Monetary Policy Implementation Regimes and Reserve Demand in the US*

Saki Bigio† Pablo D'Erasmo‡ Luis Yépez§

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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. 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 standard simultaneity problems inherent in supply-demand systems. Two distinctive features of reserve markets compound these difficulties. First, central banks actively adjust reserve supply in response to contemporaneous demand shocks—indeed, countering such shocks is often the explicit goal of monetary policy. Unlike commodity markets, where weather events or production disruptions provide natural experiments, reserve markets lack readily identifiable exogenous supply shocks that can serve as instruments. Second, monetary policy implementation frameworks evolve substantially over time, with supply rules adapting to changes in operational frameworks, legal constraints, seasonal adjustments, and institutional arrangements. These regime changes can fundamentally alter the nature of reserve demand itself, as banks' motivations for holding reserves shift with precautionary liquidity management. Consequently, credible reserve demand estimation requires not only instrumental variables that capture exogenous variation in reserve supply, but also explicit identification of demand shocks and careful delineation of distinct monetary policy regimes. This joins a recent body of papers that offer various approaches to overcome these challenges: (Lopez-Salido and Vissing-Jorgenson, 2023; Afonso et al., 2023; Lagos and Navarro, 2023). Our contribution is to develop a novel instrumental variables approach to construct reserve demand estimates for the United States across multiple monetary policy regimes.

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 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 in open-market operations (Bindseil, 2014) and is motivated by classic analysis in Poole (1970) or more recent dynamic interbank-market models (Afonso and Lagos, 2015; Bianchi and Bigio, 2025, e.g.,). 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 accute 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.

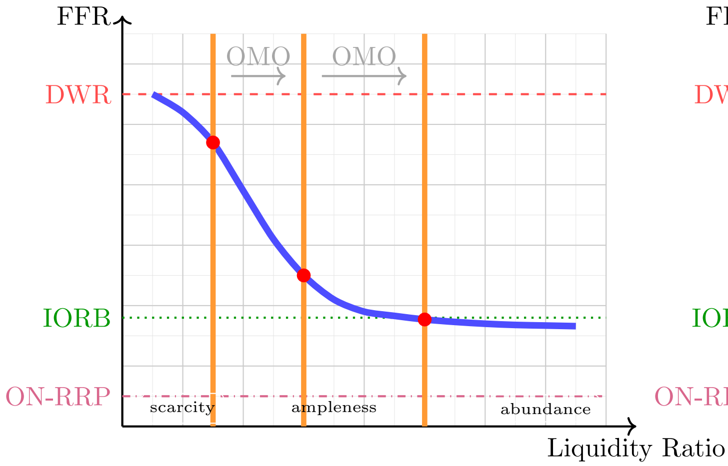
In the second step, we estimate how different Federal Reserve balance sheet instruments—Treasury securities, MBS, repos, and reverse repos—systematically respond to the identified demand and supply shocks. This step reveals that the Federal Reserve consistently accommodates both types of shocks, though 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 stage 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.

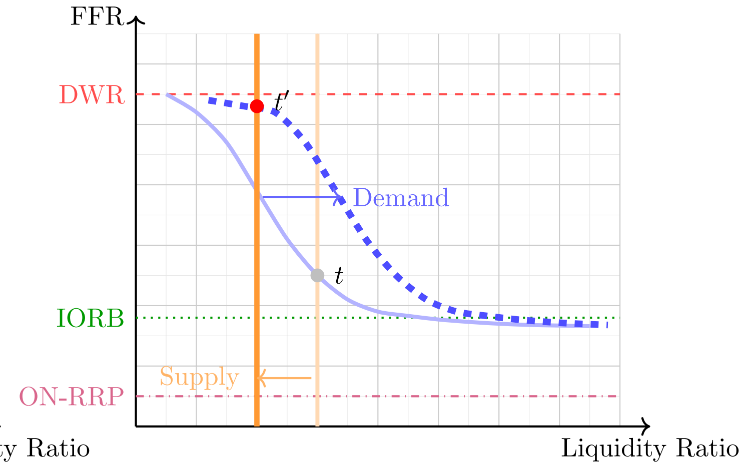
To account for fundamental changes in monetary policy implementation, we partition our estimation into distinct regimes guided by documented institutional shifts: the limited reserves era (2003–2008), the post-Global Financial Crisis period (2008–2020), and the COVID-19 super-abundant reserves regime (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.

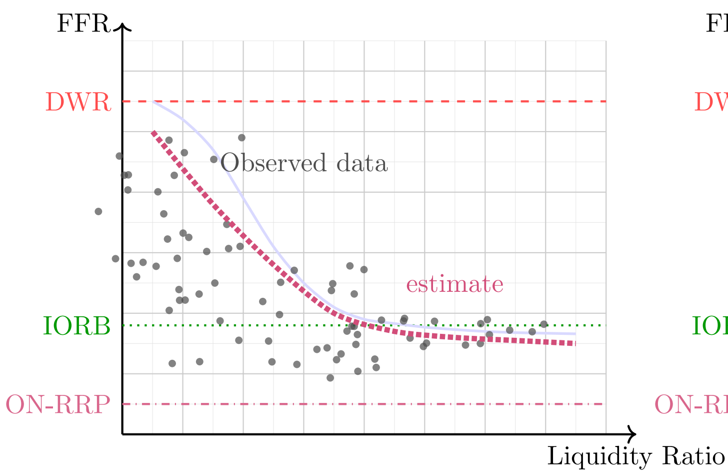
Figure 1: Identification challenges in estimating reserve demand.



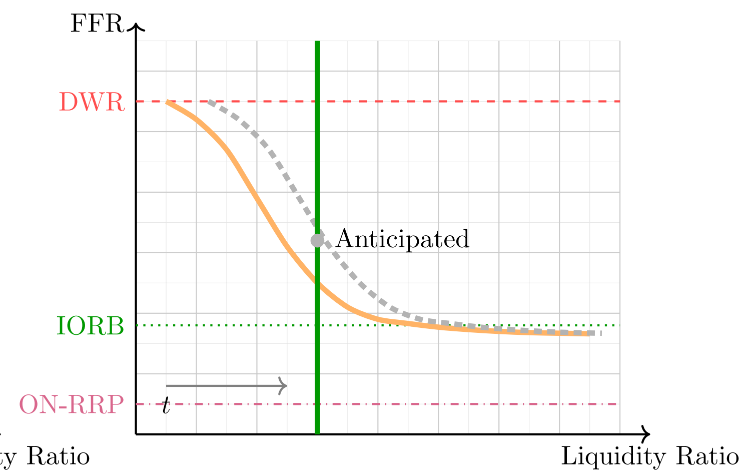
(a) Supply shifts trace out demand curve



(b) Simultaneity problem



(c) Observed equilibria and biased estimates



(d) Policy anticipation and regime shifts

Literature Review. Our paper joins a growing body of papers that estimate the demand for reserves: (TBA) Lopez-Salido and Vissing-Jorgenson (2023), Afonso et al. (2023), Lagos and Navarro (2023).

A novel aspect is that we combine xxx combine proxies for demand shocks and supply shocks.

LY: It's also robust to the addition of other operations, such as swaps

Our focus on reserve demand connects to the broader literature on money demand estimation, though reserves and currency serve distinct roles in the monetary system. The classic literature on currency demand, beginning with Baumol (1952) and Tobin (1956), established the inventory-theoretic approach where agents balance transaction needs against the opportunity cost of holding non-interest-bearing money. Miller and Orr (1966) extended this framework to firms' cash management, while Goldfeld (1973) and Goldfeld (1976) provided seminal empirical estimates of money demand functions, documenting stable relationships between real balances, income, and interest rates during the pre-1970s period. The subsequent breakdown of these relationships—the "missing money" puzzle analyzed by Judd and Scadding (1983) and Goldfeld and Sichel (1990)—highlighted the importance of financial innovation and regulatory changes for money demand. Lucas (1988) and Stock and Watson (1989) developed more sophisticated econometric approaches to address instability and identification issues, while Ball (2001) and Ireland (2009) provided modern estimates using cointegration techniques. More recently, Lucas and Nicolini (2016) and Benati (2021) have documented a remarkable stability in money demand when properly accounting for low-frequency movements in velocity. While these studies focus on currency and M1 held by the non-bank public, our analysis of reserve demand shares similar methodological challenges—particularly the endogeneity of supply and the evolution of the institutional environment. However, reserve demand is fundamentally shaped by regulatory requirements, interbank market frictions, and central bank operational frameworks rather than the transaction motives that drive currency demand. Moreover, the introduction of interest on reserves in 2008 eliminated the traditional opportunity cost that characterized currency holding, requiring new frameworks for understanding reserve demand in floor systems.

