Monetary Policy Implementation Regimes and Reserve Demand in the US*

Saki Bigio† Pablo D'Erasmo‡ Luis Yépez§

July 7, 2026

Abstract

We develop and implement a novel methodology to estimate the demand for central bank reserves across different monetary policy regimes in the United States from 2003 to 2023. Our approach addresses two challenges in reserve demand estimation: the endogenous evolution of monetary policy implementation frameworks and the endogenous response of monetary policy to demand shocks. Using a three-stage empirical strategy, we first identify exogenous supply and demand shocks to liquidity through fluctuations in the Treasury General Account and cross-sectional dispersion measures in federal funds rates and deposit growth. Second, we estimate regime-specific Federal Reserve balance sheet rules to isolate orthogonalized components of policy operations. Third, we employ these components in a two-stage instrumental variables framework to recover the causal effect of reserve availability on money market spreads. Our results reveal a stable, downward-sloping demand curve for reserves, with regime-dependent semi-elasticities.

Keywords: Monetary policy implementation; Reserve demand estimation; Federal Reserve balance sheet

JEL Classifications: E52, E58, E41, E43, E44

*The views expressed in this paper do not necessarily reflect those of the Federal Reserve Bank of Philadelphia or the Federal Reserve System.

†Department of Economics, UCLA, and NBER. E-mail: sbigio@econ.ucla.edu.

‡Research Department, Federal Reserve Bank of Philadelphia. E-mail: pablo.derasmo@phil.frb.org.

§Department of Economics, University of Chicago. E-mail: luisyepezsa@uchicago.edu.

1 Introduction

Among the various forms of money, central bank reserves constitute the cornerstone of monetary policy implementation architecture (Meltzer, 2009). When a downward-sloping demand for reserves exists—with the interbank rate serving as the price—central banks can influence market rates through operations that alter reserve supply. In practice, central banks pursue operational targets—such as an interbank rate target, exchange rate management, credit conditions, or control of broader monetary aggregates such as M1 or M2—through the lens of supply-and-demand analysis (Borio, 1997). Accurate estimates of the reserve demand curve are therefore essential for effective policy implementation, for predicting the consequences of alternative reserve supply rules, and for calibrating quantitative models of money and banking. Establishing empirical evidence of a downward-sloping reserve demand curve should interest all economists—not merely those running open-market operations departments. Understanding the optimal monetary policy targets and instruments is key to understanding the transmission mechanisms through which central bank actions affect the broader economy.

Despite its evident importance, estimating the demand for central bank reserves presents challenges that extend well beyond the century-old simultaneity problems inherent in supply–demand systems.[1] Two distinctive features of reserve markets compound these difficulties. First, central banks adjust the supply of reserves in response to contemporaneous demand shocks—indeed, offsetting such shocks is often the explicit objective of monetary operations. Thus, unlike commodity markets, where exogenous disturbances such as weather or production outages can instrument for supply, reserve markets rarely exhibit naturally occurring exogenous variation. Second, and more fundamentally, the obstacles are not merely statistical but structural. The parameters governing reserve demand are not policy-invariant. Changes in implementation frameworks, legal constraints, or institutional arrangements alter both the mapping from policy actions to reserves and the motives for holding them. As a result, shifts in operating regimes—such as transitions from corridor to floor systems—can transform the very structure of reserve demand, the core of the Lucas critique.[2]

To conceptualize these challenges, let's begin our discussion by considering a reserve demand that follows a sigmoid pattern as depicted in Figure 1. In this framework, banks' demand for reserves is a downward-sloping relationship between an interbank rate, the Federal Funds' Rate (FFR) in the case of the US, and the liquidity ratio, the ratio of reserves to

[1] Econometricians (Chernozhukov, 2022; Stock and Watson, 2001) credit Wright (1928) as the first scientific piece pointing to this issue, preceding the foundational formalization in Haavelmo (1943).

[2] See Lucas (1976) for the original formulation, and subsequent discussions in Sargent (1982) and Leeper and Zha (2003).

deposits, measuring how well covered banks are from deposit outflows. The demand curve is bounded above by the central bank's lending-facility rate (DWR, for discount window rates), which caps what rational banks will pay in the interbank market, and bounded below by the rate paid on reserves (IORB), below which no bank will lend. This curve is widely used by open-market operations departments (Bindseil, 2014) and is motivated by classic analysis in Poole (1970) or more recent dynamic interbank-market models (e.g., Afonso and Lagos, 2015; Bianchi and Bigio, 2025). The sigmoid shape arises from the ceiling and floor, which makes a linear curve an inadequate representation. There are typically three distinct regions: a steep "scarce reserves" segment where small quantity changes produce large rate movements, a transitional "ample reserves" zone with moderate sensitivity, and a flat "abundant reserves" region where banks are satiated and rates become insensitive to quantity variations, as depicted in Panel (a).

The figure helps explain the challenges. Panel (a) demonstrates the ideal case in which exogenous supply shifts—through open market operations (OMOs)—trace out the demand curve. Yet, the sigmoid function complicates the econometric analysis because the ample and abundant regions have different sensitivities than the scarce regime, suggesting that the estimation should be carried out by segments. Panel (b) illustrates the classic simultaneity problem: an observed movement in that data, from point t to point t' can be equally provoked by demand shifts or shifts in the supply of reserves. In the context of monetary policy, the problem is acute because the supply of reserves may also respond to demand shocks. Panel (c) shows a scattered data cloud that conflates movements *along* the demand curve with shifts *in* the curve. The standard solution is to use instruments for supply shocks that do not respond to demand shocks. Panel (d) illustrates yet another complexity: anticipated changes in how supply responds to demand shocks may also shift the demand curve. Likewise, structural changes—such as the post-2008 liquidity regulations—mean that the same reserve level corresponds to different rates across regimes.

This conceptual framework and the associated empirical challenges motivate our three-step estimation strategy. In the first step, we construct proxies for liquidity demand and supply shocks. This step is crucial because, unlike commodity markets where weather events or production disruptions provide natural experiments, reserve markets lack clearly exogenous supply variations. Moreover, the Federal Reserve's reaction functions have evolved across different operational regimes, requiring us to account for period-specific policy responses to both types of shocks. Following Hamilton (1997), we use changes in the Treasury General Account (TGA) as our supply-side proxy—these Treasury cash management operations directly affect reserve availability but are independent of Federal Reserve policy decisions. For demand-side variation, we employ two complementary measures: the cross-

sectional dispersion of federal funds rates used in Bianchi and Bigio (2022), and a novel series capturing dispersion in deposit growth rates across banks, which Bianchi and Bigio (2022) show theoretically captures demand shifts. After controlling for seasonal patterns and FOMC meeting effects, we treat the forecasting errors of these variables as proxies for exogenous demand and supply shocks.

In the second step, we estimate how different Federal Reserve balance sheet instruments—Treasury securities, MBS, repos, and reverse repos—systematically respond to the identified demand and supply shocks. This step reveals that the Federal Reserve consistently accommodates both types of shocks, though the specific response patterns vary across instruments and regimes. Crucially, the residuals from these estimated policy rules represent the orthogonalized component of each operation, purged of endogenous responses to liquidity conditions. These residuals serve as an input to construct an econometric instrument that captures exogenous variation in Federal Reserve operations beyond their systematic reaction to market conditions, a crucial step for our third step.

The third step conducts a two-stage instrumental variables estimation to recover the causal relationship between reserves and money market spreads. As a first-stage regression, we construct an instrumented liquidity ratio series by using the orthogonalized Federal Reserve operations from stage two, along with the original demand and supply shocks, to predict changes in the reserves-to-deposits ratio. This procedure yields a counterfactual liquidity path driven solely by exogenous policy variations and market shocks. Second, we regress our normalized federal funds spread—the position of the effective rate within the IORB-discount rate corridor—on this instrumented liquidity ratio to estimate the reserve demand curve.

To account for fundamental changes in monetary policy implementation, we partition our estimation across distinct regimes guided by documented institutional shifts: the limited-reserves era (2003–2008), the post-Global Financial Crisis period (2008–2020), and the COVID-19 super-abundant reserves regime (2020–2023). This regime-specific approach, informed by Federal Reserve communications and historical narratives of monetary policy evolution, proves essential for uncovering stable structural relationships.

Our main finding is that a downward-sloping demand curve for reserves emerges consistently across all regimes—a result that stands in sharp contrast to naive OLS regressions, which yield unstable and often wrongly-signed coefficients. The estimated elasticities exhibit the theoretically-predicted sigmoid shape, with sensitivity to reserves increasing dramatically as the system transitions from scarce to ample reserves, and then dropping again once the system features abundant reserves. Specifically, a one percent increase in the reserves-to-deposits ratio reduces normalized spreads by 7.2 percentage points in the limited reserves

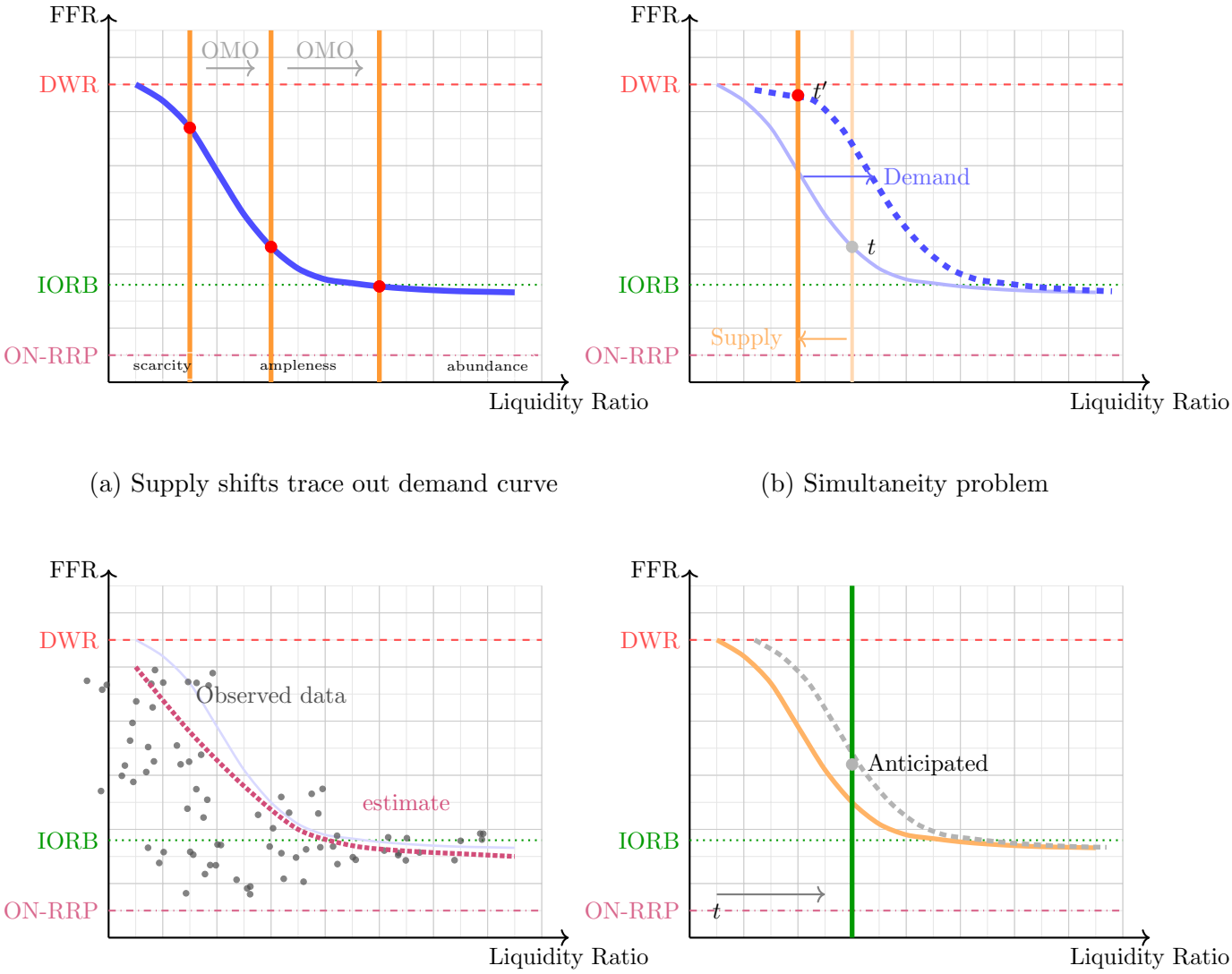
regime, but by 27.2 percentage points in the post-GFC period. Furthermore, our estimates for the post-2008 period align closely with recent studies such as Lagos and Navarro (2023), providing reassurance that our extension to earlier regimes is also well estimated. These findings prove robust to alternative specifications of the liquidity ratio, different demand-shock instruments, and variations in the specification of Federal Reserve operating rules.

Literature Review. Estimating money demand has long been central to macroeconomics, with a vast literature linking non-bank monetary aggregates such as M1 or M2 to inflation and income. Surprisingly, however, far less attention has been devoted to estimating the demand for bank reserves and its relationship to interbank rates—despite the critical importance of this relationship for monetary policy implementation (Roberds, 1998). Influential early work includes Bernanke and Blinder (1992) and Gordon and Leeper (1994), who employed VAR techniques to identify reserve demand. This research laid the foundation for pioneering applications of modern identification methods by Hamilton (1996) and Hamilton (1997), who introduced high-frequency identification and instrumental variables approaches using exogenous variation in Treasury deposits at the Federal Reserve.

Academic interest in reserve demand estimation largely dissipated by the early 2000s, likely reflecting the belief that once the Federal Reserve adopted an elastic supply doctrine—adjusting reserves automatically to hit interest rate targets—the quantity of reserves became irrelevant for policy. If interest rate targets could be achieved smoothly through infinitely elastic supply, measuring reserve demand seemed unnecessary for understanding or conducting monetary policy. This view dominated until the Global Financial Crisis forced a reconsideration of quantity-based analysis in the context of large-scale asset purchases and abundant reserves regimes.

Our paper contributes to a recent resurgence of academic interest in reserve demand estimation, joining new work by Lopez-Salido and Vissing-Jorgenson (2023), Afonso et al. (2023), and Lagos and Navarro (2023). These papers employ varied identification strategies. Lopez-Salido and Vissing-Jorgenson (2023) use fluctuations in the overnight reverse repurchase facility as an instrument for reserve supply. Afonso et al. (2023) apply VAR techniques to extract residuals as supply shock instruments. Lagos and Navarro (2023) develop and estimate a structural model of banks' reserve demand. Our approach borrows insights from all three. Following Hamilton (1997) and Lopez-Salido and Vissing-Jorgenson (2023), we exploit fluctuations in Federal Reserve balance-sheet accounts as intermediate steps to construct instruments for the liquidity ratio. However, like Afonso et al. (2023), we model these fluctuations as autoregressive processes and use innovations from these rules to generate orthogonalized variation in liquidity conditions.

Figure 1: Identification challenges in estimating reserve demand.



(a) Supply shifts trace out demand curve

(b) Simultaneity problem

(c) Observed equilibria and biased estimates

(d) Policy anticipation and regime shifts

Note: "FFR" denotes Federal Funds' Rate, "DWR" discount window rate, "IORB" interest paid on reserves, "ON-RRP" Overnight Reverse Repurchase Agreement (overnight reverse repo), "OMO" Open Market Operations, "Liquidity Ratio" the ratio of reserves to deposits. See the text for description of each panel.

We make two principal contributions to this literature. First, we combine proxies for both demand shocks and supply shocks that incorporate bank-level heterogeneity, using these to orthogonalize Federal Reserve balance-sheet operations and construct fitted values of the liquidity ratio purged of endogenous policy responses. This two-sided approach—controlling for both demand and supply factors simultaneously—yields sharper identification than methods relying on supply shocks alone. Second, whereas existing papers restrict attention to the post-GFC period, we estimate reserve demand across multiple regimes spanning 2003 to 2023. This longer sample reveals that reserve demand relationships differ fundamentally across institutional frameworks—appearing unstable when regimes are pooled but exhibiting stable, theory-consistent patterns within regimes. Most importantly, by estimating across the full modern period encompassing both scarce and abundant reserves, we recover demand slopes consistent with the sigmoid-shaped reserve demand curve predicted by theory: steep under scarcity, flat under abundance, with a well-defined transition region.

Our focus on reserve demand connects to the broader literature on money demand estimation, though reserves differ fundamentally from the currency and deposit aggregates that literature emphasizes. The theoretical foundations trace to Baumol (1952) and Tobin (1956), whose inventory-theoretic models characterize money holdings as balancing transaction needs against the opportunity cost of holding non-interest-bearing assets. Friedman (1956) developed an alternative portfolio-theoretic approach, treating money as one asset among many in a wealth-maximization framework. Early econometric implementations of these theories appeared in Metzler (1963), Laidler (1966), and Laidler (1969), establishing the empirical money demand tradition.[3]

Goldfeld (1976) provided seminal empirical estimates documenting stable relationships between real money balances, income, and interest rates during the pre-1970s period. However, this apparent stability proved fragile: the subsequent breakdown of these relationships—the "missing money" puzzle analyzed by Judd and Scadding (1983) and Goldfeld and Sichel (1990). Our discussion of regimes of implementation actually connects with issues of this instability.

Subsequent research developed more sophisticated approaches to address this instability. Lucas (1988) and Stock and Watson (1989) exploited econometric techniques for handling structural breaks and identification challenges; Ball (2001) and Ireland (2009) applied cointegration methods to recover long-run relationships. More recently, Lucas and Nicolini (2016) and Benati (2021) have documented remarkable stability in money demand once

[3] Alvarez and Lippi (2009) and Alvarez and Lippi (2017) have modernized the inventory theoretical framework to incorporate advances in payment technologies and financial innovation, showing how changes in transaction costs and the structure of payment systems fundamentally reshape money demand.

low-frequency movements in velocity are properly accounted for across various countries.

In the conclusion to this paper, we discuss how both demand estimations should be reconciled in theory and in empirical work.

2 Motivating Empirical Facts

We begin by documenting empirical patterns in the Federal Reserve's operational framework. These facts underscore significant changes in U.S. monetary policy implementation, which likely shifted the demand for reserves.

We start with a discussion of the post-World War II experience and then focus on the last 20 years (the "Modern Period"), a period at the center of our analysis since high-frequency data is available. Discussing historical episodes that precede the period covered by our econometric analysis is important for providing context and motivating our methodology.

