The Impact of Banks' Cumulative Reserve Position on Federal Funds Rate Behavior*

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We analyze the impact that reserve levels accumulated through the preceding day in a reserve maintenance period have on the level of the federal funds rate each morning prior to when open-market operations are arranged. Our empirical results and other evidence provided about intraday patterns of the federal funds rate demonstrate that the pace at which reserves are supplied over a maintenance period to meet banks' total reserve requirements is an important determinant of federal funds rate behavior.

JEL Codes: E5, G21.

1. Introduction

In this study we examine the factors that determine the level of the federal funds rate each morning, prior to when any open-market operations (OMOs) would typically be arranged by the Federal Reserve.[1] In particular, we focus on the impact from the quantity of reserves accumulated through the previous day in the same two-week

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[1] The open-market operations that this statement refers to are the final operations arranged each day that would be intended to adjust the supply of reserves that day.

reserve maintenance period. The level of the morning federal funds rate is of interest because this rate is indicative not only of trading conditions at that time but also of the general level of rates that prevails through much of the day, often until near the close of the trading session and well after the time when any new OMOs might have been arranged. Thus, knowing how the cumulative level of reserves acquired over previous days of a maintenance period may influence the morning level of rates is essential for developing a reserve management strategy designed to control the federal funds rate over a multiday maintenance period.

The federal funds rate refers to the interest rate banks pay to borrow reserve balances held by other banks at the Federal Reserve in the federal funds market.[2] In this market, the vast majority of trades settle on the trade date and mature the next business day. For years, the Federal Open Market Committee (FOMC) has set a target level of the federal funds rate as its operating objective for OMOs arranged by the Open Market Trading Desk (the Desk) of the Federal Reserve Bank of New York (FRBNY). The OMOs used by the Desk typically take the form of purchases or sales of government securities, with purchases adding to reserve supply and sales decreasing reserves. Each day, the Desk estimates the aggregate level of reserve supply for that day and for upcoming days in the maintenance period, assesses those estimates against estimates of reserve levels needed to maintain the funds rate around the target, and arranges OMOs accordingly. In making its daily decisions about the level of reserves to provide each day through OMOs, the Desk will consider current trading conditions in the federal funds market, measured by the deviation of the rate in the morning from the target. But importantly, on occasions when this morning rate deviates from the target, the Desk will not necessarily just seek to provide the level of reserves that it would expect to foster an average, or "effective," rate for that entire day that is equal to the target. Rather, in making a decision, it will also take into account the level of reserves that banks will have accumulated through that day in the

[2]Descriptions of the federal funds market can be found in Bartolini et al. (2005), Board of Governors of the Federal Reserve System (2005), and Hilton (2005). For simplicity, institutions in the funds market are referred to as "banks" in this study, although several other types of institutions actively participate in this market.

maintenance period and the expected impact of this reserve position on the federal funds rate the next morning.

Many earlier studies have looked for evidence of a liquidity effect by investigating the impact of exogenous daily reserve shocks to bank reserves and various calendar effects on the daily average level of the federal funds rate, measured relative to the target. This study represents a departure from previous efforts by examining determinants of the federal funds rate prior to the execution of any OMOs (the AM rate, defined below, measured relative to the federal funds rate target). We find that reserves accumulated through the previous day in the maintenance period generally have a negative relationship with the AM minus target rate spread, and that this relationship grows in magnitude and significance over the course of a two-week maintenance period. This result is consistent with banks' having a diminishing capacity to "average" daily reserve holdings for purposes of meeting reserve requirements as the end of the two-week maintenance period approaches. Overall, this analysis highlights the need for the Desk, and any central bank that operates with multiday reserve maintenance periods, to take into account the pace at which it provides reserves over an entire maintenance period in its daily reserve decisions.

The paper is structured as follows. Section 2 contains background information on the federal funds market, reserves and open-market operations, and the Desk's approach for controlling the federal funds rate. A literature review is found in section 3. Section 4 contains a description of the data, and empirical results can be found in section 5. Section 6 concludes.