2 Motivating Empirical Facts

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

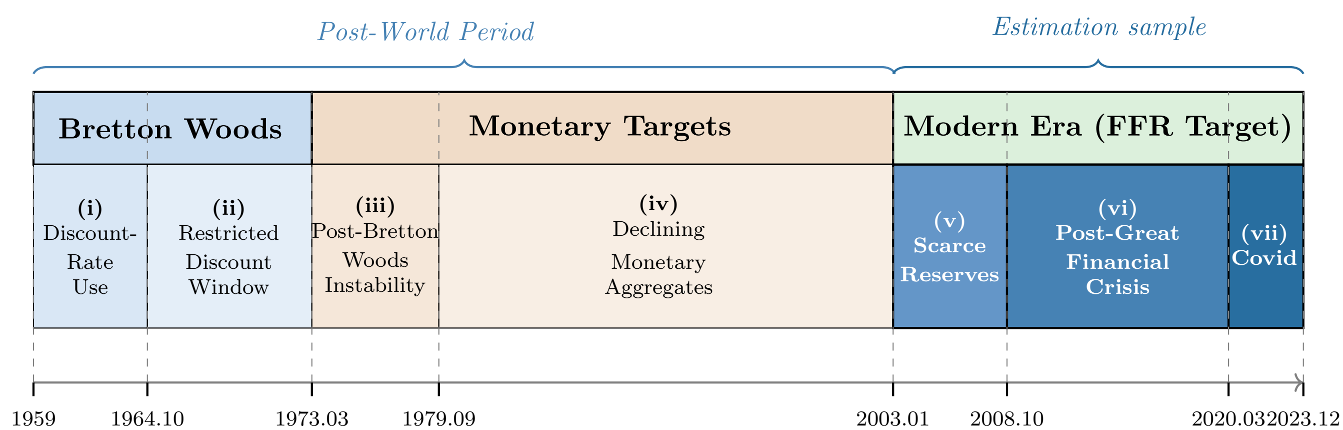
We begin with a discussion of the post-World War II experience and then focus on the last

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) withn 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.

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



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

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

where Reserves_t are the reserves balances with Federal Reserve Banks and Deposits_t are the commercial bank deposits. By construction, the ratio is expressed in logs; hence, when reserves represent a very small percentage of deposits, the liquidity ratio can take negative values. 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 variance (in parentheses) of the main rates, liquidity ratio, and spreads ratio across regimes. Figure 3 provides a historical perspective of the components of the Spreads Ratio, the FFR, the DWR and IOER. Figure 4 plots the time series of reserves and deposits. Figure 5 plots the spreads ratio and the liquidity ratio. The time series reveals apparent differences in the sequence of distinct operating regimes in U.S. monetary policy, each shaped by institutional arrangements. We discuss these differences.

2.1 Post-World War II Operational Frameworks

The post-World War II operational frameworks encompass two eras, the Bretton Woods era and the Monetary Targets era. Two remarks are important. First, the Bretton Woods is a remarkable period in that the Federal Reserve maintained a de facto *fixed exchange rate* between gold and the dollar. They conducted operations both to target the exchange rate, but were also concerned with the level of the Federal Funds rate Meltzer (2009). Thus, the maintained two targets and used various instruments for that purpose, two objectives

Table 1: Summary Statistics per regime

	Discount-Rate Use	Restricted DW	Post-BW Instability	Declining Mon. Agg	Scarce Reserves	Post-GFC	Covid-19	Full Sample
Liq. Ratio	1.73	1.44	1.26	-0.14	-1.38	2.84	2.97	0.97
	(0.02)	(0.00)	(0.02)	(0.72)	(0.25)	(0.08)	(0.01)	(2.16)
Spreads Ratio	86.91	105.69	103.61	113.18	76.38	42.10	91.14	91.88
	(393.96)	(298.00)	(448.21)	(159.04)	(132.11)	(115.30)	(15.94)	(867.89)
Period Start	1959m1	1964m11	1973m4	1979m10	2003m1	2008m11	2020m3	
Period End	1964m10	1973m3	1979m9	2002m12	2008m10	2020m2	2023m12	

mean coefficients; variance in parentheses

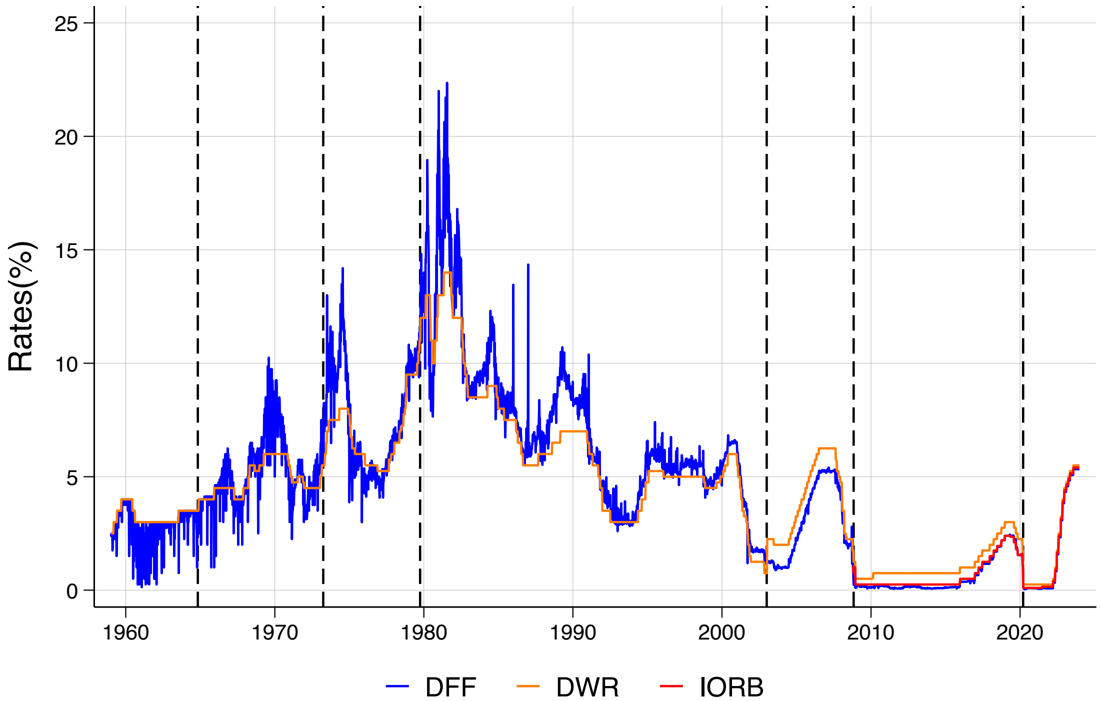
Note: "DWR Dom. Regime" refers to the Discount-Rate Dominance regime, "Collapse BW" to the Collapse of Bretton Wood period, "Post-BW" to Post Bretton Woods, "Mon. Agg." to Monetary Aggregates regime, "Post-GFC" to the post Great Financial Crisis regime. "Liq. Ratio" denotes the liquidity ratio in equation (1), "DFF" the effective federal funds rate, "IORB" the interest on reserve balances, "DWR" the discount rate (policy ceiling), and "Spreads Ratio" a normalized measure of the position of the federal funds rate within the corridor defined y the Fed's administered rates presented in equation (2). The statistics were computed based on weekly data (Wednesday values). Source: Federal Reserve Bank of St. Louis FRED.

that didn't not seem to be in conflict for policy makers but are in conflict in theories where money markets operate frictionless. Second, the monetary target period is a period where the Federal Reserve consistently attempted to alter monetary quantities, but also interest rate. The Federal Reserve was always ambivalent and never had clear goals, sometimes even lacking theoretical frameworks Meltzer (2009).

Discount-Rate Dominance. The Discount-Rate Dominance period (1959m1–1964m10) was characterized by an operational stance in which the discount window rate was a de facto binding ceiling for the Federal Funds rate. Figure 3 shows that, while extremely volatile by modern-day standards, the federal funds rate remained consistently capped by the discount rate, often hitting the ceiling of the system but never surpassing it. During the period, the liquidity ratio —the ratio of reserves to deposits —was considerably higher than in the period preceding the Great Financial Crisis (pre-2008). While the supply of reserves was relatively ample, the liquidity ratio remained stable, indicating limited supply-adjustments to counter the instability of rates. The interbank rate volatility was extremely high compared with the modern era (see Table 1).

Restricted Discount-Window. A structural shift occurred in late 1964, which led to a new regime, the restricted discount window regime (1964m11–1973m3). In this period, the funds rate persistently exceeded the discount window rate. This regime change reflected the Federal Reserve's evolving approach to discount window access. As documented in contemporaneous Board discussions, proposed legislation obligated reserve banks "to keep informed

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. Source: Federal Reserve Bank of St Louis FRED.

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" (Meltzer, 2009, p. 467). The Board could bar banks that engaged in "unsound practices" from use of the discount facility, effectively creating administrative barriers to borrowing. We interpret these passages as evidence that the Federal Reserve began to impose regulatory costs on discount window access. Presumably, this restricted access aimed to prevent commercial banks that were part of the Federal Reserve system from borrowing at the discount window to subsequently lend to non-member institutions, thereby boosting the demand for reserves among non-members.

During this period, the liquidity ratio remained high. This regime occurred during the Bretton Woods era, so it could have also been motivated by the need to support reserve demand at a time when the gold parity was under stress (Bordo, 1993). To our surprise, we found that the literature has paid little attention to this phenomenon, even though it led to the federal funds rate persistently exceeding the discount window rate.

The Post-Bretton Woods instability. This regime (1973m4–1979m9) brought heightened volatility in short-term rates, driven by oil shocks and stagflation. The liquidity ratio decreased but remained considerably high—still indicating an important amount of reserves in the market—and fluctuating spreads underscored how macroeconomic turbulence magnified the sensitivity of money markets to shifts in liquidity conditions (Hamilton, 1983).

