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The Announcement Effect: Evidence from Open Market Desk Data

I. Introduction

The textbook view of the monetary transmission mechanism rests on the central bank's ability to manipulate the overnight interest rate by controlling the reserve supply, followed by a rational-expectations mechanism that ensures that movements in the overnight rate reverberate into longer maturity rates. However, while few dispute the fact that the central bank controls the overnight rate effectively, the notion that it does so via a liquidity effect and the nature of term structure relationships needs to be reexamined.

Modern central banking is generally characterized by public announcements of an interest rate target, such as the federal funds rate target in the United States. In some cases, central banks (such as the Bank of Australia and the Bank of England) also disclose an inflation target, while in extreme cases, the banks (such as the Reserve Bank of New Zealand) disclose the parameters of the policy reaction function. These actions constitute a significant departure from traditional central banking.

It is natural to question why central banks have abandoned their once-secretive behavior in favor of public disclosures of policy moves. Likely reasons include the desire for better and more precise control of the overnight rate, and, more important, enhanced communication of future policy moves—in essence, the Holy Grail of controlling long rates by also manipulating expectations.

This paper investigates these issues as they relate to the U.S. Federal Reserve. In particular, we focus on how the Federal Reserve's 1994 policy change—by which it began announcing the target level for the federal funds rate—had an impact on the liquidity effect and the manner in which the central bank uses open market operations to control the federal funds market. We also examine what effect this policy change may have had on the behavior of the term structure.

Prior to the Federal Reserve's Federal Open Market Committee (FOMC) meeting in February 1994, monetary policy objectives for the federal funds rate and the outcome of the FOMC meeting itself had been confidential and had never been announced.[1] After the policy change occurred, and inspired by similar developments in other central banks, Demiralp and Jordá (2000), Guthrie and Wright (2000), Taylor (2001), Thornton (2001), and Woodford (2000) began to investigate a central bank's ability to control the overnight rate—not merely through traditional open market operations, but by effectively communicating the desired level of the overnight rate and standing ready to enforce that level. As Meulendyke (1998) observes, "the [federal funds] rate has tended to move to the new preferred level as soon as the banks know the intended rate." In this paper, we term this method of controlling the overnight rate the announcement effect (following Demiralp and Jordá [2000]); this effect differs from the conventional liquidity effect in that the volume of open market operations required to signal the new target level is substantially smaller because of expectations.

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The strategy we pursue to investigate the announcement effect consists of using two types of controls. The first is to analyze the data with two primary subsamples: one predating and the other postdating the 1994 policy change. The second is to compare, within subsample, the pattern of open market operations surrounding days in which the target was changed relative to the rest of the subsample.

Most of the time, open market operations conducted by the Trading Desk of the Federal Reserve Bank of New York ("the Desk") are designed to accommodate variations in the reserve needs that stem from a variety of factors, such as changes in currency holdings, float, and large Treasury balances; to manage currency in circulation; and to accommodate other variations in the supply of reserves. Based on a particular type of variation (unexpectedly large Treasury balances), Hamilton (1997) calculates the interest rate elasticity to an unanticipated shortfall in reserves. In contrast to Hamilton, we measure the elasticity of different types of open market operations to variations in the reserve needs, expectations of a target change, and enforcement of a new target level.

The expectation that policy decisions about whether to change the federal funds rate target typically will follow FOMC meetings introduces a natural discipline in term rates, and, more specifically, in the manner in which expectations regarding future rates are updated according to the FOMC calendar. Consequently, we investigate whether the market indeed follows this discipline and whether the response of term rates on the FOMC calendar is consistent with the rational-expectations hypothesis of the term structure.

Our paper is organized as follows. Section II describes the nature of the announcement effect and the role of expectations in the context of a simple model of the reserves market proposed by Taylor (2001). Based on the insights of this model, deviations of the federal funds rate from its target value emerge as indicators of the Desk's forecast error of the reserve needs. These deviations can therefore be used to assess how the Desk manages different types of open market operations to keep the funds rate on target as well as to signal changes in this target. Thus, Section III reviews the behavior of the deviation of the funds rate from target over the maintenance period while Section IV presents detailed evidence of the emergence of the announcement effect since 1994. The same mechanism that ties the formation of expectations around the FOMC calendar and gives rise to the announcement effect determines the behavior of term interest rates. Section V documents how movements in term rates are closely tied to the expectations formation associated with the FOMC calendar. Section VI summarizes our main findings.