2. Background[3]

In the portion of the federal funds market examined in this study, reserve balances in the accounts of commercial banks at the Federal

[3]The framework and procedures described in this section detail arrangements used by the Federal Reserve over the sample period of the study. Since September 2008, however, the Federal Reserve has adopted a very different approach to implementing monetary policy, one associated with interest rate objectives near zero, use of non-traditional operations, and the exercise of recently acquired authority to pay interest on reserve balances. Our sample period therefore ends with the last full maintenance period in August 2008. In the future, it is possible that the Federal Reserve will adopt operating procedures very different from the ones described and analyzed in this study.

Reserve are borrowed or loaned for one business day (overnight) and settle on the trade date. In volume, transactions with these characteristics account for the vast majority of all trading in the federal funds market. By convention, loans in this market are unsecured. Trading ends when Fedwire closes, scheduled for 6:30 p.m.[4] The rate in this market, the federal funds rate, is sensitive to the supply of reserve balances, and for many years the FOMC has implemented monetary policy by setting a target for this rate and manipulating reserve levels to achieve this rate objective.

2.1 Determinants of Reserve Supply[5]

Using a simple balance-sheet identity, the supply of reserve liabilities of the Federal Reserve can be calculated by taking the difference between the level of domestic financial assets (less liabilities) held by the Federal Reserve plus discount-window loans outstanding, plus the net value (assets less liabilities) of all other factors on the Federal Reserve balance sheet—so-called "autonomous factors" over which the Desk has little or no direct control.[6]

Changes in autonomous factors, in domestic financial assets via OMOs, or in discount-window lending will add to or decrease the supply of reserves. For example, increases in Federal Reserve notes outstanding (currency), which are liabilities of the Federal Reserve and by far the largest of these autonomous factors, reduce reserves. When a bank requests a shipment of Federal Reserve notes from the Federal Reserve to satisfy their depositors' demands for cash, the

[4]Fedwire is the wholesale electronic funds transfer network owned and operated by the Federal Reserve System. Federal funds transactions typically settle when the lending institution instructs the Federal Reserve via Fedwire to transfer reserves out of its account and into the account of the borrowing bank.

[5]In this study the term "reserves" is used to refer to the actual balances held by depository institutions at the Federal Reserve. As used in this study, the term does not include applied vault cash (which technically are reserves) and does include balances used to meet clearing-balance requirements (which technically are not reserves). Applied vault cash and clearing-balance requirements are defined below.

[6]Examples of major autonomous factors include balances in the Treasury's account at the Federal Reserve and Federal Reserve notes outstanding. Weekly averages of the main autonomous factors and other items on the Federal Reserve's balance sheet are published each Thursday by the Federal Reserve, in Publication H.4.1.

Federal Reserve debits the reserve account of the bank in payment for the currency that it ships. Although currency is the largest of these autonomous factors, some other factors are more volatile and have a less predictable impact on reserve supply.

Open-market operations—the purchase or sale of government securities by the Desk with securities dealers—are a discretionary tool that is used by the Desk to affect the supply of reserves. When the Desk purchases government securities, it pays for the securities it acquires by crediting the reserve balance of its counterparty, or of the correspondent bank of a non-bank counterparty. This action increases the supply of reserves. Sales of securities reduce reserve supply. And when the Federal Reserve extends a discount window loan to a bank, it credits the reserve balance of the borrowing bank for the amount of the loan and books the loan as an asset on its balance sheet.

2.2 Reserve Accounting: Requirements, Penalties, and Carryover Privileges[7]

Over each two-week *reserve maintenance* period beginning every other Thursday, each bank is required to hold a quantity of reserves in proportion to the quantity of transactions deposit liabilities on its balance sheet which, under lagged reserve accounting procedures in place since 1998, are based on amounts taken from a preceding two-week *reserve computation* period. This reserve requirement can be satisfied either by holding balances at the Federal Reserve during the reserve maintenance period or with cash held on a bank's premises during the reserve computation period (called "applied vault cash"). To meet the portion of reserve requirements not satisfied with vault cash, a bank must hold in total a sufficient amount of reserves over the entire maintenance period, based on its end-of-day levels. But it

[7]Several changes to the operating environment occurred over the course of the sample period, including (i) a shift from a contemporaneous to a lagged reserve accounting framework in 1998, (ii) termination of the adjustment credit facility and creation of the primary credit facility in 2003, and (iii) widespread adoption of retail sweep programs by depository institutions, which significantly reduced their deposit liabilities subject to reserve requirements. None of these developments materially affected the approach used by the Federal Reserve to control short-term interest rates. In this section, only the latest arrangements in place for the sample period are described.

may accumulate these reserves in any daily pattern it desires, subject to overdraft policies that apply to reserve positions at the end of each day.