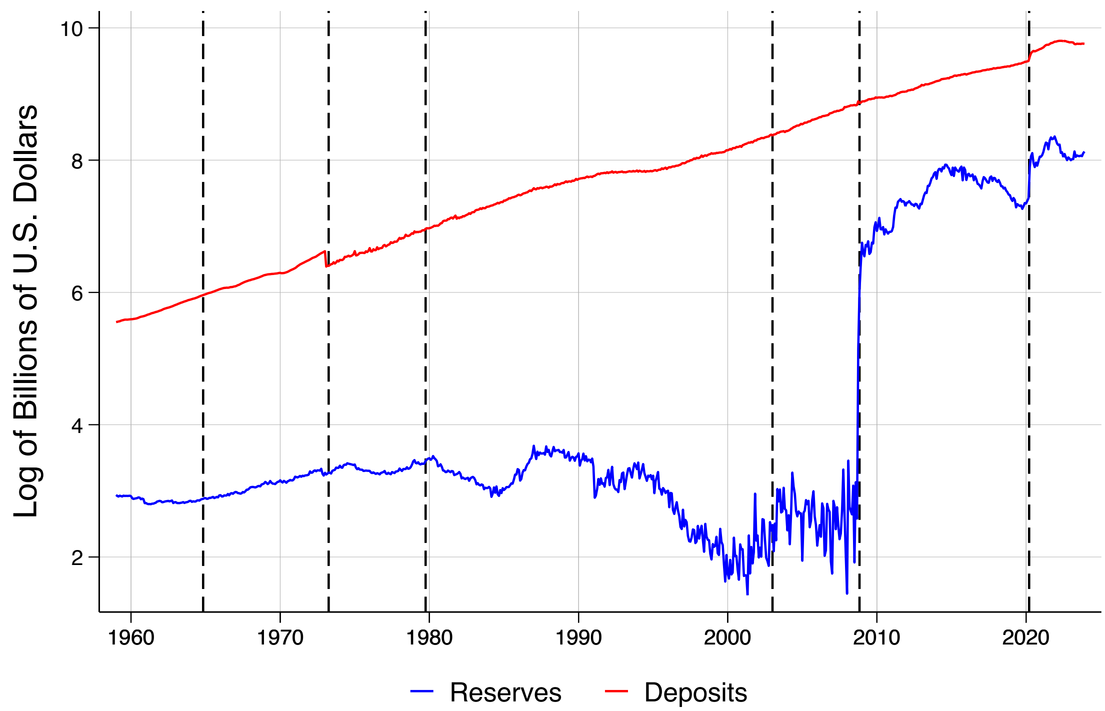
Monetary-Aggregates period. The subsequent regime (1979m10 – 2002m12) marked a turning point: under Volcker, the Federal Reserve emphasized monetary aggregates, producing exceptionally high and volatile rates and unstable spreads as the costs of disinflation were absorbed (Taylor, 1993); concurrently, the liquidity ratio underwent a pronounced and increasingly volatile decline (see Table 1), thereby amplifying money-market fragility during the disinflationary adjustment.

The Modern Period. This period expands from 2003 to the present. It is in turn, subdivided into a few regimes.

The *Limited Reserves* regime (2003m1-2008m10) experienced fluctuating short-term interest rates. Initially, interest rates remained low in 2003. However, they peaked in 2006-2007 and subsequently fell sharply. Despite fluctuations, reserve balances remained relatively low but generally stable throughout the period. This stability was largely achieved through the Federal Reserve's active open-market operations (OMOs), which aimed to smooth reserve conditions. Within this interval, the operational framework resembled a corridor system, with the discount rate serving as the upper reference for short-term funding. A significant operational change occurred on January 9, 2003, when Reserve Banks set the basic discount rate above the prevailing federal funds rate. Consequently, the federal funds rate subsequently traded below the discount rate, leading to a realignment with substantial operational implications (Stevens, 2003; Furfine, 2005). Since reserve balances were relatively low, aggregate liquidity was constrained, resulting in an increase in the implicit price of liquidity in interbank markets.

The *Post-Global Financial Crisis* regime (2008m11–2020m2) introduced interest on reserve balances (IORB) and large-scale asset purchases (LSAPs), shifting the implementation framework toward an ample-reserves (floor) system. The Federal Reserve's asset purchases and balance-sheet expansion led to a rapid and substantial increase in reserve balances. This abrupt surge significantly boosted aggregate liquidity, as it increased the supply of the most

Figure 4: Historical Reserves and Deposits



Note: The figure displays commercial bank deposits (red) and reserve balances with Federal Reserve Banks (blue). Series are expressed in log of billions of U.S. dollars and plotted as weekly observations (Wednesday values). Vertical dashed lines mark the following policy-regime dates: November 1964, April 1973, October 1979, January 2003, November 2008 and March 2020. Source: Federal Reserve Bank of St. Louis FRED.

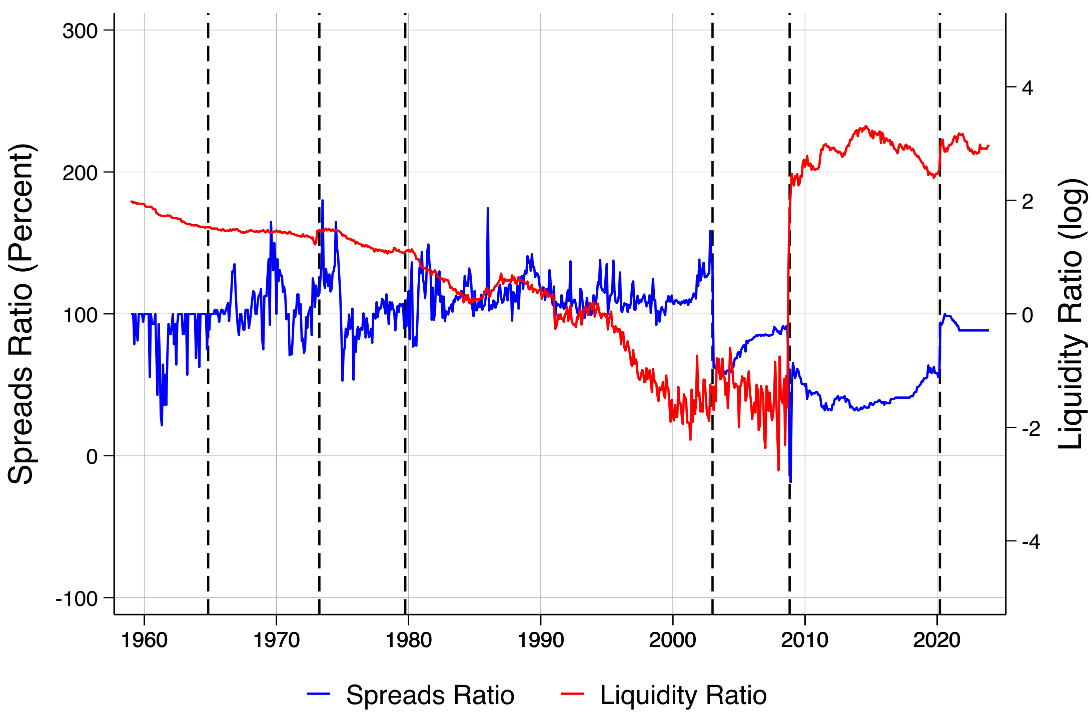
liquid asset. Consequently, the implicit "price" of liquidity in interbank markets compressed. Operationally, the federal funds rate converged closely to the IORB rate, and conventional spreads narrowed. However, liquidity heterogeneity across counterparties persisted. These changes had notable impacts 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).

The *post COVID-19* regime (2020m3–2023m12) was characterized by super-abundant reserves. Pandemic interventions, such as large-scale asset purchases, a comprehensive set of liquidity facilities, and the temporary elimination of reserve requirements, led to significantly higher reserve balances and resulted in the return of policy rates to the effective lower bound. In this abundant-reserves environment, the Federal Reserve employed an expanded operational toolkit (IORB, ON-RRP, and standing facilities) to maintain control of short-term rates (Labonté, 2021; Wong, 2021).

These regimes trace the transformation of U.S. monetary policy implementation from a scarce-reserves corridor to a floor system dominated by super-abundant reserves. They highlight the central challenge for empirical analysis: the same intervention—such as a Treasury purchase—can have very different implications for liquidity and spreads depending on the institutional environment. This motivates our strategy of estimating regime-specific responses to orthogonalized liquidity shocks.

Despite the differences in regimes and time-series shifts, a clear pattern emerges: taking the whole sample together, there is a negative relationship between the liquidity ratio (equation (1)) and the Spreads ratio (equation (2)). PD: Based on evidence in Table 2, (coefficients are not negative across regimes) I would point to a clear pattern (negative relationship) in the Modern Period and a negative correlation in the full sample driven by the correlation in this period. Maybe we should just focus on the "Modern Period" both text and table (?) .

Figure 5: Historical Spreads Ratio and Liquidity Ratio



Note: The panel displays the spreads ratio (blue line, left axis) and the liquidity ratio (red line, right axis). The spreads ratio is defined as $(DFF - IORB)/(DWR - IORB) \times 100$. The liquidity ratio is the natural log of the ratio of reserves to commercial bank deposits expressed in percentages ($log(reserves/deposits \times 100)$). Series are plotted as weekly observations (Wednesday values). Vertical dashed lines mark the following policy-regime dates: November 1964, April 1973, October 1979, January 2003, November 2008 and March 2020. Source: Federal Reserve Bank of St. Louis FRED.