II. The Federal Funds Market and Open Market Operations

The stylized model of the reserves market (discussed, for example, in Gilbert [1985], Heller [1988], and Goodfriend and Whelpey [1993]) describes a downward-sloping demand schedule of reserves as a function of the federal funds rate. This relationship reflects the demand for reservable deposits on behalf of depository institutions and therefore reserve requirements and excess reserves. The supply of reserves is depicted as a kinked schedule: a perfectly inelastic supply-of-reserves section corresponding to the level of nonborrowed reserves determined by open market operations, and an upward-sloping section corresponding to discount-window borrowing. The slope of the latter section of the supply schedule is characterized by the spread between the discount rate and the federal funds rate along with the administrative costs of having tapped a resource that is directly rationed by the corresponding regional Federal Reserve Bank. Under this simple framework, an open market sale has the effect of reducing nonborrowed reserves, thus shifting the supply schedule to the left and increasing the equilibrium level of the federal funds rate along with the amount of discount-window borrowing.

Recent developments in the reserves market require that we refine this canonical model. First, the collapse of the Continental Illinois Bank and Trust Company and other similar failures in the mid-1980s have made banks significantly more reluctant to use the discount window (although extended credit reached volumes in excess of $7 billion at the height of the crisis, this volume has remained essentially at zero levels throughout the 1990s). As a consequence, the supply of reserves is now better characterized by its inelastic section, which is determined by nonborrowed reserves alone.

Second, banks hold reserves primarily for two reasons: to meet legal reserve requirements and to facilitate interbank payments. Reserve requirement ratios were reduced in 1990 and 1992. In addition, a clarification of Fed policy and advances in computer technology since 1994 have encouraged banks to be more aggressive in "sweeping" customer deposits subject to reserve requirements into instruments exempt from such requirements.[2] These events have significantly reduced reserve requirements, from $20 billion in 1990 to $10 billion in 1996 and to $4 billion today. However, banks still need reserves to meet interbank payments and to meet the demand for currency. Third, and more important, since the February 1994 FOMC meeting, the Fed has publicly disclosed its target level for the federal funds rate. This has had a significant effect on the price-discovery process in the federal funds market and on the manner in which the market forms expectations about future policy moves.

The emphasis on the rising role of expectations in the reserves market was highlighted recently by Taylor (2001). The federal funds market is essentially a "double auction" market in which buyers and sellers ask different prices on overnight loans. Thus, the effective federal funds rate is a volume-weighted average of rates on trades reported by brokers. The Fed does not trade directly in the federal funds market, but controls the amount of reserves by trading in the repo and Treasury markets, typically once a day, in the morning (since April 5, 1999, the Trading Desk has entered the market during a ten-minute interval, around 9:30 a.m.). Trading in the federal funds market, however, concentrates near the day's closing.

Banks meet their legal reserve requirements on average over a two-week period called the maintenance period. Before August 18, 1998,[3] the requirement was calculated concurrently with the maintenance period, and the calculation was known as contemporaneous reserve accounting (CRA). As we shall see, this induced substantial volatility in the federal funds rate in the final days of the maintenance period. However, since 1998, the Fed has reverted to computing the requirement over a two-week period that precedes the maintenance period (the maintenance period begins thirty days after the start of the corresponding fourteen-day computation period; see Clouse and Dow [2000]). This practice, termed lagged reserve accounting (LRA), has eliminated any contemporaneous elasticity of reserve requirements to the interest rate. However, we note that reserve requirements have become less important in explaining a bank's desire to hold reserves relative to reserves needed to clear interbank balances.

The motivation behind Taylor's model is the observation that changes in the target may affect the federal funds rate, even without open market operations. This effect requires the belief that the Trading Desk will react appropriately to any substantial federal funds rate deviations from target. To focus the discussion on the announcement effect—and with the caveat that any model of the federal funds market is at best a rough approximation of the complexities in this market—Taylor describes the demand for reserves as:[4]

$$(1) \qquad R_t^d = -\alpha(f_t - \gamma E_t f_{t+1}) + \varepsilon_t\,,\ \alpha, \gamma > 0\,,$$

where R_t^d is the stock of reserve balances, f_t is the effective funds rate, ε_t is a demand shock, and E_t is the conditional expectation operator based on information available up to time t. The specification in equation 1 can be understood as describing within a maintenance period bank behavior and abstracting from other direct demand factors (such as other determinants of client demand for deposits) that are likely to influence reserve demand across maintenance periods.