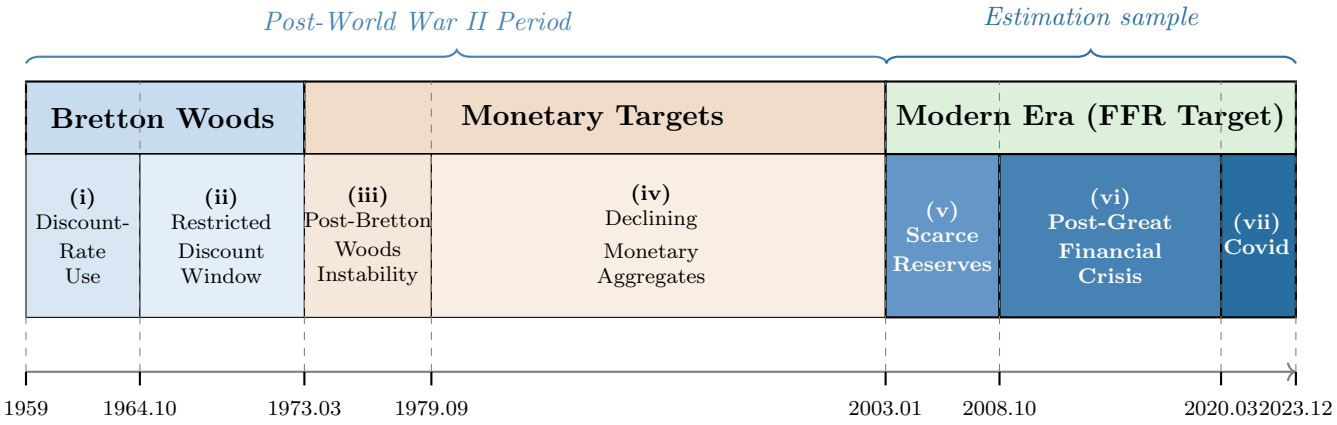
The regimes. We distinguish the following US monetary policy implementation regimes, depicted in Figure 2. Our analysis spans three broad eras: the **Bretton Woods** era (1959-1973), and the **Monetary Targets** era (1973-2003). These two eras span the post-World War II years. The third era, which we call the **Modern Period of Federal Funds Rate targeting**, covers the last 20 years (2003-2023). Within these eras, we identify seven clearly distinct operational regimes: (*i*) Discount-Rate Use (1959m1-1964m10) and (*ii*) Restricted Discount Window (1964m11-1973m3) within the Bretton Woods era; (*iii*) the Post-Bretton Woods Instability (1973m4-1979m9) and (*iv*) Declining Monetary Aggregates (1979m10-2002m12) within the Monetary Targets era; finally, the Modern Period covers three periods, (*v*) Scarce Reserves (2003m1-2008m10), (*vi*) Post-Great Financial Crisis (2008m11-2020m2), and (*vii*) COVID-19 (2020m3-2023m12) regime. Each regime is shaped by its institutional arrangements and prevailing macroeconomic environment, which we describe below. Regimes (*v*)-(*vii*), highlighted in the figure, constitute the core sample for our estimation of demand for central bank reserves.

Reserve demand variables. The variables that define the reserve demand, as explained above, behave very differently during the monetary policy implementation regimes. We formally define the variables here.

In reserve demand analysis, the relative amount of liquidity in the system is fundamental plays the role of a "quantity" variable. We define our baseline measure of liquidity, the "liquidity ratio", as

$$\text{LiqRatio}_t = \ln\left(\frac{\text{Reserves}_t}{\text{Deposits}_t} \times 100\right), \tag{1}$$

Figure 2: U.S. Monetary Policy Implementation Regimes (1959–2023).



where Reserves_t are the reserves balances with Federal Reserve Banks and Deposits_t are the commercial bank total deposits.[4] It is important to normalize reserved by a liability, as this normalization provides a sense of scarcity relative to payment needs or liquidity risks (Bianchi and Bigio, 2022).

Second, we examine how liquidity conditions influence the implementation of monetary policy and money market rates by studying the evolution of the "spreads ratio" or "normalized Federal Funds rate" defined as

$$\text{SpreadsRatio}_t = \frac{DFF_t - IORB_t}{DWR_t - IORB_t} \times 100, \tag{2}$$

where DFF_t is the effective federal funds rate, $IORB_t$ is the interest on reserve balances (the policy floor), and DWR_t is the discount rate (the policy ceiling). The spreads ratio is bounded between zero and 100 and provides a normalized measure of the position of the federal funds rate within the corridor defined by the Fed's administered rates. Values close to zero indicate ample liquidity with the funds rate anchored at the floor, whereas values near 100 reflect tight liquidity conditions with the funds rate drifting toward the ceiling. This normalization is also used in Afonso et al. (2023) and is grounded in the theory of interbank-market trades (Afonso and Lagos, 2015).

Table 1 shows the mean and standard deviation (in parentheses) of the liquidity ratio and spreads ratio across regimes. Figure 3 provides a historical perspective of the three series used to construct the Spreads Ratio, the FFR, the DWR and IOER. Figure 4 plots the time

[4]The ratio is expressed in logs; hence, when reserves represent a very small percentage of deposits, the liquidity ratio can take negative values. See the footnote to Table 1 and Section 3.1 for details on the construction of the variables.

series of reserves and deposits. Figure 5 plots the spread ratio against the liquidity ratio. These time series reveal clear breaks and changes in volatility which indicate differences in the sequence of distinct operating regimes in U.S. monetary policy, each shaped by institutional arrangements. We discuss these differences.

Table 1: Summary Statistics per regime

	Discount-Rate Use	Restricted DW	Post-BW Instability	Declining Mon. Agg	Scarce Reserves	Post-GFC	Post COVID-19	Full Sample
Liq. Ratio	1.73	1.44	1.26	-0.14	-1.38	2.84	2.97	0.97
	(0.15)	(0.05)	(0.15)	(0.85)	(0.50)	(0.29)	(0.11)	(1.47)
Spreads Ratio	91.29	108.97	109.59	115.82	77.77	41.89	91.11	94.33
	(15.40)	(18.36)	(19.12)	(14.20)	(11.39)	(10.44)	(3.97)	(30.50)
Period Start	1959m1	1964m11	1973m4	1979m10	2003m1	2008m11	2020m3	
Period End	1964m10	1973m3	1979m9	2002m12	2008m10	2020m2	2023m12	

mean coefficients; standard deviation in parentheses

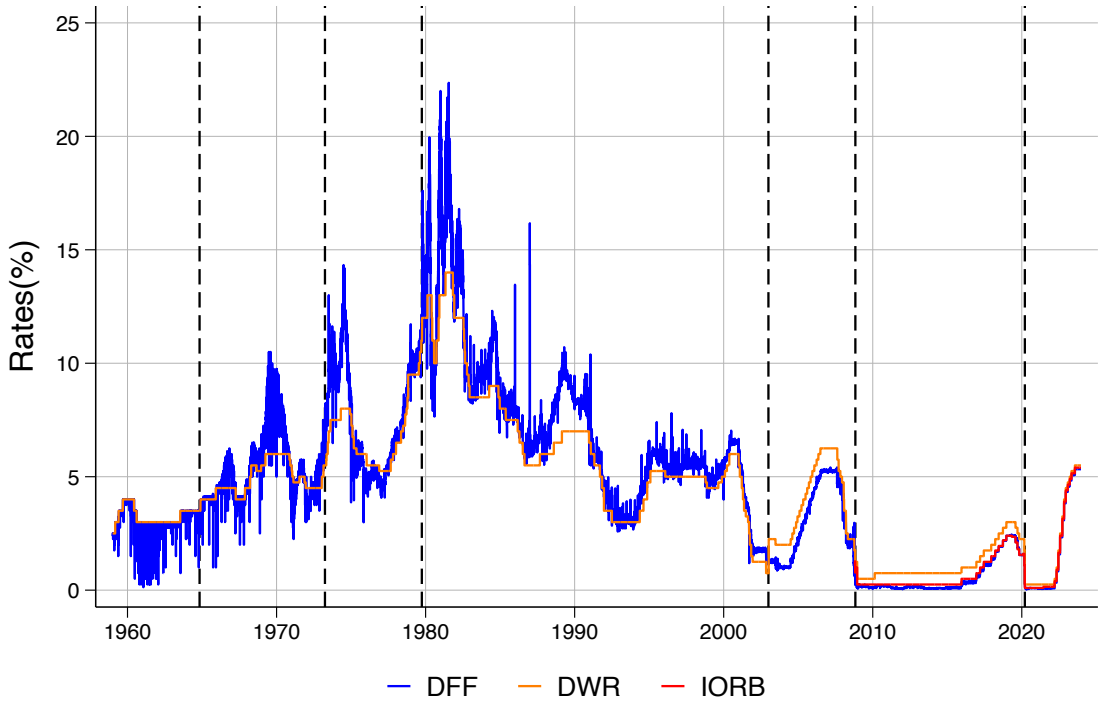
Note: "Restricted DW" refers to the Restricted Discount Window regime, "Post-BW Instability" to the Post-Bretton Woods Instability regime, "Declining Mon. Agg." to the Declining Monetary Aggregates regime and "Post-GFC" to the post-Great Financial Crisis regime. "Liq. Ratio" denotes the liquidity ratio in equation (1), and "Spreads Ratio" a normalized measure of the position of the federal funds rate within the corridor defined by the Fed's administered rates presented in equation (2). To construct the Spreads Ratio we use the effective federal funds rate (DFF_t), the discount window rate (DWR_t), and the interest on reserve balances ($IORB_t$). The effective federal funds rate (DFF_t) corresponds to series FEDFUNDS, the discount window rate (DWR_t) corresponds to the series DPCREDIT, and the interest on reserve balances ($IORB$) is set to 0 between January 2003 and October 2008, from October 2008 to July 2021 corresponds to the average of series IOER Rate and IORR Rate, and from August 2021 to December 2023 the series IORB. We constructed the variable Reserves by splicing three series: monthly RESBALNS (Jan 1959–Dec 1983), weekly WRESBAL (Jan 1984–Dec 2002), and weekly WRBWFRBL (Jan 2003–Dec 2023); and the variable Deposits by splicing four series: monthly TCDSL, STDSL, and SAVINGSL (summed to form total deposits for Jan 1959–Dec 1972), and weekly DPSACBW027SBOG (Jan 1973–Dec 2023). These two series were then used to compute the liquidity ratio. The statistics were computed based on monthly data (first observation of the month). The variable Reserves Source: Federal Reserve Bank of St. Louis (FRED).

2.1 Post-World War II Operational Frameworks

The post-World War II period through 2002 encompasses two broad eras of Federal Reserve operations: the Bretton Woods period (1959–1973) and the Monetary Targets period (1973–2002). These decades are particularly instructive because the Federal Reserve operated under multiple, not formally disclosed objectives as in modern period. These objectives were often even conflicting from the standpoint of models without frictions in capital markets.

During Bretton Woods, the Federal Reserve maintained a de facto fixed exchange rate between gold and the dollar while simultaneously managing its operations aimed a targeting various objectives: the level of the Federal Funds rate, the growth in deposits and the growth in credit (Meltzer, 2009). Policymakers appeared comfortable pursuing various objectives

Figure 3: Historical Interest Rates



Note: The figure displays selected short-term interest rates (Federal funds effective rate — DFF, Interest on Reserve Balances — IORB, and the Discount Window rate — DWR). Series are expressed in percent and plotted as weekly observations (Wednesday values). Vertical dashed lines mark the following policy-regime ending dates: November 1964, April 1973, October 1979, January 2003, November 2008 and March 2020. See footnote to Table 1 for details on series used to construct the variables. Source: Federal Reserve Bank of St. Louis (FRED).

using various instruments, even though standard monetary models suggests these targets would conflict in frictionless markets. Later, during the Monetary Targets era, the Federal Reserve attempted to control monetary aggregates while also influencing interest rates—an ambivalence that sometimes left the Fed without clear goals or even consistent theoretical frameworks (Meltzer, 2009).

Discount-Rate Dominance. The Discount-Rate Dominance period (1959m1–1964m10) operated as a traditional corridor system. The discount window rate functioned as a binding ceiling: banks could always borrow reserves at this rate, preventing the Federal Funds rate from rising above it. Figure 3 shows that while the funds rate was extremely volatile by modern standards, it remained consistently capped by the discount rate, regularly hitting, but never exceeding the discount window rate.

Reserve conditions during this period were comparatively ample. The liquidity ratio was

considerably higher than in the pre-2008 era and, importantly, remained stable. This stability suggests the Federal Reserve provided an inelastic supply of reserves, limiting the supply adjustments to counter rate volatility, allowing market forces to drive substantial day-to-day fluctuations in the funds rate within the corridor (see Table 1 for volatility statistics). To avoid movements in the exchange rate, the Federal Reserve and the US Treasury conducted a combination of operations that did not involve changes in banks reserves (Bordo, 1993).[5]

Restricted Discount-Window. A structural break occurred in late 1964 when the Federal Funds rate began persistently exceeding the discount window rate—a pattern that violates the traditional corridor logic. Figure 3 is remarkable in that regard: the Federal Funds rate would consistently cross the discount window rate and exhibit great volatility. This shift reflected deliberate changes in Federal Reserve policy toward discount window access.

Contemporaneous Board discussions reveal the mechanism behind this change. As Meltzer (2009) documents, proposed legislation required reserve banks "to keep informed about the general character and amount of the loans and investments of its member banks with a view to ascertaining whether undue or inappropriate use is being made of bank credit for the speculative carrying of or trading in securities, real estate, or commodities" (p. 467). The Board gained authority to bar banks engaged in "unsound practices" from accessing the discount facility, creating administrative barriers to borrowing.

We interpret this as the imposition of regulatory costs on discount window access. The likely motivation was to prevent Federal Reserve member banks from arbitraging cheap discount window funds by on-lending to non-member institutions—a practice that would have artificially inflated reserve demand among non-members. Yet, the timing is also significant: this regime coincided with the Bretton Woods era, when the dollar-gold parity came under increasing stress (Bordo, 1993). Limiting the discount window could have been an attempt to boost the demand for dollar reserves.

Despite this operational shift, the liquidity ratio remained high and stable throughout the period, indicating an inelastic supply of reserves. Surprisingly, the academic literature has largely overlooked the persistently volatile Federal Funds rate during that period.

Post-Bretton Woods Instability. The collapse of Bretton Woods in 1971 fundamentally altered the Federal Reserve's operational environment. No longer constrained by the fixed exchange rate, the Fed shifted toward controlling monetary aggregates while using the discount window rate to influence the Federal Funds rate—a dual approach that proved difficult

[5]In particular, in join operations with the Treasury, the Federal Reserve would enter swap arrangements, with foreign central banks to drains dollars abroad and issue long-term bonds denominated in foreign currency, known as Roosa bonds.

to implement consistently.

The immediate post-Bretton Woods period (1973m4–1979m9) brought heightened volatility to short-term rates. Figure 3 shows the Federal Funds rate frequently exceeded the discount window rate by nearly 10 percentage points. The spread ratio exhibited a standard deviation much higher than in any other period—reflecting severe instability in the demand for reserves.

Yet when we examine reserve conditions, a striking pattern emerges. The liquidity ratio had, shown in Figure 5, remained both high and stable throughout this turbulent period, with only a minor downward trend. Figure 4, shows a stable supply of reserves, with a minor upward trend in deposits. Although the ratio trended downward from its Bretton Woods peak, reserves remained abundant relative to deposits. This disconnect between rate volatility and reserve stability is noteworthy: despite macroeconomic turmoil from oil shocks and stagflation, the Federal Reserve maintained a relatively steady supply of reserves. The instability manifested in rate movements rather than in the supply of reserves.

Declining Monetary-Aggregates Period. The Volcker-era marked a decisive turning point in Federal Reserve operations. The subsequent regime (1979m10–2002m12) began with Paul Volcker explicitly targeting reductions in monetary aggregates to combat inflation—a strategy designed to tighten monetary conditions by restricting reserve supply and thereby increasing demand pressure for reserves. This pattern is clearly observed in Figure 4.

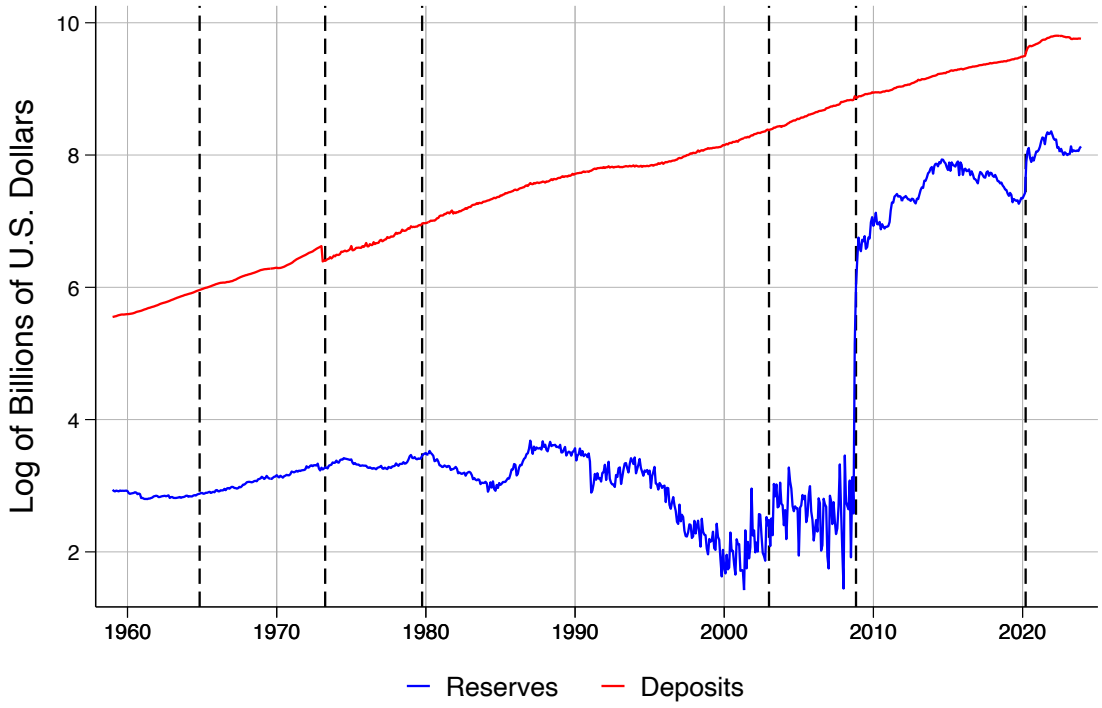
The policy initially also induced exceptionally high and volatile interest rates, with the Federal Funds rate consistently exceeding the discount window rate by a factor of 1.5. As the Federal Reserve's disinflation campaign succeeded through the mid-1980s (Taylor, 1993), however, rate volatility gradually subsided.

By the 1990s, a newfound stability in rates reflected a fundamental shift in the Federal Reserve's operational doctrine: rather than maintaining stable reserve quantities and allowing rates to fluctuate. This transition represented the gradual emergence of an *elastic supply doctrine* that is evident from Figures 7 and 4. The liquidity ratio underwent pronounced increase in volatility during this period—particularly through the 1990s—as the Federal Reserve increasingly used open market operations to accommodate or offset shifts in reserve demand, but also trended downward. In effect, the liquidity ratio absorbed the volatility that had previously appeared in the Federal Funds rate. This gradual regime change makes the anticipation effect particularly challenging for any reserve demand estimation.

By the end of this regime, the Federal Reserve had effectively inverted its earlier approach. Where once reserves were supplied relatively inelastically (forcing rates to adjust to clear the market), the Fed now adjusted reserve supply elastically to maintain target rates. This

doctrine laid the groundwork for the explicit interest-rate targeting framework that would fully emerge in the 2000s, where the Federal Reserve would set an explicit federal funds rate target and conduct operations as needed to achieve it.

