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The Pre-Crisis Monetary Policy Implementation Framework

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Abstract

This paper describes the Federal Reserve's framework for implementing monetary policy prior to the expansion of the Fed's balance sheet during the financial crisis. The pre-crisis framework was a reserve-scarcity regime in which banks demanded reserves in order to meet minimum reserve requirements. The New York Fed's open market trading desk implemented monetary policy by carefully managing the supply of reserves, primarily through the conduct of daily repo operations with primary dealers. The open market trading desk was able to achieve its monetary policy implementation objectives efficiently in the pre-crisis period without impairing financial market functioning. However, the framework deployed was complex relative to alternative implementation frameworks and required substantial intraday overdrafts from the Fed to meet banks' short-term payment needs. Once its balance sheet expanded in response to the financial crisis, the Fed was no longer able to rely on the pre-crisis framework to control the policy rate. Nevertheless, the open market trading desk successfully controlled the policy rate using the new, post-crisis framework, suggesting that effective monetary control may be achieved through different frameworks.

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

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1. Introduction

The Federal Reserve's (Fed's) monetary policy implementation framework changed during the financial crisis of 2007-2008 due to the substantial increase in reserves resulting from unconventional policy measures (Bech and Klee (2011)). The aim of this article is to assess the Fed's monetary policy framework prior to the crisis, in order to facilitate a fuller understanding of changes in monetary policy implementation since the crisis.

The primary monetary policy tool of the Fed before the crisis was a target rate for fed funds set by the Federal Open Market Committee (FOMC). Bank reserves were scarce in the pre-crisis era in the sense that banking system reserves were barely above the amount that banks were required to hold. As reserves were unremunerated, banks tried to minimize excess (of their requirements) reserve holdings, using the fed funds market to borrow or lend reserves as needed. The supply of fed funds was determined exogenously (from the point of view of market participants) by the Fed, which targeted a specific amount of reserves on a daily basis through the conduct of open market operations. The New York Fed's open market trading desk ("the Desk") managed the supply of reserves to bring supply and demand into equilibrium at a rate close to the FOMC's objective.

The goals of a monetary policy framework involve the satisfaction of monetary policy, operational and financial objectives.[1] Monetary policy objectives relate to effective control of the policy rate and its rapid transmission to other money market rates and, eventually, the broader economy. Operational objectives include efficiency (i.e. meeting objectives with as few resources as possible), transparency (i.e. operating in a manner well understood by market participants), and universality (i.e. being able to implement monetary policy under a range of economic conditions). Finally, financial objectives relate to ensuring that the operational framework does not impair market functioning—for example, that collateral policy does not distort asset liquidity and prices.

We show in this paper that the Fed's pre-crisis framework met the monetary policy objectives satisfactorily. 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.

While the Desk was successful in meeting its pre-crisis monetary policy goals, the framework was rather complex relative to alternative monetary policy frameworks, such as interest rate corridor systems widely followed by other central banks. The Fed's approach required the Desk to expend resources in forecasting reserve demand as well as changes in the supply of reserves that are outside the Desk's control, commonly referred to as autonomous factors. Then the Desk had to conduct repo or reverse

[1] 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 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.

repo operations on an almost daily basis.[2] While the process of daily liquidity management appears complex (Board of Governors, 1963), the Desk generally interpreted data consistently and avoided subjective judgments so that experts were likely able to follow the logic of its actions. However, on a day-to-day basis, market participants sometimes had difficulty understanding the Desk's actions, in part because the Desk did not routinely publish metrics of the daily desired level of reserves and forecast errors of autonomous factor changes. Nevertheless, the Desk successfully aligned the market rate to its target with minimum disruption to financial market functioning. Regarding universality, the pre-crisis operational framework relied on the Desk having discretion over the aggregate amount of reserves in the banking system, and so the framework could not continue to function when the amount of reserves in the system became substantially larger, as occurred during the financial crisis of 2007-2009.

Turning to the financial market functioning objective of the monetary policy framework, we focus on three areas: collateral policy, money markets and payments systems functioning. Assets eligible for collateral may benefit from enhanced liquidity and ability to obtain central bank credit as compared to ineligible assets. As the Fed accepts only highly liquid assets in its temporary open market operations, including Treasury and agency securities, any distortionary effects on asset prices were likely minimized. Regarding money markets, 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 more reserves than needed 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. Finally, in the pre-crisis period, the Fed routinely extended large amounts of intra-day credit to banks to meet payment system demands. 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.

The article is organized as follows. The first section discusses the basic economic premise underlying the pre-crisis framework and how rate determination in actuality deviated significantly from the textbook example. The second section details the practical aspects of how the framework was implemented, including reserve maintenance period dynamics. The third section discusses the effectiveness of the framework in meeting monetary policy objectives. The fourth section evaluates the other objectives—i.e. the operational and the financial market functioning objectives. The final section has concluding remarks on some aspects of the pre-crisis framework that have changed since the crisis.

[2] In a corridor system, the floor and the ceiling are determined by the rates on the standing deposit and lending facilities, respectively. A benefit of the corridor system is that liquidity management may be more efficient as banks take on the primary responsibility of managing their liquidity provided they have recourse to standing facilities at the central bank (Bindseil (2014)).