Table 2: Historical Demand for Reserves Regressions

	Discount-Rate Use	Restricted DW	Post-BW Instability	Declining Mon. Agg	Scarce Reserves	Post-GFC	Covid-19	Full Sample
	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio
Liq. Ratio	3.43	24.75	61.46***	0.65	-12.17***	-16.17**	1.37	-9.72***
	(11.32)	(29.78)	(14.17)	(0.95)	(2.28)	(7.21)	(4.85)	(0.69)
Constant	84.43***	62.02	17.07	113.97***	56.26***	89.01***	87.12***	99.47***
	(20.40)	(44.29)	(17.71)	(1.69)	(5.20)	(20.39)	(14.36)	(1.92)
N	70	101	78	280	69	137	45	780
Adj. R-squared	-0.01	0.05	0.24	-0.01	0.21	0.18	-0.10	0.23

Standard errors in parentheses

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

Note: "DWR Dom. Regime" refers to the Discount-Rate Dominance regime, "Collapse BW" to the Collapse of Bretton Wood period, "Post-BW" to Post Bretton Woods, "Mon. Agg." to Monetary Aggregates regime, "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 y the Fed's administered rates presented in equation (2). The statistics were computed based on weekly data (Wednesday values). Source: Federal Reserve Bank of St. Louis FRED.

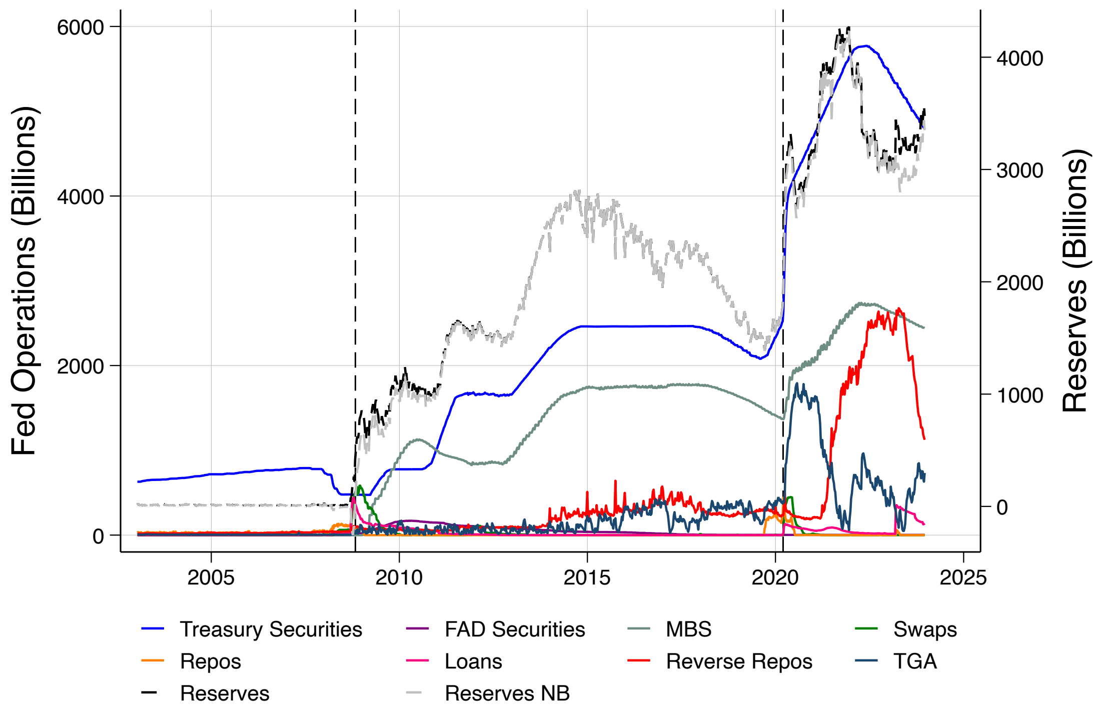
2.2 The Modern Period

In what follows, we focus mostly on the Modern Period as high frequency data, including Federal Reserve Balance-Sheet level data is available only during this time.

Balance Sheet Expansion. First, the size and composition of the Federal Reserve's balance sheet have shifted dramatically since the early 2000s (see Figure 6). Before the Global Financial Crisis, outright Treasury operations and repos dominated, while reserve balances remained scarce. After 2008, the introduction of large-scale asset purchases-Treasuries, Federal Agency Debt, and MBS-led to a structural expansion in reserves. The COVID-19 crisis marked a second turning point, with reserves reaching historically unprecedented levels and the Fed deploying a wide range of liquidity facilities.

Reverse repurchase agreements (reverse repos) and the Treasury General Account (TGA) are the liability series shown in Figure 6. In the ample reserves regime, reverse repo operations have emerged as a central operational instrument for absorbing excess balances and moderating short-term funding pressures, while fluctuations in the TGA (the Treasury's deposit at the Federal Reserve) produce large, fiscal-driven swings in the Fed's net liabilities and reserve dynamics. Emergency lending (loans) surged sharply during the Global Financial Crisis and again in 2020, temporarily enlarging the Fed's balance-sheet exposures and altering reserve dynamics. These episodic facility usages and asset reallocations help explain the close co-movement of non-borrowed reserves and total reserves around crisis dates. Foreign-currency swap lines were an important channel for supplying dollar liquidity to global counterparties during episodes of international stress.

Figure 6: Federal Reserve Operations and Reserves

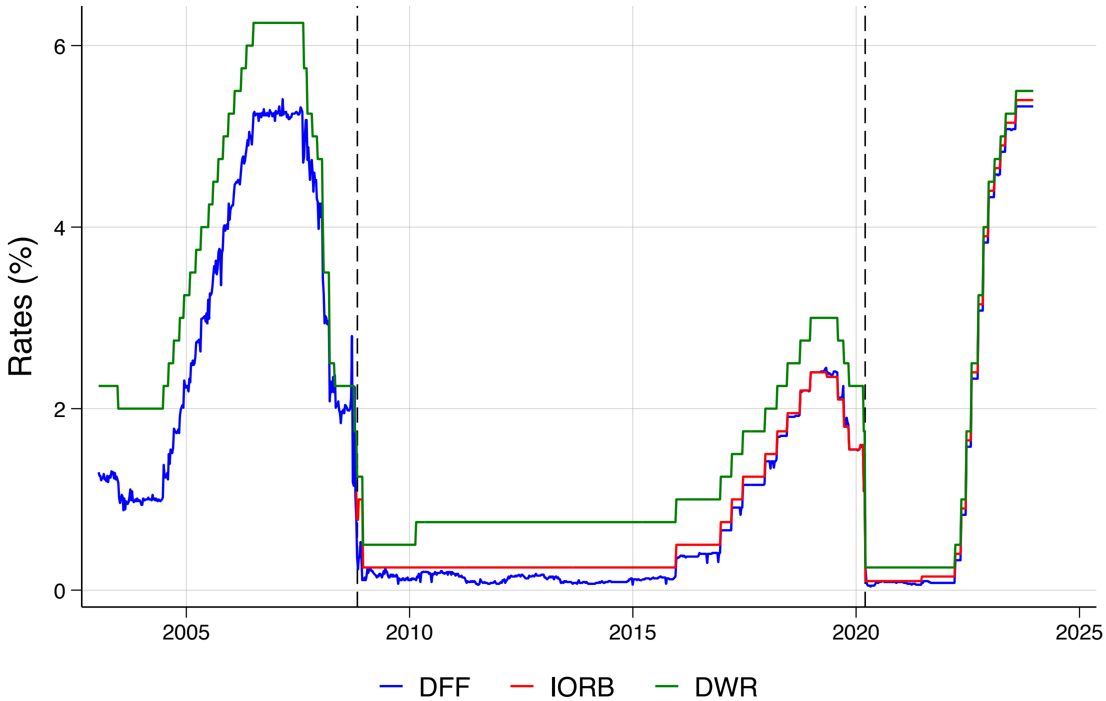


Note: The figure displays selected Federal Reserve balance-sheet components (assets and liabilities) on the left axis and reserve aggregates (total reserves and non-borrowed reserves) on the right axis; all values are expressed in billions of U.S. dollars. Series are weekly observations, taking the Wednesday value each week. Vertical dashed lines denote the start of the Global Financial Crisis (October 2008) and the COVID-19 pandemic (March 2020). The data is from the St. Louis Fred.

Corridor Rates and Fed Fund Rates. Second, the policy rates highlight the institutional shift from a corridor to a floor system. Prior to 2008, the federal funds rate moved within the corridor defined by the discount rate (ceiling) and zero (implicit floor), with open market operations steering it toward target. The introduction of interest on reserves (IORB) in October 2008 established an explicit floor. Since then, the effective federal funds rate has remained closely anchored to IORB, except during stress episodes (see Figure 7).

Liquidity-Demand shock proxies. PD: Motivate demand shock proxies, explain how they are constructed. Third, proxies for heterogeneity in liquidity demand, the dispersion of federal funds transactions PD: ??explain this?? and the cross-sectional dispersion of bank

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). The data is from the St. Louis Fred.