Figure 4: Historical Reserves and Deposits

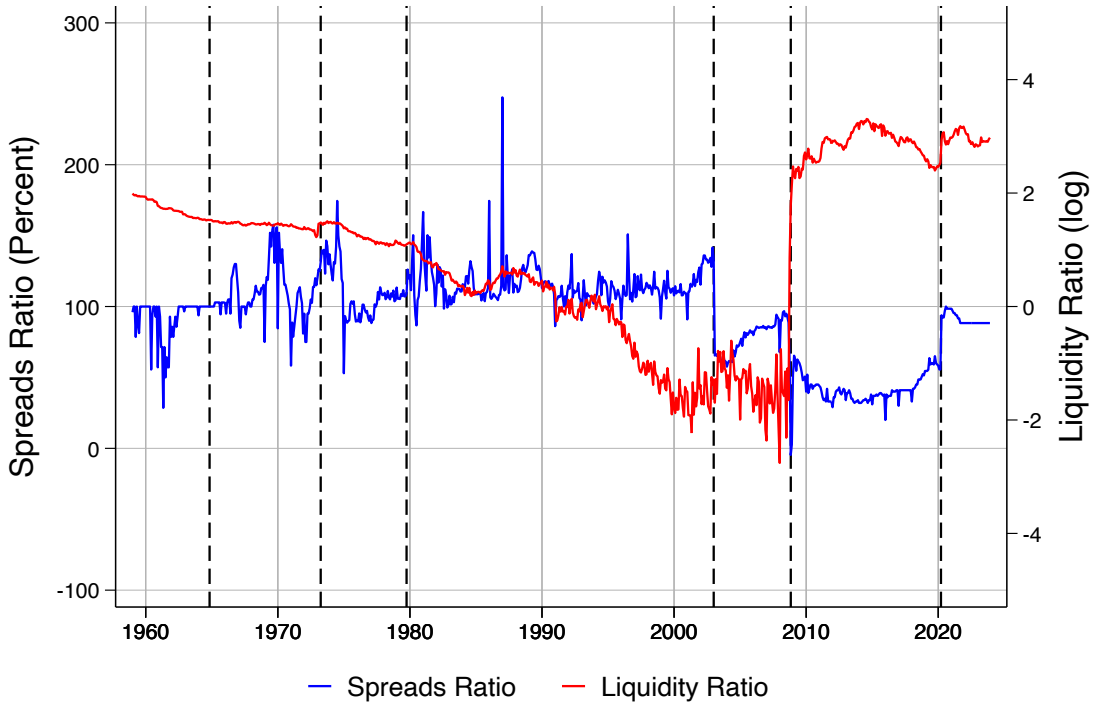


Note: The figure displays total commercial bank deposits (red) and reserve balances with Federal Reserve Banks (blue). See footnote to Table 1 for details on series used to construct the variables. Source: Federal Reserve Bank of St. Louis (FRED)

2.2 The Modern Era: 2003 to Present

The modern era of the Federal Reserve spans from 2003 to the present and marks a clear regime change from the post-World War II period. For this modern era, we also benefit from greater availability of higher-frequency data for the variables discussed above, in addition to more detailed Federal Reserve balance-sheet data (in Figure 6). The period subdivides naturally into three distinct sub-regimes, each characterized by different operational frameworks, Federal Reserve balance-sheet compositions, and reserve conditions, but sharing in common concrete and implicit targets for the Federal Funds rate announced to the public.

Figure 5: Historical Spreads Ratio and Liquidity Ratio



Note: The figure displays the spreads ratio (blue line, left axis) and the liquidity ratio (red line, right axis). The spreads ratio is defined as $(DFF - IORB)/(DWR - IORB) \times 100$ (equation (2)). The liquidity ratio is the natural log of the ratio of reserves to commercial bank deposits expressed in percentages ($log(Reserves/Deposits \times 100)$) (equation (1)). See footnote to Table 1 for details on series used to construct the variables. Source: Federal Reserve Bank of St. Louis (FRED)

Scarce Reserves. The Scarce Reserves regime (2003m1–2008m10) (also referred to as Limited Reserves) operated as a traditional corridor system with scarce reserves. As we noted, prior to the period, the Federal Funds rate consistently exceeded the discount window rate. To bring the Federal Funds Rate below the discount window rate, a significant operational change took place on January 9, 2003, when the Federal Reserve redesigned its discount window lending programs. The reform replaced the previous adjustment credit system with two new facilities: primary credit (for primary-dealer institutions) and secondary credit (for weaker institutions). Critically, the Fed set the primary credit rate 100 basis points above the federal funds target rate, establishing the discount window as an explicit ceiling for the corridor (Stevens, 2003). This above-market pricing removed arbitrage incentives, returning to the pre-1964 doctrine of "borrowing for any purpose, no questions asked."[6] The result was a functioning corridor with the discount rate as the upper bound

[6]The reform also , aiming to reduce the stigma that had made banks reluctant to use the window during the 1990s (Furfine, 2005)

and zero as the implicit floor, with the federal funds rate consistently trading below the discount window ceiling, as is evident from Figure 7 which zooms in Figure 3.

During this period, the Federal Reserve's balance sheet remained modest and stable as is clear from Figure 6. Outright Treasury securities and temporary repo operations dominated asset-side operations, providing the primary means of reserve provision. Reserve balances remained relatively low throughout the period but were volatile (Figure 4) adjusting frequently to maintain the Federal funds target. The liquidity ratio was particularly low, but the implicit elastic supply of reserves and the redisign of the discount window can explain the break in the spread ratio.

The stardard deviation of the Federal Fund rate was due, predominatly to changes in the targets rates, and not to short-term demand factors as in the past: Rates remained low in 2003, peaked in 2006–2007 as the Federal Reserve tightened policy, and then fell sharply as financial conditions deteriorated in 2008. Despite these rate movements, the corridor system functioned as intended: the funds rate remained anchored between the discount rate ceiling and the zero floor.

Post-Global Financial Crisis. The Post-Global Financial Crisis regime (2008m11–2020m2) represented a fundamental transformation of the Federal Reserve's operational framework. The introduction of interest on reserve balances (IORB) in October 2008 established an explicit floor for the federal funds rate, marking the transition from a corridor system with a varying corridor to a constant corridor. Moreover, the large Quantiative Easing operations lead to an ample-reserves regime. As Figure 7 shows, the effective federal funds rate converged closely to the IORB rate and remained anchored there throughout the regime, except during brief stress episodes. In fact, the Federal Funds rate traded below the IORB as a result of arbitrage with institutions not eligible to the IORB (Figure 7).

This operational shift was enabled by dramatic changes in the Federal Reserve's balance sheet. Large-scale asset purchases (LSAPs) of Treasury securities, Federal Agency Debt, and mortgage-backed securities (MBS) drove a structural expansion in reserves (Figure 6). The Fed's asset purchases led to a rapid and substantial increase in reserve balances.

New operational instruments emerged during this regime. Reverse repurchase agreements (reverse repos) became a central tool for absorbing excess balances and moderating short-term funding pressures. The Treasury General Account (TGA)—the Treasury's deposit at the Federal Reserve—began producing large, fiscal-driven swings in the Fed's net liabilities and reserve dynamics. Emergency lending facilities, which had surged sharply during the crisis itself, gradually unwound but remained available as backstop liquidity sources.[7]

[7]The abrupt surge in reserves significantly boosted aggregate liquidity by increasing the supply of the

Post COVID-19. The Post COVID-19 regime (2020m3–2023m12) was characterized by super-abundant reserves and represented a further intensification of the ample-reserves framework. The interventions during the COVID-19 pandemic included massive large-scale asset purchases, a comprehensive set of emergency liquidity facilities, and the temporary elimination of reserve requirements. These actions led to reserve balances reaching historically unprecedented levels, dwarfing even the post-GFC expansion.

Figure 6 shows the dramatic scale of balance-sheet expansion during this period. Treasury securities and MBS holdings surged to record levels, while emergency lending programs and foreign-currency swap lines temporarily swelled to provide dollar liquidity both domestically and to global counterparties. The COVID-19 crisis marked a second major turning point in the Fed's operational approach, with reserves far exceeding any level seen in the past.

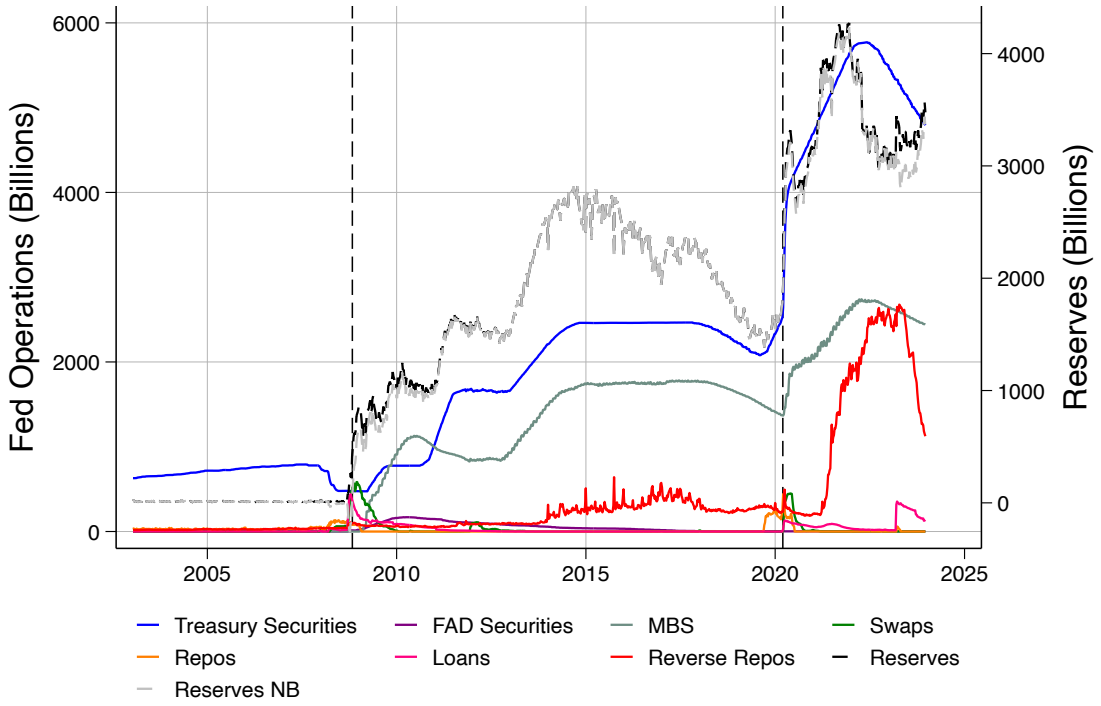
Policy rates returned to the effective lower bound, with both the federal funds rate and IORB near zero through much of 2020 and 2021 (Figure 7). In this super-abundant reserves environment, the Federal Reserve employed an expanded operational toolkit, relying on overnight reverse repurchase (ON-RRP) facility and standing repo facility to provide both an effect floor by disabling the arbitrage between institutions that could and couldn't ear interest on reserves (Labonté, 2021; Wong, 2021)

Taking Stock: Basic OLS Regressions. The description of monetary policy implementation regimes traces the transformation of U.S. monetary policy. During the Bretton Woods era, the system transitioned from a corridor with inelastic reserve supply to one with a limited discount window. This doctrine of rigid supply eventually morphed into an elastic supply regime. Only by the early 2000s did the U.S. return to a proper corridor system with the discount rate acting as a ceiling. The system finally evolved into a floor system dominated by abundant reserves, driven by balance-sheet expansions following the 2008 and 2020 crises.

For reserve-demand estimation, these transitions highlight central identification challenges: the endogeneity of supply varies across regimes, as does the nature of demand driven by banks' anticipatory behavior. A simple OLS regression of the spreads ratio on the liquidity ratio—the variables shown in Figure 5—illustrates the consequences of these challenges. We can hardly uncover the sigmoid patterns predicted by theory, or even a consistent negative slope across all regimes. Table 2 reports the results. In the early post-World War II

most liquid asset. Consequently, the implicit "price" of liquidity in interbank markets compressed, and conventional spreads narrowed. The federal funds rate traded in a tight range around IORB, demonstrating the effectiveness of the floor system. However, liquidity heterogeneity across counterparties persisted, and these structural changes had notable impacts on short-term funding conditions and on liquidity and term premia across money-market instruments (Gagnon et al., 2010; Ihrig et al., 2020; Krishnamurthy and Vissing-Jorgensen, 2011).

Figure 6: Federal Reserve Operations and Reserves

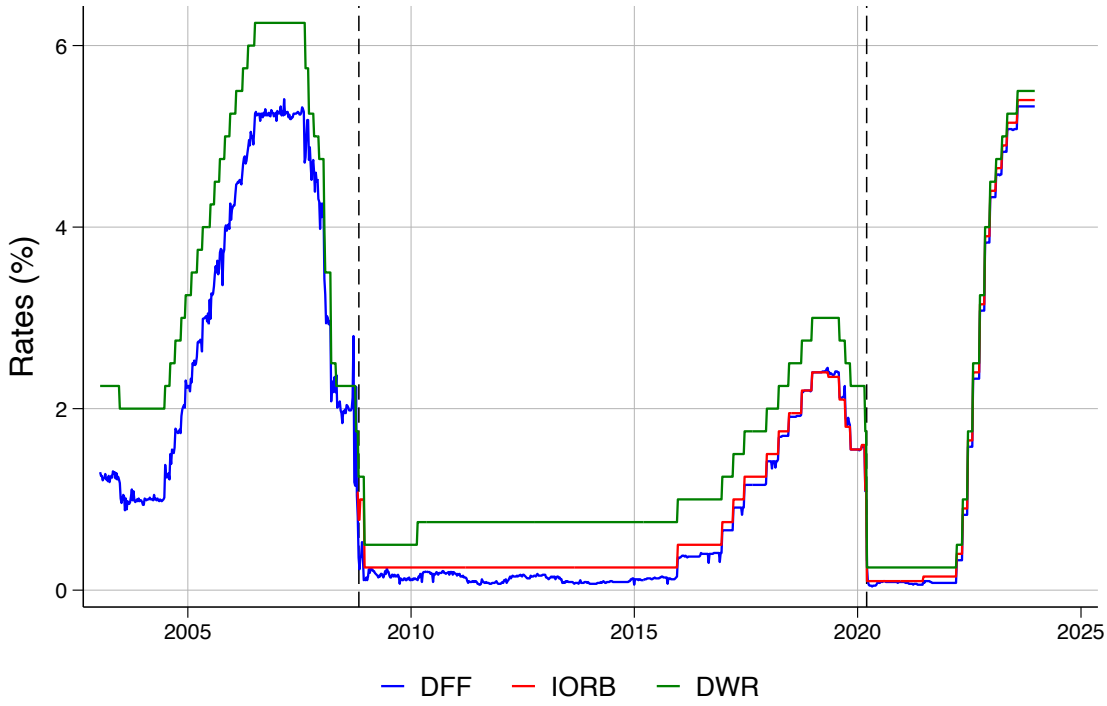


Note: The figure displays selected Federal Reserve balance-sheet components (assets and liabilities) on the left axis and reserve aggregates (total reserves and non-borrowed reserves) on the right axis; all values are expressed in billions of U.S. dollars. Series are weekly observations, taking the Wednesday value each week. Vertical dashed lines denote the start of the Global Financial Crisis (October 2008) and the COVID-19 pandemic (March 2020). Source: Board of Governors of the Federal Reserve System, H.4.1 statistical release, "Factors Affecting Reserve Balances of Depository Institutions and Condition Statement of Federal Reserve Banks."

regimes (Discount-Rate Use and Restricted DW), the coefficients are either weakly significant or insignificant, unsurprising given the stability of the liquidity ratio and the volatility of spreads during these periods. Strikingly, during the Declining Monetary Aggregates period (1979m10–2002m12), the coefficient is strongly positive (61.40, significant at 1%), reflecting the disorderly monetary conditions and volatile interest rates during the Volcker disinflation. An econometrician in the 1980s, limited to the OLS tools standard at the time, would have reasonably concluded that there was no stable relationship between reserves and interest rates—a finding that likely contributed to the profession's abandonment of quantity-based monetary analysis later on.

The modern regimes (2003 onward) show patterns more consistent with theory. The Scarce Reserves regime exhibits a strong negative coefficient (-8.25), the Post-GFC regime shows the strongest relationship with a coefficient of -20.08, and the COVID-19 regime

Figure 7: Interest Rates



Note: The figure displays selected short-term interest rates (Federal funds effective rate — DFF, Interest on Reserve Balances — IORB, and the Discount Window rate — DWR). Series are expressed in percent and plotted as weekly observations (Wednesday values). Vertical dashed lines indicate the start of the Global Financial Crisis (October 2008) and the COVID-19 pandemic (March 2020). See footnote to Table 1 for details on series used to construct the variables. Source: Federal Reserve Bank of St. Louis (FRED)

displays a negative but smaller coefficient (-4.07), likely reflecting the super-abundant reserve environment where the system operated on the flat portion of the demand curve. While these OLS regressions offer some hope of uncovering the sigmoid-shaped relationship between liquidity and spreads in the modern period, they suffer from the identification problems; an instrumental variables approach is necessary to isolate the causal effects of liquidity conditions on the spreads ratio and adequately recover reserve-demand estimates.

2.3 Proxies for Supply and Demand Conditions

During the modern era, the Federal Reserve adopted an elastic supply doctrine, systematically responding to both demand shocks and autonomous factors affecting reserve availability. To identify the causal effects of liquidity conditions on money market spreads, we must account for this endogenous reserve supply response. We construct proxies for exogenous demand and supply conditions that allow us to control for the systematic component of Fed-

Table 2: Historical Demand for Reserves Regressions

	Discount-Rate Use	Restricted DW	Post-BW Instability	Declining Mon. Agg	Scarce Reserves	Post-GFC	Post COVID-19	Full Sample
	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio
Liq. Ratio	-10.42*	11.68	61.40***	0.39	-8.25***	-20.08***	-4.07	-9.08***
	(6.10)	(15.44)	(5.39)	(0.43)	(1.91)	(2.61)	(4.89)	(0.33)
Constant	105.24***	83.36***	21.91***	112.70***	62.20***	99.99***	104.12***	98.83***
	(10.80)	(22.71)	(6.72)	(0.70)	(3.53)	(7.46)	(15.28)	(0.92)
N	304	439	339	1215	303	593	197	3390
Adj. R-sq.	-0.01	0.00	0.33	-0.00	0.18	0.29	-0.00	0.22

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: "Restricted DW" refers to the Restricted Discount Window regime, "Post-BW Instability" to the Post-Bretton Woods Instability regime, "Declining Mon. Agg." to the Declining Monetary Aggregates regime and "Post-GFC" to the post-Great Financial Crisis regime. "Liq. Ratio" denotes the liquidity ratio in equation (1), and "Spreads Ratio" a normalized measure of the position of the federal funds rate within the corridor defined by the Fed's administered rates presented in equation (2). See footnote to Table 1 for details on series used to construct the variables. Source: Federal Reserve Bank of St. Louis (FRED)

eral Reserve policy responses, thereby isolating the variation in liquidity needed to identify reserve demand.