Clearing-balance requirements represent obligations to hold reserves that are set at the discretion of a bank before each reserve maintenance period begins. Only balances held at the Federal Reserve during the two-week reserve maintenance period are eligible to satisfy clearing-balance requirements.

A bank is penalized for ending any day overdrawn on its account at the Federal Reserve, as well as for failing to meet its combined reserve and clearing-balance requirements at the end of the maintenance period. To obtain the necessary reserves to avoid these fees if it is unable to borrow the necessary amount in the market, a qualifying bank may borrow reserves directly from the Federal Reserve at the primary credit facility (commonly called the discount window) at a rate typically set 100 basis points above the target federal funds rate.[8] This spread between the primary credit facility rate and the target funds rate is generally viewed as representing a de facto penalty associated with being reserve deficient. During our sample period, the Federal Reserve did not pay interest on reserves held in excess of requirements.[9] Thus, the opportunity cost of holding excess reserves is a bank's marginal funding cost, which is represented in most studies by the federal funds rate.

To provide banks with some flexibility in meeting their requirements to avoid these penalties and costs, the Federal Reserve allows banks to apply excess reserve balances held in one maintenance period to meet reserve requirements in the following period, in an amount up to 4 percent of reserve requirements in the following period. Similarly, a bank may end a period up to 4 percent short of its

[8]During the period of market turmoil that began in the fall of 2007, the spread between the primary credit facility rate and the target funds rate was narrowed.

[9]Banks also did not earn interest on reserves used to meet reserve requirements. Banks did earn income credits, at a rate based on market rates, on the balances held to meet clearing-balance requirements. Credits earned can be used only to pay for priced services offered by the Federal Reserve, such as check-clearing fees and Fedwire transfer charges. In 2006, the Federal Reserve Act was amended, granting the Federal Reserve authority to pay interest on balances held by depository institutions, including balances used to meet reserve requirements, effective October 1, 2011. The Emergency Economic Stabilization Act of 2008 accelerated the effective date to October 1, 2008, and the Federal Reserve began paying interest on reserves on October 9, 2008.

reserve requirements and pay no penalty, so long as it holds sufficient excess reserves in the following period to offset this deficiency.[10]

2.3 Link between the Supply of Reserves and the Federal Funds Rate

Participation in the brokered segment of the federal funds market, from which the rate data used in this study is taken, is dominated by larger banking institutions. The rate in this segment of the market is influenced by the probabilities and costs these banks associate either with ending any day overdrawn or maintenance period deficient of their requirements, or with accumulating excess reserves. The probability of each of these outcomes will be influenced by the aggregate supply of reserves available on any given day and for a maintenance period as a whole.

The supply of reserves needed to maintain the federal funds rate around its target is closely linked to the level that allows banks to meet all their requirements, but without accumulating excess reserves, while simultaneously avoiding daily overdrafts.[11] When the supply of reserves is so low that some banks have no alternative but to borrow at the Federal Reserve's discount window to avoid ending a maintenance period short of their requirements or ending any day overdrawn, upward pressure on the funds rate will build, until

[10]Instead of having carryover flexibility, clearing-balance requirements are considered to have been satisfied so long as a bank accumulates an amount of reserves anywhere within a 2 percent band around its specified requirement.

[11]Smaller-sized banks that don't have access to funding markets which would allow for a quick adjustment in their reserve balance typically demand some level of excess reserves as a source of liquidity, to guard against reserve-draining shocks. As a group, these smaller banks historically have held about $1.5 billion of reserves in excess of their requirements each day. Reflecting their inability to access broad funding markets, this "frictional" demand amongst smaller banks has proven to be largely insensitive to both current trading conditions in the funds market and to the level of the funds target. In describing the link between the supply of reserves and the federal funds rate, the excess reserve demands of these banks are ignored with no loss of generality. In effect, their holdings of excess reserves are akin to an autonomous factor that reduces reserve supply, which the Desk must offset in its reserve provision to ensure that the larger banks can accumulate sufficient reserves to meet their requirements. Demands for excess reserves by small and large banking institutions are discussed in Federal Reserve Bank of New York (2006) and have been described in earlier annual reports in this series.

