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The Pre-Crisis Monetary Policy Implementation Framework

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Abstract

This article describes the Federal Reserve's monetary policy operating framework prior to the expansion of the Fed's balance sheet during the financial crisis. To implement the Fed's mandate of promoting price stability consistent with full employment, the Federal Open Market Committee (FOMC) sets a target for the overnight rate in the federal funds market, where banks trade reserve balances. In the pre-crisis framework, aggregate reserves were scarce such that relatively small changes in the level of reserves would affect rates in the fed funds market. The New York Fed's open market trading desk ("the Desk") forecasted demand for and supply of reserves on a daily basis, and then conducted repo operations with primary dealers to supply enough reserves to maintain the equilibrium rate close to its target. The Desk was successful in achieving this objective; the fed funds rate generally remained close to its target, and any deviations were quickly corrected. However, the pre-crisis operating procedures deployed were more complex and opaque than alternative operating frameworks, required substantial intraday overdrafts from the Fed to meet banks' short-term payment needs, and had to be abandoned once the Fed's balance sheet expanded in response to the financial crisis. Since the crisis, the Desk has successfully controlled the policy rate using a new framework, suggesting that effective monetary control may be achieved through a different framework.

Key words: Fed, monetary policy framework, pre-crisis

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1. Introduction

The Federal Reserve's (Fed's) monetary policy operating framework changed during the financial crisis of 2007-2009. This is because the Fed implemented an accommodative monetary policy to facilitate economic recovery from the crisis by substantially increasing the amount of reserves in the banking system and by reducing interest rates close to zero (Bech and Klee (2011)). By comparison, in the pre-crisis period, the supply of reserves was relatively scarce. The aim of this article is to assess the Fed's monetary policy framework prior to the crisis, in order to better understand the changes in monetary policy implementation since the crisis.

A monetary policy framework is a means of implementing a central bank's monetary policy and consists of an operational target and an operating framework for achieving the target. The Fed's statutory mandate in conducting monetary policy is to promote price stability consistent with full employment.[2] To implement its mandate, the Federal Open Market Committee (FOMC) sets a target for the overnight rate in the fed funds market where banks trade reserve balances or "reserves" (which are deposits held by banks with the Fed).[3] Changes in the fed funds rate are, in turn, expected to be transmitted to other interest rates and, ultimately, the real economy. The operational framework consisted of monetary policy instruments (mainly conducting open market operations or OMOs) and procedures for using these instruments to encourage banks to trade fed funds near the stated target rate. The New York Fed's Open Market Trading Desk (the "Desk") carried out OMOs to keep the overnight fed funds rate close to its target on a daily basis.

The fed funds market represents the market for bank reserves. Fluctuations in the fed funds rate reflected changes in the demand for and supply of reserves. The demand for reserves arose mainly from banks' need to meet uncertain intraday payment flows, after satisfying minimum reserve requirements. As there was no interest paid on reserves, banks wished to minimize their reserve holdings. The aggregate demand for reserves was interest rate-sensitive as reserves were scarce---the Fed supplied only a small amount of reserves in excess of what banks were required to hold in the aggregate. The daily variation in the supply of reserves was mainly determined by so-called autonomous factors (such as currency in circulation) outside the direct control of the Fed. Therefore, the Desk's job was to forecast the evolution of the autonomous factors and the demand for reserves and, on an ex-ante basis, supply enough reserves to keep the market for reserves balances in equilibrium. The aggregate amount of reserves was distributed to individual banks through the fed funds market.

We show in this paper that the Desk was generally successful in the pre-crisis period in achieving its primary objective of meeting the fed funds target. Overnight rates were generally close to the target fed funds rate even during periods of relatively high liquidity demand. Further, when the fed funds rate on occasion deviated from its target (such as at the end of quarters), it reverted back to the target within a day or two. Finally, fed funds rate changes were quickly transmitted to other overnight money market rates.

[2] In addition, the mandate requires the Fed to maintain moderate levels of the long-term interest rate (BOG, 1994).
[3] In this article, we use "bank" to mean a "depository institution." Technically, they are not equivalent since some non-bank intermediaries, such as credit union or a savings and loans association, can also take deposits.

In addition to the primary objective of controlling its operational target, a central bank might consider additional criteria to evaluate the effectiveness of its operational framework: efficiency (i.e. meeting objectives with as few resources as possible), transparency (i.e. operating in a manner well understood by market participants), universality (i.e. being able to implement monetary policy under a range of economic conditions) and promoting financial stability (ensuring that the operational framework does not impair market functioning).[4]

While the pre-crisis framework was successful in meeting its monetary objectives, the operational procedures were complex and opaque. The framework relied on a discretionary and interventionist approach (Logan, 2017) based on daily management of the supply of reserves that required detailed market intelligence and expert judgement (Bernanke, 2005). The Desk had to provide daily forecasts of reserve demand and supply over multiple days and to conduct repo or reverse repo operations on an almost daily basis. Reserve demand was difficult to forecast daily and, even predictable changes required OMOs on most days (Logan, 2017). Forecasting the autonomous factors that caused daily variations in reserves supply was also challenging. Liquidity management in such a framework appears more complex than in a symmetric corridor system with standing deposit and lending facilities, as operated by some other central banks.[5] The system also lacked transparency as the Fed did not publish its forecast of autonomous factors unlike other central banks (Hilton (2008)). Regarding universality, the pre-crisis operational framework faced difficulties in the post-crisis environment when reserves demand became highly volatile (Hilton (2008)). And, supplying reserves to meet forecasted demand became impractical post-crisis when the amount of reserves in the banking system exceeded reserve demand by a wide margin.

Turning to the goal of not impairing financial market functioning, we first focus on payments systems functioning. In particular, the Fed routinely extended large amounts of (sometimes unsecured) intra-day credit to banks in the pre-crisis period to meet payment system demands, for a fee. As banks needed these funds for only a few hours a day, they did not find it cost effective to borrow overnight in the fed funds market. While these daylight overdrafts were necessary to facilitate payments, they also exposed the Fed to the potential for loss. Moreover, the need to avoid overdrafts and meet reserve requirements, combined with no interest on holding reserves, implied that banks' cash management system was rather costly (Logan, 2017).

The Fed affected financial markets in two other areas: asset eligibility criteria for OMOs and money market functioning Assets that were eligible for purchase by the Desk, including repo operations, may benefit from enhanced liquidity and the ability to obtain central bank credit as compared to ineligible assets. As the Fed accepts only highly liquid assets in its open market operations, including Treasury and agency securities, any distortionary effects on asset prices were likely minimized. Regarding money

[4] There is no consensus in the literature as to the appropriate goals of a monetary policy framework. Our explication is loosely based on Bindseil (2014) who also discusses additional objectives that we do not consider. For example, as part of financial objectives, Bindseil (2014) includes adequate risk-adjusted financial returns on central bank assets.

[5] In a symmetric corridor system, the target rate lies in the middle of the rates for the standing lending and borrowing facilities. The benefits of such a system for liquidity management are discussed in section 5.

market functioning, the scarcity of reserves balances prior to the crisis (relative to the required and precautionary demand for reserves) resulted in large trading volumes in the fed funds market as, toward the end of the trading day, banks with surplus reserves had an incentive to trade with banks with too few reserves. While it is unclear if an active fed funds market should be a goal of a monetary policy framework, it likely facilitated both rate discovery (i.e. the determination of an equilibrium rate via trading) and the quick transmission of the target rate to related money markets.

The article is organized as follows. The first section discusses the basic economic premise underlying the pre-crisis framework, followed by how rate determination in actuality deviated substantively from the textbook example. The second section details how the framework was implemented in practice, which includes a description of the role of the reserve maintenance period. The third section discusses the effectiveness of the framework in meeting the primary monetary policy objectives. The fourth section evaluates how well the framework met the objectives of operational effectiveness and financial stability. The final section concludes with a brief summary and remarks on some aspects of the pre-crisis framework that have changed since the crisis.

2. The Economics of the Pre-Crisis Monetary Policy Operating framework

In this section, we discuss the economic foundation of the monetary policy operating framework in terms of the demand for and supply of reserves. We show that the pre-crisis monetary regime can be viewed as managing the supply of reserves so that equilibrium is maintained on the steeper, relatively inelastic portion of the demand curve for reserves. However, we further note how the actual framework deviated significantly from this idealized model.

Figure 1: The Market for Reserves

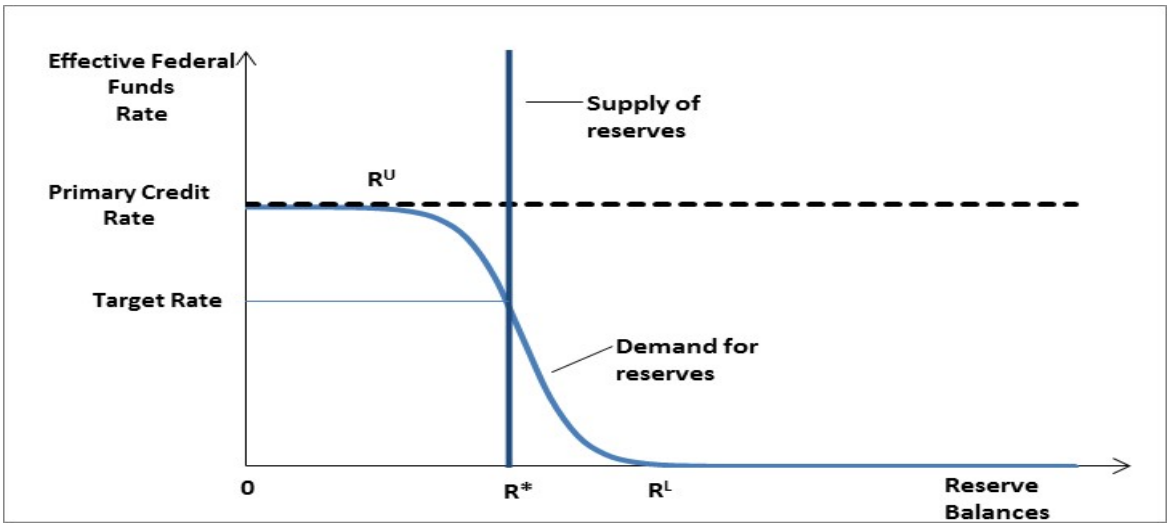


Figure 1 plots the aggregate demand for reserves, with the horizontal axis representing the total reserve balances of banks while the vertical axis represents the effective fed funds rate (EFFR), calculated as a

volume-weighted average rate of each business day's fed funds transactions.[6] A target EFFR was the primary monetary policy tool of the Fed prior to the crisis. In the fed funds market, banks traded reserves with each other on an unsecured basis, typically with an overnight tenor. The supply of fed funds was determined exogenously (from the point of view of market participants) by the Federal Reserve, which, through open market operations, targeted a specific amount of reserves R^* on a daily basis in order to meet the Desk's forecast of reserve demand.

The demand for reserves is downward sloping, reflecting the opportunity cost of holding reserves, except at the ceiling R^U and floor R^L of the EFFR, where it is flat (Keister, Martin and McAndrews 2008). Reserve requirements necessitated that banks hold minimum reserve balances on average (as a percentage of their net transaction accounts) in their accounts with Federal Reserve Banks. However, due to the uncertainty of payment flows, banks could not meet their requirements exactly. In deciding how much of additional reserves to hold, banks had to balance the income foregone from holding excess reserves against the cost of borrowing fed funds at the EFFR. Higher levels of the EFFR increases the opportunity costs of holding reserves and reduce the demand for reserves.