These proxies serve two purposes. First, they enable us to separate exogenous shifts in liquidity from endogenous Federal Reserve reactions. Second, the regime-specific behavior of these proxies—particularly the dramatic spikes during the 2008 and 2020 crises—underscores the structural breaks in both supply and demand that motivate our regime-by-regime estimation approach.

Demand Conditions Proxies. Banks' demand for reserves is driven by precautionary motives and settlement needs, which intensify during periods of funding stress or heightened uncertainty about counterparty creditworthiness. We capture these unobserved demand factors using two measures of heterogeneity in banks' funding conditions: the *federal funds range* and the cross-secttional *dispersion of deposit growth*.[8] The first measure of funding conditions (i.e., reserve demand), the *federal funds range*, is defined as the daily spread between the maximum and minimum federal funds transaction rates reported by the Federal Reserve Bank of New York. More specifically, we compute the daily spread between the 99th and 1st percentiles of transaction rates. The resulting series is expressed in basis points and then converted to weekly frequency by retaining Wednesday observations. A widening of this range signals greater dispersion in interbank funding costs, consistent with either

[8]See Section 3.1 for details on the construction of these two measures of funding conditions.

tighter access to funding or increased concerns about counterparty solvency—both of which strengthen precautionary demand for reserves.

Our second measure of funding conditions, the *dispersion of deposit growth*, reflects heterogeneity in liquidity positions and settlement needs across banks. This series is computed from the distribution of weekly deposit growth across reporting institutions using daily confidential data from the Federal Reserve. Specifically, we construct the distribution of weekly deposit growth for every day in the sample, take the difference between the 99th and 1st percentiles of this distribution and retain a weekly value for consistency with other series.When some banks experience large deposit inflows while others face outflows, aggregate settlement imbalances increase, raising the demand for reserve balances to smooth payment flows.

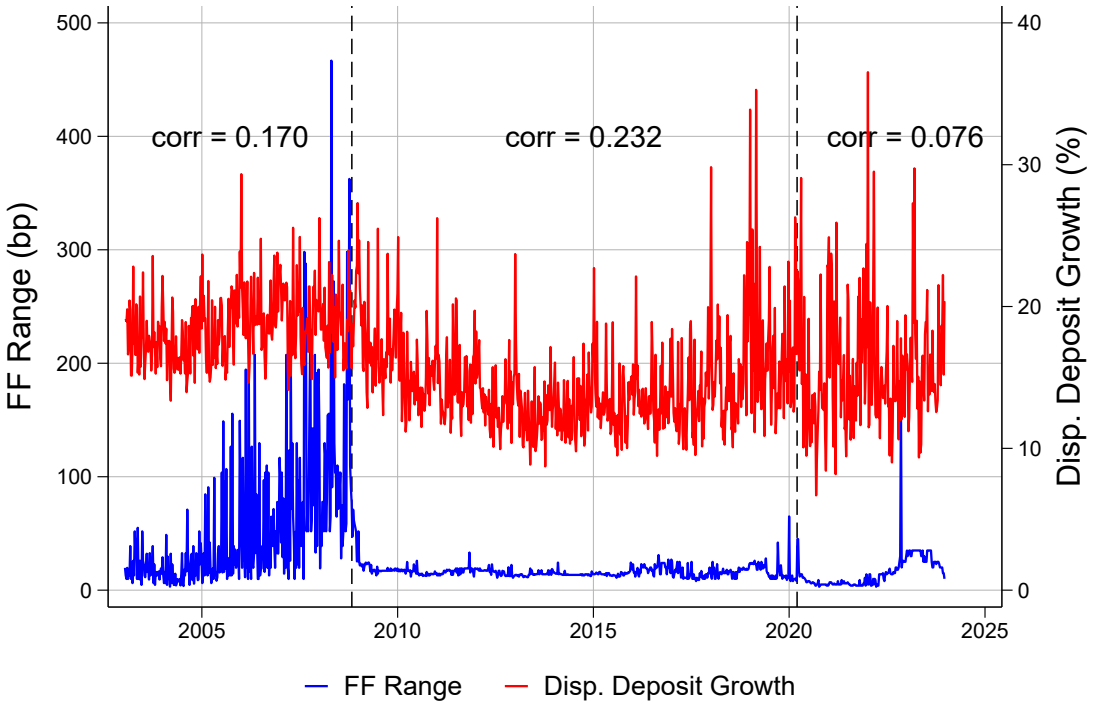
Figure 8 plots both demand proxies. The series are positively correlated and exhibit substantial variation, with pronounced spikes during the 2008 financial crisis and the COVID-19 pandemic. These episodes of heightened dispersion reflect periods when heterogeneity in funding conditions intensified sharply—precisely when we would expect demand for reserves to increase most strongly. As we demonstrate below, both measures correlate positively with the spreads ratio, confirming their validity as proxies for unobserved shifts in reserve demand.

Supply Conditions Proxies. While banks' reserve demand responds to funding conditions and settlement needs, the supply of reserves also fluctuates due to factors outside the Federal Reserve's control. We identify exogenous shifts in reserve supply using innovations in the *Treasury General Account* (TGA) held at the Federal Reserve—a classic instrument introduced by Hamilton (1997). The TGA is recorded as a liability on the Fed's balance sheet: increases in the account withdraw reserves from the banking system, whereas drawdowns inject reserves back into circulation.

Because TGA fluctuations stem from Treasury cash management operations—such as tax receipts, debt issuance, and fiscal disbursements—rather than from monetary policy actions, they provide a natural source of exogenous variation in reserve supply. When the Treasury builds up its account at the Fed, reserves are drained from the banking system independently of the Federal Reserve's open market operations or balance-sheet policy decisions. Conversely, when the Treasury draws down its account to make payments, reserves flow back to banks through purely fiscal channels.

Figure 9 plots the TGA over our sample period. The series exhibits substantial variation, with particularly large movements during crisis episodes. Prior to 2008, the TGA remained relatively small and stable, reflecting the Treasury's traditional practice of minimizing its Federal Reserve deposits. However, following the Global Financial Crisis, the TGA grew

Figure 8: Demand Liquidity Shocks

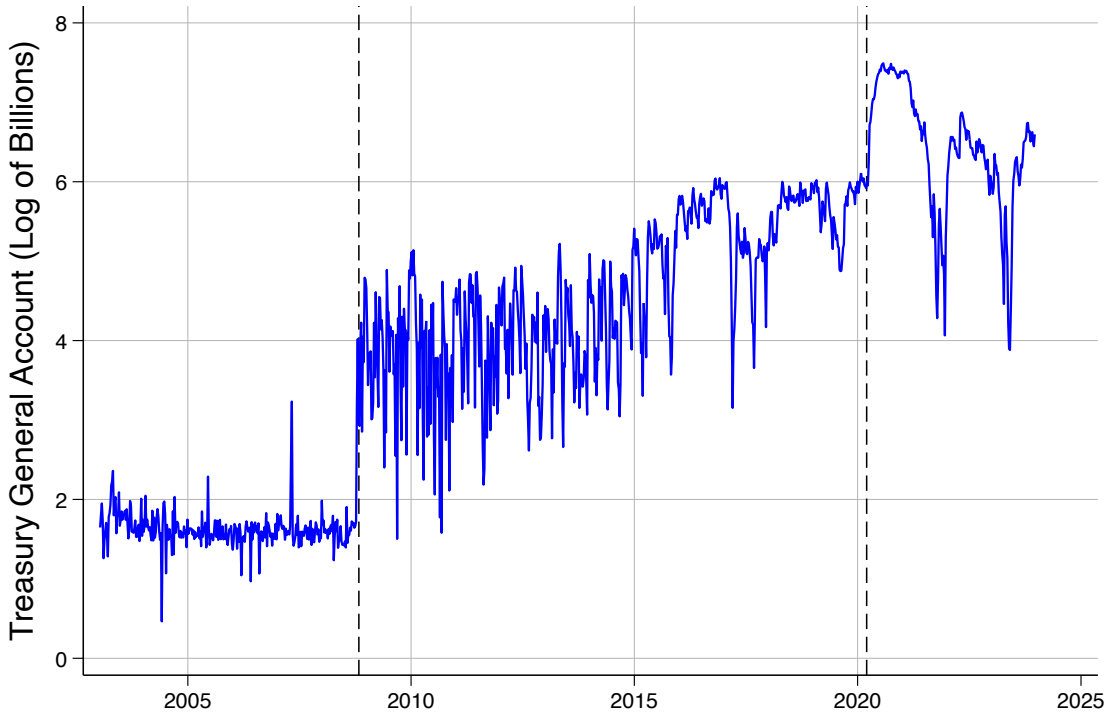


Note: FF Range refers to the daily spread between the maximum and minimum federal funds rates observed in the interbank market, computed using the daily distribution of rates provided by the New York Fed and "Disp. Deposit Growth" to the difference of the percentile 1 to percentile 99 of the bank level distribution of weekly deposit growth. The figure displays the dispersion of deposit growth (percentages) on the left axis and the federal funds range (basis points) on the right axis. Series are weekly observations, taking the Wednesday value each week. Vertical dashed lines denote the start of the Global Financial Crisis (October 2008) and the COVID-19 pandemic (March 2020). Source: Federal Reserve Bank of New York and Federal Reserve "Report of Deposits and Vault Cash" (FR 2900)

substantially in both size and volatility, reaching unprecedented levels during the COVID-19 pandemic as fiscal interventions drove massive cash flows. These large, fiscally driven swings in the TGA produced corresponding fluctuations in reserve availability that were orthogonal to the Federal Reserve's policy intentions—the variation needed to identify how exogenous supply shocks transmit to money market conditions.

From Levels to Innovations: how to use the proxies. Two features of our proxies merit discussion. First, both the levels and volatility of the series differ substantially across regimes. For the demand proxies, the federal funds range naturally exhibits lower dispersion in ample-reserves regimes, where abundant liquidity reduces funding pressures and compresses spreads. Deposit growth dispersion, while more stable across regimes, also reflects the changing structure of the banking system and payment flows. For the supply proxy,

Figure 9: Supply Liquidity Shock - Treasury General Account



Note: The figure displays the Treasury General Account (liability) expressed in log of billions of U.S. dollars. The series has weekly observations, taking the Wednesday value each week. Vertical dashed lines denote the start of the Global Financial Crisis (October 2008) and the COVID-19 pandemic (March 2020). Source: Source: Board of Governors of the Federal Reserve System, H.4.1 statistical release, "Factors Affecting Reserve Balances of Depository Institutions and Condition Statement of Federal Reserve Banks."

TGA movements might not be strictly exogenous: as Afonso et al. (2023, p. 12) note, Treasury cash management decisions can respond to broader financial conditions, introducing potential correlation with demand factors.

Second, and most critically for our identification strategy, we employ *innovations* to these series rather than their levels. This distinction is essential for two reasons. First, using innovations allows us to isolate unexpected shifts in demand and supply conditions—the shocks that require systematic Federal Reserve responses. A predictable seasonal increase in the TGA or a typical level of rate dispersion does not trigger policy actions; it is the surprise component that matters for identifying how the Fed adjusts reserve supply. Second, because the levels of these series have shifted dramatically across regimes, a regime-specific estimation of the innovation process is necessary.

3 Methodology and Data

3.1 Data

Our empirical analysis uses weekly data from January 2003 to December 2023. We present results for the modern regimes—Scarce/Limited Reserves (2003m1–2008m10), and Ample Reserves (2008m11–2023m12) and we further split the later into Post-GFC (2008m11–2020m2), and Post COVID-19 (2020m3–2023m12). We utilized several data sources. The main source for the Federal Reserve balance sheet data is the Federal Reserve's H.4.1 release, which reports all balance sheet items at a weekly frequency as of each Wednesday. From there, we collect Treasury securities, agency debt, agency MBS, repos, swaps, reserves, reverse repos, and the Treasury General Account (TGA).[9] Policy rates used to construct the Spreads Ratio (equation (2))—the effective federal funds rate (DFF_t), the discount window rate (DWR_t), and the interest on reserve balances ($IORB_t$)—are obtained from the Federal Reserve of St Louis, FRED. In particular, the effective federal funds rate (DFF_t) corresponds to series FEDFUNDS, the discount window rate (DWR_t) corresponds to the series DPCREDIT, and the interest on reserve balances ($IORB$) is set to 0 between January 2003 and October 2008, from October 2008 to July 2021 corresponds to the average of series IOER Rate and IORR Rate, and from August 2021 to December 2023 the series IORB. The liquidity ratio is set as the log of the ratio of aggregate Reserves to Aggregate Deposits (equation (1)). We constructed the variable Reserves using the series Reserve Balances with Federal Reserve Banks: Wednesday Level (WRBWFRBL), and the variable Deposits using the series Deposits, All Commercial Banks (DPSACBW027SBOG).

All non-rate variables are expressed in natural logarithms, whereas interest rates remain in levels. As a robustness check, we construct an alternative liquidity ratio that nets reserves from loans to depository institutions, as reported in the H.4.1 release and available from FRED. These loans represent short-term credit extended by the Federal Reserve—such as discount window borrowing—and excluding them ensures that our measure of reserves captures purely liquid balances rather than temporary increases driven by central bank credit operations.

As we described in the previous section, we work with two measures of demand conditions (i.e., the variables used to derived our demand shocks): the *federal funds range* and the cross-sectional *dispersion of deposit growth*. To construct the weekly series of the *federal funds range*, we use daily data from the New York Fed containing the distribution of federal funds

[9] See https://www.federalreserve.gov/releases/h41/ (link last accessed Oct 28, 2025) for the time series data as well as weekly snapshots of the Federal Reserve balance sheet.

transaction rates.[10] We compute the daily spread between the 99th and 1st percentiles of transaction rates; when these are unavailable, we substitute the difference between the reported intraday high and low. To ensure consistency across periods, we rescale the two measures using their relative average values over the 2011–2016 overlap period. The resulting series is expressed in basis points and then converted to weekly frequency by retaining Wednesday observations. To construct the cross-sectional *dispersion of deposit growth* we use confidential daily data at the bank level from the Federal Reserve's "Report of Deposits and Vault Cash" (FR 2900), where respondents submit daily data once a week reflecting a Tuesday through Monday report week. Our measure of deposits includes demand deposits due to the public, ATS and NOW accounts, as well as savings deposits. We compute weekly deposit growth at the bank level, construct the distribution for each day in the sample, and take the difference between the 99th and 1st percentiles as our measure of dispersion. We retain the Wednesday value to maintain consistency with all other time series.

All variables are used in raw form, without seasonal adjustment or winsorization. This choice reflects the nature of our dataset: financial series at weekly frequency exhibit little systematic seasonality, and extreme values often contain economically meaningful information (e.g., stress episodes). Imposing adjustments or trimming outliers would risk removing precisely the variation most relevant for our analysis. In all regressions, we include quarterly fixed effects and FOMC event dummies, which equal 1 in weeks containing a FOMC meeting (scheduled and unscheduled), to account for macroeconomic variation and institutional shifts.

3.2 Empirical Framework

Our methodology proceeds in three stages, designed to separate identification, institutional behavior, and propagation.

In the first stage, we identify exogenous supply and demand shocks. For that purpose, we model our proxies for supply and demand conditions as autoregressive processes with FOMC-dates as dummies and quarterly fixed effects, estimated separately by regime, to capture regime-specific means and dynamics. The residuals from these regressions represent deviations from the systematic, predictable component of each series, which we take our demand and supply shocks.

In the second step, we estimate the Federal Reserve's balance sheet rules, modeling how the System Open Market Account (SOMA) assets and liability instruments considering how these rules respond to supply and demand shocks identified in the first step. The estimation

[10] See https://www.newyorkfed.org/markets/reference-rates/effr (link last accessed June 22, 2025).

is de facto an estimation of the Federal Reserve supply rule by instrument. Residuals from the rules orthogonalized variables with respect to exogenous liquidity shocks and predictable conditions represent exogenous supply shocks. These orthogonal components capture the Federal Reserves's independent operational choices beyond mechanical balance sheet adjustments.

In the third step, we employ the liquidity ratio in a two-step instrumental-variables (IV) framework to recover the demand for reserves and evaluate how Federal Reserve operations affect policy implementation. In the first stage, we estimate variations in the liquidity ratio as a function of orthogonalized balance-sheet components (assets and liabilities) in step 2 together with the identified supply and demand shocks. This stage delivers fitted values for changes in the liquidity ratio, which are used to reconstruct the path of the liquidity ratio itself and isolate the causal component of liquidity conditions, net of simultaneity and sterilizing operations. In the second stage, we regress spread ratio on these predicted liquidity conditions, thereby capturing the demand for reserves and quantifying how balance-sheet operations transmit to policy implementation. The two-step IV of this third step is designed to isolate the causal effect of liquidity on the effectiveness of monetary policy, disentangling genuine reserve demand from mechanical co-movements between spreads and contemporaneous balance-sheet flows.

Step 1: Identification of Liquidity-Demand and Liquidity-Supply Shocks. As we explained above, we need to extract innovations in the demand and supply conditions proxies.

We estimate auto-regressive models augmented with controls for Federal Open Market Committee (FOMC) meetings (scheduled and unscheduled) and seasonal effects. Formally, each series is projected on its own lag, lagged FOMC dummies, and quarterly fixed effects:

$$X_t^k = \varphi_0^k + \varphi_1^k X_{t-1}^k + \varphi_2^k \text{FOMC}_{t-1} + \gamma_{q(t)}^k + \varepsilon_t^k, \tag{3}$$

where $k \in S = \{\text{Supply}, \text{Demand}\}$ (i.e., $X_t^{\text{Supply}} \equiv TGA_t$ and $X_t^{\text{Demand}} \in \{FF \text{ Range}_t, \text{Disp. Deposit Growth}_t\}$), $\gamma_{q(t)}$ captures quarterly fixed effects, and ε_t^k is the corresponding demand or supply innovation. We employ the estimated shocks ε_t^k as the corresponding demand and supply surprises.

Step 2: Estimation of Federal Reserve Operational Rules. The second stage of our methodology characterizes the systematic behavior of the Federal Reserve in managing key balance-sheet items. While the balance sheet reflects policy implementation, its weekly fluctuations combine mechanical accounting adjustments with discretionary operations. To

isolate the latter, we estimate regression rules separately for major asset and liability categories. In particular, we focus on *Securities* and Repurchase Agreements (*Repos*) on the asset side, and on *Reverse Repos* on the liability side.