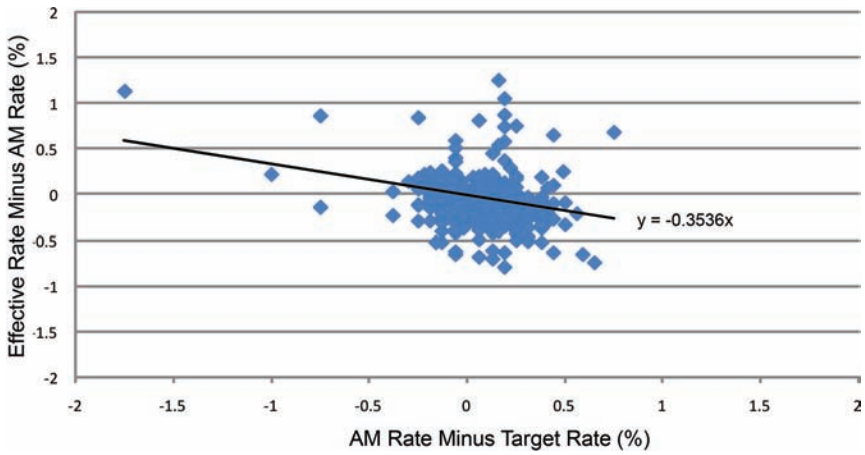
market rates reach a level at which a bank would prefer to pay the primary credit facility rate for borrowing directly from the Federal Reserve. And when reserve supply is so high that some banks face the prospect of accumulating unwanted excess reserves for the period, rates will fall off. In effect, at least for larger banks that actively manage their reserve balance by trading in the federal funds market, requirements are binding and are the principal determinant of reserve demand over an entire maintenance period.

Despite the ability of banks to freely substitute reserve holdings between days within a maintenance period for purposes of meeting their requirements, the funds rate can be influenced by the daily distribution of reserve supply, even if the level of reserves provided for the period as a whole is consistent with banks just meeting their requirements and sufficient each day to allow banks to avoid daily overdrafts. For example, relatively high levels of reserves provided by the Desk early in a period could put downward pressure on rates at that point in the period by fostering a perception among banks that they face a heightened risk of ending the maintenance period with excess reserves. Conversely, a low pace of reserve provision in the early part of a maintenance period could place upward pressure on rates early in a period, by raising fears among banks that they are at greater risk of failing to meet their requirements before the end of the period. Counterparty credit limits that all banks impose as lenders and face as borrowers reinforce these perceptions, as they constrain any bank's ability to make large adjustments to its daily or cumulative reserve position over short intervals without potentially having to make severe rate concessions on trades in the market, irrespective of the aggregate supply of reserves that subsequently might be available.

2.4 Daily Desk Operating Procedures and Intraday Rate Behavior

In making a decision each day about the level of reserves to provide that same day through OMOs, the Desk will consider current trading conditions in the federal funds market, measured by the deviation of the rate in the morning from target, with a goal of pushing the rate in the desired direction in later trading. However, when this morning rate differs from the target, the Desk will not just simply seek to provide the level of reserves that it estimates would yield an average rate

Figure 1. Scatter Plot for AM Rate Minus Target Rate



Note: Observations between −.01% and .01% and the first, middle, and last business day of each month are removed.

for the day equal to the target. Doing so would require a deliberate engineering of above-target (below-target) levels of the rate later in the day to offset below-target (above-target) rates that might have prevailed earlier in the day. Moreover, empirical evidence indicates that the federal funds rate tends to be relatively stable over much of the trading session, from the opening often until very late in the day, well after the time any new OMOs might have been arranged (Bartolini et al. 2005). Thus, seeking to fully offset morning deviations in rate levels from target could entail a very substantial overshooting of rates relative to the target late in the session.