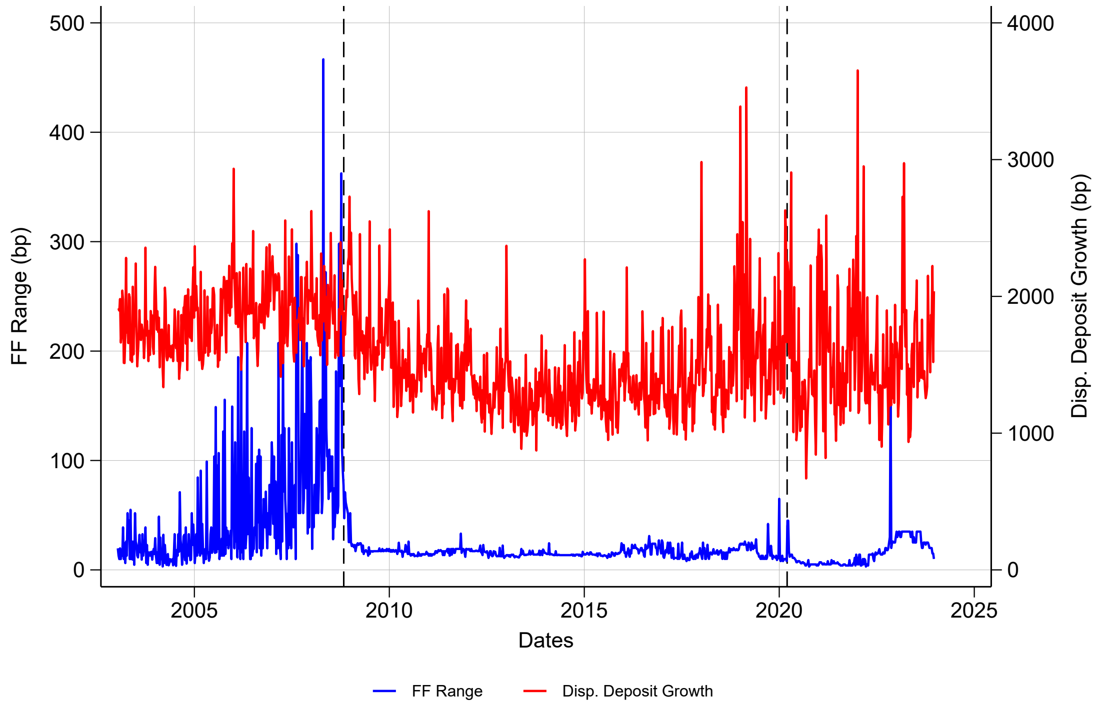
level deposit growth exhibit large swings during episodes of market stress (see Figure 8).[1] The 2008 financial crisis and the COVID-19 shock stand out as periods when dispersion spiked, reflecting frictions in banks' access to funding and sharp differences in liquidity needs across institutions.

Liquidity-Supply shock proxies. PD: Describe Supply Shock here...

Taken together, these facts underscore two key points: (i) both the supply and demand for liquidity have undergone structural shifts across regimes, and (ii) short-term interest

[1] To construct the cross-section dispersion of deposit growth we use confidential daily data at the bank level. The data comes from the Federal Reserve "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 saving deposits. We compute daily the weekly deposit growth at the bank level, compute the distribution and take the difference between the percentile 1 and the percentile 99 as a measure of dispersion. We keep the Wednesday value to make the daily consistent with all other time series.

Figure 8: Demand Liquidity Shocks



Note: FF Range refers to the federal funds range computed as the spread between the maximum and minimum interbank transaction rates reported by the New York Fed (PLEASE CHECK THIS IS CORRECT) 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 (basis points) 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). The data on dispersion of deposit growth is constructed from underlying data in the Call Reports, Federal Reserve "Report of Deposits and Vault Cash" (FR 2900), and the federal funds range is based on data from the New York Fed.

rates continue to be shaped by liquidity conditions even in a floor system with abundant reserves. These observations motivate a systematic framework to quantify how Fed balance-sheet operations transmit to money market spreads.

3 Methodology and Data

3.1 Data

Our empirical analysis uses weekly data from January 2003 to December 2023. The main source is the Federal Reserve's H.4.1 release, which reports balance sheet items at a weekly frequency as of each Wednesday. From this source we collect Treasury securities, agency debt, agency MBS, repos, swaps, reserves, reverse repos, and the Treasury General Account (TGA). Policy rates—the effective federal funds rate (DFF_t), the discount rate, and the interest on reserve balances (IORB)—are obtained from the Federal Reserve Board. We also use confidential data from the Federal Reserve "Report of Deposits and Vault Cash" (FR 2900) where respondents submit daily data once a week reflecting a Tuesday through Monday report week to derive a measure of liquidity. The series in the last two sources are available at a daily frequency but we retain only Wednesday observations to align them with the weekly H.4.1 data.

We construct two measures of heterogeneity in liquidity demand. The first is the federal funds range, defined as the spread between the maximum and minimum interbank transaction rates reported by the New York Fed. The second is the dispersion of deposit growth, derived from the daily distribution of seven-day deposit growth at the bank level.[2] We compute the distribution and take the difference between the percentile 1 and the percentile 99 as our measure of dispersion. For both measures, we retain Wednesday observations to match the weekly frequency of the H.4.1 release.

Our baseline measure of liquidity is the ratio of reserves to commercial bank deposits, expressed in percentage terms (see equation (1)). The numerator is total reserves from the H.4.1 release, while the denominator is deposits of all commercial banks, obtained from the Federal Reserve. 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 where reserves are net of loans to depository institutions, also 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.

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 informa-

[2] Our measure of deposits includes demand deposits due to the public, ATS and NOW accounts as well as saving deposits.

tion (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, where the latter equal one in weeks containing a FOMC meeting, to account for macroeconomic variation and institutional shifts.

3.2 Empirical Framework

The central challenge is to measure how liquidity conditions, shaped by the Federal Reserve's balance sheet, affect short-term money market spreads across monetary regimes. Our methodology proceeds in three stages, designed to separate identification, institutional behavior, and propagation.

First, we identify proxies for exogenous supply and demand shocks to liquidity. These shocks capture variations in reserves that are orthogonal to policy and allow us to trace causal effects rather than endogenous responses of the Federal Reserve to macroeconomic or financial conditions.

Second, we estimate the Federal Reserve's balance sheet rules, modeling how the System Open Market Account (SOMA) assets and liability instruments such as Securities, Repos and Reverse and Repos adjust to these shocks. This stage delivers variables that are orthogonalized with respect to exogenous liquidity shocks and to the simultaneity of offset operations. For example, when liquidity-providing actions are sterilized through concurrent withdrawals so that aggregate liquidity is unchanged. These orthogonalized components capture the independent operational choices of the Fed beyond mechanical balance sheet adjustments. From them, we construct an internally consistent liquidity ratio that summarizes the net liquidity injection or withdrawal effectively transmitted to the market.

Third, 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) together with the identified supply and demand shocks. This stage delivers fitted values of the changes in the liquidity ratio, which serve 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 money market spreads on these predicted liquidity conditions, thereby capturing the demand for reserves and quantifying how balance-sheet operations transmit to policy implementation. This two-step IV procedure isolates 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.

This three-stage framework ensures that we (i) isolate exogenous shocks, (ii) characterize the Federal Reserve's operational behavior through its balance sheet rules, and (iii) recover the demand for reserves and quantify how balance-sheet operations transmit to money market spreads.

Step 1: Identification of Liquidity-Demand and Liquidity-Supply Shocks. Liquidity conditions in U.S. money markets are shaped by both supply-side and demand-side factors. To disentangle these forces, we estimate auto-regressive models augmented with controls for Federal Open Market Committee (FOMC) events PD: Does "events" refers to the dates of the FOMC meetings? If yes, let's be more explicit about it. and seasonal effects.

We identify supply shocks from innovations in the Treasury General Account (TGA). The TGA is recorded as a liability on the Federal Reserve's balance sheet; increases in the account withdraw reserves from the banking system and reduce market liquidity, while drawdowns inject reserves and expand liquidity. Because these fluctuations reflect Treasury cash management rather than Federal Reserve policy decisions, they provide a natural source of exogenous variation in reserve supply.

We proxy demand shocks with two complementary measures: the cross-sectional dispersion of the federal funds rate ("FF Range"), which captures heterogeneity in access to interbank funding and counterparty frictions, and the cross-sectional dispersion of seven-day deposit growth ("Disp. Deposit Growth"), which reflects heterogeneity in banks' liquidity needs and demand for reserve balances.

Formally, each series is projected on its own lag, lagged FOMC dummies, and quarterly fixed effects:

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

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.[3]

PD: What does FAD stand for? Can we spell it out? Explain that the set of assets changes by regime. For each asset category (*Treasury Securities*, *Mortgage Backed Securities (MBS)*, *Federal Agency Debt (FAD) Securities*, *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 announcements, 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*, *Mortgage Backed Securities (MBS)*, *Federal Agency Debt (FAD) Securities*, *Repurchase Aggreements (Rep*
we estimate

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

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 announcements, and seasonal fixed effects:

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

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.

Goes here? Simplified version (SB)

The Federal Reserve's operating framework has undergone significant shifts over our sample. From January 2003 to October 2008, the Fed operated under a corridor system with scarce reserves, in which the effective federal funds rate was steered through open market operations and reserve supply was kept tight relative to banks' demand. In this limited-reserves regime, liquidity was managed primarily through outright purchases of Treasury

[3] Securities could include Treasury securities, federal agency debt securities, or MBS, according to the regime.

securities and temporary repo operations.