2. The Economics of the Pre-Crisis Monetary Policy Implementation Framework

In this section, we discuss the economic foundation of the monetary policy implementation 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.

The primary monetary policy tool of the Fed prior to the crisis was the target for the effective fed funds rate (EFFR), calculated as an average volume-weighted rate of each business day's fed funds transactions.[3] In the fed funds market, banks traded reserves with each other on an unsecured basis, typically with an overnight tenor. Demand for fed funds was based on two countervailing features (Ihrig, Meade and Weinbach 2015):

1. Reserve requirements necessitated that banks hold minimum balances (as a percentage of their net transaction accounts) in their accounts with Federal Reserve Banks.
2. Banks were averse to holding large reserve balances since they received no interest on them.

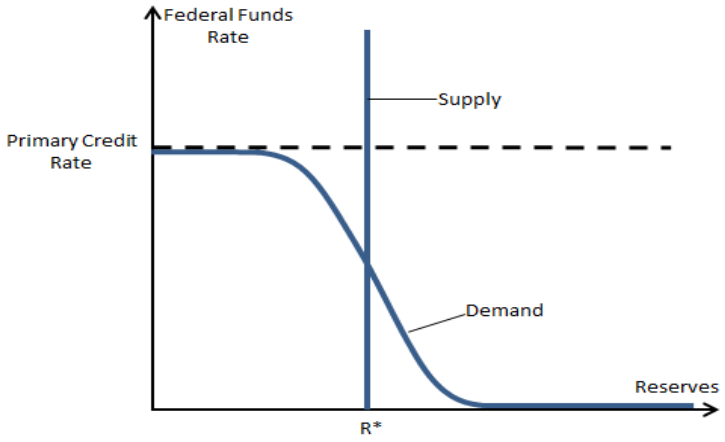
The supply of fed funds was determined exogenously (from the point of view of market participants) by the Federal Reserve, which, through open market operations, targeted a specific amount of reserves on a daily basis.

Since banks did not receive interest on reserves in the pre-crisis period, the lower bound for the fed funds rate was zero, at or below which banks had no incentive to lend reserves since they could earn zero interest by simply keeping reserves in their own accounts (Figure 1). 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, the primary credit rate should in theory act as a ceiling above which banks would not borrow in the private market.[4] 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)).

[3] 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 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 report.

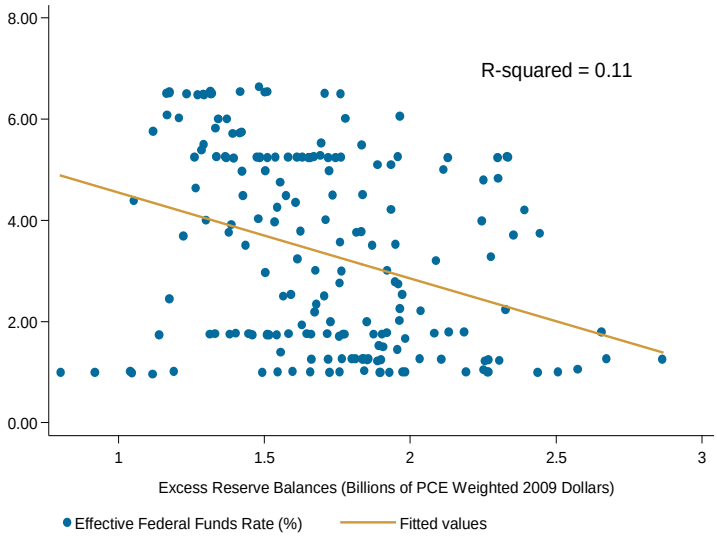
[4] Under Regulation A on January 9 2003, financially strong and well-capitalized banks can borrow under the Fed's primary credit program at a penalty rate above the target fed funds rate (rather than a subsidized rate as was the case prior to this regulation).

Figure 1: The Market for Reserves



Before the crisis, the Federal Reserve carried out monetary policy by operating in the relatively inelastic (downward sloping) region of the demand curve for reserves. Conceptually, the Federal Reserve could raise rates by draining reserves (decreasing supply) and lower rates by adding reserves (increasing supply) to the system. Thus, the reserve demand curve is expected to be negatively sloped. Indeed, in a simple plot of the effective federal funds rate against excess reserves (both averaged over 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

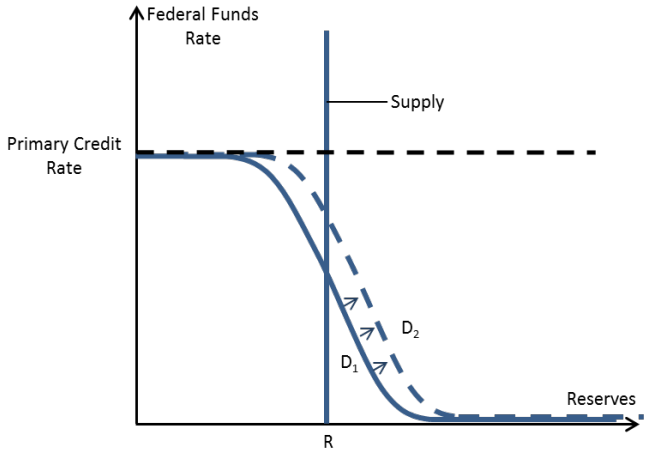


Time Period: 1/1/2000 to 7/1/2007
Source: The Federal Reserve Bank of St. Louis, Authors' Calculations
Note: Maintenance period averages; exceptionally high reserve balance periods dropped, such as the period around 9/11/2001

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 away 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.