As evidence of this proposition, we examine the relationship between the spread between the morning rate and the federal funds rate target (AM – Tar) and the spread between the daily effective federal funds rate and the AM rate (Eff – AM) from 1994 to 2008 on days when the morning rate is more than 1 basis point either above or below the target.[12] The following simple relationship is estimated and the underlying data presented in figure 1:

$$(\text{Eff} - \text{AM})_t = \beta'(\text{AM} - \text{Tar})_t + \varepsilon_t.$$

[12]The morning rate and the effective rate will be more thoroughly defined in section 4.

Consistent with the Desk's intention to push rates toward the target late in the day when the rate deviates from the target in the morning, this relationship is negative. But the estimate of β ($-.3536$) is less than -1, indicating that the Desk does not generally seek to achieve an *average* daily rate equal to the target when making its reserve decisions on days when the morning rate deviates substantially from the target.[13]

In choosing the quantity of reserves to leave in place on any given day, the Desk will also take into account the cumulative level of reserves that banks will have acquired through that day in the maintenance period as a result of any new OMOs it arranges, and the expected impact of this cumulative reserve position on the federal funds rate the next morning (which, based on the findings in Bartolini et al. 2005 cited earlier, would also be expected to prevail over much of the trading session the next day). For this reason, the relationship between cumulative reserve levels and morning rates is a critical factor that helps determine the pace at which the Desk will provide reserves over an entire two-week reserve maintenance period consistent with its operating objective for targeting the federal funds rate.

3. Literature Review

The earlier literature up through the mid-1990s examining the impact of monetary policy focused on the relationship between the monetary aggregates (e.g., M1 and M2) and interest rates, and used low-frequency data (monthly or quarterly). The goal was to investigate the existence of a liquidity effect, basically a negative relationship between the money supply and interest rates. The interest rate examined was either the federal funds rate or a short-term interest rate such as the rate on three-month Treasury bills (see table 2 in Pagan and Robertson 1995 for a summary of selected studies). Studies employing a single equation, typically regressing the interest rate on the money supply and other economic variables, tended to find no liquidity effect. Later studies employed simultaneous-equation estimation techniques and were more likely to find evidence of a liquidity effect (for example, Galí 1992 and Sims 1992).

[13]The coefficient has a t-statistic of -14.98 and the adjusted-R^2 value is .104.

The work of Hamilton (1997) was among the first that focused on the federal funds market at the daily frequency. Hamilton examined the change in the daily average federal funds rate and its relationship with a supply shock to reserves, namely the forecast miss for Treasury's account held at the Federal Reserve. His results suggest the presence of a liquidity effect, although only on certain days of a maintenance period.

Thornton (2001) reexamines Hamilton's study and finds that Hamilton's results are driven by a few outliers. In addition, Hamilton's results do not appear to hold for other sample periods. Thornton then examines the relationship between non-borrowed reserves (total reserves less borrowing from the discount window) and changes in the target federal funds rate. Thornton does not find a statistically significant relationship and concludes that a liquidity effect does not exist at the daily frequency.

Carpenter and Demiralp (henceforth C&D) (2006b) examine the relationship between the effective federal funds rate minus the target rate and forecast misses for all the autonomous factors, not just the Treasury balance. This approach provides a more direct measure of a shock to the supply of bank reserves. They find that the liquidity effect exists at the daily frequency, and also that the liquidity effect is non-linear in that only large forecast misses ($1 billion or more in absolute value) have a significant effect in the federal funds market. More recently, Thornton (2006) has extended C&D's analysis in a number of dimensions. For example, Thornton examines the change in the effective federal funds rate, examines a longer sample period, and deletes outlier observations. Thornton's results confirm C&D's findings of a liquidity effect, but the magnitude of the relationship is smaller.

Taking a different perspective, Bartolini, Bertola, and Prati (2002) examine the biweekly maintenance period patterns of the federal funds rate for evidence of a "martingale effect," but they do not explicitly consider how cumulative reserve positions might influence the daily pattern in rates over a maintenance period. Carpenter and Demiralp (2006a) do include a cumulative measure of excess reserves in their analysis of the effective federal funds rate, but the basis of this relationship is not explicitly explored. In contrast, our study focuses on the direct link between cumulative reserve levels

and the formation of rates in the federal funds market before new OMOs are arranged, and considers how this relationship influences the strategy for controlling the federal funds rate over an entire reserve maintenance period.