In October 2008, the Global Financial Crisis triggered the introduction of interest on reserve balances (IORB) and a sharp expansion of the Fed's balance sheet, marking the transition to an ample-reserves floor system. Within this broad regime, we distinguish two subperiods. The post-GFC phase (2008m11–2020m2) was characterized by sustained large reserve balances and a reliance on IORB to anchor short-term rates. During this period, new instruments became central to liquidity provision: large-scale purchases of Treasury Securities, Federal Agency Debt (FAD) Securities and Agency Mortgage-Backed Securities (MBS) drove the liquidity ratio, while reverse repos emerged as an additional tool to absorb reserves.

The onset of the COVID-19 crisis in March 2020 inaugurated a distinct regime of super-abundant reserves (2020m3–2023m12). This phase was marked by unprecedented balance-sheet expansion, emergency lending and liquidity facilities, and massive interventions in Treasuries and MBS markets. Reverse repos continued to be employed, but the overwhelming size of reserve balances and credit facilities defined the monetary framework during this period.

Separating the data into these regimes allows us to capture both the structural break associated with the shift from a corridor to a floor system in 2008, and the distinct dynamics introduced by the COVID-19 interventions after 2020. Estimating regressions separately across these periods provides insight into how the effectiveness of specific liquidity operations evolved as the Federal Reserve's toolkit expanded and the reserve environment changed. Rolling regressions complement this analysis by offering a continuous measure of how the sensitivity of spreads to liquidity shifted over time, beyond discrete regime boundaries.

Step 3: First-Stage IV: Instrumented Liquidity Ratio. The third stage 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 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)). PD: Luis please check this last paragraph

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):

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

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 stage, 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 ??? $\widehat{\text{Demand}}_t$ is the fitted series used to construct the demand shocks identified in Section 2.2???. PD: The end of this sentence is not clear. Where is $\widehat{\text{Demand}}_t$ coming from? Is this fitted X^{Demand} from equation 3 when using FF-Range)? There is nothing in Section 2.2. Let's explain this and adjust notation in Table 4

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.

4 Results

4.1 Demand Shock: Fed Funds Range

First Stage. Table 3 reports regime-specific first-stage estimates that map balance-sheet components and liquidity shocks into weekly changes in the liquidity ratio. Three main facts emerge. First, the effectiveness of traditional asset purchases is highly regime-dependent: a 1 percentage-point unexpected increase in Treasury purchases raises the liquidity ratio by an economically large amount in the Limited-Reserves sample (approximately a 10.2 percentage-point increase) but has much smaller point estimates once reserves are ample (close to a 1 percentage-point increase, with a somewhat stronger effect in the COVID-19 regime). Repos are also powerful liquidity providers under scarcity: an unexpected 1 percentage-point increase in repos leads to about a 2.1 percentage-point rise in the liquidity ratio. After 2008, MBS purchases emerge as a nontrivial source of liquidity-their impact is roughly 0.11 percentage points in the Ample regime and is larger in the COVID-19 subsample, broadly in line with Treasury securities. By contrast, FAD securities do not produce a statistically significant effect on liquidity-ratio growth, although their point estimates are positive and directionally consistent with other asset-side interventions.

Second, operations designed to absorb liquidity show the opposite pattern. Reverse repos carry sizeable and statistically significant negative coefficients after 2008: an unexpected 1 percentage-point increase in this liability leads to decreases of 0.11 and 0.27 percentage points in liquidity-ratio growth in the Post-GFC and COVID-19 regimes, respectively — consistent with their role as active drains. Importantly, prior to 2008, in the Limited-Reserves regime, this operation did not have a significant impact on liquidity.

Third, TGA buildups (negative liquidity-supply shocks) likewise reduce liquidity across regimes. However, the effect is not statistically significant in the Limited-Reserves sample; by contrast, in the Ample, Post-GFC, and COVID-19 regimes an unexpected 1 percentage-point increase in the TGA is associated with a statistically significant decline in liquidity-ratio growth of roughly $0.03 - 0.04$ percentage points. Figure 6 corroborates this timing: the TGA series is essentially flat before 2008 but exhibits substantial buildups and withdrawals during the Post-GFC and COVID periods, consistent with the detectable negative coefficients. Mechanically, TGA buildups withdraw balances from the banking system into the Treasury's account at the Fed, directly reducing reserves available to banks and thereby lowering the reserves-to-deposits ratio. The insignificance in the Limited-Reserves era likely reflects limited TGA variation and the dominance of conventional OMOs when reserves were scarce; conversely, in the Ample-reserves era fiscal drains generate statistically detectable impacts because (i) even relatively small proportional changes in the TGA imply sizable absolute withdrawals given large aggregate reserves, and (ii) operational linkages and market adjustments transmit these withdrawals to money-market liquidity. Finally, while each per-surprise effect is small, persistent or large TGA movements can accumulate and become economically meaningful for liquidity over longer horizons.

Fourth, movements in interbank dispersion (the fed funds range) have economically small coefficients on a per-basis-point scale but a sign that depends on the reserve regime. In the Limited-Reserves sample, the coefficient is positive, indicating that a 10-basis-point widening of dispersion raises the liquidity ratio growth by approximately 0.035 percentage points. This is consistent with tighter interbank funding conditions inducing banks to hoard reserves, thereby increasing the reserves-to-deposits ratio. However, after 2008, the coefficient flips sign. In the Ample and Post-GFC regimes, the coefficient is negative, suggesting that an increase of 10 basis points in the fed funds range leads to a decrease of 0.005 and 0.016 percentage points in the liquidity ratio growth, respectively. This reversal is plausibly driven by a change in what dispersion measures. Under scarcity, dispersion largely reflects demand shocks and precautionary hoarding. Conversely, under ample reserves, dispersion more often signals a lack of arbitrage or intermediary stress (dealer balance-sheet constraints, repo specialness, margin/collateral pressures) and is correlated with supply-side drains or policy absorbent activity (e.g., reverse-repo/ON-RRP spikes, TGA moves). In this environment, wider dispersion tends to accompany events that reduce usable reserves, resulting in a negative marginal effect on effective liquidity. Nevertheless, in the Covid-19 regime, we still observe a negative liquidity effect, but it is not significant.

Finally, explanatory power and instrument strength decline across regimes: adjusted R^2 falls from 0.63 in the Limited sample to 0.46 in Ample, 0.48 in Post-GFC and 0.39 in COVID, while first-stage F-statistics are 75.33, 34.02, 34.67 and 6.27, respectively. The results imply that the relevance condition is comfortably satisfied in the Limited, Ample and Post-GFC samples but not in the COVID subsample, indicating materially weaker instruments there. This pattern likely reflects two forces. First, the post-GFC and COVID eras feature greater operational heterogeneity and the concurrent use of multiple absorbent and provision tools, which reduces the share of variation in liquidity that any single orthogonalized instrument can explain. Second, the COVID window is short and dominated by large, contemporaneous balance-sheet interventions; even after orthogonalization, this simultaneity raises residual volatility and lowers first-stage precision. The practical implication is that nominally identical balance-sheet actions and market indicators of funding conditions, such as the fed funds range, transmit very differently to effective market liquidity depending on the institutional reserve environment, so regime differentiation is necessary to recover the economically meaningful transmission of Fed operations.

Table 3: First Stage Estimates by Regime (equation (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 ($u^{A,T}$)	10.1799**	0.9206***	0.5074**	1.2867***
	(5.06)	(0.25)	(0.25)	(0.29)
MBS ($u^{A,MBS}$)		0.1110***	0.1070***	0.2742**
		(0.03)	(0.03)	(0.13)
FAD Securities ($u^{A,FADS}$)		0.0268	0.0228	
		(0.03)	(0.03)	
Reverse Repos ($u^{L,RR}$)	0.1040	-0.1273***	-0.1371***	-0.0555
	(0.59)	(0.01)	(0.01)	(0.04)
Repos ($u^{A,Repos}$)	2.1239***			
	(0.09)			
Surprise TGA ($\varepsilon^{\text{Supply}}$)	-0.0493	-0.0284***	-0.0280***	-0.0382***
	(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**	-0.0038	-0.0041	-0.0046
	(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	33.99	35.27	6.16

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 $\varepsilon^{\text{Demand}}$ the demand and supply surprises from equation (3) when demand shocks are estimated with FF-Range.

Second Stage. The second-stage IV estimates in Table 4 show that our fitted liquidity ratio - constructed from first stage results - has a robust, negative effect on the normalized position of the federal funds rate within the Fed's administered corridor. In the regime estimates, the fitted liquidity coefficient is statistically significant and negative in all the regimes, with the effect peaking in the Post-GFC regime; the point estimates are -7.2320

(Limited), -9.1202 (Ample) and -27.1974 (Post-GFC), while the COVID-era point estimate is smaller in magnitude and only weakly significant (-7.4716). For example, if we take the Post-GFC regime, we have that an increase of 1% in the ratio Reserves/Deposits leads to a decrease of 0.271 percentage points, which aligns with the results from (Lagos and Navarro, 2023)[4]. These patterns are economically sensible: when reserves are scarce, conventional asset purchases and repos exert measurable but modest effects on the funds-rate position, whereas after 2008, the same proportional changes in reserves translate into substantially larger re-positioning of the funds rate toward the floor.