For each asset category (*Treasury Securities*, *Mortgage Backed Securities (MBS)*, *Federal Agency Debt (FAD) Securities*[11], *Repurchase Aggreements (Repos)*), we regress changes in the item on contemporaneous movements in liabilities (mostly Reverse Repos) ΔL_t^{RR}, the identified supply and demand shocks ε_t^k, FOMC meetings, seasonal fixed effects, *and the other asset categories in* t. This specification ensures that the estimated residuals are net of common dynamics across assets as well as balance-sheet accounting constraints. Formally, for each asset $j \in A = \{$*Treasury Securities*, *MBS*, *FAD Securities*, *Repos*$\}$ we estimate

$$\Delta A_t^j = \beta_0^j + \sum_{\substack{k \in A \\ k \neq j}} \beta_{1,k}^j \Delta A_t^k + \beta_2^j \Delta L_t^{RR} + \beta_3^j \varepsilon_t^{Supply} + \beta_4^j \varepsilon_t^{Demand} + \beta_5^j \text{FOMC}_{t-1} + \gamma_{q(t)}^j + u_t^{A,j}, \quad (4)$$

where ΔA_t^k denotes the contemporaneous changes in the other asset category.

For the liability side, we model changes in Reverse Repos as a function of contemporaneous changes in all major asset categories, the identified supply and demand shocks, FOMC meetings, and seasonal fixed effects:

$$\Delta L_t^{RR} = \psi_0 + \sum_{j \in A} \psi_{1j} \, \Delta A_t^j + \psi_2 \varepsilon_t^{Supply} + \psi_3 \varepsilon_t^{Demand} + \psi_4 \text{FOMC}_{t-1} + \gamma_{q(t)}^{RR} + u_t^{L,RR}. \quad (5)$$

We interpret the series residuals $u_t^{A,j}$ and $u_t^{L,RR}$, which correspond to the orthogonalized components of changes in assets and liabilities, as balance-sheet innovations for each asset and liability class. These orthogonalized series provide the fundamental building blocks for constructing the liquidity ratio. By design, they capture the variation in the Federal Reserve operations that is not mechanically explained by accounting identities, exogenous liquidity shocks, or simultaneous offsetting actions across instruments.

Step 3: First-Stage IV: Instrumented Liquidity Ratio. The third step of our methodology aggregates the orthogonalized innovations from the balance-sheet rules into a single measure of effective liquidity provision. The need for such a measure arises because the Federal Reserve conducts a wide array of operations simultaneously on both sides of its balance sheet. Some of these operations are mechanical adjustments dictated by accounting identities, while others are sterilized against each other (for example, reserve-providing actions

[11] Federal agency debt securities are bonds issued by government-sponsored enterprises (GSEs) and other federal agencies, not the U.S. Treasury itself.

offset by concurrent reserve-absorbing transactions). Looking at individual items in isolation therefore provides a distorted view of the net liquidity conditions faced by the banking system.

To address this, we construct a *liquidity ratio* that condenses the effective stance of balance-sheet policy into a single interpretable indicator. Conceptually, the liquidity ratio captures the marginal net effect of the Fed's operations on reserve availability after purging exogenous Treasury flows, shocks to liquidity demand, and predictable responses to policy events. In practice, we estimate a first-stage regression of the form

$$\begin{aligned}\Delta\text{LiqRatio}_t =& \alpha_0 + \sum_{j\in A} \alpha_{1,j}\, u_t^{A,j} + \alpha_2\, u_t^{L,RR} + \alpha_3\, \varepsilon_t^{Supply} + \alpha_4\, \varepsilon_t^{Demand} \\ &+ \alpha_5\, \text{FOMC}_{t-1} + \gamma_{q(t)} + \epsilon_t,\end{aligned} \tag{6}$$

where $u_t^{A,j}$ and $u_t^{L,RR}$ denote, respectively, the orthogonalized innovations from asset- and liability-side operations (see equations (4) and (5)), and ε_t^{Supply} and ε_t^{Demand} are the exogenous liquidity shocks (see equation (3)).

From the fitted values of (6), we then update the level of the liquidity ratio recursively (i.e., we construct the one-period ahead forecast of the liquidity ratio):

$$\widehat{\text{LiqRatio}}_t = \text{LiqRatio}_{t-1} + \widehat{\Delta\text{LiqRatio}}_t. \tag{7}$$

By construction, $\widehat{\text{LiqRatio}}_t$ provides a synthetic measure of the net liquidity effectively injected into, or withdrawn from, the banking system. It consolidates heterogeneous balance-sheet operations into a parsimonious statistic that is orthogonal to exogenous shocks and mechanical simultaneity. This indicator is the key input into our second-stage analysis, where we examine how liquidity conditions shape the alignment of money market rates with the Federal Reserve's policy targets.

Step 3: Second-Stage IV: Uncovering Reserve Demand. In the final step, we examine how liquidity conditions influence the implementation of monetary policy in money markets. Our outcome variable is the *spreads ratio*, defined as (2). To quantify the effect of liquidity, we estimate the second-stage regression

$$\text{SpreadsRatio}_t = \delta_0 + \delta_1 \widehat{\text{LiqRatio}}_t + \delta_2 \widehat{X}_t^{\text{Demand}} + \gamma_{q(t)} + e_t, \tag{8}$$

where $\widehat{\text{LiqRatio}}_t$ is the fitted liquidity ratio from the first stage (equation (7)) and $\widehat{X}_t^{\text{Demand}}$ is the fitted series used to construct the demand shocks mentioned in Step 1 (equation (3)).

The parameter of interest is δ_1, which measures the marginal impact of liquidity conditions on the alignment of market rates with the Federal Reserve's target range. Because $\widehat{\text{LiqRatio}}_t$ is constructed from orthogonalized balance-sheet innovations and exogenous shocks, this specification isolates a causal propagation channel rather than reflecting an endogenous co-movement between liquidity and money market spreads. In other words, δ_1 traces the effective transmission of the Fed's balance-sheet operations into the pricing of overnight credit. We include the fitted value of the demand proxy, $\widehat{X}_t^{\text{Demand}}$, to control for predictable demand pressures that vary with the degree of liquidity abundance. This term captures systematic shifts in the cross-sectional dispersion of funding conditions across regimes.

4 Results

In this section, we present the reserve demand estimates for the modern regimes—Scarce (or Limited) Reserves (2003m1–2008m10) and Ample Reserves (2008m11–2023m12) which we further split into Post-GFC (2008m11–2020m2), and Post COVID-19 (2020m3–2023m12)—using both the federal funds range and deposit growth dispersion as demand proxies. In the main text, we describe the results for the final step of our three step reserve-demand estimation procedure (i.e., Step 3 of our methodology "First-stage IV: Instrumenting Liquidity Ratio" and "Second-stage IV: Uncovering Reserve Demand").[12] We begin with the results that use the federal funds range as a proxy for demand conditions to then present the estimates using the dispersion of deposit growth as proxy for funding conditions.

4.1 Results: Fed-Funds Range Demand Proxy

First Stage IV. Table 3 reports regime-specific first-stage estimates that map orthogonalized balance-sheet components and liquidity shocks into weekly changes in the liquidity ratio. Five key patterns emerge from the estimation.

First, the effectiveness of Treasury operations varies dramatically across regimes. Consistent with Figure 6, Treasury securities were the primary instrument in the Limited Reserves regime but continued to play an important role thereafter. A 1 percentage-point unexpected increase in Treasury purchases raises the liquidity ratio by approximately 10.2 percentage points in the Limited Reserves sample—an economically large effect reflecting the scarcity of reserves and that this was a predominantly used instrument. Once reserves become ample,

[12] Results for Step 1 "Identification of Liquidity-Demand and Liquidity and Liquidity-Supply Shocks" are reported in Appendix A. Results for Step 2 "Estimation of Federal Reserve Operational Rules" are reported in Appendix B.

however, the same operation produces much smaller impacts: roughly 1 percentage point in the Post-GFC regime, with a somewhat larger effect (1.3 percentage points) during COVID-19. This pattern is reassuring: because the liquidity ratio is defined in percentage terms, the marginal impact of a given dollar injection should decline as the base level of reserves rises. Repos also served as powerful liquidity providers under scarcity: an unexpected 1 percentage-point increase in repos raises the liquidity ratio by about 2.1 percentage points in the Limited Reserves regime.

Second, mortgage-backed securities emerge as an important instrument after 2008. MBS purchases have a statistically significant positive effect on liquidity in both ample-reserves regimes, with coefficients of approximately 0.11 percentage points in Post-GFC and 0.27 percentage points during COVID-19—magnitudes broadly comparable to Treasury operations in those periods. By contrast, Federal Agency Debt (FAD) securities do not produce statistically significant effects on liquidity growth, although point estimates are positive and directionally consistent with other asset-side interventions.

Third, reverse repos function as effective liquidity drains in ample-reserves regimes. The operations designed to absorb liquidity show the expected negative pattern. Reverse repos carry sizeable and statistically significant negative coefficients after 2008: an unexpected 1 percentage-point increase in this liability reduces liquidity-ratio growth by 0.11 percentage points (Post-GFC) and 0.27 percentage points (COVID-19), consistent with their role as active reserve drains. Notably, in the Limited Reserves regime, reverse repos show no significant impact on liquidity, likely because any absorptive effect was offset by other contemporaneous operations in a system where the Fed actively managed scarce reserves.

Fourth, Treasury General Account movements drain liquidity in ample-reserves regimes but not under scarcity. TGA buildups (negative liquidity-supply shocks) reduce liquidity in the expected direction only in the abundant reserve regimes—after 2008. In the Post-GFC and COVID-19 regimes, an unexpected 1 percentage-point increase in the TGA produces a statistically significant decline in liquidity-ratio growth of approximately 0.03–0.04 percentage points. Figure 6 corroborates this pattern: the TGA remained essentially flat before 2008 but exhibited substantial buildups and withdrawals during later periods. The insignificance in the Limited Reserves era likely reflects minimal TGA variation when conventional open market operations dominated. In contrast, under ample reserves, even proportionally small TGA changes imply large absolute reserve withdrawals, generating detectable impacts on money-market liquidity through both direct balance-sheet effects and market adjustment mechanisms.

Fifth, the federal funds range exhibits regime-dependent coefficients reflecting changes in market structure. In the Limited Reserves sample, the coefficient is positive—consistent with

tighter funding conditions inducing precautionary reserve hoarding by banks. After 2008, however, the coefficient becomes negative. This sign reversal reflects a fundamental change in what dispersion measures. This is consistent with tighter interbank funding conditions inducing banks to hoard reserves, thereby increasing the reserves-to-deposits ratio. That is, this reversal is plausibly driven by a change in what drove dispersion: under scarcity, dispersion largely reflects demand shocks and precautionary hoarding. Conversely, in the post-GFC, dispersion more often signals greater arbitrage opportunities between banks with access to IOER and non-bank institutions that were not paid interest.

Table 3: First-Stage IV Regressions Using the Federal Funds Demand Proxy (Eq. (6))

	Limited Regime	Ample Regime	Post-GFC Regime	Post COVID-19 Regime
	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio
Treasury Securities ($u^{A,T}$)	10.1805**	0.9214***	0.5067**	1.2883***
	(5.06)	(0.25)	(0.25)	(0.28)
MBS ($u^{A,MBS}$)		0.1111***	0.1070***	0.2742**
		(0.03)	(0.03)	(0.13)
FAD Securities ($u^{A,FADS}$)		0.0267	0.0228	
		(0.03)	(0.03)	
Reverse Repos ($u^{L,RR}$)	0.1041	-0.1273***	-0.1371***	-0.0551
	(0.59)	(0.01)	(0.01)	(0.04)
Repos ($u^{A,Repos}$)	2.1240***			
	(0.09)			
Surprise TGA ($\varepsilon^{\text{Supply}}$)	-0.0493	-0.0284***	-0.0279***	-0.0379***
	(0.20)	(0.00)	(0.00)	(0.01)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	0.0035***	-0.0005***	-0.0016***	-0.0001
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	0.1415**	-0.0037	-0.0041	-0.0044
	(0.07)	(0.00)	(0.00)	(0.00)
Constant	0.0140	0.0075***	0.0066**	0.0097**
	(0.07)	(0.00)	(0.00)	(0.00)
N	302	779	582	196
Adj. R-squared	0.63	0.46	0.49	0.39
F-statistic	76.10	33.92	35.26	6.13

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $u^{A,j}$ correspond to the errors from equation (4), $u^{L,RR}$ the errors from equation (5), $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ are the supply and demand surprises from equation (3), when demand shocks are estimated with Fed-Funds Range.

Second Stage IV. Table 4 reports the second-stage IV estimates, which reveal the causal effect of liquidity conditions on money market spreads. The fitted liquidity ratio—constructed

from the orthogonalized first-stage estimates—exhibits a robust negative relationship with the spreads ratio across all three regimes, confirming that reserve abundance drives the federal funds rate closer to the interest rate floor. Moreover, the pattern of coefficients across regimes captures the sigmoid shape predicted by reserve demand theory.

The fitted liquidity coefficient is statistically significant and negative in all three regimes: -7.2 (Limited Reserves), -27.2 (Post-GFC), and -7.5 (COVID-19). When we pool the two ample-reserves regimes, the coefficient is -9.1. These magnitudes are economically sensible and vary systematically with reserve abundance. The Post-GFC estimate of -27.2 is particularly noteworthy as it aligns closely with existing structural estimates. An increase of 1% in the reserves-to-deposits ratio reduces the spreads ratio by approximately 0.27 percentage points, a magnitude consistent with Lagos and Navarro (2023)[13] and Afonso et al. (2023).[14] The steeper slope in the Post-GFC regime reflects the transition to a floor system where the relationship between reserve quantity and the federal funds rate became more mechanical and predictable, as banks' precautionary demand for reserves was largely satiated.

The demand proxy coefficients provide additional validation of our identification strategy.

[13]Our regressor is $LiqRatio = \ln(reserves/deposits \times 100)$ and the dependent variable is the normalized $SpreadsRatio = (\text{DFF} - \text{IORB})/(\text{DWR} - \text{IORB}) \times 100$. Using the Post-GFC second-stage estimate, $\delta_1^{Post-GFC} = -27.1972$, a \$1 bn increase in reserves (holding deposits fixed) implies $\Delta SpreadsRatio/\$1\text{bn} \approx \delta_1^{Post-GFC} \times \frac{1}{R_0} = -27.1972/1,568.26 \approx -0.01734$ percentage points per \$1 bn, i.e., -1.734 basis points per \$1 bn on the spreads-ratio scale (using $R_0 = \$1,568.26$ bn as reference, the 2019 reserves value in Lagos and Navarro 2023). To map this into the unnormalized spread DFF $-$ IORB (the unit used by Lagos and Navarro 2023), note that $\Delta(\text{DFF} - \text{IORB}) \approx (\text{DWR} - \text{IORB})/100 \cdot \Delta\text{SpreadsRatio}$. Taking a benchmark corridor width DWR $-$ IORB ≈ 0.65 percentage points (65 bps), as calibrated in Lagos and Navarro 2023, yields $\Delta(\text{DFF} - \text{IORB})/\$1\text{bn} \approx \frac{0.65}{100} \times (-0.01734) \approx -0.0001127\text{pp} = -0.0113\text{bps}$ per \$1bn. This is directly comparable to Lagos and Navarro 2023's post-GFC estimate ($\gamma \approx -0.0119$; their dependent variable is EFFR$-$IOR in basis points per \$1 bn).

[14]To compare the magnitude of our results with Afonso et al. (2023), note that their Table 6 reports the 2019 bi-variate estimate of the federal funds rate elasticity to deposit-normalized reserves as -0.66, measured in basis points of (EFFR $-$ IORB) per one–percentage–point increase in R/D. In our framework, the second-stage coefficient in the Post-GFC regime is $\delta_1^{Post-GFC} = -27.1972$, where the regressor is $LiqRatio_t = \ln((reserves/deposits) \times 100)$ and the dependent variable is the normalized spread ratio $(\text{DFF} - \text{IORB})/(\text{DWR} - \text{IORB}) \times 100$. Using 2019 averages of $R_0 = 1,568.26$ bn (as Lagos and Navarro 2023) and $D_0 = 12,799.67$ bn (our average annual deposit data for 2019), we obtain $\bar{R}/\bar{D} = 12.26\%$, implying that a one–percentage–point increase in R/D corresponds to $\Delta LiqRatio \approx 1/12.26$. Hence, $\Delta\text{SpreadsRatio} \approx -27.1972/12.26 = -2.22$ percentage points. Multiplying by the benchmark corridor width (DWR $-$ IORB) $= 0.65$ pp yields $\Delta(\text{EFFR} - \text{IORB}) \approx 0.65/100 \times (-2.22) = -1.44$ bps per one–percentage–point increase in R/D. Thus, when expressed in Afonso's units, our Post-GFC elasticity is approximately -1.44 bps/pp—about twice as large in magnitude as their 2019 estimate (-0.66 bps/pp)—but of similar order, reinforcing the consistency of our identification approach. If we instead consider the period 2010–2019 to ensure greater comparability with Afonso et al. (2023), using $R_0 = 10,320.31$ bn, $D_0 = 1,947.834$ bn, and (DWR $-$ IORB) $= 0.51$ pp (the averages for the period based on our data), the same calculation yields an implied elasticity of approximately -0.03 bps per one–percentage–point increase in R/D. Over the same period, Afonso et al. (2023) report an average elasticity of -0.33 bps/pp, suggesting that although our estimate is smaller in magnitude, it remains consistent in sign and order with their findings.

In the Limited Reserves regime, a 1% increase in the federal funds range raises the spreads ratio by approximately 20 basis points, statistically significant and positive. This reflects that under reserve scarcity, wider dispersion in funding rates signals greater heterogeneity in banks' liquidity positions and stronger precautionary demand—both of which push the federal funds rate upward within the corridor. By contrast, in the ample-reserves regimes, the coefficient becomes small and statistically insignificant, with the opposite sign. This reversal confirms our interpretation that the federal funds range measures different economic phenomena across regimes: precautionary demand under scarcity versus arbitrage opportunities between banks and non-banks under abundance.

To ensure that our results are not driven by the specific composition of the Federal Reserve's balance sheet or by the particular liquidity measure employed, we conduct two robustness exercises.[15] First, we extend the set of Federal assets to include swap operations for the Post-GFC and Post COVID-19 regimes and re-estimate our baseline regressions. This exercise evaluates whether accounting for swap interventions—an important policy tool that can affect the supply of liquidity during these periods—alters our results. Second, we replace total reserves with non-borrowed reserves to verify that our findings are not influenced by discount-window borrowing. Both exercises yield coefficients that remain stable and significant in the Limited-Reserves and Post-GFC regimes, whereas in the Post COVID-19 regime, the effects tend to lose statistical significance, reflecting the weaker transmission of liquidity shocks in the super-abundant-reserves environment.

Table 4: Second-Stage IV Regressions Using the Federal Funds Demand Proxy (Eq. (8))

	Limited Regime	Ample Regime	Post-GFC Regime	Post COVID-19 Regime
	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio
Liq. Ratio Est. ($\widehat{\text{LiqRatio}}_t$)	-7.2316***	-9.1171***	-27.1972***	-7.4830*
	(2.73)	(2.40)	(0.76)	(3.85)
FF Range Est. ($\widehat{X_t^{\text{Demand}}}$)	0.2009***	-0.2307	-0.0175	-0.2155**
	(0.06)	(0.31)	(0.09)	(0.10)
Constant	54.5286***	83.4687***	120.5619***	117.0885***
	(3.57)	(9.85)	(2.99)	(12.92)
N	302	779	582	196
Adj. R-squared	0.22	0.01	0.73	0.13

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

[15] Results using swap operations are reported in Appendix C, while those using non-borrowed reserves appear in Appendix D.