4. Data

The daily data used in our study cover the first full maintenance period starting in March 1994, roughly corresponding to when the Federal Reserve first began to publicly announce changes in the target federal funds rate, and run through the last full maintenance period in August 2008, when long-standing operating procedures and arrangements for implementing monetary policy were upended amid the financial crisis. The maintenance period that includes September 11, 2001, is omitted from the sample.

Data on the effective federal funds rate (Eff) and the target federal funds rate (Tar) is available from the FRBNY public web site (www.newyorkfed.org). The effective federal funds rate is a trade-weighted average of federal funds transactions provided to the Desk by a group of the major brokers in this market. The morning (AM) federal funds rate is a representative rate quote taken from an informal "reading" of the market conducted by the Desk, which is made by calling the major brokers, typically close to 9 a.m. The dispersion in rate quotes provided by the individual brokers is almost always extremely small. The morning federal funds rate and data on the supply of bank reserves are obtained from FRBNY's proprietary database.

The focus of this study is on the determinants of the morning rate minus the target rate $(\mathrm{AM}-\mathrm{Tar})_t$.[14] The key explanatory variable is reserves accumulated through the previous day $t-1$ (CR_{t-1}), measured relative to total maintenance period requirements (TMPR)—the quantity of reserves banks must accumulate over the course of an

[14]Note that we now include all observations during the sample period, aside from the observations in the maintenance period that includes September 11, 2001, as opposed to the analysis for figure 1.

Table 1. Summary Statistics

	Mean	Std. Dev.	Min.	Max.
Effective Minus Target (%)	0.013	0.16	−1.51	2.55
AM Minus Target (%)	0.034	0.12	−1.75	1.50
Effective Minus AM (%)	−0.021	0.14	−1.51	2.36
Cumulated Reserves/TMPR	0.463	0.30	0	1
Obs. = 3,634				

entire period to meet all requirements.[15] We expect that the measure of reserves accumulated through the previous day $(\mathrm{CR}_{t-1})/\mathrm{TMPR}$ will have a negative influence on the morning funds rate $(\mathrm{AM}-\mathrm{Tar})_t$.

We control for a variety of calendar events that influence the behavior of the funds rate by including separate dummy variables for each day of a two-week maintenance period and for several calendar events (such as month start and month end dates, mid-month dates, and days after holidays). We also include a dummy variable for the day after the Northeast blackout on August 14, 2003, which had a pronounced impact on trading and rates.

To control for market expectations of policy changes in the target federal funds rate, we allow for anticipation effects up to five days ahead of each scheduled FOMC meeting date, but only for those days ahead of a meeting that fell within the same maintenance period as the meeting. Table 1 presents summary statistics for the main variables of interest in this study.

5. Empirical Framework and Results

A Lagrange multiplier test for no ARCH effects is rejected at the 95 percent confidence level, so we will present results from

[15]Note that TMPR has the same value on all days in a given maintenance period but may change from period to period. The calculation of TMPR was adjusted upward to include the Desk's estimate of frictional excess reserve demand of smaller banks. It also captures carryover positions larger banks brought into a maintenance period that could have generated some positive or negative excess demand. TMPR was constructed by taking actual total reserves provided during an entire maintenance period, less the size of any reserve supply projection miss made on the last day of the period and less primary credit discount borrowing on the final day. Carpenter and Demiralp's (2006a) measure of cumulative reserves is not standardized by a TMPR measure.

the Threshold GARCH (TARCH) model based on Glosten, Jagannathan, and Runkle (1993). The model is as follows:

$$(\mathrm{AM}-\mathrm{Tar})_{\mathrm{t}} = \alpha + \beta' X_{\mathrm{t}} + \varepsilon_{\mathrm{t}}$$

$$\mathrm{Var}(\varepsilon_{\mathrm{t}}) = \sigma_{\mathrm{t}}^2 = \gamma_0 + \gamma_1 \varepsilon_{\mathrm{t}-1}^2 + \gamma_2 \varepsilon_{\mathrm{t}-1}^2 (1(\varepsilon_{\mathrm{t}-1} < 0)) + \gamma_3 \sigma_{\mathrm{t}-1}^2.$$

The γ_1 coefficient will capture ARCH effects, and the γ_3 coefficient will capture GARCH effects. The γ_2 coefficient will capture whether or not negative shocks ($\varepsilon_{\mathrm{t}-1} < 0$) have an asymmetric effect on the conditional variance (TARCH effects).