The demand for reserves is flat at the lower and upper bounds of the EFFR. The lower bound for the EFFR was zero as banks had no incentive to lend reserves at a negative rate, since they could earn zero interest by simply keeping reserves in their Fed account (Figure 1). At R^L, where the demand curve intersects the horizontal axis, banks hold sufficient reserves to meet all possible payment needs. Thus, banks are indifferent to holding any reserves to the right of R^L because the opportunity cost of holding reserves is zero. Since the discount window's primary credit facility is an alternative to the fed funds market as a source of reserves for financially sound banks with adequate collateral,[7] the primary credit rate (which exceeds the target rate) acts as the upper bound above which banks would not borrow in the fed funds market.[8] When the EFFR equals the primary credit rate, banks are indifferent between holding reserves and borrowing at the discount window and so the demand curve is flat to the left of R^U.

Before the crisis, the Federal Reserve carried out monetary policy by operating in the downward sloping region of the demand curve for reserves. This implies that the Fed raised rates by draining reserves (decreasing supply) and lowered rates by adding reserves (increasing supply) to the system. Empirically, in a simple plot of the effective federal funds rate against excess reserves (both averaged over

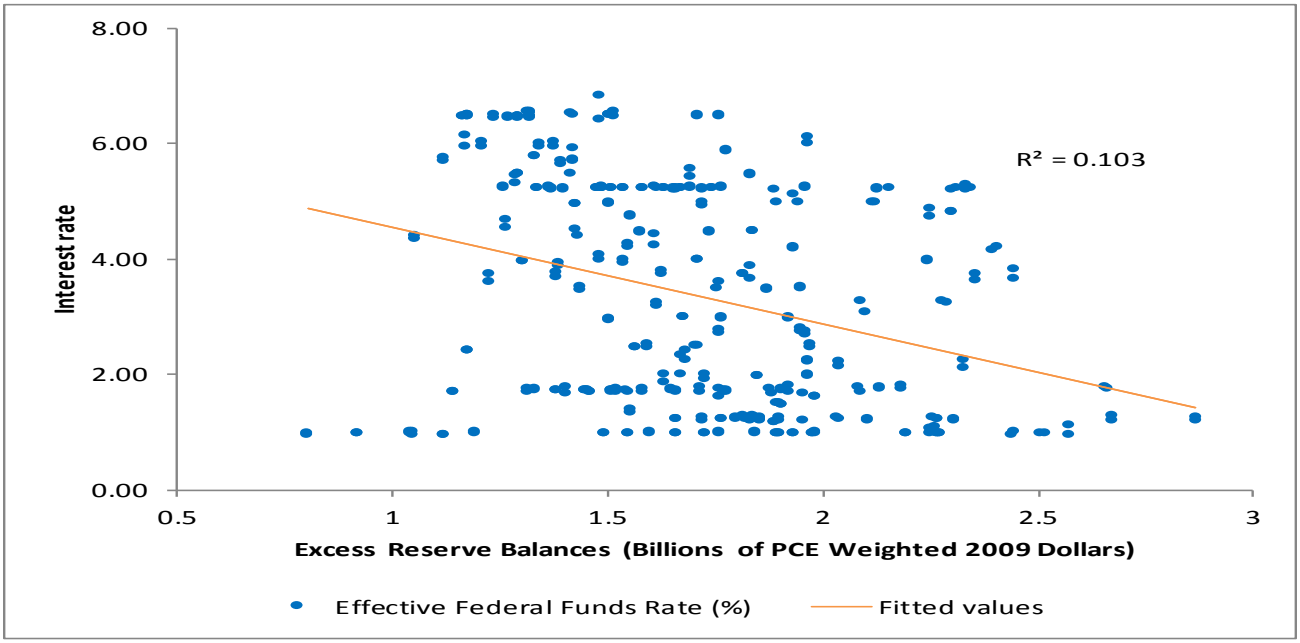
[6] As the market fed funds rate varied from trade to trade depending on the creditworthiness of borrowers and other factors, the Fed used a weighted average of market rates as its policy target. Prior to March 1, 2016 the EFFR was calculated as a weighted average based on fed funds transactions as reported to the Desk by fed funds brokers. Effective March 1, 2016, the EFFR calculation was changed from a weighted average mean to a volume weighted median and the source data was changed to the FR 2420 report. The EFFR is published by the Desk in the morning of the business day following the day of the report.

[7] Under Regulation A on January 9 2003, financially strong and well-capitalized banks can borrow under the Fed's primary credit program at a penalty rate above the target fed funds rate (rather than a subsidized rate as was the case prior to this regulation).

[8] In reality, the stigma associated with borrowing from the Fed deters banks from using the facility, resulting in some borrowing at market rates in excess of the primary credit rate (Armantier et al. (2015) and Furfine (2001)). Prior to 2003, discount window borrowers had to satisfy the Fed that it had exhausted private sources of funding and that it had a genuine business need for the funds, which likely contributed to stigma. Since 2003, the discount window has been a "no questions asked" facility but stigma has continued to exist.

maintenance periods---a two-week time period over which reserve requirements are applied), the fitted relationship is negative and statistically significant (Figure 2).

Figure 2: The Empirical Relation between Excess Reserve Balances and the EFFR: 2000-2007



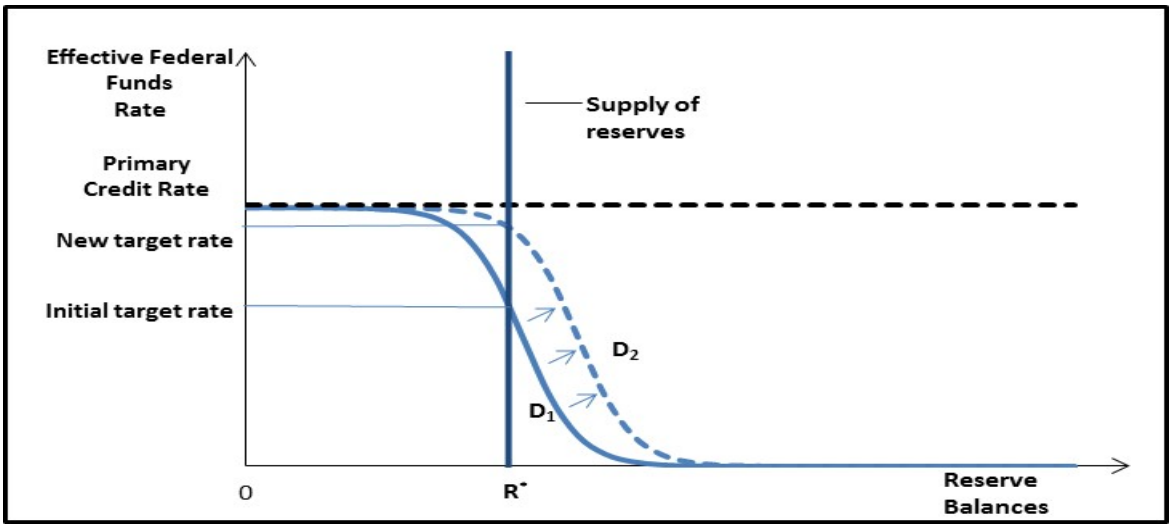
Time Period: 1/1/2000 to 7/1/2007
Source: The Federal Reserve Bank of St. Louis, Authors' Calculations
Note: Maintenance period averages; exceptionally high reserve balance periods dropped, such as the period around 9/11/2001

However, as Figure 2 notes, excess reserve balances explain only 11 percent (R-squared=0.11) of the variation in the fed funds rate. The high level of noise in the relation between rates and reserves in the data indicates that, in practice, the relationship between reserve balances and the fed funds rate is more complicated than the stylized theory illustrated in Figure 1 (as also noted by Judson and Klee, (2010)). One complication is that the distribution of reserves across banks matters. Since larger institutions traded excess reserve balances more actively than smaller institutions, a temporary concentration of reserves in large institutions could entail lower rates. Therefore, the aggregate amount of reserves was not the only variable that mattered. Nevertheless, Ennis and Keister (2008) show how the basic conclusions from the simple analysis do not change even after accounting for bank heterogeneity.

An additional complication is that the demand for reserves likely shifts over time, due to both long-term changes in the need for liquidity (for example, due to technological and regulatory changes) and short-term fluctuations in liquidity needs and expectations of rate changes throughout the maintenance period. For instance, Carpenter and Demiralp (2006a) present evidence of increases in bank reserve demand in expectation of an FOMC rate increase, illustrated as the shift from D_1 to D_2 (Figure 3). These demand movements complicate the relationship between the Desk's actions and changes in the fed

funds rate since the EFFR can move in the absence of any intervention by the Desk. Several researchers have identified the demand curve more precisely by estimating unexpected shocks to the supply of reserves (see Hamilton (1997), Carpenter and Demiralp (2006b), and Judson and Klee (2010)).

Figure 3: Shifts in the Demand for Reserves



3. Conduct of Monetary Operations in the Pre-Crisis Era

Just as the actual shifts in the demand for reserves occurred for reasons absent in the stylized model, the day-to-day implementation of monetary policy also involved additional complications beyond those discussed earlier. For example, in managing daily liquidity, the Desk had to account for variations within a reserve maintenance period. [9] Depository institutions only had to maintain the required reserve balance *on average* over the reserve maintenance period. The task of the Desk was to accurately forecast the supply and demand for reserve balances for each day of the two-week maintenance period, adjusting it daily based on market conditions and the distribution of reserves among banks. In the remainder of this section, we describe the maintenance period structure and the Desk's forecasting exercise.

The reserve maintenance period

Reserve maintenance periods begin on a Thursday and end on the second Wednesday thereafter. Some smaller depository institutions have a weekly maintenance period. Reserve requirements and the portion that is satisfied with cash holdings (vault cash) are calculated before the start of each reserve maintenance period (known as "lagged reserve accounting"). In order to allow depository institutions greater flexibility in maintaining account balances, banks' holdings of reserve balances are averaged

[9] Theoretical models that incorporate a reserve maintenance period include Gaspar and Rodrigues-Mendizabal (2004) and Ennis and Keister (2008).

over these two weeks in determining whether or not banks' reserve holdings met requirements.[10] Averaging allowed banks to effectively manage unexpected payment shocks which would cause them to hold too few or too many reserves relative to requirements on any given day in a maintenance period. Since the flexibility offered by averaging diminishes as the number of remaining days in a maintenance period declines (until they have no flexibility on the maintenance period settlement day), banks generally tended to hold relatively few balances early in a maintenance period in order to maximize their flexibility in absorbing payment shocks later in the period. Another feature of the reserve maintenance period that helped smooth volatility of the EFFR towards the end of the period was the ability of depository institutions to carry over (subject to restrictions) excess balances from one maintenance period to the next. This ability reduced distortions that could result from the incentive to offload excess reserves in the last few hours of the maintenance period.