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 concerns unaccounted for in the simpler theoretical models. In managing daily liquidity, the Desk had to account for variations within a reserve maintenance period. 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

In order to allow depository institutions greater flexibility in maintaining minimum account balances, the Federal Reserve calculates balances averaged over two-week periods known as maintenance periods in order to determine whether or not banks met requirements.[5] The periods always begin on a Thursday and end on the second Wednesday thereafter. Reserve requirements are known with certainty at the beginning of the period, and so averaging allows 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 as few balances as possible 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

The Desk forecasted the demand for and supply of reserves daily over the entire maintenance period, and then adjusted the supply of reserves to ensure that the EFFR was close to the target rate. In practice, the Desk relied on temporary open market operations to achieve the daily changes in reserves which typically involved conducting repurchase agreement operations (repos) with primary dealers in order to affect the supply of reserves.[6] The Desk would routinely increase (decrease) the supply of reserves by expanding (contracting) the size of its repo operations with primary dealers, a process that is much easier to execute for the purpose of changing the level of reserves than outright operations (i.e. continually purchasing and selling Treasury securities in the secondary trading markets). Using repos allowed the Desk to easily expand or contract the level of reserves with minimal disruption to the functioning of the market where the underlying securities traded.

[5] In practice, some banks voluntary agreed to hold significant levels of clearing balances to supplement their required reserve levels. The Desk managed reserve levels to meet Required Operating Balances which were equal to reserve requirements plus clearing balances. Banks were compensated on their clearing balances based off of three month Treasury bill rates. Clearing balances provided banks with increased flexibility in holding reserves across the maintenance period. For simplicity, we refer to "required operating balances" as "reserve requirements" for the remainder of this memo.

[6] 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.

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 purchases (typically of Treasury securities) just below the level of aggregate reserves required by the banking system. This shortfall was offset by the aforementioned temporary open market operations which the Desk utilized to control the level of the fed funds rate. Because the level of reserves was relatively low, banks had an incentive to actively trade on the fed funds market in order to meet reserve requirements.

Reserve demand was driven by reserve requirements and banks' liquidity needs. Reserve requirements created a base level of aggregate demand for reserves, since depository institutions were penalized if these requirements were not met. Using requirements along with forecasted demand for liquidity, the Desk estimated total reserve demand for the entire maintenance period and for each day of the maintenance period. The Desk used the term "excess reserves" to describe the amount of reserves that banks would be provided beyond their aggregate requirements for the reserve maintenance period.

The Desk forecasted the average excess reserves over the maintenance period based on the maintenance period-to-date distribution of reserve holdings among different types of banks. 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. In other circumstances, the Desk would reduce its estimate for "period average excess" reserves. Average reserve balances in 2006 were about $17.5 billion, or $2.0 billion above average requirements of about $15.5 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 Appendix 4.

It was also necessary for the Desk to forecast supply. While the Desk could affect the aggregate level of reserves through open market operations, there were other determinants of aggregate reserves outside of the Fed's control known as "autonomous factors." Major autonomous factor categories are currency-in-circulation, the Treasury's balance at the Fed, foreign central bank investments in a "repo pool" and float.[7] The Desk expended considerable resources in tracking and forecasting autonomous factor movements. The Desk had to forecast changes in autonomous factors and their resulting impact on

[7] Float refers to a timing difference in processing check payments that may temporarily increase or reduce reserves. The magnitude of float timing differences has decreased as more transfers are conducted electronically. As 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. Changes in account holders' balances at the Fed also affect reserves as electronic funds that are kept at the Fed are, by definition, not in the private market. Fed account holders include the Treasury's General Account and foreign repo pool customers. The latter have accounts at the Fed as a result of fiduciary services provided by FRBNY Markets Group's Central Bank and International Account Services division. Account holders' balances at the Fed are represented as Reverse repurchase agreements – Foreign official and international accounts and U.S. Treasury, General Account in the H.4.1 Federal Reserve Statistical Release which is published weekly (https://www.federalreserve.gov/releases/h41/current/).