Equation 1 is a rational-expectations setting in which the demand for reserves is now a function of the *expected* federal funds rate: that is, changes in the *effective* rate lead to movements along the demand curve but changes in the *expected* rate lead to shifts in the demand schedule, thus eliminating any arbitrage opportunities.

When the Federal Reserve is more open about current policy actions and future goals, the process of expectations formation about future policy actions becomes more accurate and reliable: the timing of the change is tied down by the dates of FOMC meetings (with a few exceptions since 1994), and the magnitude of the change is usually either a .25 or a .50 percentage-point change (the norm since 1994, except for one .75 percentage-point change). Therefore, one would expect the demand for reserves to adjust in anticipation of the forthcoming policy move. This shift in demand then may or may not be offset by the Federal Reserve.

The supply of reserves in Taylor's model is defined as a function of the gap between the effective federal funds rate and the target rate, f_{t-1}^*:

$$(2) \qquad R_t^s = R_{t-1} + \beta(f_{t-1} - f_{t-1}^*),\ \beta > 0\,.$$

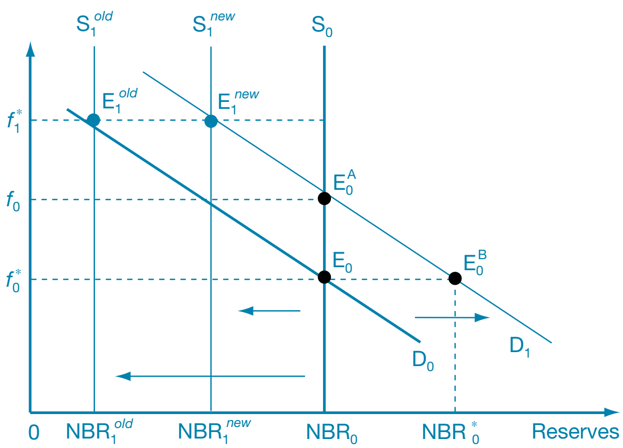
Accordingly, the Federal Reserve changes the reserve supply for two reasons: to accommodate an unexpected variation in the reserve needs (that is, whenever the funds rate is expected to deviate from the given target), or, for a given level of the funds rate, to adjust the pressure in the reserves market in a manner consistent with a new target level. Orphanides (2001) suggests that equation 2 may be too simple a specification of the supply curve. Among other things, it is perhaps more realistic to describe the Fed as actually forecasting the reserve needs on the basis of $E_{t-1}(f_t) - f_{t-1}^*$, rather than reacting to past deviations $f_{t-1} - f_{t-1}^*$. However, for the purposes of our discussion, there is little loss in proceeding with Taylor's original specification, leaving for future work alternative variations on equation 2.

The role of expectations and the behavior of interest rates in the reserves market can be seen in Chart 1. The chart depicts the usual downward-sloping demand schedule and an inelastic supply schedule set at the level of nonborrowed reserves, or NBR (recall that there is almost zero discount-window borrowing at present). In the chart, we consider three mechanisms by which the federal funds rate target increases from f_0^* to f_1^*. In the first scenario, there is no anticipation of the policy actions and the Federal Reserve has to signal the entire target change through open market operations by reducing reserves from NBR_0 to NBR_1^{old}.

The second and the third scenarios consider the role of expectations in the reserves market. When the market anticipates an increase in the target, it is more profitable for banks to borrow prior to the announcement and lend after the announcement, which leads to a rightward shift of the demand curve before the announcement, from D_0 to D_1. Note that the

Chart 1

A General Model of the Reserves Market with Anticipated Policy Actions



corresponding intermediate change in the equilibrium funds rate from f_0^* to f_0 is independent of any open market operations and is due purely to the anticipation of the new target level.

The Federal Reserve can respond to this shift in expectations either by accommodating and thus temporarily offsetting the expectational demand shift to D_1 so that the federal funds rate is kept at the present level, f_0^*, or by remaining inactive and allowing the federal funds rate to rise in anticipation of the target change. If the Fed accommodates in anticipation of an increase in the federal funds rate, the Desk will actually expand (rather than contract) reserves to the level NBR_0^* before contracting them to the level NBR_1^{new}. Whether or not the Fed decides to accommodate, the better the market anticipates the Fed's actions, the smaller the contraction from NBR_0 to NBR_1^{new}—that is, the Fed requires a smaller volume of open market operations to signal to the market an increase in the federal funds rate, which is the essence of the announcement effect.