The Desk's forecasts and operations

In order to ensure that rates remained responsive to changes in reserves, the Desk typically left a "structural deficit" in the banking system. In other words, the Desk left the total amount of reserves backed by outright Treasury purchases (i.e. purchasing Treasury securities in the secondary trading markets) just below the level of aggregate reserves required by the banking system. Maintaining a structural deficit helped the Desk efficiently interact with its primary dealer counterparties. As primary dealers are the Desk's traditional counterparties, and dealers are natural seekers of funding and providers of collateral, it was more effective to maintain a repo book of variable size with the dealers than maintaining a reverse repo book, as dealers typically had limited capacity to invest funds / receive collateral.

An implication of the "structural deficit" was that the Desk effectively faced a downward sloping demand for reserves (Figure 1). Further, the practice of not paying interest on reserves meant that banks were highly sensitive to the opportunity cost of holding reserves—in other words, the slope of the demand curve was relatively steep. Given its forecasts of the demand for reserves and of changes in the supply of reserves, the Desk would fine-tune the level of reserves by conducting daily repo operations, thereby adding reserves to or subtracting reserves from the system. This procedure, if successfully carried out, ensured that the EFFR remained close to the target rate on a daily basis. The aggregate reserves were then redistributed within the banking system as reserve-deficit banks traded with reserve-surplus banks in the fed funds market.

The demand for reserves had three components: required reserves, contractual clearing balances and "excess" reserves to meet intraday payment flows (Figure 4). For example, in 2004, required reserves averaged $11 billion, contractual clearing balances were $10.4 billion and excess reserves were $1.6 billion (BOG, 2005). Banks are required to hold reserves against transactions deposits, which are

[10] In practice, the Desk managed reserve levels to meet Required Operating Balances which were equal to reserve requirements plus contractual clearing balances which were amounts that some banks voluntary held at their Reserve Banks to defray the cost of Federal Reserve services (further discussed below). For simplicity, we refer to "required operating balances" as "reserve requirements" for the remainder of this article.

Figure 4: The Market for Balances at the Federal Reserve Before 2007

Required reserve balances
- held to satisfy reserve requirements
- do not earn interest

SOMA securities portfolio
- holdings of U.S. Treasury and Agency MBS securities and repurchase agreements

Contractual clearing balances
- held to meet contractually agreed-upon amount
- generate earnings credits that defray cost of Federal Reserve priced services

Discount Window Loans
- credit extended to depository institutions through discount window

Excess reserves
- held to provide additional protection against overnight overdrafts and reserve or clearing balance deficiencies

Autonomous factors
- other items on the Federal Reserve's balance sheet such as Federal Reserve notes, Treasury's balance at the Federal Reserve, and Federal Reserve float

checking accounts and other interest-bearing accounts offering unlimited checking privileges. In practice, changes in required reserves reflected changes in transactions deposits as the Fed rarely changed the required reserves ratio (BOG, 2005).

Some banks voluntarily held significant levels of contractual clearing balances at their Reserve Banks, in addition to their required reserve balances. Clearing balances also provided banks with increased flexibility in holding reserves across the maintenance period. Banks were compensated on their clearing balances based off of three-month Treasury bill rates. However, the income credits could only be used to defray the cost of Federal Reserve services such as check clearing and Fedwire services, thus limiting their value (Hilton (2008)). Penalties apply if a bank has not accumulated enough balances over a two-week maintenance period to meet its reserve requirements and clearing balance obligations, or if it ends any day overdrawn in its Fed account (Hilton (2008)). Therefore, the sum of reserve requirements and contractual balances created a predictable level of demand for reserves.

"Excess reserves" is the amount of reserves that banks held in excess of required reserves and contractual balances to meet unexpected intraday payment needs that otherwise might create an intra-day or overnight overdraft on its account. The daily demand for excess reserves was the least predictable element of the demand for reserves since it depended on the volume and volatility of daily payment flows (BOG, 2005). Average reserve balances in 2006 were about $17.5 billion, of which excess reserves were $2.0 billion. The total level of reserves was quite small relative to daily payment flows, which had significant implications for the ability of banks to meet payment needs during the day, as we discuss below in Section 5 and in Box 6.

Using reserve requirements along with the forecasted demand for liquidity, the Desk forecasted the average excess reserves over a maintenance period based on expectations that different types of banks typically hold different levels of reserve balances. In particular, small banks with limited access to funding markets demanded some level of excess reserves each day, typically between $1.5 billion and $2 billion, as a cushion against liquidity shocks (Hilton (2008)). The Desk had to take account this component of reserve demand in its daily calculations of reserve supply needed to maintain equilibrium in the fed funds market.

The Desk estimated total reserve demand for the entire 14-day maintenance period. For example, if the Desk observed that a bank already held more reserves than it needed to meet its requirement for the entire maintenance period, a situation known as a "lock in," then the Desk would increase its estimate for excess reserve demand for that specific maintenance period (since the "locked in" reserves are not available to be lent to banks with a reserves deficit). In addition, for each day of the maintenance period, the Desk estimated reserves demand based, in part, on the maintenance period-to-date distribution of reserve holdings.

There are three sources of the supply of Federal Reserve balances to banks: The Fed's portfolio of securities and repurchase agreements; loans through the Fed's discount window facility; and liabilities on the Fed's balance sheet that are outside the Desk's control known as autonomous factors (Figure 4). The securities portfolio--which consisted of outright purchases of securities and repurchase agreement

operations (repos) -- was the most important source of reserve supply. Discount window lending was the least important, since banks rarely borrowed from the facility. For example, no discount window loan was outstanding on the Fed's balance sheet on August 8 2007, the start of the financial crisis (Hilton (2008)). Autonomous factors caused large daily variations in the supply of reserves. Major autonomous factor categories are currency-in-circulation, the Treasury's balance at the Fed, foreign central bank investments in a "repo pool" and Federal Reserve float (see Box 2 for further discussion of the foreign repo pool and other autonomous factors).

The Desk had to forecast changes in autonomous factors extending several weeks into the future (BOG 2005) and their resulting impact on reserves so this could be factored into the desired size of daily OMOs. For example, if autonomous factor changes were forecasted to increase (reduce) reserves by say $1.0 billion, then the Desk might reduce (increase) the size of its outstanding repo operations by the same amount, *ceteris paribus*. The largest autonomous factor was Federal Reserve notes. When the Fed issues currency to a bank, it debits the bank's account at the Fed, causing reserves to fall. The Treasury's account at the Fed is the next largest contributor to fluctuations in autonomous factors. As the Treasury is not a bank, changes in its account balance results in corresponding changes in the supply of reserves. Treasury balances, the float and the foreign repo pool are the autonomous factors most difficult to predict on a daily basis (Hilton (2008)).

Each day, the Desk compares forecasts of the supply of reserve balances from autonomous factors with its projections of reserves demand and determines the need for OMOs.[11] In addition to forecasting daily changes in autonomous factors, the Desk also forecasted longer-term trends, such as seasonal growth in currency in circulation (e.g. demand for currency tends to increase around Thanksgiving and Christmas) and the long-term growth rate of currency. If these longer-term projections indicated that the supply of reserves was likely to be low for several weeks, then outright purchases of Treasury securities or long-term repos might be needed.[12] Outright holdings of Treasury securities were preferred due to operational considerations and to limit direct credit extensions to private market participants (Hilton (2008)).

In practice, the Desk generally relied on temporary open market operations to achieve the daily changes in reserves required to keep the fed funds rate near its target. These typically involved conducting repos and reverse repos (generally of overnight durations) to, respectively, increase and decrease the supply of reserves with primary dealers.[13] For example, in 2004, the Desk conducted 299 repo operations for about $1.9 trillion and purchased outright $50 billion worth of securities (BOG 2005). Using repos allowed the Desk to easily expand or contract the level of reserves with minimal disruption to the

[11] The Desk also forecast the supply of reserves from Discount Window lending but, as previously mentioned, these amounts were generally small.

[12] The Desk may also sell Treasury securities outright but such transactions are extremely rare. In addition, the Fed may transact with foreign officials and international customers at market prices to make small adjustments to its portfolio without entering the market (see Box 2).

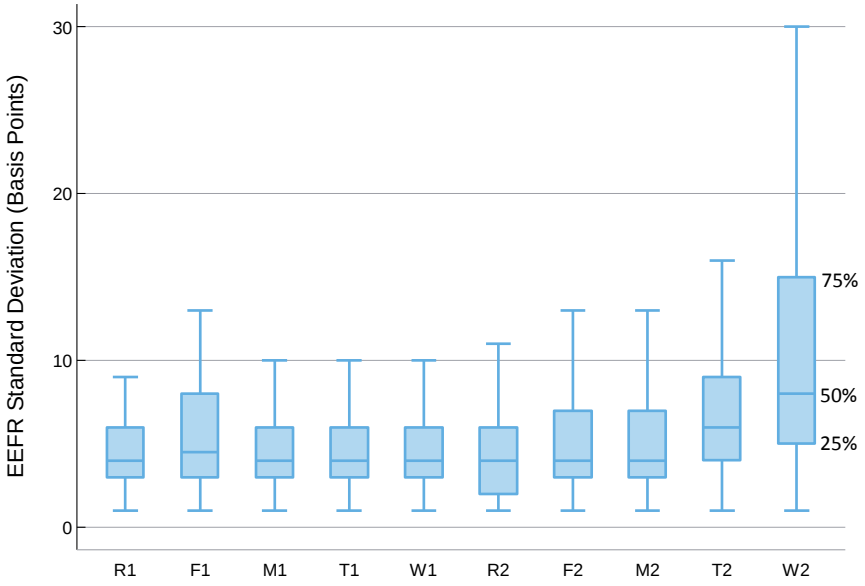
[13] Certain broker-dealers are designated primary dealers. These institutions must meet certain standards and serve as trading counterparties to the Federal Reserve Bank of New York in carrying out monetary policy. They also participate in auctions of government securities and make markets for these instruments.

functioning of the market where the underlying securities were traded. Further, repo transactions reduced the need to make frequent temporary downward adjustments to outright holdings. (Box 1 discusses how the Fed conducted repo operations when dealer inventories were low).

Volatility of rates during the reserve maintenance period

While the reserve maintenance period allowed depository institutions greater flexibility in managing reserve balances, it also posed challenges to forecasting and interest rate control. One concern was that reduced flexibility toward the end of the maintenance period would make the fed funds rate particularly sensitive to shocks, inhibiting the ability of the Federal Reserve to achieve the target. This challenge is evident in the relatively high intraday standard deviation in the fed funds market towards the end of reserve maintenance periods, consistent with Bartolini et al. (2000) (see Figure 5). In the next section, we examine the Desk's ability to manage end-of-maintenance-period volatility.

Figure 5: Intraday Standard Deviation of Fed Funds Effective Rate during Maintenance Period



Time Period: 7/3/2000 to 8/1/2007
Source: FRBNY, Authors' Calculations
Note: Using data on the daily standard deviation of the effective fed funds rate (https://apps.newyorkfed.org/markets/autorates/fed-funds-search-result-page), the chart shows box-whisker Tukey plots of its distribution by day in the reserve maintenance period. 50% indicates the median level, and 25% and 75% indicate the 25th and 75th percentiles of the distribution, respectively. Ends of the whiskers represent observations up to 1.5 times the inter-quartile range. R1/2=first/second Thursday of the maintenance period; F1=first/second Friday of the maintenance period; M1/2=first/second Monday of the maintenance period; T1/2=first/second Tuesday of the maintenance period; W1/2=first/second Wednesday of the maintenance period; W2 is the settlement date.