The fed-funds range affects the spreads ratio through an indirect channel operating via the liquidity ratio and a direct channel capturing residual dispersion effects. In the Limited-reserves regime, the two channels move in opposite directions: a widening of the range increases the liquidity ratio (first stage), and higher liquidity lowers spreads, producing a negative indirect effect, while the direct effect of dispersion is positive and significant (i.e. a 1 basis point increase in FF Range raises the Spreads Ratio by 0.20 percentage points), reflecting that scarce reserves magnify the role of poor liquidity distribution. By contrast, in the Ample and Post-GFC regimes, the indirect effect is positive-greater dispersion is associated with lower liquidity and thus higher spreads-while the direct effect is negative but statistically insignificant, consistent with the buffering role of abundant reserves and the IORB floor. Finally, in the Covid-19 regime, the same sign pattern emerges, but the direct effect is significantly negative and dominates, reflecting that in an environment of superabundant reserves and intensive Fed interventions (ON-RRP, TGA, SRF), widening dispersion tends to anchor the EFFR closer to the floor of the corridor.

Finally, the explanatory power of the second stage varies markedly across regimes: the adjusted R^2 is 0.22 under Limited reserves, while within the Ample-reserves period it differs sharply-rising to 0.73 in the Post-GFC subperiod but falling to only 0.13 during Covid-19-yielding an aggregate fit of just 0.01 for the full Ample window. This pattern indicates that the model explains spreads well under reserve scarcity and in the immediate post-crisis years, but far less during the later phase of super-abundant reserves.

[4] 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, $\delta_1^{Post-GFC} = -27.1974$, a \$1 bn increase in reserves (holding deposits fixed) implies $\Delta SpreadsRatio/\$1\text{bn} \approx \delta_1^{Post-GFC} \times \frac{1}{R_0} = -27.1974/1,568.26 \approx -0.01734$ 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 $\triangle(\text{DFF} - \text{IORB}) \approx (\text{DWR} - \text{IORB})/100 \cdot \triangle\text{SpreadsRatio}$. 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) post-GFC estimate ($\gamma \approx -0.0119$; their dependent variable is EFFR - IOR in basis points per \$1 bn).

Table 4: Spreads Ratio Estimates by Regime (equation (8))

	Limited Regime	Ample Regime	Post-GFC Regime	Covid-19 Regime
	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio
Liq. Ratio Est.	-7.2320***	-9.1202***	-27.1974***	-7.4716*
	(2.73)	(2.40)	(0.76)	(3.85)
FF Range Est.	0.2009***	-0.2307	-0.0175	-0.2154**
	(0.06)	(0.31)	(0.09)	(0.10)
Constant	54.5281***	83.4791***	120.5624***	117.0557***
	(3.57)	(9.85)	(2.99)	(12.91)
N	302	779	582	196
Adj. R-squared	0.22	0.01	0.73	0.13

Standard errors in parentheses

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

4.2 Demand Shock: Dispersion of Deposit Growth

First Stage. Table 5 illustrates the first-stage, where the demand shock proxy is unexpected fluctuations in the dispersion of deposit growth. As we observe, the majority of the results align with those presented in Table 3. Nevertheless, when the cross-sectional dispersion of deposit growth (DDG) spikes, it signals uneven deposit flows-some banks face outflows while others do not. Under Limited reserves, such dispersion tends to drain systemwide usable reserves: stressed banks settle payments and meet withdrawals by drawing on reserves or liquidating assets, and some flows migrate to money funds, so the aggregate liquidity ratio falls (negative and significant), even if a few strong banks hold more cash. This mechanism 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. Importantly, in both Limited and Post-GFC the DDG coefficients are economically tiny—statistically detectable but close to zero—so deposit-dispersion shocks operate as marginal liquidity drains compared with the larger movements captured by other drivers.

Second Stage. In Table 6, we presented the second-stage IV estimates of this specification. These results align with Table 4, except that we don't find a significant impact of the liquidity ratio in the Covid-19 regime and the ample reserves regime. In the Limited regime, DDG shocks drain liquidity (indirect channel positive) and also raise spreads through deposit-

Table 5: Liquidity Ratio Estimates by Regime (equation 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 ($u^{A,T}$)	3.5206	0.9411***	0.5777**	1.2816***
	(4.48)	(0.25)	(0.25)	(0.28)
MBS ($u^{A,MBS}$)		0.1121***	0.1084***	0.2879**
		(0.03)	(0.03)	(0.13)
FAD Securities ($u^{A,FADS}$)		0.0251	0.0185	
		(0.03)	(0.03)	
Reverse Repos ($u^{L,RR}$)	0.2226	-0.1289***	-0.1429***	-0.0526
	(0.59)	(0.01)	(0.01)	(0.04)
Repos ($u^{A,Repos}$)	2.1769***			
	(0.09)			
Surprise TGA ($\varepsilon^{\text{Supply}}$)	0.0041	-0.0287***	-0.0286***	-0.0395***
	(0.20)	(0.00)	(0.00)	(0.01)
Surprise Disp. Deposit Growth ($\varepsilon^{\text{Demand}}$)	-0.0003*	-0.0000	-0.0000**	0.0000
	(0.00)	(0.00)	(0.00)	(0.00)
L.FOMC	0.1415**	-0.0037	-0.0044	-0.0038
	(0.07)	(0.00)	(0.00)	(0.00)
Constant	0.0140	0.0070***	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	75.33	34.02	34.67	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 $\varepsilon^{\text{Demand}}$ the demand and supply surprises from equation (3) when demand shocks are estimated with the dispersion in the distribution of deposit growth.

side segmentation (direct channel positive). Both effects reinforce each other, so dispersion in deposit growth is a strong signal of tightening. By contrast, FF Range shocks raise measured liquidity (indirect channel negative) but simultaneously worsen its distribution (direct channel positive). This offsetting structure means FF Range combines "more liquidity in the aggregate but poorly allocated", whereas DDG is "less liquidity in the aggregate and poorly allocated". The difference arises from what each proxy captures under scarcity: DDG tracks quantity pressures from uneven deposit flows (withdrawals/reallocation at stressed banks), which mechanically reduce systemwide reserves; FF Range tracks price dispersion in interbank funding that triggers precautionary hoarding, lifting the aggregate liquidity ratio even as redistribution frictions prevent reserves from reaching the banks that most need them.

In the Post-GFC regime, the two measures look more alike: both reduce liquidity and thus have a positive indirect effect; but while DDG still has a small positive direct impact (deposit heterogeneity pushes EFFR up), FF Range's direct effect is statistically weak, implying that deposit imbalances were more salient than interbank price dispersion. The similarity arises because once reserves became ample, precautionary hoarding was no longer the dominant response to dispersion. Instead, both uneven deposits and wider spreads in interbank quotes pointed to reserves being passively parked at the Fed (IORB/ON-RRP) or siphoned by nonbank intermediaries, effectively reducing liquidity in circulation. Thus, under abundance, both DDG and FF Range captured comparable mechanisms of "reserves abundant in aggregate but less available for trading", unlike the offsetting logic that prevailed under scarcity. In the Covid-19 regime, neither channel of DDG is operative-deposit dispersion carries no explanatory power-while FF Range turns significantly negative, consistent with policy facilities (ON-RRP, TGA, SRF) anchoring the EFFR near the floor. In the Ample aggregate window, which includes both Post-GFC and Covid-19 regimes, DDG retains a positive direct effect even without an indirect channel, while FF Range remains flat, underscoring that variation in deposit growth across banks mattered more than interbank price dispersion in explaining spreads under abundant reserves.

Table 6: Spreads Ratio Estimates by Regime (equation (8))

	Limited Regime	Ample Regime	Post-GFC Regime	Covid-19 Regime
	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio
Liq. Ratio Est.	-8.5019***	-2.9296	-26.6709***	0.8994
	(2.50)	(2.49)	(0.82)	(2.35)
Disp. Deposit Growth Est.	0.0386***	0.0439***	0.0028*	-0.0055
	(0.01)	(0.01)	(0.00)	(0.00)
Constant	-10.1834	-8.2584	114.4371***	98.4297***
	(25.03)	(15.88)	(4.18)	(9.87)
N	302	780	582	197
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 Rolling Regressions Results

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. Figures 9-11 show the Spreads Ratio against the liquidity ratio with the fitted values from the rolling estimates using the two demand proxies (FF Range and Dispersion of Deposit Growth). Taken together, the two regimes trace out a stylized S-shaped demand curve: relatively flat under limited reserves, a sharp slope in the post-GFC environment, and flattening again once reserves become abundant and the effective rate is anchored near the floor.

The rolling exercise both replicates and refines the regime results from the in-sample analysis: coefficients rise markedly in magnitude after the GFC but do so continuously over time rather than only at discrete regime breaks, indicating a time-varying and level-dependent reserve semi-elasticity. Because the pattern emerges with both demand proxies and after winsorization, it is unlikely to be driven by a single instrument or by outliers. The key policy implication is that identical reserve injections produce very different outcomes depending on the system's initial reserve position-smaller marginal effects under scarcity, larger effects post-GFC, and muted effects under full abundance-so policy calibration and theoretical models should allow reserve elasticities to vary with the level of reserves.