The results in table 2 show that all but three of the cumulated excess coefficients are negative, as expected. The three positive coefficients are all found in the first week of the maintenance period and are statistically insignificant. These results indicate that there is generally a negative relationship between cumulated excess reserves ($\mathrm{CR}_{\mathrm{t}-1}/\mathrm{TMPR}$) and the $(\mathrm{AM}-\mathrm{Tar})_{\mathrm{t}}$ spread for day t. Furthermore, the magnitude of the coefficients increases noticeably for the last two days of the maintenance period compared with the preceding days in the period. The estimated coefficients are not statistically significant on most of the days within the first week of a maintenance period, but are significant over most of the second week. These findings suggest that the sensitivity of the morning funds rate (relative to its target) to variations in the level of reserves cumulated through the previous day tends to rise as a maintenance period progresses. Overall, the results suggest that banks have a diminishing capacity to "average" reserve holdings as a maintenance period unfolds.[16]

Using the estimated constant terms and coefficients on the cumulative reserves variable ($\mathrm{CR}_{\mathrm{t}-1}/\mathrm{TMPR}$) from table 2, for each day within a maintenance period, we calculate the level of cumulated reserves through the previous day associated with the morning funds rate being at the target (i.e., $(\mathrm{AM}-\mathrm{Tar})_{\mathrm{t}} = 0$). For example, for the second Wednesday (W2) of the maintenance period, this

[16]The estimated values of the coefficients on the reserve variables and the day-in-period dummy variables are difficult to interpret directly. However, the expected deviation of the morning rate from the target associated with a given level of reserves accumulated through the previous day in the maintenance period can be calculated by summing the day-in-period dummy term for that day with the product of the cumulated reserves coefficient and the level of reserves cumulated through the previous day in the period.

Table 2. TARCH Results

Dependent Variable: AM Minus Target	Coeff.	t-stat.
AM minus Target$_{t-1}$	0.536	41.3
f1-Cumulated Reserves$_{t-1}$/TMPR	0.159	0.9
m1-Cumulated Reserves$_{t-1}$/TMPR	−0.071	−1.0
t1-Cumulated Reserves$_{t-1}$/TMPR	0.008	0.2
w1-Cumulated Reserves$_{t-1}$/TMPR	0.019	0.6
r2-Cumulated Reserves$_{t-1}$/TMPR	−0.137	−2.5
f2-Cumulated Reserves$_{t-1}$/TMPR	−0.101	−2.0
m2-Cumulated Reserves$_{t-1}$/TMPR	−0.094	−1.7
t2-Cumulated Reserves$_{t-1}$/TMPR	−0.280	−4.8
w2-Cumulated Reserves$_{t-1}$/TMPR	−0.681	−7.2
r1	0.012	7.2
f1	−0.022	−1.7
m1	0.035	1.9
t1	−0.003	−0.2
w1	−0.011	−0.9
r2	0.072	2.8
f2	0.047	1.7
m2	0.084	2.1
t2	0.230	4.8
w2	0.623	7.3
month start/end or mid-month date	0.057	38.3
day after month start/end or mid-month date	−0.033	−14.9
day before quarter end (excluding year end)	−0.008	−3.6
quarter end (excluding year end)	0.163	40.0
quarter start (excluding year start)	0.011	1.1
day after quarter start (excluding year start)	−0.026	−3.0
day before year end	−0.078	−28.1
year end	0.019	1.8
year start	0.032	1.6
day after year start	−0.004	−0.2
day after Monday holiday	0.031	9.4
second day after Monday holiday	0.006	1.6
day after other holiday	0.024	4.5
second day after other holiday	0.010	2.3
FOMC$_{t-5}$*target change	0.001	4.4
FOMC$_{t-4}$*target change	0.0005	3.0
FOMC$_{t-3}$*target change	0.002	17.5
FOMC$_{t-2}$*target change	0.002	19.4