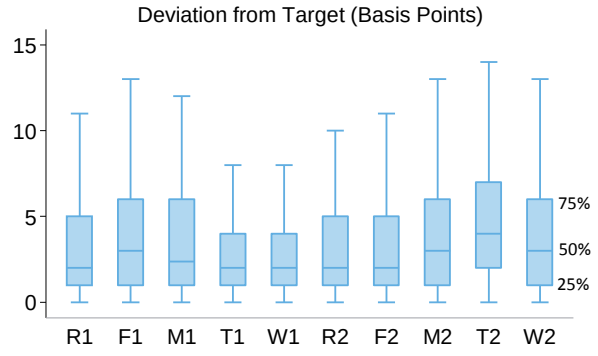
4. Effectiveness in Meeting Primary Monetary Policy Objectives

How effective was the pre-crisis framework in meeting the primary monetary policy objectives? In this section, we focus on the Desk's control of short-term rates and whether changes in the policy rate were quickly transmitted from the fed funds market to other money markets. We show that, in spite of increasing intraday dispersion of the fed funds rate towards the end of the maintenance period, the effective rate remained close to target levels. Second, while the fed funds rate deviated from its target towards the end of quarters (when demand for liquidity was high), it quickly reverted to normal levels within one day. Finally, we document that policy rate changes were rapidly transmitted from the fed funds rate to other money market rates.

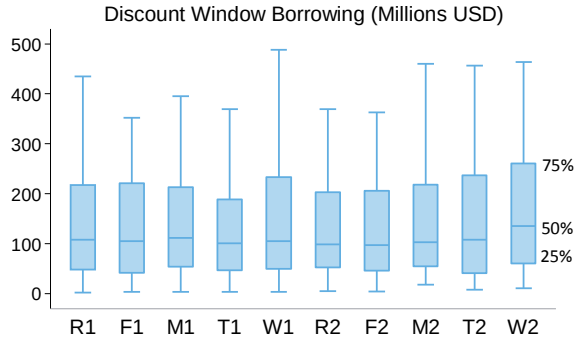
Control of the Policy Rate

As the left panel of Figure 6 shows, the deviations from the target were small (rarely in excess of 20 basis points). Moreover, the deviations do not appear to be persistent---instead, larger deviations are generally followed by smaller ones. This was true even towards the end of the maintenance period when there was greater dispersion of rates (Figure 5), indeed, the EFFR did not drift significantly from the target rate at the end of maintenance periods relative to other days in the maintenance period. This small deviation was not due to banks borrowing heavily from the discount window to meet their demand for reserves. As the right panel of Figure 6 shows, while depository institutions tended to borrow more from the discount window on the last day of the maintenance period, the amount borrowed was small relative to the amount of excess reserves. In other words, the low volatility of fed funds during the end of maintenance periods cannot be attributed to banks smoothing their demand for reserves through discount window borrowings. Rather, the evidence from Figure 6 suggests that the Desk was successful in managing reserves throughout the maintenance period and, in particular, the end of maintenance periods did not significantly impair the Desk's ability to implement monetary policy.

Figure 6: Absolute Deviation of Fed funds effective rate from Target and Discount Window Borrowing by Day of Maintenance Period



Time Period: 7/1/2001 to 8/1/2007
Source: FRBNY, Authors' Calculations



Time Period: 1/1/2003 to 6/30/2007
Source: FRBNY, Authors' Calculations

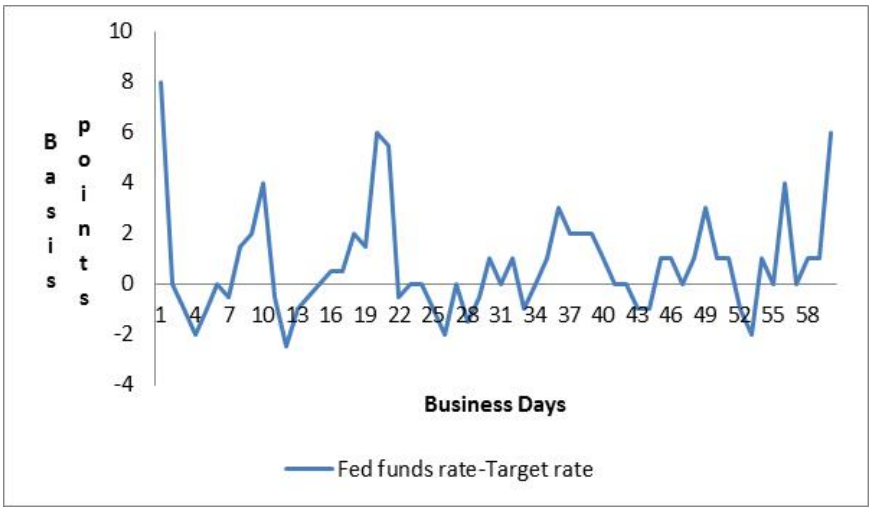
Note: The left chart shows box-whisker Tukey plots of the distribution of the absolute deviation of the fed funds rate from the target rate by day during the maintenance period. The right chart shows the distribution of discount window borrowings by day during the maintenance period. 50% indicates the median level, and 25% and 75%

indicate the 25th and 75th percentiles of the distribution, respectively. Ends of the whiskers represent observations up to 1.5 times the inter-quartile range. R1/2=first/second Thursday of the maintenance period; F1=first/second Friday of the maintenance period; M1/2=first/second Monday of the maintenance period; T1/2=first/second Tuesday of the maintenance period; W1/2=first/second Wednesday of the maintenance period; W2 is the settlement date.

While the fed funds rate was close to its target on average, on occasion the rate could deviate from its target. Typically, there could be movement in autonomous factors that the Desk would forecast imperfectly that would result in small supply-demand mismatches. Other deviations were generally predictable (which allowed the Desk to anticipate and partially offset these deviations) and well understood. For example, there could be large rate moves within a reserve maintenance period ahead of a widely anticipated FOMC rate change; rates would typically fall on the first Friday of each maintenance period and typically increase on high payment flow days. More importantly, rates quickly reverted to the target following such deviations.

To illustrate the resilience of the policy rates during periods of high volatility, we consider the behavior of fed funds rates during quarter-ends (see Box 3 for further details). Heightened volatility around quarter-end dates typically caused the fed funds rate to deviate from the target. This deviation increased by an average of 6 basis points on the last day of the quarter (day 60 in Figure 7) and by 8 basis points the following day (day 1 in Figure 7, which is the first day of the following quarter). By contrast, on more "typical" days (i.e. excluding the quarter-end date plus the 2 days before and after it), the fed funds rate was within a basis point of the target on average. The fed funds rate sometimes increased sharply at the end of months, which accounts for the spike on day 20, but volatility on these days was not unusually high.

Figure 7: Fed Funds Rate Spikes around the End of Quarters: Q4 2004 to Q2 2007



Source: FRBNY. The figure shows the median of the difference between fed funds rate and the target rate across quarters for each day. Day 60 is quarter-end. Day 1 is start of the quarter. The quarters are standardized to 60 days by using the first 30 days from quarter-start and the last 30 days from quarter-end, excluding days in the middle for quarters with more than 60 days.

In order to stabilize fed funds rates around quarter-end dates, the Desk supplied extra reserves to meet the surge in demand (see Box 3). Moreover, the Desk planned to leave relatively low levels of reserves on other days in the same reserve maintenance period. Otherwise the supply of reserves would have exceeded demand over the non-quarter-end days of the maintenance period, pushing rates below the target once the quarter-end passed. Consequently, the deviation of the fed funds rate from its target was short-lived, generally falling back to the target rate on the 2nd day after quarter-end (Figure 7).

Transmission of the Policy Rate to Other Money Markets

The FOMC traditionally implements monetary policy by announcing a policy target rate for the EFFR, with the expectation that its decisions will quickly be transmitted to all money market rates. Because the Fed does not directly control market interest rates, it relies on arbitrage forces in money markets for the change in the fed funds rate to be transmitted to other short-term rates.[14] A variety of market participants can be arbitrageurs, including primary dealers who operate in most short-term money markets and hedge funds who seek to profit from price discrepancies in related markets. In this section, we examine the effectiveness of arbitrage before the recent financial crisis.

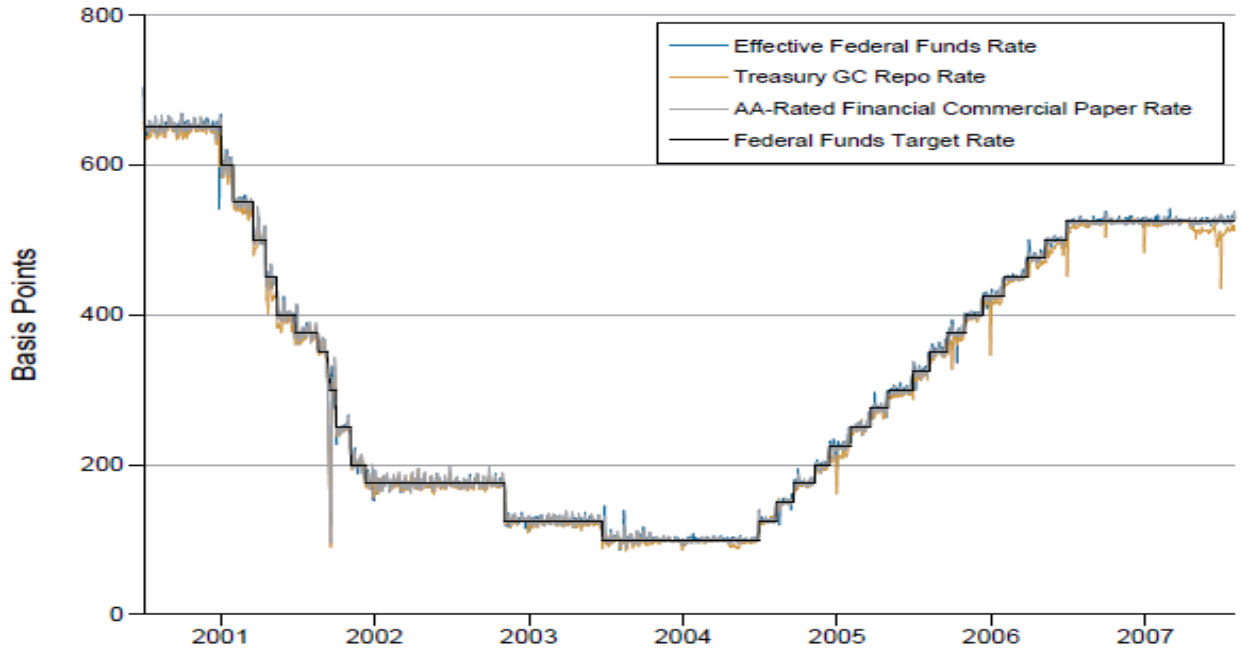
In the pre-crisis period, arbitrage kept money market rates aligned as banks active in multiple money markets could earn a profit when those rates were misaligned, facilitating the transmission of monetary policy. As shown in Figure 8, the overnight AA Financial Commercial Paper rate, the EFFR and the overnight general collateral (GC) Treasury[15] repo rate were highly correlated before the crisis, as would be expected with effective arbitrage.[16] Other short-term money market rates such as Eurodollar rates (not shown in the figure) were also tightly aligned to the EFFR.