4.2 Results: Deposit Growth Dispersion Proxy

We now turn to the results corresponding to the deposit growth dispersion proxy.

First Stage. Table 5 illustrates the first-stage, where the demand shock proxy is unexpected fluctuations in the dispersion of deposit growth. the results align very well with those presented in Table 3. The key difference is the the dispersion in deposit growth in this case appears with negative and statistically significant signs, except for the Post COVID-19 regime. The pattern could reflect that when the cross-sectional dispersion of deposit growth (DDG) spikes, it deposits outflows outside of the banking system. For example, deposits may migrate to money funds or GSEs, which in turn, settle these movements draining liquidity from banks. Under Limited reserves, such dispersion tends to drain system wide usable by a greater share of the liquidity ratio. This effect contrasts with FF Range in the same regime, where wider price dispersion induces precautionary hoarding and shows up as a higher liquidity ratio (positive first-stage sign). By Post-GFC, both proxies move in the same (negative) direction: with abundant reserves and easy access to IORB/ON-RRP, dispersion-whether in prices or deposits—coincides with reserves parking at the Fed or flowing to money funds, leaving fewer reserves circulating across banks and thus a lower measured liquidity ratio.

Second Stage. Table 6, presents the second-stage IV estimates when we use the dispersion in deposit growth as a proxy for demand conditions. These results align with Table 4, but we note that, in the ample reserve regime, while the estimated impact of the liquidity ratio is negative, the effect is no longer statistically significant. When looking within the subperiods of the ample reserve regime, the coefficient in the Post-GFC regime aligns well with the estimated using the Fed Funds range but it becomes insignificant in the Post COVID-19 regime. However, the magnitude of the coefficients and the overall patter of coefficients is similar.

Regarding the demand proxy, this appears with the expected sign in the limited reserves regime and post-GFC regime, but is closer to zero in the post COVID-19 regime. The result contrasts with flip in sign that occurs with the dispersion in the Federal Funds. As we explained, this difference could reflect that the dispersion in rates captures arbitrage opportunities in the aftermath of the GFC regime, when interest was paid on reserves but limited to banks.

Table 5: First-Stage IV Regressions Using the Deposit Growth Dispersion Proxy (Eq. (6))

	Limited Regime	Ample Regime	Post-GFC Regime	Post COVID-19 Regime
	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio
Treasury Securities ($u^{A,T}$)	3.5205	0.9378***	0.5770**	1.2826***
	(4.48)	(0.25)	(0.25)	(0.28)
MBS ($u^{A,MBS}$)		0.1116***	0.1084***	0.2873**
		(0.03)	(0.03)	(0.13)
FAD Securities ($u^{A,FADS}$)		0.0245	0.0185	
		(0.03)	(0.03)	
Reverse Repos ($u^{L,RR}$)	0.2227	-0.1290***	-0.1429***	-0.0522
	(0.59)	(0.01)	(0.01)	(0.04)
Repos ($u^{A,Repos}$)	2.1769***			
	(0.09)			
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0041	-0.0285***	-0.0286***	-0.0394***
	(0.20)	(0.00)	(0.00)	(0.01)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	-0.0257*	-0.0000	-0.0007**	0.0010
	(0.01)	(0.00)	(0.00)	(0.00)
L.FOMC	0.1415**	-0.0038	-0.0044	-0.0044
	(0.07)	(0.00)	(0.00)	(0.00)
Constant	0.0140	0.0074***	0.0065**	0.0097**
	(0.07)	(0.00)	(0.00)	(0.00)
N	302	779	582	196
Adj. R-squared	0.62	0.46	0.48	0.39
F-statistic	75.32	33.75	34.63	6.24

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $u^{A,j}$ correspond to the errors from equation (4), $u^{L,RR}$ the errors from equation (5), $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ are the supply and demand surprises from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

Table 6: Second-Stage IV Regressions Using the Deposit Growth Dispersion Proxy (Eq. (8))

	Limited Regime	Ample Regime	Post-GFC Regime	Post COVID-19 Regime
	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio
Liq. Ratio Est. ($\widehat{\text{LiqRatio}}_t$)	-8.5016***	-3.1194	-26.6708***	0.9230
	(2.50)	(2.49)	(0.82)	(2.36)
Disp. Deposit Growth Est. ($\widehat{X_t^{\text{Demand}}}$)	3.8611***	4.3430***	0.2816*	-0.5370
	(1.48)	(0.75)	(0.16)	(0.49)
Constant	-10.1831	-6.9248	114.4370***	98.0706***
	(25.03)	(15.92)	(4.18)	(9.89)
N	302	779	582	196
Adj. R-squared	0.20	0.05	0.73	-0.01

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

5 Sigmoid Function Fit

Without a proper estimate of a response function for the Federal Reserve, a structural estimation will suffer from the same endogeneity concerns as does a reduced-form estimation. In this section, we exploit our reduced-form estimates to construct pseudo-data that partials out the endogenous response of supply shocks. We use this pseudo-data set to estimate a sigmoid function for the demand for reserves, a demand that is fully microfounded.

To construct our pseudo-data, we apply the same empirical procedure used for the in-sample regressions to 3-month rolling windows over the 2003-2020 sample (limited reserves and post-GFC regimes), after winsorizing the series to reduce the influence of extreme weekly events.

Structural Parameter Estimation. To connect our reduced-form estimates to structural interpretations, we fit the data to the sigmoid-shaped reserve demand curve that arises from the microfounded interbank market in Bianchi and Bigio (2025). We favor this structural approach because it delivers a theoretically-grounded sigmoid functional form that emerges naturally from banks' optimal liquidity management decisions in an over-the-counter (OTC) settlement market with search frictions, with additional restrictions stemming from observable market outcomes (e.g., discount window lending).

In the framework, the normalized federal funds spread is determined by:

$$\text{SpreadsRatio}_t = 100 \times \frac{\bar{\theta}_t/\theta_t - \left(\bar{\theta}_t/\theta_t\right)^{\eta}}{\bar{\theta}_t/\theta_t - 1} \tag{9}$$

where η is a parameter capturing the borrowers' bargaining power in the Federal Funds market and θ_t is the initial market tightness (the ratio of aggregate borrowing needs to reserve surpluses). This tightness depends on the liquidity ratio $\mu_t \equiv \ln(R_t/D_t)$ and two structural parameters: σ, which captures cross-sectional dispersion in deposit growth, and ρ, a voluntary liquidity buffer:

$$\theta_t = \frac{\sigma + \rho - \mu_t}{\sigma + \rho + \mu_t} \tag{10}$$

In turn, $\bar{\theta}_t$ represents the terminal tightness at the end of the trading session in the interbank market. Using a Leontief matching function, terminal tightness evolves according to:

$$\bar{\theta}_t = \begin{cases} 1 + (\theta_t - 1)e^{\lambda}, & \theta_t > 1, \\ \dfrac{\theta_t}{\theta_t + (1-\theta_t)e^{\lambda}}, & \theta_t < 1 \end{cases} \tag{11}$$

where λ is the matching efficiency parameter governing how quickly settlement imbalances are resolved in the OTC market. The reader does not need to know the full details of the model; replacing (11) and (10) back in (9), we recover a sigmoid function that maps the liquidity ratio μ_t to the spread ratio.

We estimate the structural parameters $\{\sigma, \rho, \lambda, \eta\}$ by minimizing the absolute deviation between the theoretical sigmoid relationship in equation (9) and our reduced-form fitted values of normalized spreads and liquidity ratios. To account for the profound changes in money market structure following the 2008 financial crisis, we allow for a structural break in all parameters at September 2008, coinciding with Lehman Brothers' collapse and the Federal Reserve's subsequent balance sheet expansion. We let the data speak for itself regarding this break.

The estimation procedure focuses exclusively on matching the federal funds rate relationship.[16] The approach identifies the parameter values that best capture the reserve demand curve for each monetary policy regime, separately isolating the supply responses.

Table 7 reports the estimated parameters for the pre-2008 (limited reserves) and post-2008 (ample/abundant reserves) periods. The results reveal stark changes in market structure. First, the voluntary liquidity buffer ρ increased from 0.015 to 0.100, reflecting banks' dramatically elevated precautionary demand for reserves in the post-crisis regulatory environment of higher capital and liquidity requirements. Second, matching efficiency is stable although it declined , from 3.37 to 2.16. This is consistent with reduced interbank trading activity that could be interpreted as being associated with greater perceived counterparty risk. Third, borrowers' bargaining power η increased from 0.32 to 0.40, indicating that deficit banks gained modest negotiating leverage in a market with plentiful reserves, potentially reflecting their ability to access cheaper funding from institutions that did not earn interest on reserves. Finally, the dispersion parameter σ is also stable, increasing from 0.17 to 0.20—the increase indicates a rise in heterogeneity in liquidity needs across banks during the post-crisis period. These parameter shifts collectively paint a picture where most parameters, except the one associated with regulation, remained close to each other.

Figure 10 presents the fit of the structural model to the data. Panel (a) plots the time series of the normalized federal funds rate alongside the model's predicted values. The blue series shows the fitted values from our reduced-form instrumental variables estimation (the "data"), while the red curve presents the structural model's fit. The model successfully tracks the evolution of money market rates across the post-2008 period. However, it ex-

[16]The estimation focuses squarely on matching the federal funds rate relationship without incorporating moments of discount window volume. Alternative procedures can bring extra moment conditions into bearing.

Table 7: Structural Parameter Estimates

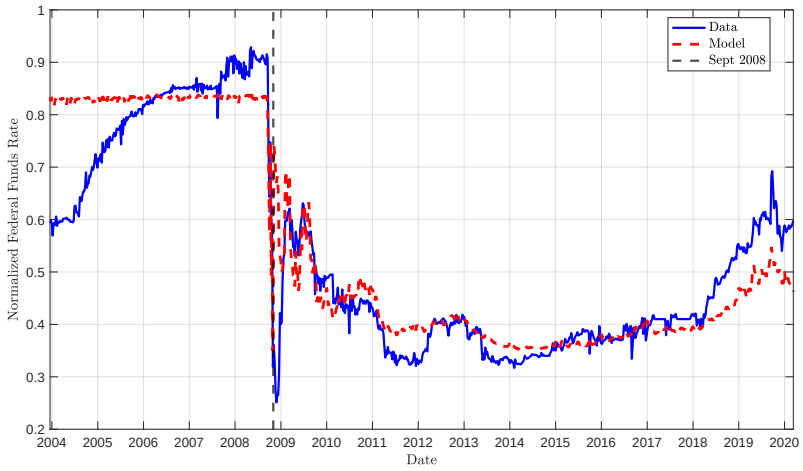
Parameter	Pre-2008	Post-2008	Interpretation
σ (dispersion)	0.170	0.198	Cross-sectional dispersion in deposit flows
λ (matching)	3.369	2.159	Interbank market matching efficiency
η (bargaining)	0.319	0.400	Borrowers' bargaining power
ρ (buffer)	0.015	0.100	Voluntary liquidity buffer
Observations	348	574	

Notes: Structural parameters estimated by minimizing absolute deviations between equation (9) and reduced-form fitted values of normalized spreads and liquidity ratios. We plot the sample in October 2008. Pre-2008 corresponds to the limited-reserves regime (2003.1–2008.10); Post-2008 spans the ample and abundant-reserves eras (2008.10–2020.12). Standard errors omitted as parameters are estimated on generated regressors from the first-stage reduced form.

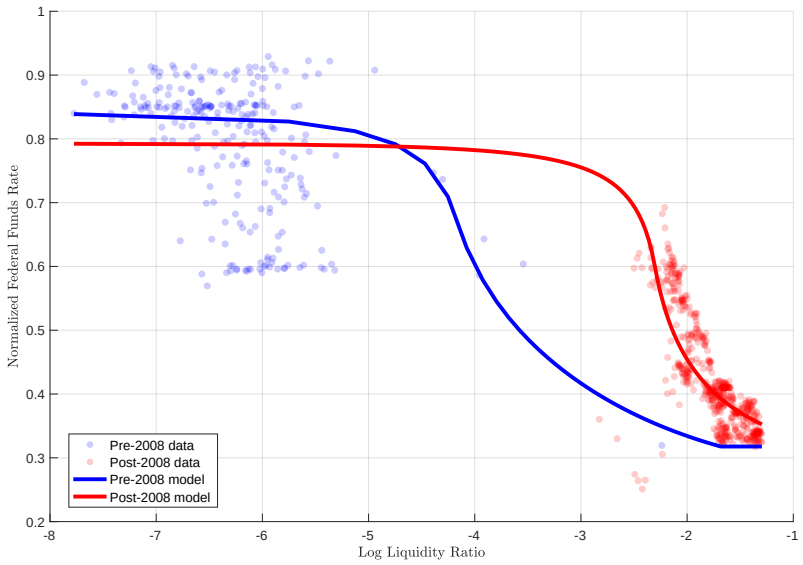
hibits a high volatility in the spread ratio during the limited-reserves period (2003–2008). Panel (b) presents the same relationship in the reserve scarcity space, plotting the normalized spread against the log liquidity ratio. The scatter points represent the reduced-form fitted values, color-coded by regime: pre-2008 observations (blue) correspond to the limited-reserves period, while post-2008 observations (red) span the ample and abundant-reserves eras. The solid curves show the estimated sigmoid functions from the structural model for each regime. The pronounced shift between the pre- and post-2008 curves illustrates the structural break in reserve demand, which is particularly driven by the parameter governing the liquidity buffer. The post-crisis sigmoid-positioned spread ratio, for higher liquidity levels, reflects changes in liquidity regulation. For low liquidity levels, both curves converge, and any differences are attributed to the slight variations in the bargaining power estimates.

The structural-estimation exercise is meant to be suggestive of the potential uses of our reduced form estimates.

Figure 10: Structural Estimates of Reserve Demand



(a) Federal funds rate: data vs model



(b) Structural break in reserve demand

Note: The figure shows the estimated reserve demand with a structural break around September 2008. Panel (a) shows the time series fit of the model to observed federal funds rates. Panel (b) shows the estimated relationship between liquidity ratios and rates, revealing a significant shift in reserve demand behavior following the financial crisis. See Section 3.1 for a description of data variables. Source: Federal Reserve Bank of St Louis and author's calculations

6 Conclusions

This paper develops a framework to understand how Federal Reserve balance-sheet operations transmit to money market conditions across different monetary policy implementation regimes. Our regime-specific instrumental variables approach yields three central findings. First, the reaction rules of balance-sheet instruments varies dramatically across regimes. Second, despite these institutional shifts, our estimates reveal a stable reserve demand relationships within each regime, with economically sensible properties—steeper curves in scarce-reserves regimes where marginal liquidity is highly valued, flatter under abundant reserves where banks are satiated. The fitted liquidity ratio constructed from orthogonalized balance-sheet innovations explains a substantial share of variation in the federal funds rate's position within the corridor, successfully is, where marginal liquidity is highly valued, and flatter in abundant-reserves regimes. Finally, we observe shifts in the estimated demand curves.

Our findings speak to a longstanding debate in monetary economics: the apparent instability of money demand relationships led to the abandonment of quantity-based monetary analysis by the 1990s. We contend that the observed instability is associated with the Federal Reserve's response function, that showcases discrete shifts in regulatory frameworks, payment technologies, and operating procedures. However, there is a downward sloping demand for reserves that can be uncovered with appropriate econometric techniques. This perspective suggests that rather than abandoning quantity-theoretic approaches entirely, researchers should embrace that theory and explicitly model regime changes in monetary policy reaction functions. A research agenda that takes institutional factors seriously—modeling them explicitly rather than treating them as nuisances—may yet recover the stable, policy-relevant relationships that motivated the original monetarist program. We have the data and the econometric techniques to do so.

Indeed, our framework raises an intriguing question for future research: did the shift from quantity-based to interest-rate targeting with an elastic money supply itself contributed to the secular decline in real interest rates observed across advanced economies since the 1980s?

References

Afonso, Gara and Ricardo Lagos, "Trade Dynamics in the Market for Federal Funds," *Econometrica*, 2015, *83* (1), 263–313.

_ , Domenico Giannone, Gabriele La Spada, and John C. Williams, "Scarce, Abundant, or Ample? A Time-Varying Model of the Reserve Demand Curve," June 2023. Federal Reserve Bank of New York Staff Reports 1019.

Alvarez, Fernando and Francesco Lippi, "Financial Innovation and the Transactions Demand for Cash," *Econometrica*, March 2009, *77* (2), 363–402.

_ and _ , "Cash Burns: An Inventory Model with a Cash-Credit Choice," *Journal of Monetary Economics*, October 2017, *90*, 99–112.

Ball, Laurence, "Another Look at Long-Run Money Demand," *Journal of Monetary Economics*, 2001, *47* (1), 31–44.

Baumol, William J., "The Transactions Demand for Cash: An Inventory Theoretic Approach," *Quarterly Journal of Economics*, 1952, *66* (4), 545–556.

Benati, Luca, "Long-Run Evidence on the Quantity Theory of Money," *Journal of Monetary Economics*, 2021, *117*, 897–911.

Bernanke, Ben S. and Alan S. Blinder, "The Federal Funds Rate and the Channels of Monetary Transmission," *American Economic Review*, 1992, *82* (4), 901–921.

Bianchi, Javier and Saki Bigio, "Banks, liquidity management, and monetary policy," *Econometrica*, 2022, *90* (1), 391–454.

_ and _ , "Portfolio Choice and Settlement Frictions: a Theory of Endogenous Convenience Yields," 2025. Working Paper.

Bindseil, Ulrich, *Monetary Policy Operations and the Financial System*, first ed., Oxford University Press, 2014.

Bordo, Michael D., "The Bretton Woods International Monetary System: A Historical Overview," in Michael D. Bordo and Barry Eichengreen, eds., *A Retrospective on the Bretton Woods System: Lessons for International Monetary Reform*, Chicago: University of Chicago Press, 1993, pp. 3–108.

Borio, Claudio E. V., "Monetary Policy Operating Procedures in Industrial Countries," BIS Working Paper No. 40, Bank for International Settlements March 1997. 94 pp.

Chernozhukov, Victor, "Foundations of Causal Inference and Econometrics: From Wright to Today," 2022. Lecture notes and discussions, American Economic Association continuing education series.

Friedman, Milton, *Studies in the Quantity Theory of Money*, Chicago: University of Chicago Press, 1956.

Furfine, Craig H., "Discount Window Borrowing: Understanding Recent Experience," Technical Report No. 212, Federal Reserve Bank of Chicago March 2005.

Gagnon, Joseph, Matthew Raskin, Julie Remache, and Brian Sack, "Large-Scale Asset Purchases by the Federal Reserve: Did They Work?," *Federal Reserve Bank of New York Staff Report*, March 2010, *441* (Staff Report). Staff Report; documents LSAPs, balance-sheet expansion and effects on term/liquidity premia.

Goldfeld, Stephen M., "The Case of the Missing Money," *Brookings Papers on Economic Activity*, 1976, *1976* (3), 683–739.