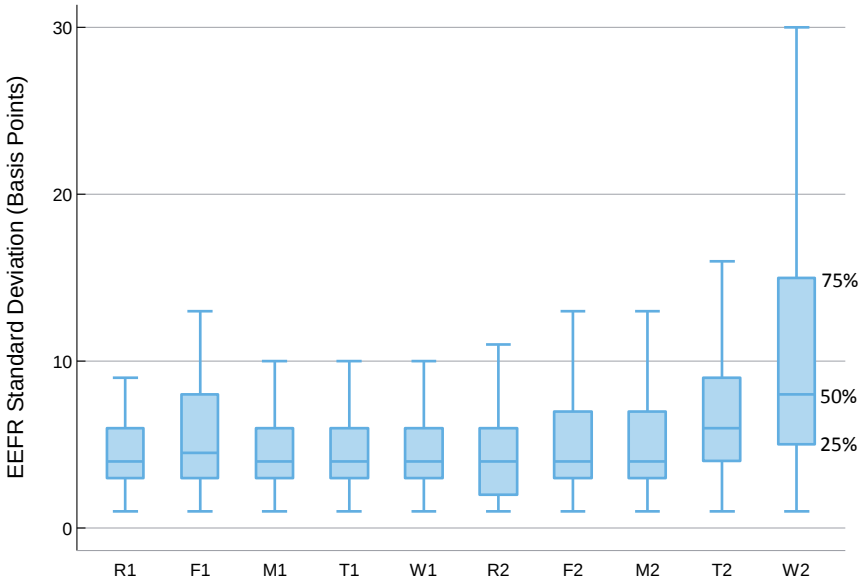
reserves so this could be factored into the desired size of repo operations. If autonomous factor changes were forecasted to increase (reduce) reserves by say $1.0 billion, then the Desk would reduce (increase) the size of its outstanding repo operations by the same amount, *ceteris paribus*.

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. currency tends to increase around Thanksgiving and Christmas) and the long-term growth rate of currency. To adjust for these factors, the Desk complemented its use of overnight repos with longer-term repos for seasonal changes and used outright purchases of Treasury securities to offset increases in currency in circulation that were viewed as "permanent."

Reserve maintenance period dynamics

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 4). In the next section, we examine the Desk's ability to manage end-of-maintenance-period volatility.

Figure 4: Fed funds effective rate Intraday Standard Deviation around Maintenance Period End



Time Period: 7/3/2000 to 8/1/2007
Source: FRBNY, Authors' Calculations
Note: The chart shows box-whisker plots of the distribution of the standard deviation of excess reserves 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. 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.

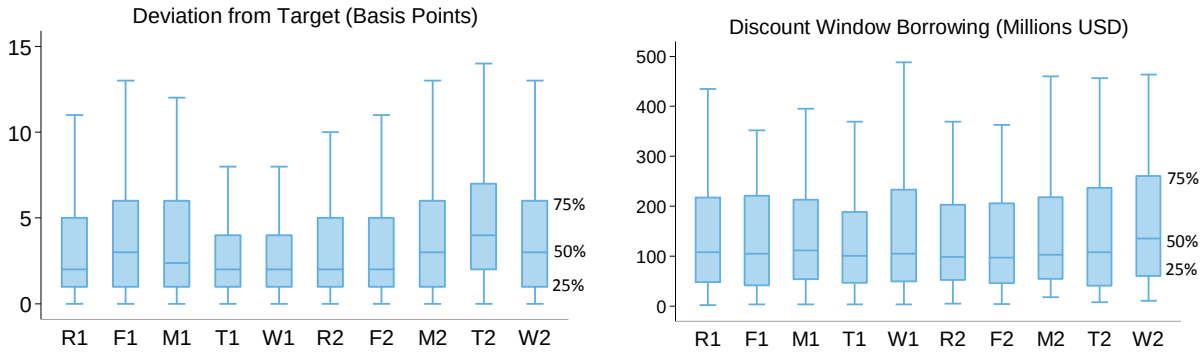
4. Effectiveness in Meeting the Monetary Policy Objectives

How effective was the Fed in meeting its monetary policy objectives? In this section, we focus on three aspects of effectiveness: the deviation of fed funds rates from the target, the resiliency of rates (i.e. how quickly rates reverted to the target during periods of high liquidity demand and volatility), 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 markets.

Control of the Policy Rate

Despite greater dispersion of rates (Figure 4), the EFFR did not drift significantly from the target rate at the end of maintenance periods relative to other days in the maintenance period. As the left panel of Figure 5 shows, the deviations from the target were small (rarely in excess of 20 basis points) and not persistent. 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 5 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. This suggests that the Desk was successful in managing reserves to keep the EFFR close to the target throughout the maintenance period. In other words, the end of the maintenance period did not significantly impair the Desk's ability to implement monetary policy.

Figure 5: 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

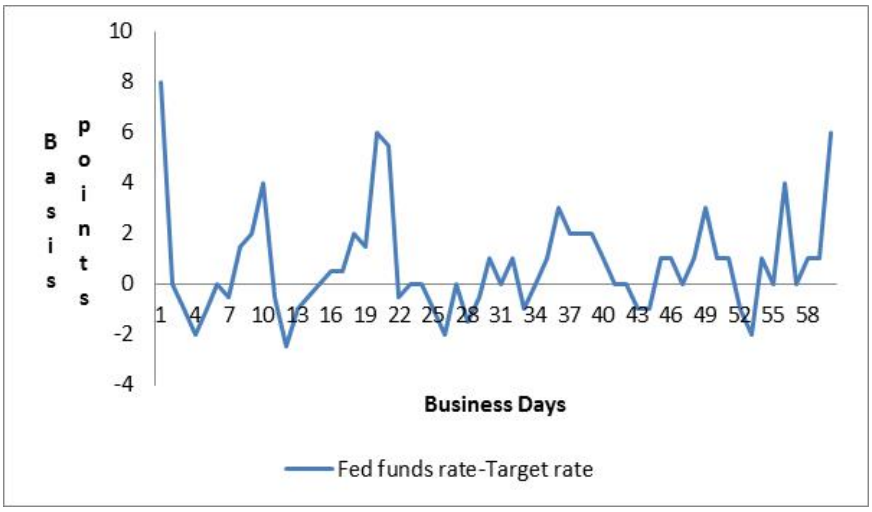
Time Period: 1/1/2003 to 6/30/2007
Source: FRBNY, Authors' Calculations