[14] See Bernanke (2005).

[15] General collateral Treasury securities are those that have no special features such as unusually high market demand.

[16] The repo rate is the Desk's 9 AM Primary Dealer Repo Survey Treasury GC rate. Prior to March 1, 2016 the EFFR was calculated by the Desk from broker submissions. Since then the EFFR is calculated off of borrowing data submitted by banks in the Report of Selected Money Market Rates.

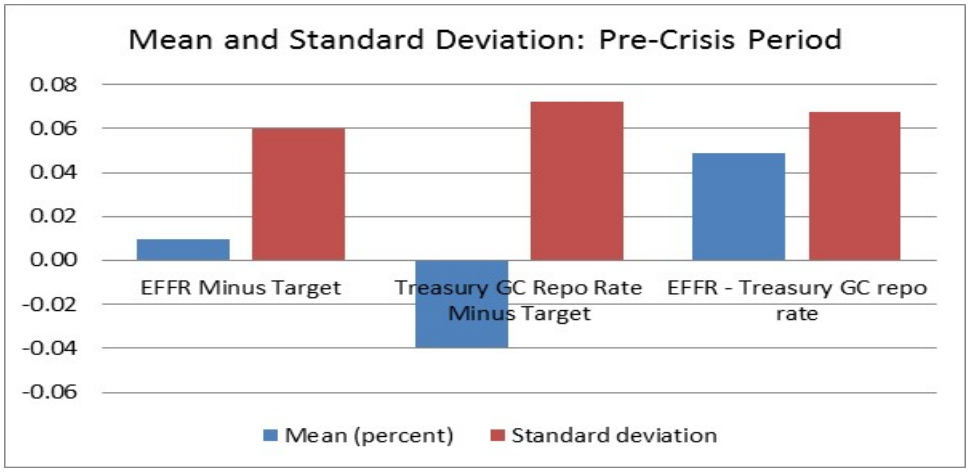
Figure 8: Overnight Money Market and Target Fed Funds Rates: July 2000-July 2007



Source: Federal Reserve Bank of New York, Bloomberg. All rates are of overnight tenor.

On average, the EFFR and the Treasury repo rate generally remained close to the FOMC's target rate (Figure 9). Also, the repo rate was consistently below the fed funds rate, as should be expected since repos are secured and fed funds are not. As a result, the average difference between the EFFR and repo rates (or the spread) was positive. A notable observation is the relatively high standard deviation of both rates relative to the respective mean and, in particular, the EFFR. To the extent that the volatility is fundamental, the relatively high standard deviation may represent price discovery (i.e. discovery of the rate equilibrating demand and supply of reserves) occurring in the actively traded fed funds market. We return to this issue in section 5, where we discuss the advantages of active trading in the money markets for monetary policy implementation.

Figure 9: Deviations from the Target Fed Funds Rates: January 2002-December 2006



Note: The chart shows the means and standard deviations, respectively, of the fed funds and repo rates, measured as deviations from the target fed funds rate during the pre-crisis period. Also shown are the mean and standard deviation of the spread (i.e. the EFFR minus the repo rate).

In Box 4, we report a formal test of monetary policy transmission from Granger causality tests using daily data. We show that past values of the EFFR "causes" (or predicts) the current repo rate in the pre-crisis period, a pattern one would expect if arbitrageurs operated to keep inter-market rates aligned. In turn, the existence of arbitrage activity likely facilitated the transmission of target rate changes to the repo market. The results further show that the repo rate also Granger-causes the EFFR in the pre-crisis period, indicating two-way flows of information between the fed funds and repo markets. This result indicates that neither market is dominant in an informational sense.

In addition to the fed funds market, we also examined transmission between the Eurodollar market and the repo market. We find that Eurodollar rate changes are also transmitted to the repo rate (as might be expected since the Eurodollar and the EFFR have historically been tightly connected).

5. Operational Effectiveness and Financial Market Functioning

In addition to its primary task of controlling the fed funds target, a monetary policy framework may be evaluated with respect to operational and financial market functioning objectives. In this section, we evaluate the pre-crisis framework's operational effectiveness by discussing the efficiency and transparency of the Desk's day-to-day actions and procedures in managing liquidity, as well as the concept of universality—whether or not the framework remains applicable in different states of the economy. The financial objectives are evaluated by examining the impact of the Fed's collateral policy, money market activity and effects on payment systems.

Operational objectives: Efficiency and Transparency of Procedures

The Desk's procedures for controlling short-term interest rates were complex and resource-intensive, resulting from the need for daily liquidity management and consequently, for forecasting reserve supply

and demand conditions daily—a technically challenging task (Bernanke, 2005).[17] In addition, the Fed did not publish its forecasts, which made the procedures rather opaque to market participants.

In a multiple-day reserve maintenance system, the daily distribution of reserves may, in theory, be less important since reserve requirements only had to be met by the end of the period. But because total requirements were low relative to the daily volatility of autonomous factors, the Desk had to evaluate reserve supply and demand conditions closely every morning. The Desk was active most days, conducting these activities daily:

a. Forecast numerous autonomous factors over a multi-day horizon
b. Forecast reserve demand for multi-day horizons and for different types of banks; and
c. Execute, plan and conduct the repo or reverse repo operations.

A typical day in the life of the Desk (as described in BOG, 2005) provides a sense of the resources required on a daily basis to conduct monetary operations. The day would start with independent projections of the supply of and demand for reserves by two groups of staff members, one at the NY Fed and the other at the Board of Governors in Washington. This would be followed by a conference call between the SOMA manager in New York, staff at the Board of Governors and a Federal Reserve Bank president who is currently a member of the FOMC. Participants would discuss the day's forecasts for reserves and financial market developments, especially in the federal funds market. Based on this information, a plan for conducting OMOs would be formulated and the decision announced to the markets at around 9:30 a.m., typically with the conduct of a repo operation with primary dealers. Longer-term repos would typically be arranged earlier in the morning, usually on a specific day of the week. If an outright operation was also needed, it would typically be executed later in the morning, after the daily repo operation was complete.

As the Desk did not publish its forecasts, unlike many other central banks (Hilton (2008)), market participants sometimes had difficulty in interpreting the Desk's actions. For example, market participants would often speculate that day-to-day changes in outstanding repo operations matched the Fed's estimate for daily changes in the demand for reserves. This speculation was inherently flawed as it ignored the equally important impact of forecasted changes to autonomous factors, which market participants had limited insight into. The Desk did not publish its daily targeted level of reserves on an ex-post basis and intended repo operation sizes were not announced concurrent with the operations. Repo market participants often had only a vague idea of what the repo operation sizes would be at the time that the operations were announced and then had difficulty in interpreting the results after they were released.

Would an alternative framework achieve the intended monetary policy goals with less operational complexity? In theory, a symmetric corridor system, with the target rate in the middle of the standing deposit and lending rates, might require less daily intervention by the Desk as long as banks were able and willing to access the central bank's standing facilities. This ensures that expected rates in the

[17]Indeed, it could be challenging to explain the daily monetary operations even to experts, as implied by the Board's own description of the open market policy process (BOG, 1963).

maintenance period are around the target rate since it would be equally likely that banks will be in reserve deficit or surplus over the maintenance period and, further, the costs of both outcomes are symmetric around the policy rate (Hilton (2008) and Bindseil (2014)). However, the interest rate corridor in the US was not symmetric as there was no standing interest bearing deposit facility. Instead, the effective deposit rate was zero since no interest was paid on reserves. Since banks' opportunity cost of holding reserves was zero, the cost of having surplus reserves was more than being in deficit, resulting in a bias towards rates below the fed funds target (Hilton (2008)). Bindseil (2014) examines a number of alternative monetary policy frameworks with symmetric corridors and shows that, during the pre-crisis period, they were all effective in meeting their monetary policy objectives, suggesting that the Fed could have met its monetary policy objectives in a simpler framework.

Why was the Desk able to meet its monetary policy objectives in spite of a complex and opaque operating framework? Hilton (2008) suggests that one factor might have been the Desk's daily fine-tuning of reserve supply, whereby it responded when rates deviated from the target by adjusting daily reserve supply to induce rate movements in the reverse direction. This behavior may have helped to ensure that expected future rates remained anchored around the target rate. Market participants responded appropriately to the Desk's fine tuning because the Desk had built up a consistent record of success in forecasting reserve demand and supply factors. The Desk's forecasting ability and market confidence were mutually reinforcing elements that anchored market expectations and ensured that the EFFR stayed close to the policy target rate.

Operational Objectives: Universality

A universal (state-independent) framework remains effective across different financial and macroeconomic conditions. All else equal, a more universal framework is desirable, since it allows the central bank to avoid the fixed costs of designing, testing and implementing new frameworks as conditions change. A more universal framework could also help avoid unexpected, forced changes to the operating framework if conditions change rapidly (e.g., during a crisis). Such sudden changes to the operating framework could be suboptimal if they are made under time constraints, as during a crisis.

One disadvantage of the pre-crisis framework is that the Desk required control over the size of the Federal Reserve's balance sheet for the purpose of controlling the fed funds rate. If the Federal Reserve needed to change the amount of reserves for a reason other than altering the fed funds rate, the Desk could lose control of the policy rate in the pre-crisis framework. This limitation became relevant in 2008 when the provision of large amounts of liquidity undermined interest rate control, a topic we explore in the concluding remarks.

A second disadvantage with the pre-crisis framework is that active daily management of reserves, and the attendant forecasts of reserves demand and supply conditions, proved to be particularly problematic during crisis periods. For example, during the early stages of the financial crisis (primarily in 2007 and 2008), reserves demand proved particularly hard to predict, resulting in large intraday swings in the fed funds rates (Hilton (2008)).

Financial Market Functioning Objectives: Asset Eligibility Policy

Central banks impact market functioning via their asset eligibility framework, including Discount Window collateral eligibility. Assets eligible for collateral may benefit from increased liquidity and enhanced ability to obtain credit, as compared to ineligible assets.[18] Further, to the extent that haircuts do not fully reflect risks (e.g., if they do not vary by counterparty), the price of eligible assets might be distorted. These market impacts are likely to be higher, the broader the set of collateral assets. For example, if the central bank accepts a wide range of collateral assets, then banks may have an incentive to structure their balance sheets to maximize access to central bank credit (Bindseil 2014).[19]

The Federal Reserve Act (FRA) limits the types of assets that the Federal Reserve may acquire through open market operations. In practice, the Fed accepted only high-quality assets in its open market operations, namely Treasury debt and debt issued or fully guaranteed by US federal agencies, which includes agency mortgage-backed securities (agency MBS). A wider variety of assets, including government and private-sector securities, mortgages and consumer and commercial loans, is eligible to be pledged against discount window loans. Since discount window borrowings were negligible in normal times, the eligibility criterion for OMOs was the binding constraints. The strictness of the OMO eligibility criteria likely reduced distortionary effects on asset prices since the additional liquidity benefits of being granted eligibility is likely small for these types of assets.[20]

An alternative view is that the central bank should actively use its collateral policy to support an important asset market that is currently illiquid. Indeed, in the 1920s and 1930s, the Fed took an active role in enhancing the liquidity of the US Treasury bond markets, in part by including them as collateral for its nascent open market operations (Garbade (2012)). Later, the US Treasury bond markets developed into one of the most liquid asset markets, and so there was no longer a need for the Fed to actively support these markets through its collateral policy. Under this view, inclusion of a broader range of assets for collateral eligibility, even if that involves including illiquid assets, may be desirable.