_ **and Daniel E. Sichel**, "The Demand for Money," *Handbook of Monetary Economics*, 1990, *1*, 299–356.

Gordon, David B. and Eric M. Leeper, "The Dynamic Impacts of Monetary Policy: An Exercise in Tentative Identification," *Journal of Political Economy*, 1994, *102* (6), 1228–1247.

Haavelmo, Trygve, "The Statistical Implications of a System of Simultaneous Equations," *Econometrica*, 1943, *11* (1), 1–12.

Hamilton, James D., "The Daily Market for Federal Funds," *Journal of Political Economy*, 1996, *104* (1), 26–56.

_ , "Measuring the Liquidity Effect," *American Economic Review*, 1997, *87* (1), 80–97.

Ihrig, Jane E., Zeynep Senyuz, and Gretchen C. Weinbach, "The Fed's "Ample-Reserves" Approach to Implementing Monetary Policy," *Finance and Economics Discussion Series (Board of Governors of the Federal Reserve System)*, February 2020, *2020* (022). Survey and primer on the ample-reserves operating framework, IOR and implementation issues.

Ireland, Peter N., "On the Welfare Cost of Inflation and the Recent Behavior of Money Demand," *American Economic Review*, 2009, *99* (3), 1040–1052.

Judd, John P. and John L. Scadding, "The Search for a Stable Money Demand Function: A Survey of the Post-1973 Literature," *Journal of Economic Literature*, 1983, *20* (3), 993–1023.

Krishnamurthy, Arvind and Annette Vissing-Jorgensen, "The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy," *Brookings Papers on Economic Activity*, 2011, *42* (2 (Fall)), 215–287. Discusses liquidity, safety and duration channels of QE and implications for liquidity premia.

Labonté, Marc, "The Federal Reserve's Response to COVID-19: Policy Issues," Report R46411, Congressional Research Service February 2021. Summary of Fed actions in March–May 2020, including LSAPs, liquidity facilities, reserve requirement changes, and balance-sheet expansion.

Lagos, Ricardo and Gastón Navarro, "Monetary Policy Operations: Theory, Evidence, and Tools for Quantitative Analysis," *NBER Working Paper Series*, June 2023, (31370).

Laidler, David E. W., "Some Evidence on the Demand for Money," *Journal of Political Economy*, 1966, *74* (1), 55–68.

_ , "The Demand for Money: Theories and Evidence," *International Textbook Company*, 1969. Later editions 1977, 1985, 1993.

Leeper, Eric M. and Tao Zha, "Modest Policy Interventions," *Journal of Monetary Economics*, 2003, *50* (8), 1673–1700.

Lopez-Salido, David and Annette Vissing-Jorgenson, "Reserve Demand, Interest Rate Control, and Quantitative Tightening," 2023. Working Paper.

Lucas, Robert E., "Econometric Policy Evaluation: A Critique," *Carnegie-Rochester Conference Series on Public Policy*, 1976, *1*, 19–46.

_ , "Money Demand in the United States: A Quantitative Review," *Carnegie-Rochester Conference Series on Public Policy*, 1988, *29*, 137–167.

_ **and Juan Pablo Nicolini**, "On the Stability of Money Demand," *Journal of Monetary*

Economics, 2016, *73*, 48–65.

Meltzer, Allan H., *A History of the Federal Reserve, Volume 2, Book 1: 1951-1969*, Chicago: University of Chicago Press, 2009.

Metzler, Lloyd A., "The Demand for Money: A Cross-Section Study of Business Firms," *Quarterly Journal of Economics*, 1963, *77* (3), 405–422.

Poole, William, "Optimal Choice of Monetary Policy Instruments in a Simple Stochastic Macro Model," *The Quarterly Journal of Economics*, 1970, *84* (2), 197–216.

Roberds, William, "The Supply and Demand for Federal Reserve Deposits: A Comment," *Carnegie-Rochester Conference Series on Public Policy*, 1998, *49*, 45–52.

Sargent, Thomas J., "Beyond Supply and Demand Curves in Macroeconomics," *American Economic Review*, 1982, *72* (2), 382–389.

Stevens, Edward, "The New Discount Window," Economic Commentary EC 5/15/2003, Federal Reserve Bank of Cleveland May 2003.

Stock, James H. and Mark W. Watson, "Interpreting the Evidence on Money-Income Causality," *Journal of Econometrics*, 1989, *40* (1), 161–181.

_ **and** _ , "Philip G. Wright Meets the Econometricians: Instrumental Variables Before Its Time," *Journal of Economic Perspectives*, 2001, *15* (4), 101–115.

Taylor, John B., "Discretion versus Policy Rules in Practice," *Carnegie–Rochester Conference Series on Public Policy*, 1993, *39*, 195–214.

Tobin, James, "The Interest-Elasticity of Transactions Demand for Cash," *Review of Economics and Statistics*, 1956, *38* (3), 241–247.

Wong, Russell, "The Borrower of Last Resort: What Explains the Rise of ON RRP Facility Usage?," Economic Brief 21-43, Federal Reserve Bank of Richmond December 2021. Economic Brief summarizing channels behind the rise in ON-RRP usage and its implications for operations in an ample-reserves environment.

Wright, Philip G., *The Tariff on Animal and Vegetable Oils*, New York: Macmillan, 1928. Contains Appendix E, *"The Determination of Supply and Demand Curves"*, widely recognized as the first use of instrumental variables in econometrics.

Appendix

A Step 1 Results - Identification of Liquidity-Supply and Liquidity-Demand Shocks

Table A.1: Identification of Liquidity-Supply Shock (Eq. (3))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	TGA	TGA	TGA	TGA
L.TGA	0.46***	0.91***	0.81***	0.96***
	(0.15)	(0.02)	(0.03)	(0.04)
L.FOMC	-0.04*	-0.01	0.01	0.02
	(0.03)	(0.04)	(0.05)	(0.05)
Constant	0.88***	0.46***	0.87***	0.25
	(0.24)	(0.12)	(0.17)	(0.25)
N	302	789	592	196
Adj. R-squared	0.20	0.82	0.66	0.91

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.2: Identification of Liquidity-Demand Shock using Fed-Funds Range (Eq. (3))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	FF Range	FF Range	FF Range	FF Range
L.FF Range	0.30***	0.55***	0.60***	0.53**
	(0.07)	(0.18)	(0.11)	(0.25)
L.FOMC	14.11	1.31	-0.24	4.90
	(9.58)	(1.26)	(0.45)	(4.77)
Constant	30.73***	7.38**	6.68***	6.84
	(6.82)	(3.01)	(1.75)	(4.28)
N	302	789	592	196
Adj. R-squared	0.08	0.31	0.38	0.29

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A.3: Identification of Liquidity-Demand Shock using Deposit Growth Dispersion (Eq. (3))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Disp. Deposit Growth	Disp. Deposit Growth	Disp. Deposit Growth	Disp. Deposit Growth
L.Disp. Deposit Growth	0.22***	0.31***	0.36***	0.14*
	(0.05)	(0.04)	(0.04)	(0.08)
L.FOMC	0.56	1.13***	1.18***	0.63
	(0.42)	(0.31)	(0.34)	(0.65)
Constant	14.35***	10.82***	9.52***	15.25***
	(0.96)	(0.71)	(0.68)	(1.87)
N	302	789	592	196
Adj. R-squared	0.09	0.16	0.19	0.12

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

B Step 2 Results - Estimation of Federal Reserve Operational Rules

B.1 Fed-Funds Range Demand Proxy

Table B.1: Estimation of Fed's Treasury Securities Operating Rules (Eq. (4))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Treasury Securities	Δ Treasury Securities	Δ Treasury Securities	Δ Treasury Securities
Δ MBS		0.0019	0.0003	0.2293**
		(0.00)	(0.00)	(0.10)
Δ FAD Securities		0.0213**	0.0204**	
		(0.01)	(0.01)	
Δ Reverse Repos	-0.0032	0.0044	-0.0001	0.0379
	(0.01)	(0.01)	(0.00)	(0.05)
Δ Repos	0.0008			
	(0.00)			
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0014	-0.0002	-0.0011*	0.0086*
	(0.00)	(0.00)	(0.00)	(0.00)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	-0.0000**	-0.0001	-0.0001**	-0.0001
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0017	0.0011	0.0002	0.0012
	(0.00)	(0.00)	(0.00)	(0.00)
Constant	-0.0019	0.0031***	0.0028***	0.0023
	(0.00)	(0.00)	(0.00)	(0.00)
N	302	779	582	196
Adj. R-squared	0.05	0.02	0.02	0.14

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the Fed-Funds Range.

Table B.2: Estimation of Fed's MBS Operating Rules (Eq. (4))

	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ MBS	Δ MBS	Δ MBS
Δ Treasury Securities	0.1809	0.0719	0.3214**
	(0.25)	(0.60)	(0.14)
Δ FAD Securities	0.3165	0.3267	
	(0.21)	(0.22)	
Δ Reverse Repos	-0.0025	0.0048	-0.0084
	(0.01)	(0.01)	(0.02)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0088	0.0071	-0.0018
	(0.01)	(0.01)	(0.00)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	-0.0002	-0.0008	-0.0001
	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0097**	-0.0125**	-0.0007
	(0.00)	(0.01)	(0.00)
Constant	0.0225	0.0286	0.0016
	(0.01)	(0.02)	(0.00)
N	779	582	196
Adj. R-squared	0.01	0.01	0.07

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the Fed-Funds Range.

Table B.3: Estimation of Fed's FAD Securities Operating Rules (Eq. (4))

	Ample Regime	Post-GFC Regime
	Δ FAD Securities	Δ FAD Securities
Δ Treasury Securities	0.2940***	0.6819***
	(0.11)	(0.19)
Δ MBS	0.0449**	0.0460**
	(0.02)	(0.02)
Δ Reverse Repos	-0.0160	-0.0193*
	(0.01)	(0.01)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	-0.0033**	-0.0048***
	(0.00)	(0.00)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	0.0002*	0.0007***
	(0.00)	(0.00)
L.FOMC	0.0024	0.0033
	(0.00)	(0.00)
Constant	-0.0025	-0.0041
	(0.00)	(0.00)
N	779	582
Adj. R-squared	0.02	0.03

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the Fed-Funds Range.

Table B.4: Estimation of Fed's Repos Operating Rules (Eq. (4))

	Limited Regime
	Δ Repos
Δ Treasury Securities	1.1538
	(3.16)
Δ Reverse Repos	0.4850
	(0.30)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.1269*
	(0.07)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	0.0011***
	(0.00)
L.FOMC	0.0910*
	(0.05)
Constant	-0.0154
	(0.04)
N	302
Adj. R-squared	0.06

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the Fed-Funds Range.

Table B.5: Estimation of Fed's Reverse Repos Operating Rules (Eq. (5))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Reverse Repos	Δ Reverse Repos	Δ Reverse Repos	Δ Reverse Repos
Δ Treasury Securities	-0.2990	0.6349	-0.0227	1.4098
	(0.81)	(0.92)	(0.44)	(1.44)
Δ MBS		-0.0036	0.0060	-0.2243
		(0.01)	(0.01)	(0.61)
Δ FAD Securities		-0.1662	-0.1705	
		(0.14)	(0.14)	
Δ Repos	0.0311**			
	(0.01)			
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0199	0.0154**	0.0156**	-0.0599**
	(0.03)	(0.01)	(0.01)	(0.02)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	-0.0000	0.0012	0.0053***	-0.0001
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0009	0.0222**	0.0190	0.0293*
	(0.02)	(0.01)	(0.01)	(0.02)
Constant	-0.0071	-0.0094	-0.0148	0.0150
	(0.01)	(0.01)	(0.01)	(0.01)
N	302	779	582	196
Adj. R-squared	0.01	0.01	0.04	0.07

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the Fed-Funds Range.

B.2 Deposit Growth Dispersion Demand Proxy

Table B.6: Estimation of Fed's Treasury Securities Operating Rules (Eq. (4))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Treasury Securities	Δ Treasury Securities	Δ Treasury Securities	Δ Treasury Securities
Δ MBS		0.0021	0.0005	0.2339**
		(0.00)	(0.00)	(0.10)
Δ FAD Securities		0.0197**	0.0192**	
		(0.01)	(0.01)	
Δ Reverse Repos	-0.0022	0.0040	-0.0008	0.0388
	(0.01)	(0.01)	(0.00)	(0.05)
Δ Repos	-0.0006			
	(0.00)			
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0015	-0.0003	-0.0012**	0.0082*
	(0.00)	(0.00)	(0.00)	(0.00)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	-0.0001	0.0001	0.0001	0.0003*
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0016	0.0011	0.0002	0.0012
	(0.00)	(0.00)	(0.00)	(0.00)
Constant	-0.0019	0.0031***	0.0028***	0.0022
	(0.00)	(0.00)	(0.00)	(0.00)
N	302	779	582	196
Adj. R-squared	0.01	0.02	0.02	0.14

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

Table B.7: Estimation of Fed's MBS Operating Rules (Eq. (4))

	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ MBS	Δ MBS	Δ MBS
Δ Treasury Securities	0.2023	0.1144	0.3307**
	(0.24)	(0.58)	(0.14)
Δ FAD Securities	0.3221	0.3287	
	(0.21)	(0.22)	
Δ Reverse Repos	-0.0032	0.0006	-0.0090
	(0.01)	(0.01)	(0.02)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0092	0.0073	-0.0015
	(0.01)	(0.01)	(0.00)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	-0.0008	-0.0010	-0.0002
	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0098**	-0.0126**	-0.0007
	(0.00)	(0.01)	(0.00)
Constant	0.0224	0.0283	0.0015
	(0.01)	(0.02)	(0.00)
N	779	582	196
Adj. R-squared	0.01	0.01	0.06

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

Table B.8: Estimation of Fed's FAD Securities Operating Rules (Eq. (4))

	Ample Regime	Post-GFC Regime
	Δ FAD Securities	Δ FAD Securities
Δ Treasury Securities	0.2697***	0.6333***
	(0.10)	(0.18)
Δ MBS	0.0454**	0.0459**
	(0.02)	(0.02)
Δ Reverse Repos	-0.0155	-0.0161
	(0.01)	(0.01)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	-0.0037**	-0.0052***
	(0.00)	(0.00)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	0.0009***	0.0015***
	(0.00)	(0.00)
L.FOMC	0.0025	0.0034
	(0.00)	(0.00)
Constant	-0.0024	-0.0038
	(0.00)	(0.00)
N	779	582
Adj. R-squared	0.02	0.04

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

Table B.9: Estimation of Fed's Repos Operating Rules (Eq. (4))

	Limited Regime
	Δ Repos
Δ Treasury Securities	-0.8088
	(2.73)
Δ Reverse Repos	0.5175*
	(0.31)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.1460*
	(0.08)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	-0.0088
	(0.01)
L.FOMC	0.0878
	(0.06)
Constant	-0.0188
	(0.04)
N	302
Adj. R-squared	0.02

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

Table B.10: Estimation of Fed's Reverse Repos Operating Rules (Eq. (5))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Reverse Repos	Δ Reverse Repos	Δ Reverse Repos	Δ Reverse Repos
Δ Treasury Securities	-0.1962	0.5812	-0.2579	1.4483
	(0.76)	(0.93)	(0.48)	(1.45)
Δ MBS		-0.0047	0.0007	-0.2364
		(0.01)	(0.01)	(0.61)
Δ FAD Securities		-0.1626	-0.1476	
		(0.14)	(0.14)	
Δ Repos	0.0313**			
	(0.01)			
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0162	0.0155**	0.0177**	-0.0579**
	(0.03)	(0.01)	(0.01)	(0.02)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	0.0038**	0.0005	0.0018	-0.0014
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0008	0.0224**	0.0198	0.0292*
	(0.02)	(0.01)	(0.01)	(0.02)
Constant	-0.0069	-0.0091	-0.0136	0.0149
	(0.01)	(0.01)	(0.01)	(0.01)
N	302	779	582	196
Adj. R-squared	0.02	0.01	0.00	0.08

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

C Robustness: Swaps as an Asset in Federal Reserve Operating Rules

C.1 Fed-Funds Range Demand Proxy

Table C.1: Step 2 - Estimation of Fed's Treasury Securities Operating Rules (Eq. (4))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Treasury Securities	Δ Treasury Securities	Δ Treasury Securities	Δ Treasury Securities
Δ MBS		0.0020	0.0005	0.2348**
		(0.00)	(0.00)	(0.10)
Δ FAD Securities		0.0227**	0.0228**	
		(0.01)	(0.01)	
Δ Reverse Repos	-0.0032	0.0032	0.0004	0.0100
	(0.01)	(0.01)	(0.00)	(0.04)
Δ Repos	0.0008			
	(0.00)			
Δ Swaps		0.0012	-0.0001	0.0089***
		(0.00)	(0.00)	(0.00)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0014	-0.0003	-0.0013*	0.0063
	(0.00)	(0.00)	(0.00)	(0.00)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	-0.0000**	-0.0001	-0.0001**	-0.0001
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0017	0.0009	0.0002	-0.0002
	(0.00)	(0.00)	(0.00)	(0.00)
Constant	-0.0019	0.0032***	0.0027***	0.0023
	(0.00)	(0.00)	(0.00)	(0.00)
N	302	703	506	196
Adj. R-squared	0.05	0.03	0.03	0.35

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the Fed-Funds Range.

Table C.2: Step 2 - Estimation of Fed's MBS Operating Rules (Eq. (4))

	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ MBS	Δ MBS	Δ MBS
Δ Treasury Securities	0.2082	0.1357	0.4255***
	(0.27)	(0.69)	(0.14)
Δ FAD Securities	0.3179	0.3280	
	(0.21)	(0.22)	
Δ Reverse Repos	-0.0024	0.0063	0.0002
	(0.01)	(0.01)	(0.02)
Δ FAD Securities	0.3179	0.3280	
	(0.21)	(0.22)	
Δ Swaps	-0.0003	0.0004	-0.0040***
	(0.00)	(0.00)	(0.00)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0104	0.0084	-0.0016
	(0.01)	(0.01)	(0.00)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	-0.0002	-0.0008	-0.0001
	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0108**	-0.0145**	-0.0001
	(0.01)	(0.01)	(0.00)
Constant	0.0241	0.0316	0.0013
	(0.02)	(0.02)	(0.00)
N	703	506	196
Adj. R-squared	0.01	0.01	0.09

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the Fed-Funds Range.

Table C.3: Step 2 - Estimation of Fed's FAD Securities Operating Rules (Eq. (4))

	Ample Regime	Post-GFC Regime
	Δ FAD Securities	Δ FAD Securities
Δ Treasury Securities	0.3309***	0.8587***
	(0.12)	(0.20)
Δ MBS	0.0445**	0.0453**
	(0.02)	(0.02)
Δ Reverse Repos	-0.0171	-0.0215
	(0.01)	(0.01)
Δ Swaps	0.0004	0.0010
	(0.00)	(0.00)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	-0.0035*	-0.0053**
	(0.00)	(0.00)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	0.0002*	0.0007***
	(0.00)	(0.00)
L.FOMC	0.0029	0.0043
	(0.00)	(0.00)
Constant	-0.0021	-0.0038
	(0.00)	(0.00)
N	703	506
Adj. R-squared	0.02	0.03

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the Fed-Funds Range.