Figure 9: Estimated Reserve Demand: Fed Funds Range as Demand Shock

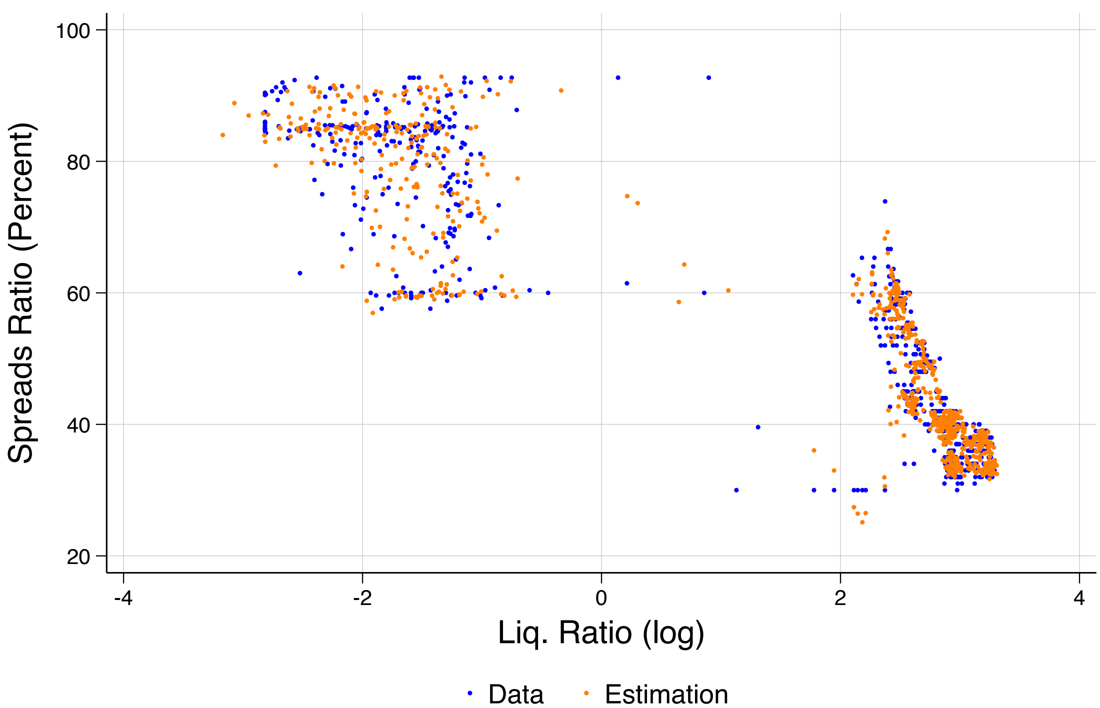
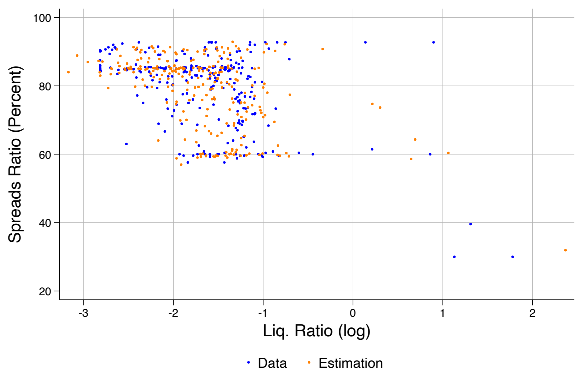
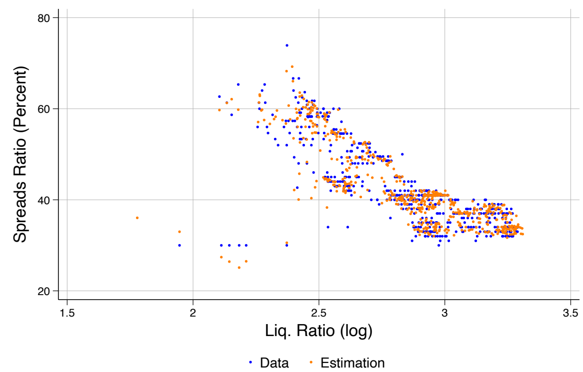


Figure 10: Estimated Reserve Demand: Fed Funds Range as Demand Shock

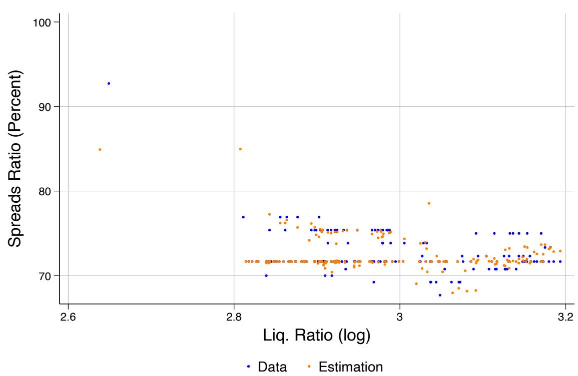
(a) Panel A: Limited Reserves Regime



(b) Panel B: Post-GFC Regime



(c) Panel C: Covid-19 Regime



(d) Panel D: Limited Reserves and Post-GFC Regimes

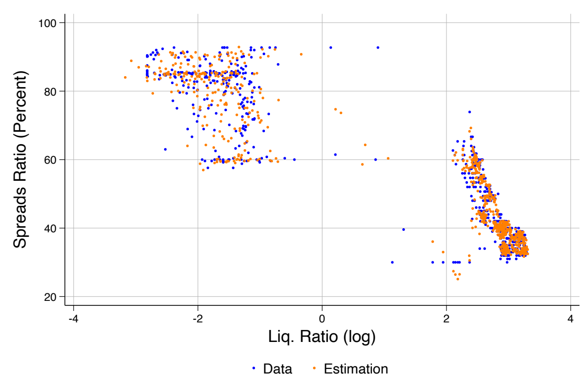
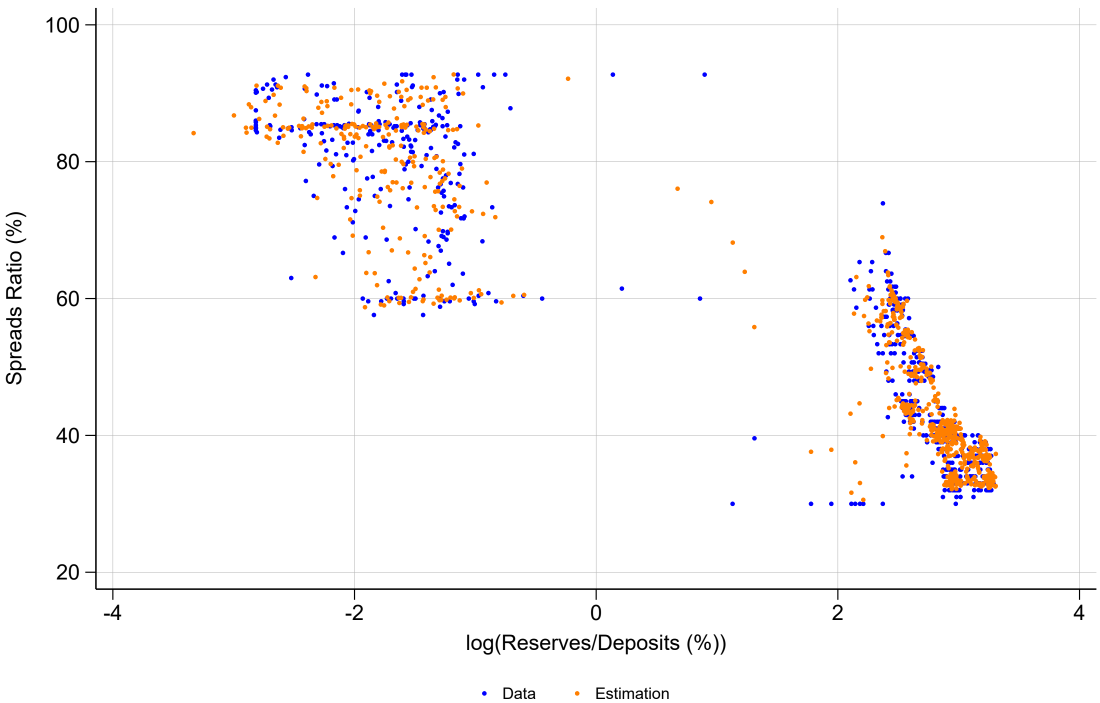


Figure 11: Estimated Reserve Demand: Dispersion of Deposit Growth as Demand Shock



6 Conclusions

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implications for operations in an ample-reserves environment.

Appendix

Table 7: Historical Demand for Reserves Regressions

	Limited Regime	Post-GFC Regime	Covid-19 Regime	Full Sample
	Spreads Ratio	Spreads Ratio	Spreads Ratio	Spreads Ratio
log_liq_ratio	-9.66***	-20.41***	-3.32***	-5.72***
	(0.80)	(1.15)	(1.29)	(0.08)
Constant	59.68***	101.15***	82.30***	67.99***
	(1.51)	(3.29)	(3.98)	(0.37)
N	1517	2965	1360	5842
Adj. R-squared	0.25	0.29	0.08	0.36

Standard errors in parentheses

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

Note: "Post-GFC" refers 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 y the Fed's administered rates presented in equation (2). The statistics were computed based on weekly data (Wednesday values). Source: Federal Reserve Bank of St. Louis FRED.