Note: The left chart shows box-whisker 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. 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. The reasons for these deviations were generally predictable 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 important, 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 Appendix 1 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 6) and by 8 basis points the following day (day 1 in Figure 6, which is the first day of the following quarter). 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.

Figure 6: 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 Appendix 1). 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. Consequently, the deviation of the fed funds rate from its target was short-lived, falling to within 3 basis points on the 2nd day after quarter-end (Figure 6).

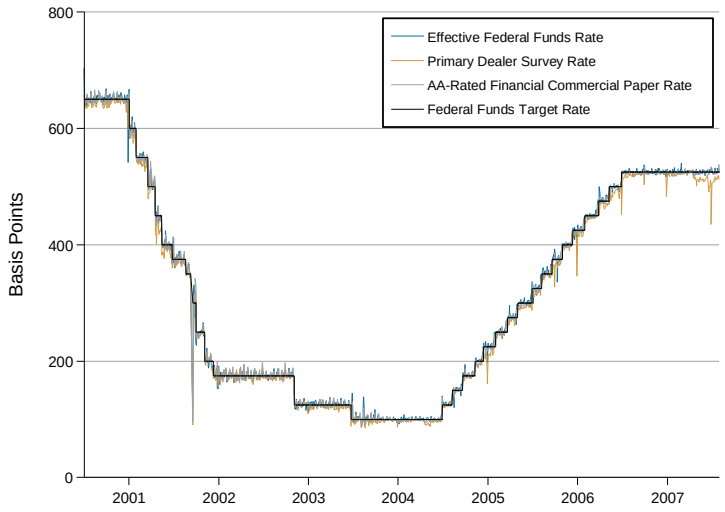
Transmission of the Policy Rate to Other Money Markets

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.[8] 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. The EFFR and the overnight general collateral repo rate ("repo rate" from now on) co-moved tightly before the crisis, as would be expected with effective arbitrage (Figure 7).[9]

Figure 7: Short-term Money Market and Target Fed Funds Rates: July 2000-July 2007

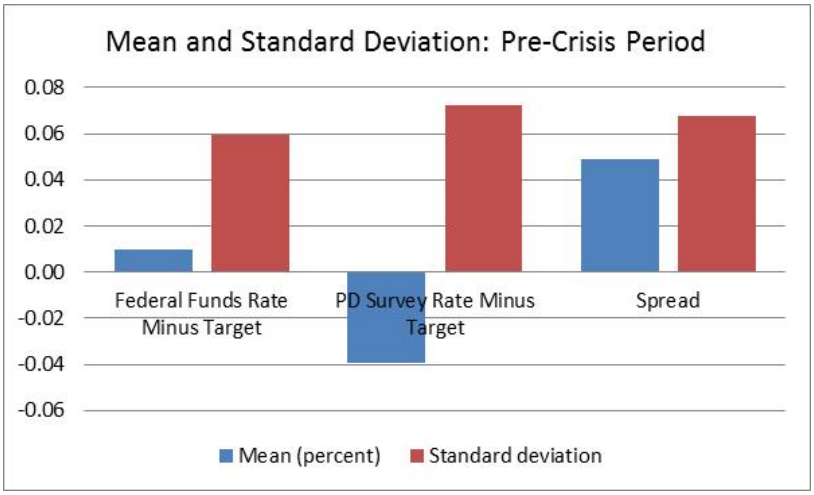


Source: Federal Reserve Bank of New York, Bloomberg

On average, the EFFR and the repo rate generally remained close to the FOMC's target rate (Figure 8). 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 means. To the extent that the volatility is fundamental, the high standard deviation may indicate a substantial amount of information flows, consistent with price discovery (i.e. discovery of the rate equilibrating demand and supply of reserves) occurring on the fed funds market. In turn, effective price discovery was likely facilitated by an active 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.

[8] See Bernanke (2005).
[9] The repo rate is the Desk's 9 AM Primary Dealer Repo Survey Treasury GC rate. The EFFR is calculated by the Desk from broker submissions.

Figure 8: 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 Appendix 2, 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 Granger-causes the EFFR in the pre-crisis period, indicating two-way flows of information between the fed funds and repo markets. In addition to the fed funds market, we also examine 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 fed funds rate have historically been tightly connected).