Table C.4: Step 2 - Estimation of Fed's Repos Operating Rules (Eq. (4))

	Limited Regime
	Δ Repos
Δ Treasury Securities	1.1538
	(3.16)
Δ Reverse Repos	0.4850
	(0.30)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.1269*
	(0.07)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	0.0011***
	(0.00)
L.FOMC	0.0910*
	(0.05)
Constant	-0.0154
	(0.04)
N	302
Adj. R-squared	0.06

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the Fed-Funds Range.

Table C.5: Step 2 - Estimation of Fed's Swaps Operating Rules (Eq. (4))

	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Swaps	Δ Swaps	Δ Swaps
Δ Treasury Securities	14.3265	-2.6198	27.9495*
	(11.52)	(4.37)	(15.50)
Δ MBS	-0.0321	0.0408	-7.0293**
	(0.13)	(0.09)	(3.28)
Δ FAD Securities	0.3428	0.7168	
	(0.77)	(0.82)	
Δ Reverse Repos	1.5760***	1.2693**	2.0799*
	(0.52)	(0.56)	(1.07)
Surprise TGA	0.0960*	0.0962*	0.0191
	(0.05)	(0.06)	(0.15)
Surprise FF Range	0.0062	0.0148	0.0046
	(0.01)	(0.01)	(0.00)
L.FOMC	0.1018	0.0924	0.1260
	(0.09)	(0.11)	(0.11)
Constant	-0.1802***	-0.1856**	-0.0650
	(0.06)	(0.08)	(0.09)
N	703	506	196
Adj. R-squared	0.05	0.03	0.32

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the Fed-Funds Range.

Table C.6: Step 2 - Estimation of Fed's Reverse Repos Operating Rules (Eq. (5))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Reverse Repos	Δ Reverse Repos	Δ Reverse Repos	Δ Reverse Repos
Δ Treasury Securities	-0.2990	0.4315	0.1260	0.4629
	(0.81)	(0.85)	(0.45)	(1.68)
Δ MBS		-0.0031	0.0067	0.0056
		(0.01)	(0.01)	(0.60)
Δ FAD Securities		-0.1571	-0.1665	
		(0.14)	(0.14)	
Δ Repos	0.0311**			
	(0.01)			
Δ Swaps		0.0179***	0.0137**	0.0307*
		(0.01)	(0.01)	(0.02)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0199	0.0139*	0.0142*	-0.0567***
	(0.03)	(0.01)	(0.01)	(0.02)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	-0.0000	0.0011	0.0052***	-0.0002
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0009	0.0218*	0.0203	0.0236
	(0.02)	(0.01)	(0.01)	(0.01)
Constant	-0.0071	-0.0082	-0.0163	0.0161
	(0.01)	(0.01)	(0.01)	(0.01)
N	302	703	506	196
Adj. R-squared	0.01	0.04	0.06	0.13

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the Fed-Funds Range.

Table C.7: First-Stage IV Regressions (Eq. (6))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio
Treasury Securities ($u^{A,T}$)	10.1805**	0.9242***	0.4075	1.7138***
	(5.06)	(0.26)	(0.28)	(0.34)
MBS ($u^{A,MBS}$)		0.1108***	0.1066***	0.2822**
		(0.03)	(0.03)	(0.13)
FAD Securities ($u^{A,FADS}$)		0.0281	0.0252	
		(0.03)	(0.03)	
Reverse Repos ($u^{L,RR}$)	0.1041	-0.1315***	-0.1417***	-0.0588
	(0.59)	(0.01)	(0.01)	(0.04)
Repos ($u^{A,Repos}$)	2.1240***			
	(0.09)			
Swaps ($u^{A,Swaps}$)		0.0002	-0.0015**	0.0181***
		(0.00)	(0.00)	(0.00)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	-0.0493	-0.0281***	-0.0272***	-0.0379***
	(0.20)	(0.00)	(0.00)	(0.01)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	0.0035***	-0.0005***	-0.0017***	-0.0001
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	0.1415**	-0.0050*	-0.0061*	-0.0044
	(0.07)	(0.00)	(0.00)	(0.00)
Constant	0.0140	0.0089***	0.0084***	0.0097**
	(0.07)	(0.00)	(0.00)	(0.00)
N	302	703	506	196
Adj. R-squared	0.63	0.46	0.49	0.40
F-statistic	76.10	25.70	27.97	8.43

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $u^{A,j}$ correspond to the errors from equation (4), $u^{L,RR}$ the errors from equation (5), $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ are the supply and demand surprises from equation (3), when demand shocks are estimated with Fed-Funds Range.

Table C.8: Second-Stage IV Regressions (Eq. (8))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio
Liq. Ratio Est. ($\widehat{\text{LiqRatio}}_t$)	-7.2316***	-5.0636*	-27.8056***	-7.7398**
	(2.73)	(2.69)	(0.77)	(3.88)
FF Range Est. ($\widehat{X_t}^{\text{Demand}}$)	0.2009***	-0.1896	0.0349	-0.2168**
	(0.06)	(0.29)	(0.08)	(0.10)
Constant	54.5286***	72.7427***	121.6525***	117.8723***
	(3.57)	(10.11)	(2.96)	(13.00)
N	302	703	506	196
Adj. R-squared	0.22	0.00	0.76	0.13

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

C.2 Deposit Growth Dispersion Demand Proxy

Table C.9: Step 2 - Estimation of Fed's Treasury Securities Operating Rules (Eq. (4))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Treasury Securities	Δ Treasury Securities	Δ Treasury Securities	Δ Treasury Securities
Δ MBS		0.0022	0.0007	0.2401**
		(0.00)	(0.00)	(0.10)
Δ FAD Securities		0.0216**	0.0215**	
		(0.01)	(0.01)	
Δ Reverse Repos	-0.0022	0.0029	-0.0005	0.0111
	(0.01)	(0.01)	(0.00)	(0.04)
Δ Repos	-0.0006			
	(0.00)			
Δ Swaps		0.0012	-0.0002	0.0087***
		(0.00)	(0.00)	(0.00)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0015	-0.0004	-0.0014**	0.0063
	(0.00)	(0.00)	(0.00)	(0.00)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	-0.0001	0.0001	0.0001	0.0001
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0016	0.0009	0.0002	-0.0002
	(0.00)	(0.00)	(0.00)	(0.00)
Constant	-0.0019	0.0032***	0.0026***	0.0022
	(0.00)	(0.00)	(0.00)	(0.00)
N	302	703	506	196
Adj. R-squared	0.01	0.03	0.02	0.34

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

Table C.10: Step 2 - Estimation of Fed's MBS Operating Rules (Eq. (4))

	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ MBS	Δ MBS	Δ MBS
Δ Treasury Securities	0.2260	0.1902	0.4327***
	(0.26)	(0.67)	(0.14)
Δ FAD Securities	0.3238	0.3304	
	(0.21)	(0.22)	
Δ Reverse Repos	-0.0041	0.0001	-0.0000
	(0.01)	(0.01)	(0.02)
Δ Swaps	0.0001	0.0009	-0.0041***
	(0.00)	(0.00)	(0.00)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0108	0.0086	-0.0015
	(0.01)	(0.01)	(0.00)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	-0.0009	-0.0012	-0.0001
	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0109**	-0.0146**	-0.0001
	(0.01)	(0.01)	(0.00)
Constant	0.0241	0.0315	0.0012
	(0.02)	(0.02)	(0.00)
N	703	506	196
Adj. R-squared	0.01	0.01	0.09

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

Table C.11: Step 2 - Estimation of Fed's FAD Securities Operating Rules (Eq. (4))

	Ample Regime	Post-GFC Regime
	Δ FAD Securities	Δ FAD Securities
Δ Treasury Securities	0.3122***	0.8005***
	(0.12)	(0.20)
Δ MBS	0.0450**	0.0454**
	(0.02)	(0.02)
Δ Reverse Repos	-0.0154	-0.0159
	(0.01)	(0.01)
Δ Swaps	-0.0000	0.0003
	(0.00)	(0.00)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	-0.0040**	-0.0056***
	(0.00)	(0.00)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	0.0009***	0.0015***
	(0.00)	(0.00)
L.FOMC	0.0031	0.0045
	(0.00)	(0.00)
Constant	-0.0022	-0.0037
	(0.00)	(0.00)
N	703	506
Adj. R-squared	0.02	0.04

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

Table C.12: Step 2 - Estimation of Fed's Repos Operating Rules (Eq. (4))

	Limited Regime
	Δ Repos
Δ Treasury Securities	-0.8088
	(2.73)
Δ Reverse Repos	0.5175*
	(0.31)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.1460*
	(0.08)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	-0.0088
	(0.01)
L.FOMC	0.0878
	(0.06)
Constant	-0.0188
	(0.04)
N	302
Adj. R-squared	0.02

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with tthe dispersion in the distribution of deposit growth.

Table C.13: Step 2 - Estimation of Fed's Swaps Operating Rules (Eq. (4))

	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Swaps	Δ Swaps	Δ Swaps
Δ Treasury Securities	13.2524	-4.0633	27.3048*
	(11.49)	(4.38)	(15.55)
Δ MBS	0.0142	0.0836	-7.0989**
	(0.11)	(0.08)	(3.48)
Δ FAD Securities	-0.0172	0.2405	
	(0.71)	(0.72)	
Δ Reverse Repos	1.6074***	1.3230**	2.1220**
	(0.52)	(0.52)	(1.06)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0688	0.0609	0.0002
	(0.05)	(0.06)	(0.16)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	0.0476***	0.0732***	0.0134
	(0.01)	(0.02)	(0.01)
L.FOMC	0.1083	0.1012	0.1261
	(0.09)	(0.12)	(0.11)
Constant	-0.1817***	-0.1845**	-0.0633
	(0.06)	(0.08)	(0.09)
N	703	506	196
Adj. R-squared	0.08	0.07	0.32

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

Table C.14: Step 2 - Estimation of Fed's Reverse Repos Operating Rules (Eq. (5))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Reverse Repos	Δ Reverse Repos	Δ Reverse Repos	Δ Reverse Repos
Δ Treasury Securities	-0.1962	0.3855	-0.1361	0.5061
	(0.76)	(0.84)	(0.51)	(1.68)
Δ MBS		-0.0054	0.0001	-0.0007
		(0.01)	(0.01)	(0.60)
Δ FAD Securities		-0.1435	-0.1291	
		(0.14)	(0.14)	
Δ Repos	0.0313**			
	(0.01)			
Δ Swaps		0.0188***	0.0154**	0.0310*
		(0.01)	(0.01)	(0.02)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0162	0.0148*	0.0179**	-0.0541**
	(0.03)	(0.01)	(0.01)	(0.02)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	0.0038**	-0.0007	0.0001	-0.0017
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	-0.0008	0.0219*	0.0206	0.0234
	(0.02)	(0.01)	(0.02)	(0.01)
Constant	-0.0069	-0.0078	-0.0149	0.0159
	(0.01)	(0.01)	(0.01)	(0.01)
N	302	703	506	196
Adj. R-squared	0.02	0.04	0.02	0.13

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ correspond to the errors from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

Table C.15: First-Stage IV Regressions (Eq. (6))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio
Treasury Securities ($u^{A,T}$)	3.5205	0.9389***	0.4928*	1.6837***
	(4.48)	(0.26)	(0.28)	(0.34)
MBS ($u^{A,MBS}$)		0.1114***	0.1080***	0.2958**
		(0.03)	(0.03)	(0.13)
FAD Securities ($u^{A,FADS}$)		0.0256	0.0199	
		(0.04)	(0.03)	
Reverse Repos ($u^{L,RR}$)	0.2227	-0.1336***	-0.1489***	-0.0559
	(0.59)	(0.01)	(0.01)	(0.04)
Repos ($u^{A,Repos}$)	2.1769***			
	(0.09)			
Swaps ($u^{A,Swaps}$)		-0.0000	-0.0018**	0.0172***
		(0.00)	(0.00)	(0.00)
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0041	-0.0284***	-0.0282***	-0.0394***
	(0.20)	(0.00)	(0.00)	(0.01)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	-0.0257*	0.0000	-0.0006*	0.0010
	(0.01)	(0.00)	(0.00)	(0.00)
L.FOMC	0.1415**	-0.0051*	-0.0064**	-0.0044
	(0.07)	(0.00)	(0.00)	(0.00)
Constant	0.0140	0.0089***	0.0084***	0.0097**
	(0.07)	(0.00)	(0.00)	(0.00)
N	302	703	506	196
Adj. R-squared	0.62	0.45	0.48	0.40
F-statistic	75.32	25.55	26.54	8.65

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $u^{A,j}$ correspond to the errors from equation (4), $u^{L,RR}$ the errors from equation (5), $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ are the supply and demand surprises from equation (3), when demand shocks are estimated with the dispersion in the distribution of deposit growth.

Table C.16: Second-Stage IV Regressions (Eq. (8))

	Limited Regime	Ample Regime	Post-GFC Regime	COVID-19 Regime
	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio
Liq. Ratio Est. ($\widehat{\text{LiqRatio}}_t$)	-8.5016***	1.4620	-27.2967***	0.7012
	(2.50)	(2.72)	(0.84)	(2.37)
Disp. Deposit Growth Est. ($\widehat{X_t}^{\text{Demand}}$)	3.8611***	4.6726***	0.2987*	-0.5321
	(1.48)	(0.76)	(0.16)	(0.49)
Constant	-10.1831	-24.0366	116.1733***	98.6475***
	(25.03)	(16.25)	(4.24)	(9.92)
N	302	703	506	196
Adj. R-squared	0.20	0.05	0.76	-0.01

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

D Robustness: Non-Borrowed Reserves

D.1 Fed-Funds Range Demand Proxy

Table D.1: First-Stage IV Regressions (Eq. (6))

	Limited Regime	Ample Regime	Post-GFC Regime	Covid-19 Regime
	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio
Treasury Securities ($u^{A,T}$)	41.3306**	0.8841***	0.5569**	1.1805***
	(17.49)	(0.23)	(0.27)	(0.26)
MBS ($u^{A,MBS}$)		0.1390***	0.1346***	0.2798**
		(0.04)	(0.04)	(0.13)
FAD Securities ($u^{A,FADS}$)		0.0316	0.0268	
		(0.04)	(0.04)	
Reverse Repos ($u^{L,RR}$)	-1.3345***	-0.1301***	-0.1380***	-0.0677*
	(0.45)	(0.01)	(0.01)	(0.04)
Repos ($u^{A,Repos}$)	2.1645***			
	(0.08)			
Surprise TGA ($\varepsilon^{\text{Supply}}$)	-0.2615*	-0.0298***	-0.0294***	-0.0382***
	(0.14)	(0.00)	(0.00)	(0.01)
Surprise FF Range ($\varepsilon^{\text{Demand}}$)	0.0028***	-0.0005***	-0.0017***	-0.0002
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	0.0629	-0.0044*	-0.0048	-0.0046
	(0.07)	(0.00)	(0.00)	(0.00)
Constant	-0.0570	0.0072***	0.0072**	0.0065*
	(0.08)	(0.00)	(0.00)	(0.00)
N	267	779	582	196
Adj. R-squared	0.72	0.47	0.49	0.40
F-statistic	96.93	34.94	35.52	6.27

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $u^{A,j}$ correspond to the errors from equation (4), $u^{L,RR}$ the errors from equation (5), $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ are the supply and demand surprises from equation (3), when demand shocks are estimated with Fed-Funds Range.

Table D.2: Second-Stage IV Regressions (Eq. (8))

	Limited Regime	Ample Regime	Post-GFC Regime	Covid-19 Regime
	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio
Liq. Ratio Est. ($\widehat{\text{LiqRatio}}_t$)	-5.2283***	-10.6829***	-24.0570***	-7.4595
	(1.08)	(2.13)	(0.71)	(4.52)
FF Range Est. ($\widehat{X_t^{\text{Demand}}}$)	0.2513***	-0.2638	-0.0341	-0.2246*
	(0.03)	(0.32)	(0.11)	(0.12)
Constant	55.1913***	88.2799***	111.3076***	117.0298***
	(2.28)	(9.49)	(3.12)	(15.17)
N	267	779	582	196
Adj. R-squared	0.27	0.01	0.71	0.13

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

D.2 Deposit Growth Dispersion Demand Proxy

Table D.3: First-Stage IV Regressions (Eq. (6))

	Limited Regime	Ample Regime	Post-GFC Regime	Covid-19 Regime
	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio	Δ Liq. Ratio
Treasury Securities ($u^{A,T}$)	34.3386*	0.9049***	0.6284**	1.1851***
	(18.15)	(0.22)	(0.27)	(0.26)
MBS ($u^{A,MBS}$)		0.1396***	0.1360***	0.2932**
		(0.04)	(0.04)	(0.13)
FAD Securities ($u^{A,FADS}$)		0.0306	0.0225	
		(0.04)	(0.04)	
Reverse Repos ($u^{L,RR}$)	-1.2069**	-0.1318***	-0.1439***	-0.0657*
	(0.48)	(0.01)	(0.01)	(0.04)
Repos ($u^{A,Repos}$)	2.1921***			
	(0.09)			
Surprise TGA ($\varepsilon^{\text{Supply}}$)	-0.2133	-0.0299***	-0.0301***	-0.0391***
	(0.15)	(0.00)	(0.00)	(0.01)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	-0.0344***	-0.0002	-0.0007**	0.0006
	(0.01)	(0.00)	(0.00)	(0.00)
L.FOMC	0.0705	-0.0045*	-0.0051	-0.0046
	(0.07)	(0.00)	(0.00)	(0.00)
Constant	-0.0571	0.0072***	0.0071**	0.0065**
	(0.09)	(0.00)	(0.00)	(0.00)
N	267	779	582	196
Adj. R-squared	0.71	0.47	0.48	0.40
F-statistic	95.16	34.75	34.91	6.33

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Note: $u^{A,j}$ correspond to the errors from equation (4), $u^{L,RR}$ the errors from equation (5), $\varepsilon^{\text{Supply}}$ and $\varepsilon^{\text{Demand}}$ are the supply and demand surprises from equation (3), when demand shocks are estimated with Fed-Funds Range.

Table D.4: Second-Stage IV Regressions (Eq. (8))

	Limited Regime	Ample Regime	Post-GFC Regime	Covid-19 Regime
	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio
Liq. Ratio Est. ($\widehat{\text{LiqRatio}}_t$)	-7.5772***	-5.0368**	-23.5005***	1.5597
	(0.95)	(2.19)	(0.76)	(2.21)
Disp. Deposit Growth Est. ($\widehat{X_t}^{\text{Demand}}$)	3.6074***	4.1953***	0.3117*	-0.5403
	(1.02)	(0.76)	(0.18)	(0.49)
Constant	-4.6256	0.8289	104.3711***	96.2569***
	(18.52)	(15.55)	(4.26)	(9.78)
N	267	779	582	196
Adj. R-squared	0.22	0.05	0.71	-0.01

Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$