[18] See ECB Monthly Bulletin (2007).

[19] It is possible that, with a wider range of assets, more asset prices are distorted but there's less distortion for each asset.

[20] The ECB, in contrast, accepts a broad range of illiquid collateral but, to avoid distorting prices, uses objective and publicly available criteria in its asset selection and ensures that assets with similar properties are treated in a similar manner. See ECB Monthly Bulletin (2007).

Financial Market Functioning Objective: Money Market Activity

A reserve scarcity framework is likely to encourage higher interbank trading activity than a one with reserve abundance. Indeed, a scarcity of reserves balances relative to required and precautionary demand for reserves, such as the one in place during in the pre-crisis period, resulted in large volumes of trading between banks. Trading volumes would typically increase toward the end of the trading day as banks with more reserves than necessary would have an incentive to trade with banks that had too few reserves. For example, in the fourth quarter of 2006, brokered fed funds activity averaged $95 billion per day. In contrast, under a reserve abundant regime in the fourth quarter of 2015, brokered fed funds volume averaged only $42 billion per day (see Box 5 for a more detailed discussion of changes in fed funds market activity since the crisis).

As a general matter, it is unclear if supporting active money markets should be a goal of a monetary policy framework. Active money markets may promote the transmission of changes in policy rates to the broader market by facilitating arbitrage, enabling price discovery and promoting market discipline. However, alternative markets (such as short-term funding markets) may be available for providing these benefits. The potential signaling benefits from money markets are also hard to quantify. Changes in trading volumes may not be driven by fundamentals but rather by idiosyncratic payments shocks. Further, participant efforts to monitor the credit quality of counterparties vary considerably and it may be difficult to internalize the value from such monitoring, given that contagious credit and liquidity shocks may force lenders to withdraw funding broadly. [21]

In the particular circumstances of the pre-crisis period, however, activity in the fed funds markets likely provided some benefits. An active fed funds market likely promoted rate discovery which facilitated the quick transmission of changes to the EFFR to other money market rates (see section 4).

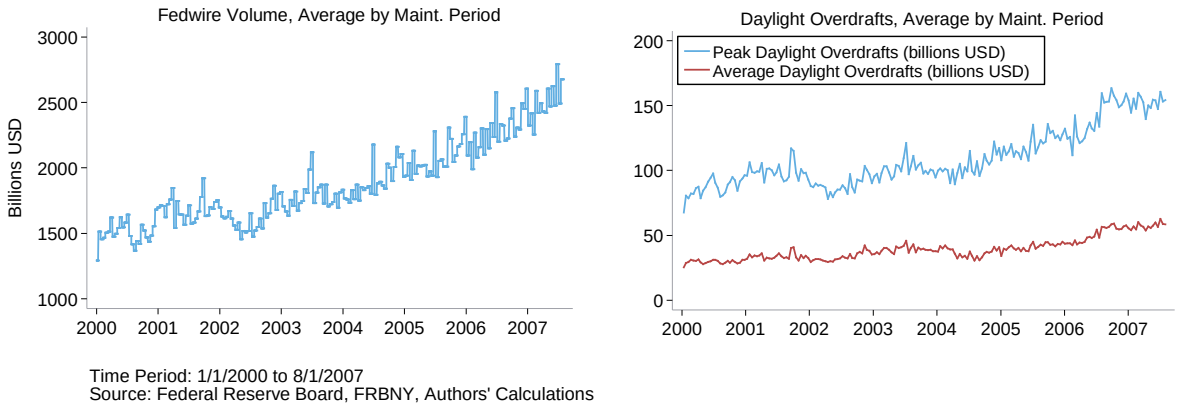
Financial Market Functioning Objective: Payment System Activity

In the pre-crisis period, banks relied on substantial provisions of intra-day, or daylight overdraft, credit from the Fed as the level of reserves was insufficient to cover clearing needs of payment system. Since the Fed charged low fees to banks when providing intra-day credit, banks relied on the Fed as a source of intra-day funding and did not necessarily borrow in the wholesale funding markets to address intra-day shortfalls. With average daily Fedwire volume of $2.28 trillion and average reserve balances of just $9 billion held at Federal Reserve Banks in 2006, large daylight overdrafts were a likely consequence of the low levels of reserves in the system. (Box 6 discusses to what extent private solutions to the problem of intraday credit existed).

Figure 10 shows the peak daylight overdrafts (the largest total amount of credit outstanding at any time) as well as average overdrafts by maintenance period over the pre-crisis period. In 2006, intra-day overdraft use averaged roughly $51 billion during operating hours, and on average $140 billion was outstanding at peak use over a maintenance period (roughly 6% of average payment volume over Fedwire). Peak overdraft use steadily increased since 2000 in the pre-crisis period.

[21] See Potter (2016) for a discussion of these issues.

Figure 10: Time Series of Fedwire Volume and Daylight Overdrafts by Maintenance Period



Time Period: 1/1/2000 to 8/1/2007
Source: Federal Reserve Board, FRBNY, Authors' Calculations

While daylight overdrafts facilitate payments, they also expose the Fed to the potential for loss, should the institutions incurring negative balances fail to replenish their funds. (See Box 6 for more discussion of the evolution of the Fed's Payment System Risk policy).

6. Concluding Remarks

The primary policy tool of the Fed's pre-crisis operating framework was control over the fed funds rate. In order to exert this control, the Fed relied on reserve scarcity to ensure that the fed funds rate would be sensitive to the level of reserves in the system. To adjust the rate, the Desk forecasted reserves demand and supply daily, and then typically increased or decreased the amount of reserves available to banks relative to forecasted demand by changing the size of daily repo operations. The aggregate amount of reserves was distributed among banks via trading in the fed funds market. The framework was aided by arbitrageurs in transmitting changes in the fed funds rate to other short-term interest rates and to the real economy more broadly. We discussed the desirability of the pre-crisis framework in the context of meeting monetary policy objectives while conducting monetary operations in an efficient and transparent manner, such that financial market functioning was not impaired.

The pre-crisis framework was effective at meeting monetary policy objectives. First, the Desk was able to maintain the EFFR close to the target rate set by the FOMC even during periods of significant volatility in bank reserve demand. Furthermore, deviations were not persistent—the Desk was generally able to correct any short-term movements in the fed funds rate. Finally, changes in the target rate were quickly transmitted to the other money market rates.

The pre-crisis framework receives mixed review in terms of unimpaired financial market functioning. Having a relatively restricted set of collateral eligible for open market operations ensured that the Desk's operations did not significantly impact the relative pricing of risk. The reserve scarcity paradigm also ensured relatively active trading in the interbank market. However, the reserve scarcity paradigm

placed strains on the interbank payment system, leading to heavy use of daylight overdraft credit from the Fed.

The pre-crisis operational framework scores less well in terms of efficiently and transparently meeting monetary objectives. The operating procedures were complex to implement and opaque, which meant that market participants generally found them difficult to understand. Finally, the framework lacked universality in that large changes in aggregate reserve balances could undermine the Desk's ability to control the policy rate. This critique became relevant in 2008 when the Federal Reserve implemented emergency lending programs to combat the effects of the financial crisis. These programs expanded the aggregate amount of reserve balances for reasons other than monetary policy, causing the Desk to lose control over the policy rate. Further, the daily operational procedures did not adapt well to crisis market conditions as reserves demand became difficult to predict, resulting in high intraday volatility.

In order to regain control of the policy rate, the pre-crisis framework was abandoned in favor for a framework that would allow the Desk to continue to carry out FOMC objectives regardless of the amount of reserves in the banking system. Unlike the pre-crisis framework, the current monetary policy framework is one of reserve abundance whereby, through the use of administered rates, the fed funds rate is kept within a range set by the FOMC. Using this new framework, the Desk has continued to maintain the policy rate within the target objective set by the FOMC. This demonstrates that while the pre-crisis framework offered effective monetary control, this was not unique to that paradigm.

The reserve-abundant framework has resulted in changes to other aspects of the pre-crisis framework. With the abandonment of reserve scarcity, banks no longer rely heavily on overdraft credit from the Federal Reserve. As a further by-product, the reserve-abundant framework has diminished the need to transact in the fed funds market, causing a reduction in volume (see Box 5). However, the benefits of active money markets are debatable and must be weighed against reduced EFFR volatility (Potter 2016).

While the current framework will likely evolve as the FOMC considers its appropriateness in meeting future monetary policy challenges, a return to the pre-crisis framework is not necessarily desirable. As we have shown in this paper, the pre-crisis framework contained several shortcomings that can probably be improved upon.

Box 1: How did the Desk avoid conducting under-subscribed repo operations?

As discussed in this article, the Desk generally conducted daily repo operations to change the overall level of reserves in the system to match the Desk's daily forecast of demand for these reserves. The near daily conduct of these operations, which typically settled on a T+0 basis (i.e. on the same day as when the trade occurs), raises the question of how did the Desk avoid having under-subscribed operations, which would have resulted in supplying less reserves than intended? This risk is not insignificant, because dealers submitting winning propositions in repo operations must pledge unencumbered collateral to the Desk through their designated tri-party clearing agent in order for the transaction to settle and for intended reserves to hit the banking system. What if there isn't much unencumbered collateral around on dealer balance sheets?

In practice, the temporary open market operations were rarely under-subscribed, even though the typical operation time of 9:30 am was after the time when most repo volume occurs on a daily basis. The main reason for this is that the Desk's typical take-down in short term repo operations was about $7.0 billion a day, much less than the typical overnight repo volumes that are conducted in the private market. In addition, from past experience, the Desk could often anticipate when collateral shortages might develop and planned around them accordingly. The following table provides an illustrative example of how the Desk arranged repo operations to avoid under-subscribed operations ahead of the March 2006 quarter-end date.[22]

Date	Term (days)	Propositions Received (billion $)	Propositions Accepted (billion $)
Wednesday 3/29/06	5 (spanned weekend)	37.9	5.50
Thursday 3/30/06	5 (spanned weekend)	22.95	5.00
Thursday 3/30/06	1	29.65	3.25
Friday 3/31/06	3 (spanned weekend)	11.55	4.25

From the table above, we observe that the Desk conducted two short-term repo operations that not only provided reserves on the day they were conducted (Wed., 3/29 and Thur., 3/30) but the tenor of these repo operations was such that they provided reserves over the upcoming weekend, thus providing reserves for the upcoming Friday, March 31 quarter-end date. In this manner, the Desk added 10.5 billion of reserves that were outstanding over the quarter-end date. On the quarter-end date itself, the Desk added an additional 4.25 billion, such that total

[22] This table ignores the conduct of "longer term repos" which are discussed elsewhere.

short term repo operations increased reserve levels over the quarter end date by 14.75 billion. As the Desk observed that dealers were more likely to be short of collateral over quarter-end dates, this strategy enabled the Desk to successfully avoid an under-subscribed operation. Note that total propositions submitted for the repo operation conducted on 3/31/06 were only 11.55 billion, suggesting that a straight-forward, over the weekend operation with a desired target amount of 14.55 billion would have been under-subscribed. The Desk frequently referred to this approach as “layering in reserves.”