5. Effectiveness in Meeting the Operational and Financial Market Functioning Objectives

As discussed in the introduction, a monetary policy framework may be evaluated with respect to three goals regarding monetary policy, operational and financial market functioning objectives. We have already demonstrated that the pre-crisis framework performed quite well in terms of meeting monetary policy objectives. We now focus our attention to an evaluation of the remaining objectives. The pre-crisis framework's operational goals are evaluated by discussing the tradeoff between the effectiveness versus the complexity and transparency of the Desk's day-to-day actions and procedures, 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 the payment systems.

Operational objectives: Effectiveness versus Complexity of Procedures

The Desk's procedures could well appear complex to non-experts. This complexity included the execution, planning and conduct of the Desk's operations. The Desk's approach required a daily cycle of:

a. Forecasting autonomous factors
b. Receipt and review of end-of-day and maintenance period-to-date reserve balance holdings and requirements detailed by bank type; and by specific bank for relatively large banks
c. Size and conduct of repo / reverse repo operations.

From an expert's perspective, the Desk generally applied only relatively minor, subjective judgment in interpreting objective data, and the Desk had a consistent daily goal of assessing the supply and demand for reserves followed by the conduct of repo operations to provide a level of reserves that would encourage trading around the fed funds target rate.[10] However, market participants sometimes had difficulty in understanding the significance of the Desk's actions on a daily basis. 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 markets 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.

Alternative frameworks, such as the corridor system, would presumably require less daily intervention by the Desk since liquidity management would be more decentralized as long as banks had access to the central bank's standing deposit and borrowing facilities. Bindseil (2014) examines a number of alternative monetary policy frameworks and shows that, during the pre-crisis period, they were all effective in meeting their monetary policy objectives. Thus, operational complexity is not necessary to meet monetary policy goals. Despite the lack of transparency in its procedures to market participants, the Desk enjoyed their confidence by building 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 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

[10]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 (see "The Open Market Policy Process" by the Board of Governors (1963)).

costs of designing and testing new frameworks as conditions change. A more universal framework could also help avoid unexpected, forced changes to the implementation framework if conditions develop rapidly (e.g., during a crisis). Such sudden changes to the implementation framework could be suboptimal if they are made under time constraints.

One disadvantage of the pre-crisis framework was 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 would lose control of the policy rate in the pre-crisis framework. This limitation became relevant in 2008 when the Desk could no longer sterilize additional reserves that were demanded under various liquidity programs, a topic we explore in the concluding remarks.

Financial Market Functioning Objectives: Collateral Policy

Central banks impact market functioning via their collateral acceptance framework. Assets eligible for collateral may benefit from increased liquidity and enhanced ability to obtain credit, as compared to ineligible assets.[11] 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).

In both pre- and post-crisis periods, the Fed accepted only high quality assets in its open market operations, namely Treasury, agency and agency MBS securities. This strict eligibility criterion reduces distortionary effects on asset prices since the additional liquidity benefits of being granted eligibility is likely small for these types of assets.[12]

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.

Financial Market Functioning Objective: Money Market Activity

A reserve scarcity framework is likely to encourage higher interbank activity than a one with reserve abundance. Indeed, a scarcity of reserves balances relative to required and precautionary demand for

[11] See ECB Monthly Bulletin (2007).

[12] 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).

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 Appendix 3 for a more detailed discussion of changes in fed funds market activity since the crisis).

As a general matter, it is unclear if 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 providing market discipline. However, alternative markets (such as lending 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 force lenders withdraw funding broadly. [13]

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

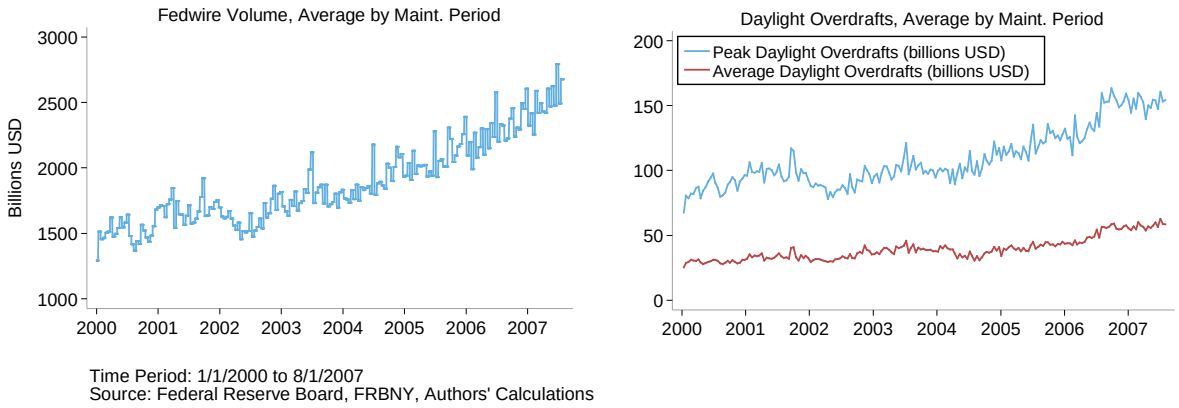
Financial Market Functioning Objective: Payment System Activity

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. Banks resorted to intraday credit from the Fed as this was likely a cheaper source of funding than borrowing overnight in the fed funds market and boosting their clearing balances. 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.