III. Preliminary Considerations: Deviations of the Federal Funds Rate from Target

Our empirical analysis uses the deviation of the effective federal funds rate from the target level during the previous day as an indicator of reserve imbalances. Changes in the target typically are announced around 2:15 p.m. ET, after open market operations for that day have already been executed. Conditional on other factors, the response of open market operations to these imbalances gives us an indirect measure of the liquidity effect. Let f_t denote the federal funds rate and f_t^* denote the target; the variable we explore therefore is $(f_{t-1} - f_{t-1}^*)$.[5] Recall that the Fed typically executes open market operations in the morning, whereas most of the trading in the federal funds market takes place near the close of the trading day. Therefore, deviations of the federal funds rate from target can be interpreted as forecast errors in the reserve needs for that day. This argument certainly characterizes the majority of our sample up to August 18, 1998, when the Fed switched from CRA to LRA. After the change to LRA, uncertainty regarding reserve requirements was virtually eliminated, although uncertainty regarding balances for transaction purposes still remained.

To get a better sense of the persistence of this forecast error (or, in other words, how quickly it is eliminated) and the effects of the seasonality of the maintenance period on both the magnitude and the dynamics of $(f_{t-1} - f_{t-1}^*)$, we experiment with the following specification:

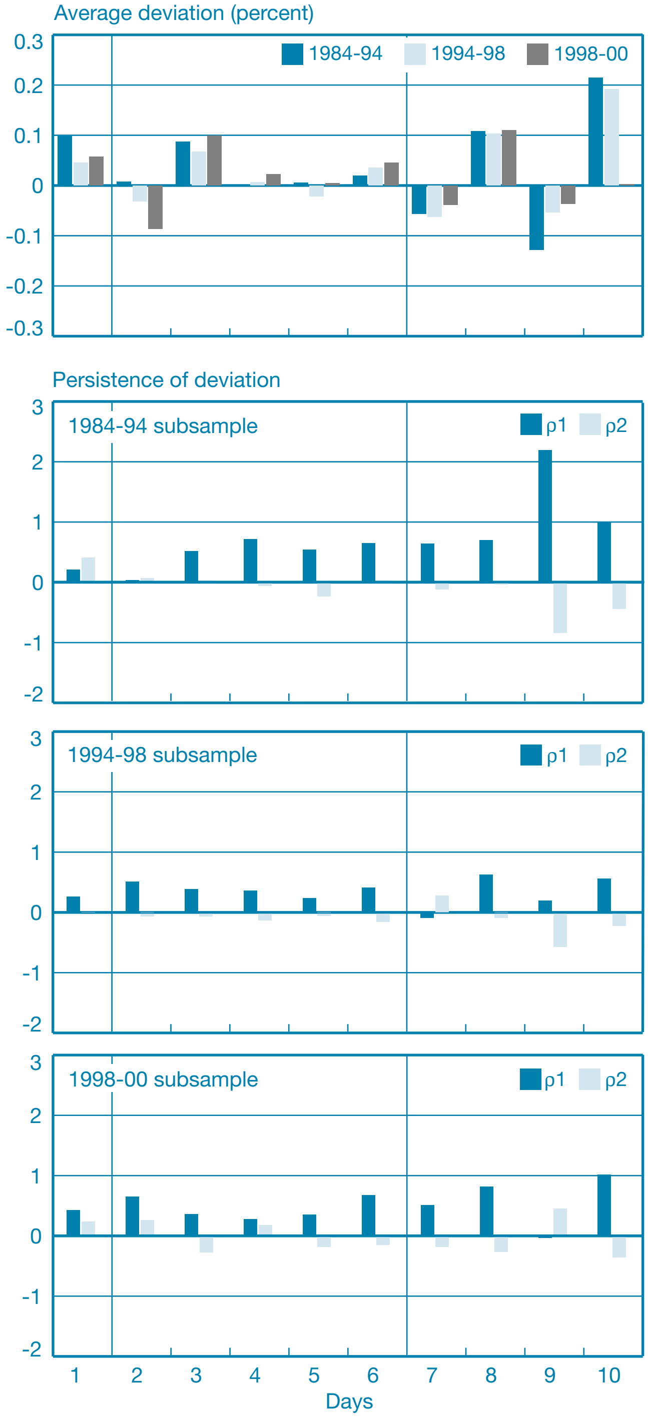
$$(3)\quad f_t - f_t^* = \alpha_t + \rho_{1t}(f_{t-1} - f_{t-1}^*) + \rho_{2t}(f_{t-2} - f_{t-2}^*) + \beta \Delta f_t^* + \varepsilon_t,$$