Box 2: What are Autonomous Factors?

The term "autonomous factors" refers to items in the Federal Reserve's balance sheet that are outside of the control of the Open Market Desk of the Federal Reserve Bank of New York (the "Desk"). The Desk needs to forecast changes in autonomous factors because they change the level of reserves in the banking system. For example, when Treasury's account balance at the Fed increased, this would effectively drain reserves as funds are de facto transferred from the private sector into Treasury's Fed account. Conversely, when the Fed spends money, for example, on employee salaries or remittances to the Treasury, this would increase the level of reserves in the system. Most daily changes on the Fed's balance sheet are too small to make a difference in monetary policy implementation. However, changes in some balance sheet categories were routinely large enough to matter, i.e. these types of balance sheet changes routinely had a significant impact on the overall level of reserves and needed to be considered as the Desk developed its plans for the appropriate size of open market operations. The Desk's routine forecasts of these balance sheet categories, or autonomous factors, are discussed below.

Currency in circulation

Currency in circulation is typically the largest and most important autonomous factor to forecast. When a bank places an order for currency with a Federal Reserve Bank, the latter fills the order and debits the bank's account at the Fed and total reserve balances decline. Currency is fungible with reserves; bank actions to withdraw (deposit) currency from their Fed account will increase (reduce) currency-in-circulation thus reducing (increasing) reserves. The outstanding level of currency-in-circulation varies with both seasonal and longer-term trends. Longer term trends include transactional demand for currency as well as foreign demand to hold US dollars as a store of value. As the demand for currency grows with the economy, reserves would decline and the fed funds rate rise, if the Fed did not offset diminishing reserves by conducting repo operations or by purchasing securities. The expansion of Federal Reserve notes in circulation is the primary reason that the Fed's holdings of securities grew over time during the pre-crisis period.

Float

Federal Reserve float is created when credit to the account of the bank presenting a check for payment occurs on a different day than debit to the account of the bank on which the check is drawn. Float temporarily adds reserve balances when there is a delay in debiting the paying institution's account; conversely, float temporarily drains balances when the payer's account is debited before the payee receives credit. Float tended to be quite high and variable whenever the normal check-delivery process was disrupted, such as during bad weather when travel delays could slow down the delivery and processing of physical checks. The magnitude of float timing differences has decreased in recent years as more transfers are conducted electronically.

Treasury General Account (TGA) Balance

The Fed serves as fiscal agent for the US Treasury and the TGA functions as the checking account for the US Treasury. The Treasury draws on this account to make payments by check or direct deposit for all

types of federal spending. As the Treasury is not a bank, its payment to the public reduces the TGA balance and increases reserve balances available to banks. Changes in the TGA balance tend to be less predictable following corporate and individual tax dates, especially in the weeks following the April 15 deadline for federal income tax payments. Before the crisis of 2007-2009, Treasury could redirect funds from the TGA account to private banks via the Treasury Tax & Loan program (https://www.newyorkfed.org/aboutthefed/fedpoint/fed21.html). This helped moderate day-to-day volatility of this liability on the Fed's balance sheet, which would complicate reserve forecasting.

Foreign Repo Pool

About 250 central banks and foreign official institutions have accounts with the New York Fed's Central Bank and International Account Services (CBIAS) division which offers payment, custody and investment services to these accounts (see https://www.newyorkfed.org/aboutthefed/fedpoint/fed20.html). CBIAS also offers an investment product, known as the foreign repo pool, in which CBIAS accounts can invest overnight funds in a repo arrangement backed by SOMA collateral. Funds that are held in CBIAS accounts at the New York Fed, whether in the foreign repo pool or in transaction accounts, drain reserves from the banking system (by definition, funds held at the Fed reduces the supply of reserves held by the private sector).

Till the mid-1990's the Desk sometimes directed CBIAS accounts to conduct repo with private market participants as a means of fine-tuning the level of reserves in the system. The Desk stopped this process in the mid-1990s by moving to a framework in which CBIAS accounts were encouraged to keep consistent, albeit fairly low, balances in their foreign repo pool accounts. CBIAS staff would counsel accounts to encourage stability in their holdings. As stability was encouraged in these accounts, the Desk would treat typical foreign repo pool balances as a "permanent" reserve drain and the day-to-day fluctuations in the foreign repo pool became a significant autonomous factor[23].

Before the crisis, balances in the foreign repo pool averaged around $40 billion. Currently, foreign repo balances tend to be around $230 billion to $250 billion. The use of the pool has increased over time as the constraints placed on CBIAS customer usage of the pool have been removed (see https://www.newyorkfed.org/newsevents/speeches/2016/pot160222). This new paradigm has increased both the level and the variability of the foreign repo pool, but such variability no longer causes issues with monetary policy implementation as the Desk no longer actively manages reserve balance levels.

CBIAS balances are published under the heading "Reverse Repurchase Agreements – Foreign official and international accounts" in the H.4.1 Federal Reserve Statistical Release which is published weekly (https://www.federalreserve.gov/releases/h41/current/).

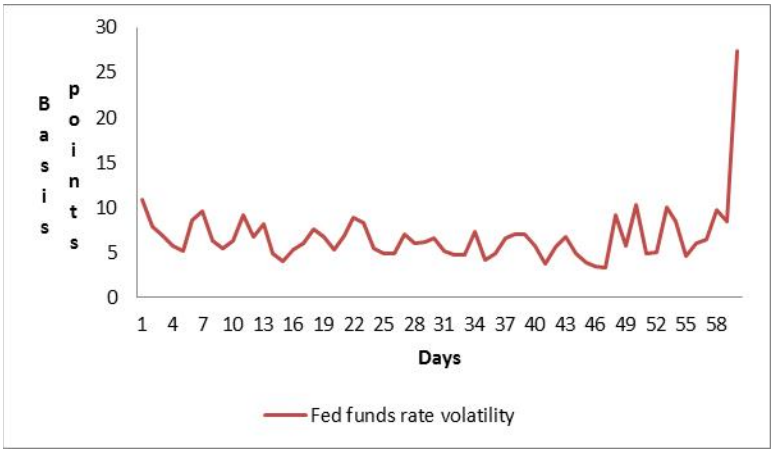
[23] The Desk had another CBIAS investment product that helped control the level of reserves on a daily basis. On a voluntary basis, the Desk would sell fed funds as agents for pooled CBIAS funds. This allowed the accounts to earn a return on unexpected end-of-day balances, while minimizing disruption to the supply of reserves resulting from unexpected operational issues, such as a failure to receive delivery on the purchase of Treasury securities.

Box 3: Quarter-end Dynamics of Fed Funds Rate

Quarter-end Volatility of Fed Funds Rates

Quarter-end volatility remained a feature of the fed funds markets in the years before the financial crisis emerged. The chart below plots the intra-day volatility of the fed funds rate for each day of the quarter, averaged across quarters from Q4 2004 – Q2 2007. During this time period, there was a clear trend of elevated intraday volatility on the quarter-end date.

Volatility of Fed Funds Rates Spikes on the Last Day of the Quarter: Q4 2004 to Q2 2007

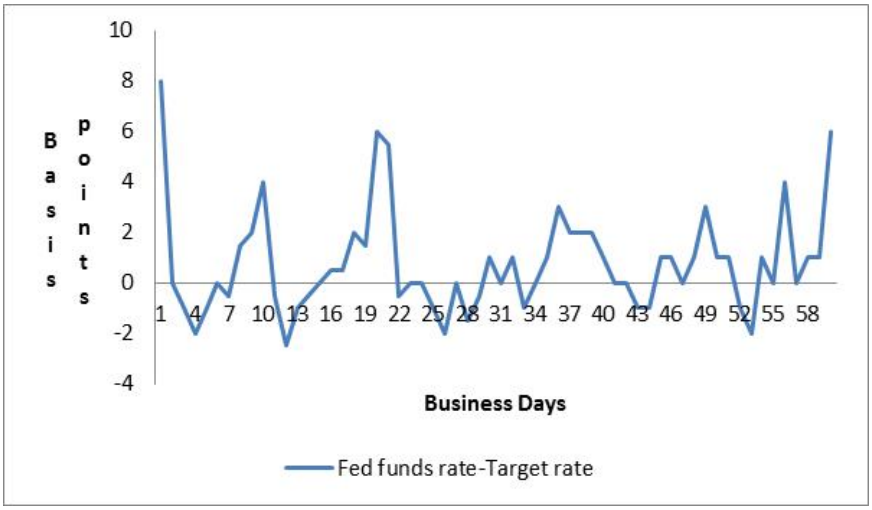


Source: http://www.newyorkfed.org/markets/omo/dmm/historical/fedfunds. The figure shows, for each day "t", the median of the intraday standard deviation of the fed funds rate across quarters. Day 60 is the quarter-end date. Day 1 is the start of the quarter. The quarters are standardized to 60 days by using the first 30 days from quarter-start and the last 30 days from quarter-end, excluding days in the middle for quarters with more than 60 days. Rates are in basis points.

Level of Fed Funds Rates during Quarter-ends

Heightened volatility around quarter-end dates typically caused the fed funds rate to deviate from the target. This deviation increased by an average of 6 basis points on the last day of the quarter (day 60) and by 8 basis points the following day (day 1) (see chart below). By contrast, on more "typical" days (excluding the quarter-end date plus the 2 days before and after it), the fed funds rate was within a basis point of the target on average. The fed funds rate sometimes increased sharply at the end of months, which accounts for the spike on day 20, but volatility on these days was not unusual (as shown above).

Fed Funds Rate Spikes around the End of Quarters: Q4 2004 to Q2 2007



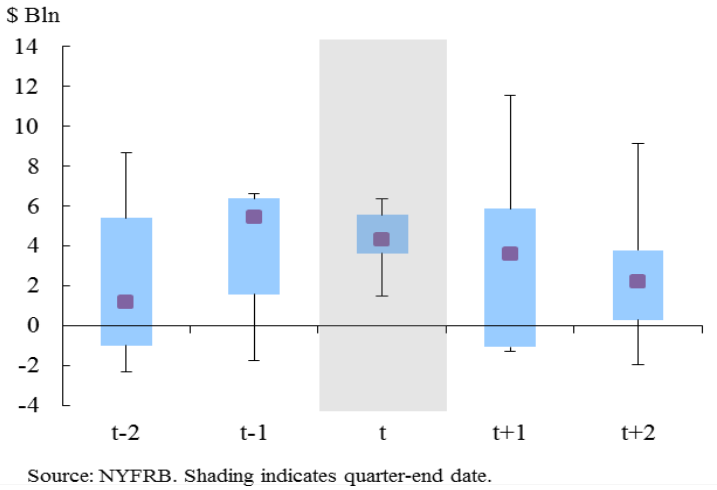
Source: FRBNY. The figure shows the median of the difference between fed funds rate and the target rate across quarters for each day. Day 60 is quarter-end. Day 1 is start of the quarter. The quarters are standardized to 60 days by using the first 30 days from quarter-start and the last 30 days from quarter-end, excluding days in the middle for quarters with more than 60 days.