(continued)

Table 2. (Continued)

Dependent Variable: AM Minus Target	Coeff.	t-stat.
$FOMC_{t-1}$*target change	0.003	19.7
FOMC date*target change	−0.004	−20.1
day after FOMC date*target change	−0.000005	−0.01
day after Blackout	0.195	4.9
Conditional Variance:		
arch	0.239	18.0
tarch	0.296	13.3
garch	0.744	147.7
constant	−10.246	−65.5

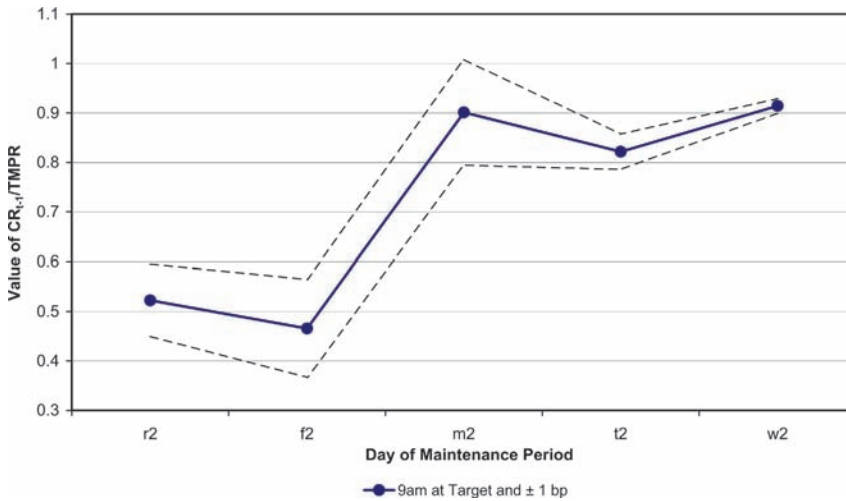
value is (.623/.681) = .914.[17] That is, the funds rate would be expected to be at the target on the morning of the second Wednesday so long as banks accumulated about 90 percent of their total requirements for the maintenance period through the second Tuesday. These calculated values for each day over the second week of a maintenance period are presented in figure 2, along with the values for (CR_{t-1}/TMPR) for each day of the period associated with the funds rate in the morning being 1 basis point above and 1 basis point below the target. As expected, the values of (CR_{t-1}/TMPR) associated with keeping the funds rate around the target in the morning generally rise and approach a level of "1" in value. Moreover, the range of values of cumulative reserve levels associated with the morning funds rate being within 1 basis point of the target narrows as the period progresses.

6. Discussion and Conclusion

Our empirical analysis is differentiated from previous work in two important ways. First, it examines the federal funds rate prior to the execution of any daily OMOs. Second, accumulated reserve levels

[17]These calculations are based on an assumption that the values for all other variables in the equation, such as the dummy variables for high-payment-flow days, are zero.

Figure 2. Estimated Relation between CR_{t-1}/TMPR and 9 a.m. Rate Relative to Federal Funds Target: Second Week of Maintenance Period



through the preceding day in a maintenance period are studied as a key variable of interest and determinant of this rate.

We cite previous empirical work and provide new evidence to support the argument that when the Desk makes its reserve management decisions each day, it may not simply seek to achieve an *average* daily rate for that day that is equal to the target on days when the morning rate deviates from the target. We then show that the level of accumulated reserves through the preceding day has a significant impact on the level of the morning rate. This impact strengthens as a maintenance period progresses, a finding that is consistent with banks' having a diminishing capacity to "average" reserve holdings as the number of days remaining in the period falls. These results highlight the need for the Desk, and analogously for other central banks that operate with multiday reserve maintenance periods, to consider the impact of cumulative reserve positions on the behavior of the funds rate on different days of a maintenance period when developing a reserve management strategy designed to control the federal funds rate for an entire maintenance period.

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