that is, a second-order autoregression where the parameters are allowed to vary according to the day of the maintenance period,[6] except for β since Δf_t^*—which denotes a change in the target on date *t*—is nonzero only when the target is changed. Equation 3 is estimated over three samples: April 25,1984-February 4, 1994, February 4, 1994-August 17, 1998, and August 18, 1998-August 14, 2000. These subsamples correspond, respectively, to the period before the policy of announcing the target, the period after that change in policy with CRA, and the period in which the Fed switched from CRA to LRA. Chart 2 displays the variation in this average deviation and its persistence as a function of the day of the maintenance period for these three samples.[7]

The average deviation of the federal funds rate from target is significantly higher (up to 20 basis points on average) on the last day of the maintenance period for the first two subsamples. However, after reserve accounting was modified from CRA to LRA, this average deviation has dwindled to essentially zero. Deviations from target also tend to be lower on Fridays. This observation is consistent with Hamilton (1997) and Clouse and Dow (2000), who argue, although for different reasons, that reserves on Fridays are relatively more expensive. The dynamic pattern of these deviations has also changed substantially across samples. It is most persistent in the first sample and toward the final days of the maintenance period. These observations are consistent with the high volatility that the

Chart 2

Maintenance Period Pattern of Deviations of the Federal Funds Rate from Target



Note: The vertical lines indicate Fridays.

federal funds rate typically exhibits during the last days of the maintenance period. It is safe to say that over time the Fed has managed to reduce the average deviations from target, and it has reduced the amount of time it takes to eliminate these perturbations.

The estimates of β in equation 3 suggest how well target changes are forecast. For each of the three subsamples, these estimates (with standard errors in parenthesis) are 0.59 (0.12), 0.37 (0.17), and 0.43 (0.17), respectively. If target changes were completely unexpected, the coefficient on the variable Δf_t^* would be close to 1 in value. This hypothesis is clearly rejected in all subsamples, but, perhaps more important, the decrease in this coefficient from 0.59 to 0.37—after the policy of announcing target changes was introduced—is statistically significant. This shift suggests that expectations of policy moves may have improved after 1994—an issue that we now explore in greater detail.

IV. The Announcement Effect versus the Liquidity Effect

This section investigates the manner in which the Trading Desk juggles different types of open market operations in response to variations in reserve needs and, more important, to changes in the federal funds rate target. In particular, we address two key questions:

1. Following the 1994 change in policy, is there evidence that the liquidity effect has been complemented by the announcement effect, and therefore an appreciable difference exists in the type and size of operations needed to signal the new target level for the federal funds rate?

2. Are there any differences in the portfolio of operations conducted during days when the target is changed relative to other days?

The second question complements the first one in that differences in the portfolio of operations during target day changes may help corroborate or disavow whether the Fed is any more responsive to these changes than it is to variations in reserve needs. Our sample period extends from April 25, 1984, to August 14, 2000, and includes 115 target changes. The sample is split: first, according to the February 4, 1994, Fed decision to announce publicly any changes in the federal funds rate target, and second, according to the August 18, 1998, decision to move from CRA to LRA.

The Endogenous Variables: Types of Open Market Operations and Transformations

The available open market data consist of ten different types of operations that can be grouped roughly according to whether the operation injects or drains liquidity and according to the relative degree of the operation's permanence. Table 1 classifies these data and assigns the abbreviations we use: PB, TB, and OB for permanent, temporary, and overnight purchases, respectively (which add liquidity), and PS, TS, and OS for permanent, temporary, and overnight sales, respectively (which drain liquidity). This grouping method affords us a greater degree of freedom at little cost: although the Fed does not consider domestic and foreign purchases complete substitutes (chiefly because of the clarity of the signal that they deliver to the market with the former tool), they certainly fulfill different liquidity needs relative to shorter term operations.[8]

Each of these operations needs to be transformed further before we begin our analysis. We start by standardizing the volume of each type of operation by the volume of total reserves held during the maintenance period prior to when the operation is executed. Our purpose is to filter trends in the volume of reserves, such as the increase in the demand for currency described above. The second transformation is motivated by reserve accounting practices and the different effects that operations have according to type and according to when they are executed within the maintenance period.