Supply of Reserved during Quarter-ends

In order to stabilize fed funds rates around quarter-end dates, the Desk supplied extra reserves to meet the surge in demand. Moreover, the Desk planned to leave relatively low levels of reserves on other days in the same reserve maintenance period (i.e. the period over which banks' required reserves are calculated). Otherwise the supply of reserves would have exceeded demand over the non-quarter-end days of the maintenance period, pushing rates below the target once the quarter-end passed.

The box-whisker plot of the distribution of excess reserves in the chart below shows that the Desk left an average of more than $4 billion of excess reserves around quarter-end dates. In contrast, the Desk on average left less than $0.5 billion of excess reserves on non-quarter end days of the maintenance period. The chart further indicates that the *range* of excess reserves was relatively narrow, between $3 billion and $6 billion on most quarter-end dates. This suggests that the Fed chose not to eliminate reserve demand shocks completely, as also found by Bartolini, Bertola and Prati (2002).

Excess Reserves around Quarter-end: Q4 2004 to Q2 2007



Source: NYFRB. Shading indicates quarter-end date.

Note: Day "t" is the quarter-end date. The figure plots the distribution of excess reserves for the five quarter-end dates. The blue box includes values between the 25th and 75th percentiles of the distribution, with the median indicated by the brown box. The "whiskers" indicate outliers beyond this range.

Box 4: Testing Monetary Policy Transmission with Granger Causality Tests

To evaluate the strength of monetary policy transmission, we conduct a Granger causality test using daily data. Past values of the EFFR "causes" (or predicts) the current repo rate in the pre-crisis period (Table 1), indicating that the Fed's monetary policy decisions were transmitted to the repo market. Also, the results show that repo rate Granger-causes the EFFR in the pre-crisis period, showing two-way flow of information between the fed funds and repo markets.

Table 1: Does the Fed Funds Rate Predict the Repo Rate: January 2002 – December 2006

	Result:
Does the fed funds rate predict the repo rate?	Yes
Does the repo rate predict the fed funds rate?	Yes

Note: The table shows results from a Granger Causality test. Rates are measured relative to the target fed funds rate.

A concern with the analysis is that the reporting time of the data is not synchronized: the repo rate is reported as of 9 AM EST whereas the EFFR is all-day rate. To address this issue, we estimate the Granger causality between the one-day lagged value of EFFR and the repo rate and, further, between the GCF Treasury repo rate (which is reported at the end of the day) and the EFFR.[24] In both cases, we obtain a similar result: there is bi-directional causality between EFFR and the repo rate during the pre-crisis period.

We focus on the transmission from EFFR to the repo rate due to the historical importance of the fed funds market and the availability of a long time series of EFFR data. However, in unreported analysis, we also find that Eurodollar rate changes are transmitted to the repo rate (as might be expected since the Eurodollar and fed funds rate have historically been tightly connected).

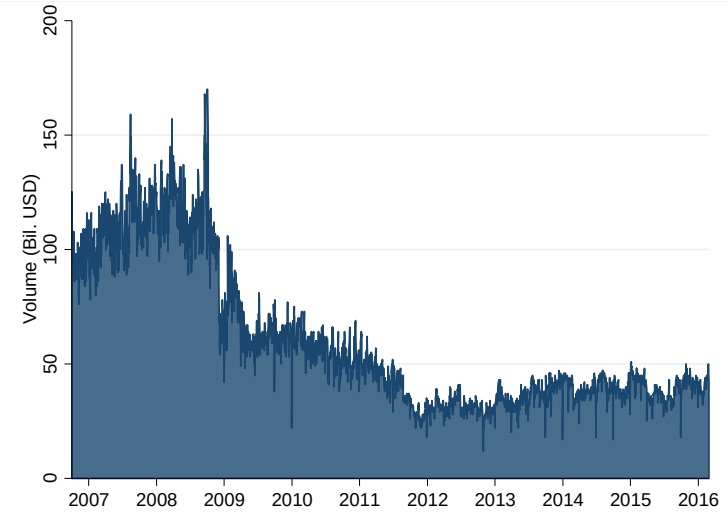
[24] Another alternative is to use a morning funds rate, such as the Broker's Fed Funds open. However, these rates represent quotes and not transactions and, moreover, they are not based on meaningful volumes.

Box 5: Fed funds Market Activity before and after the Crisis

The pre-crisis period was characterized by significant inter-bank trading. Banks would trade fed funds for a variety of reasons including avoiding overnight overdrafts, smoothing daily balances emanating from day-to-day fluctuations in both assets and liabilities and to meet reserve requirements over the two-week reserve maintenance period cycle. In addition, because the yield curve was typically upward sloping, some banks established a "structural short" position wherein they would effectively fund longer term assets via consistent borrowing in the fed funds market.

Along with the shift to reserve abundance since the crisis of 2007-2009, fed funds trading volume declined sharply. This is evident in the chart below which shows a roughly 50% decrease in brokered fed funds volume after the crisis.

Brokered Fed Funds Rate Volume: Oct. 2006-Feb. 2016



Source: Federal Reserve Bank of New York
The data is the result of aggregating daily total volumes voluntarily supplied by fed funds brokers.

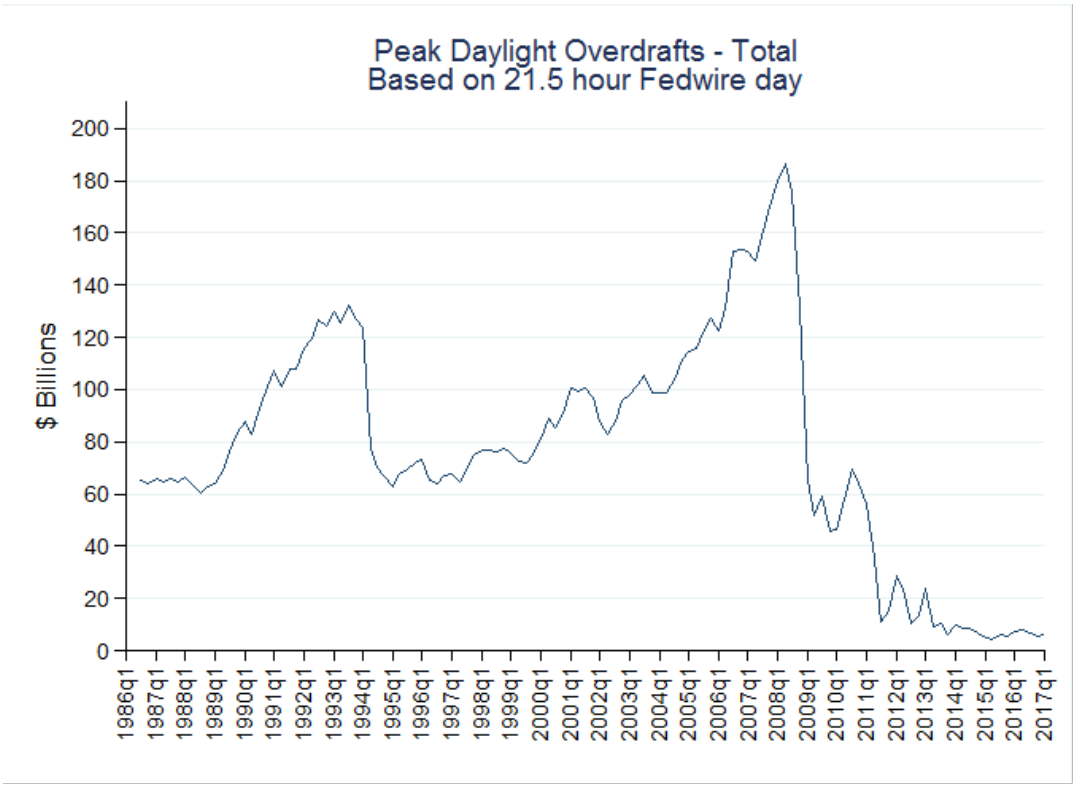
Activity in the fed funds market is currently dominated by investors that were ineligible to receive interest on excess reserves (IOER) interacting with mostly foreign banking organizations that generally leave the borrowed proceeds at the Fed to earn IOER, in a trade known as IOER arbitrage. As such, the fed funds market is now fundamentally different than it was pre-crisis. Most, if not all, of the pre-crisis motivations for borrowing and selling fed funds have changed significantly and new Basel III regulations discourage banks from funding longer-term assets with short term liabilities. As a consequence, fed funds trading volumes are now persistently lower than they were pre-crisis.

Box 6: Changes to the Payments System Risk Policy Overdraft Regarding Overdrafts

The Federal Reserve's Payment System Risk Policy

The extension of intraday credit by Federal Reserve Banks is governed by the Fed's Payment System Risk (PSR) policy. The policy addresses the risks that payment, clearing and settlement activities present to the Fed and the financial system as a whole and it also governs Reserve Banks' provision of intraday credit to account holders.[25]

The policy was first written in 1985, and has been amended multiple times since then. The policy was modified in 1994 to charge banks fees for their use of intraday credit. In 2001, changes to the PSR policy allowed institutions meeting certain criteria to obtain collateralized overdrafts above their authorized capacity, known as net debit caps. In 2006, the policy was revised to require government sponsored enterprises (GSEs) and international organizations to pre-fund Fedwire payments of principal and interest due on their outstanding debt, thus precluding the Fed from granting intraday credit to these institutions. In 2008, the policy was once again revised by setting the fee for collateralized overdrafts at zero and raising the fee for uncollateralized overdrafts to 50 basis points. This policy was intended to improve the efficiency of the payment system while also limiting the credit exposure of Federal Reserve Banks. These changes went into effect in 2011.



[25] https://www.federalreserve.gov/paymentsystems/psr_about.htm

Changes in Peak Intraday Overdraft Activity

The chart above presents peak intraday overdraft activity by quarter since 1986.[26] We observe a temporary slowdown in the growth of intraday credit around the time of the implementation of the GSE restriction. However, it is difficult to attribute causation as other factors may have been responsible for the slowdown. Peak intraday credit resumed growing later in 2006 and ultimately peaked sometime in 2008.

The most striking feature of the chart above is the dramatic decline in the usage of intraday overdraft credit once the Fed's balance sheet expanded in the fourth quarter of 2008. Excess reserve balances grew dramatically during this time, first from draws on various liquidity facilities and then from the Fed's large-scale asset purchase programs. As excess reserve levels have remained high, demand from banks to borrow funds from the Fed on an intraday basis has remained low for many banks.

Private Solutions to the Need for Intraday Overdrafts

During the period of high intraday credit usage, a private market for providing this specific type of credit did not materialize. However, there existed some informal market-oriented solutions to provide credit on an intra-day basis. One solution was for large GSEs to obtain a collateralized intra-day credit line from a large money center bank. The other solution for borrowers who were facing large intra-day credit needs was to borrow overnight money in the brokered fed funds market on a "fill or kill" basis. With a "fill or kill order," the lender agrees to send the funds promptly, say in a 15-minute window, which the borrower will return within a 23-hour window by market convention. The borrower is willing to pay a little more to borrow funds in this manner and thereby receives immediate relief on intra-day credit issues by receiving the funds promptly. This solution was widely used by market participants in the pre-crisis period.

[26] https://www.federalreserve.gov/paymentsystems/psr_data.htm

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