Figure 9 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.

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

Figure 9: 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 Appendix 4 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 implementation framework was control over the fed funds rate. In order to exert this control, the Fed relied on reserve scarcity such that banks needed to trade in the fed funds market to meet regulatory requirements over the course of a two week maintenance period. To adjust the rate, the Desk increased or decreased the amount of reserves available to banks relative to forecasted demand by changing the size of daily repo operations. The framework was aided by arbitrageurs in transmitting changes to 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 is not impaired.

The pre-crisis framework was effective at meeting monetary policy objectives. First, the Desk was able to maintain the EFFR very close to the policy target 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, target rate changes were quickly transmitted to 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 a relatively robust 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 framework scores less well in terms of efficiently meeting operational objectives. Although the Desk was quite successful in steering the EFFR toward the stated target rate, the framework was complex to implement and generally difficult for non-experts to understand. Finally, the framework lacked universality in that it did not allow for increases or decreases in aggregate reserve balances for reasons unrelated to adjustments to the fed funds rate. This last 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.

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 the fed funds rate is controlled through the use of administered rates that keep the EFFR 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 Appendix 3). However, the benefits of active money markets are debatable and must be weighed against reduced EFFR volatility (Potter 2016).

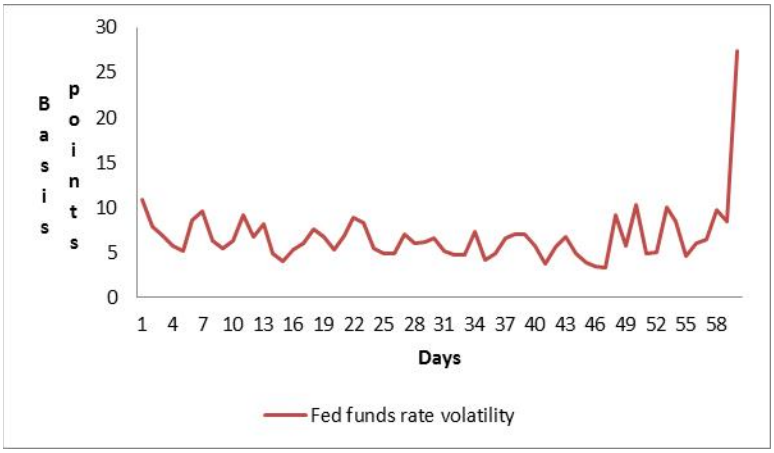
While the current framework will likely evolve as the FOMC considers its appropriateness in meeting future monetary policy challenges, a return to the pre-crisis framework is not necessarily desirable. As we have shown in this paper, the pre-crisis framework contained several shortcomings that can probably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

Appendix 1: Quarter-end Dynamics of Fed Funds Rate

Quarter-end Volatility

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.

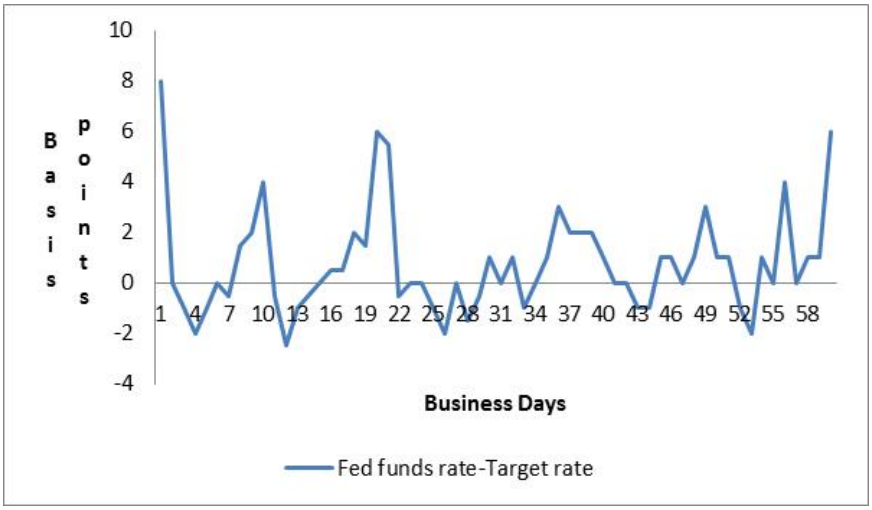
Volatility of Fed Funds Rates Spikes on the Last Day of the Quarter: Q4 2004 to Q2 2007



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.

