\frac{Reserves}{BankAssets\,t}$ is the ratio of total federal reserve balances to total domestic bank assets. We include bank and month fixed effects. Standard errors are clustered at the bank level. t statistics are shown in parentheses. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10. Source: (1) FR 2900 Savings and Loans; (2) FFIEC Call Reports; (3) FR 2420; (4) FR H.8

Appendix

Figure A.1: Cumulative Price and Quantities of Domestic and Foreign Bank Borrowing in the fed funds Market.



Cumulative average trading quantities and spreads in the fed funds market, separated by lending volumes from banks (blue/yellow dots) and non-banks (red/green dots).

	$\Delta(FF_{all,t} - IOR\_t)$		$\Delta(FF_{banks,t} - IOR\_t)$		$\Delta(FF_{non\text{-}banks,t} - IOR\_t)$	
	(1) First Stage	(2) Second Stage	(3) First Stage	(4) Second Stage	(5) First Stage	(6) Second Stage
$\Delta ln(Volume_{all,t})$		0.035***				
		(6.30)				
$\Delta ln(Volume_{banks,t})$				0.18***		
				(6.15)		
$\Delta ln(Volume_{non\text{-}banks,t})$						-0.0023
						(-0.39)
$\Delta(TotalDeposits_{i,t})$	1.10***		0.62***		1.99***	
	(3.69)		(3.75)		(3.57)	
Observations	454829	454829	453446	453446	453446	453446
First-Stage F statistic		13.6		14.1		12.8
Month FE?		Yes		Yes		Yes
Lagged LHS?		Yes		Yes		Yes

	$\Delta(FF_{all,t} - IOR\_t)$		$\Delta(FF_{banks,t} - IOR\_t)$		$\Delta(FF_{non\text{-}banks,t} - IOR\_t)$	
	(1) First Stage	(2) Second Stage	(3) First Stage	(4) Second Stage	(5) First Stage	(6) Second Stage
$\Delta ln(Volume_{all,t})$		0.025***				
		(4.19)				
$\Delta ln(Volume_{banks,t})$				0.19***		
				(17.01)		
$\Delta ln(Volume_{non\text{-}banks,t})$						-0.036**
						(-2.32)
$\Delta(TotalDeposits_{i,t})$	89.0***		73.6***		116.6***	
	(4.48)		(7.12)		(2.93)	
Observations	290719	290719	289691	289691	289691	289691
First-Stage F statistic		20.0		50.7		8.56
Month FE?		Yes		Yes		Yes
Lagged LHS?		Yes		Yes		Yes

Table A.1: Elasticity of Supply in the Fed funds Market Using Total Deposits.

This table shows the two stage strategy to estimate supply elasticity, first using equation (2) and then equation (3), using total deposit shocks to all and small domestic banks. The results of a weekly IV panel regression between October 27, 2015 and January 26, 2024, with Panel A using shocks to 1,822 all domestic banks in our sample and Panel B using shocks to 1,294 small domestic banks in our sample (banks with total assets last quarter less than \$10 billion USD), to examine the elasticity of supply in the fed funds market. Columns 1, 3, and 5 show the results of the first stage regression where we regress $\Delta ln(Volume_{L,t})$ where L refers to the type of lender and $L \in \{all, banks, non\text{-}banks\}$ on $\Delta TotalDeposits_{i,t}$, expressed in trillions. The dependent variable, $\Delta(FF_{L,t} - IOR_t)$ is the aggregate volume-weighted average borrowing rate to lender type L in the fed funds market on day t minus IORB. We include bank and month fixed effects. Standard errors are clustered at the bank level. t statistics are shown in parentheses. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10. Source: (1) FR 2900 Savings and Loans; (2) FFIEC Call Reports; (3) FR 2420

	$\Delta(FF_{all,t} - IOR_t)$			$\Delta(FF_{banks,t} - IOR_t)$			$\Delta(FF_{non\text{-}banks,t} - IOR_t)$		
	(1) First Stage	(2) First Stage	(3) Second Stage	(4) First Stage	(5) First Stage	(6) Second Stage	(7) First Stage	(8) First Stage	(9) Second Stage
$\Delta ln(Volume_{all,t})$			0.30***						
			(6.73)						
$\Delta ln(Volume_{banks,t})$						0.39***			
						(9.90)			
$\Delta ln(Volume_{non\text{-}banks,t})$									0.052
									(0.69)
$\Delta ln(Volume_{all,t}) \times \frac{Reserves}{BankAssets\,t}$			-1.84***						
			(-5.94)						
$\Delta \ln(Volume_{banks,t}) \times \frac{Reserves}{BankAssets\,t}$						-1.43***			
						(-5.38)			
$\Delta ln(Volume_{non\text{-}banks,t}) \times \frac{Reserves}{BankAssets\,t}$									-0.54
									(-1.15)
$\frac{Reserves}{BankAssets\,t}$	-3.73***	-0.58***	-0.22***	-2.51***	-0.33***	-0.59***	-5.37***	-0.90***	-0.14
	(-60.20)	(-55.13)	(-5.69)	(-32.46)	(-27.43)	(-19.17)	(-49.83)	(-51.21)	(-1.40)
$\Delta(TotalDeposits_{i,t})$	14.8	-10.7		172.8***	10.3**		-239.9	-53.0	
	(0.22)	(-0.84)		(4.97)	(2.35)		(-1.25)	(-1.48)	
$\Delta(TotalDeposits_{i,t}) \times \frac{Reserves}{BankAssets\,t}$	497.0	163.9		-691.1***	-0.82		2416.5	490.6*	
	(0.87)	(1.52)		(-3.11)	(-0.02)		(1.52)	(1.68)	
Observations	290719	290719	290719	289691	289691	289691	289691	289691	289691
First-Stage F statistic			20.8			28.9			10.4
Month FE?			Yes			Yes			Yes
Lagged LHS?			Yes			Yes			Yes

Table A.2: How Elasticity of Supply in the Fed funds Market Using Total Deposits Changes With Aggregate Reserves.

This table shows the two stage strategy to estimate supply elasticity, first using equation (2) and then equation (3), using total deposit shocks to small domestic banks; augmented by including an interaction term of the level of aggregate reserves to total bank deposits. This table shows the results of a weekly IV panel regression between October 27, 2015 and January 26, 2024 for 1,294 small domestic banks (banks with total assets last quarter less than $10 billion USD). Columns 1, 3, and 5 show the results of the first stage regression where we regress $\Delta ln(Volume_{L,t})$ where L refers to the type of lender and $L \in \{all, banks, non\text{-}banks\}$ on $\Delta(DemandDeposits)_{i,t}$, expressed in trillions. The dependent variable, $\Delta(FF_{L,t} - IOR_t)$ is the aggregate volume-weighted average borrowing rate to lender type L in the fed funds market on day t minus IORB. $\frac{Reserves}{BankAssets\,t}$ is the ratio of all reserve balances held at the Fed to total domestic bank assets. We include bank and month fixed effects. Standard errors are clustered at the bank level. t statistics are shown in parentheses. Statistical significance: *** p $\leq$ .01, ** p $\leq$ .05, * p $\leq$ .10. Source: (1) FR 2900 Savings and Loans; (2) FFIEC Call Reports; (3) FR 2420; (4) FR H.8