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

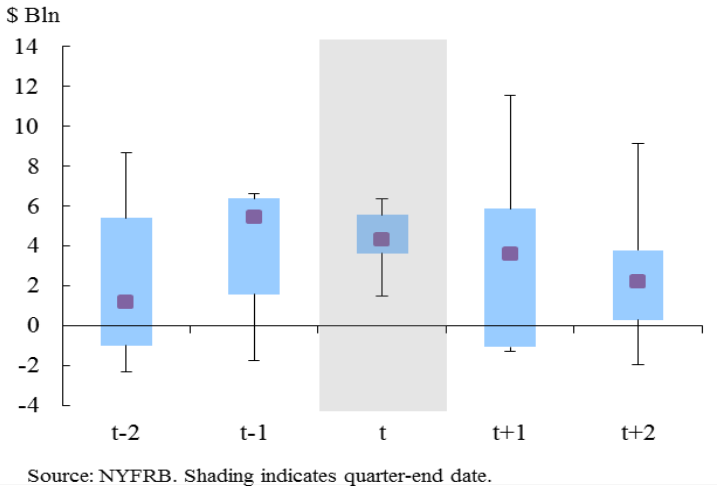


Source: FRBNY. The figure shows the median of the difference between fed funds rate and the target rate across quarters for each day. Day 60 is quarter-end. Day 1 is start of the quarter. The quarters are standardized to 60 days by using the first 30 days from quarter-start and the last 30 days from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

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.

Appendix 2: 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.[14] 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).

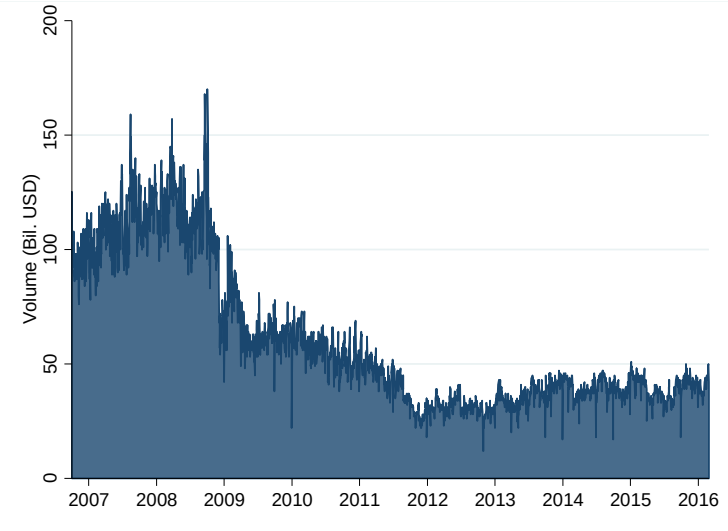
[14] Another alternative is to use a morning funds rate, such as the Broker's Fed Funds open. However, these rates represent quotes and not transactions and, moreover, they are not based on meaningful volumes.

Appendix 3: 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.

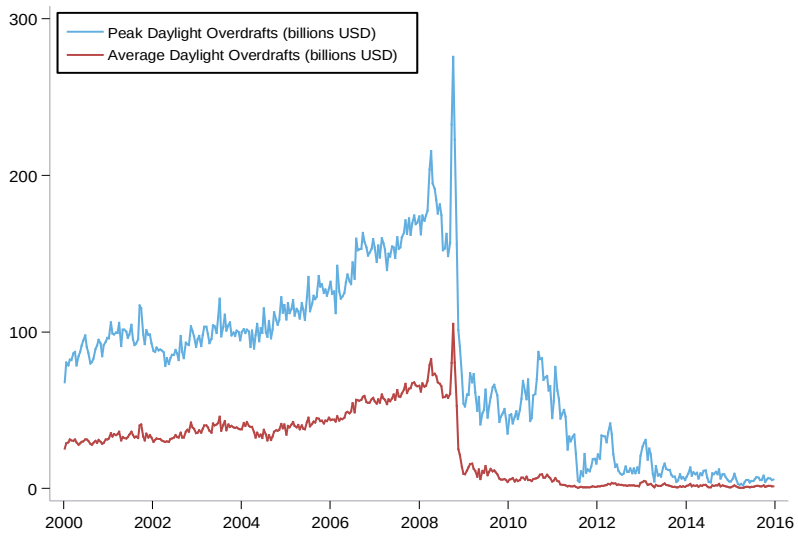
Activity in the fed funds market is currently dominated by non-IOER eligible investors interacting with mostly foreign banking organizations who generally leave the borrowed proceeds at the Fed to earn IOER, in a trade known as IOER arbitrage. As such, the fed funds market is now fundamentally different 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.

Appendix 4: Changes to the Payments System Risk Policy Overdraft Regarding Overdrafts

The Federal Reserve's Payment System Risk Policy

The extension of credit by Federal Reserve Banks is governed by the Federal Reserve's Payment System Risk (PSR) policy. The policy was first written in 1985, and has been amended multiple times since then. Each eligible borrower faces a maximum limit, or net debit cap on overdrafts. The PSR policy was modified in 1992 to charge participants fees for their use of intraday credit, which went into effect in April 1994. In 2001, changes to the PSR policy allowed institutions meeting certain criteria to have collateralized overdrafts above their net debit caps. In 2008, the policy was again revised with respect to intraday credit 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 payment liquidity while also limiting the credit exposure of Federal Reserve Banks. Those changes went into effect on March 24, 2011.

Time Series of Peak Daylight Overdrafts, avg. by maintenance period



Time period: 1/1/2000 to 1/1/2016
Source: Federal Reserve Board

The chart above plots the time series of overdrafts from 2000 to 2016. The striking feature is the dramatic decline in daylight overdraft use during the financial crisis, likely due to the large increase in excess reserve balances that resulted from unconventional monetary policy measures.

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