Following Feinman (1993), we adjust temporary and overnight operations according to the number of days spanned by the transaction, adjusting for weekends and holidays, and then divide by the number of days in the maintenance period: fourteen.[9] If the temporary transaction spans beyond the maintenance period, we adjust by the number of days remaining in the current maintenance period. Because we normalize by the volume of total reserves in the preceding maintenance period, temporary transactions that spill over adjacent maintenance periods have the reverse effect during the maintenance period in which they mature.

For instance, a normalized 0.1[10] matched sale-purchase transaction with a four-day maturity (that is, a generic temporary sale, or TS) executed on Tuesday of the second week of the maintenance period has the effect of lowering the normalized volume of reserves by 2/14 of 0.1. At its maturity—Friday of the first week of the following maintenance period—it will raise the normalized volume of liquidity by 12/14 of 0.1 (assuming that the level of total reserves has remained constant over the two maintenance periods, leaving the normalization unaffected). It is important to emphasize that the effect of this matched sale-purchase transaction during the maintenance period in which it matures forms part of the information set available when the operation is executed. Accordingly, an increase in the forecast for the reserve needs may not prompt the Fed to inject liquidity if several of these temporary transactions are slated to mature during that maintenance period. Similarly, outright operations are assumed to be reversible only by a counterpart outright transaction; consequently, they are considered permanent. Therefore, they are also adjusted by the number of days remaining in the maintenance period. Each type of operation normalized with the procedure described above is collected in the vector $X_t = (PB_t, TB_t, OB_t, PS_t, TS_t, OS_t)'$.

The Explanatory Variables: Decomposing the $f_t - f_t^*$ Deviations

Our empirical strategy requires us to analyze the motivation behind the different types of open market operations the Desk

Table 1
Types of Open Market Operations

Operation	Adds Liquidity (Purchases)	Abbreviation	Drains Liquidity (Sales)	Abbreviation
Permanent (outright)	T-bill domestic purchases T- bill foreign purchases Coupon domestic purchases Coupon foreign purchases	PB	T-bill sales Coupon sales	PS
Temporary	Term RP purchases	TB	Term matched sale-purchases	TS
Overnight	Overnight RP purchases	OB	Overnight matched sale-purchases	OS

chooses to execute on a given day. As we have seen, the Desk may intervene in the market for several reasons: 1) to accommodate shocks in the demand for reserves in order to maintain the federal funds rate aligned with the target, 2) to accommodate expectations of future target changes reflected in the demand for reserves, and 3) to enforce a new target level. Accordingly, we argued earlier that the most natural candidate for explanatory variable is the deviation of the federal funds rate from target, $(f_t - f_t^*)$. However, to separate each of these three motivations, we refine this deviation into three components:

(4) $$NEED_t \equiv f_t - [f^*_{m(t)-1} + w_t E_{m(t)-1}(\Delta f^*_{m(t)})]$$

$$EXPECT_t \equiv E_{m(t)-1}(\Delta f^*_{m(t)})$$

$$SURPRISE_t \equiv \Delta f^*_t - E_{m(t)-1}(\Delta f^*_{m(t)}) .$$

The time subscript *m(t)* denotes the maintenance period *m* to which observation *t* belongs. Therefore, $f^*_{m(t)-1}$ denotes the value of the target at the start of the maintenance period to which observation *t* belongs, w_t denotes the relative probability that a target change occurs in day *t* of the current maintenance period, and $E_{m(t)-1}(\Delta f^*_{m(t)})$ denotes expectations of a target change for the maintenance period to which observation *t* belongs, conditional on information available at the beginning of the maintenance period. Consequently, the variable *NEED* is designed to proxy for reserve projections and reflects variations in the approximated reserve needs per se, but factors expectations of a target change. Note that expectations of a target change are formed at the beginning of a maintenance period, rather than daily. (This is the type of expectation we explore in Section V, as we are interested in learning how those expectations affect the average volume of reserves over the maintenance period.) The weights w_t then assign each day of the maintenance period the probability that the expected target change will be realized on that particular day. These weights correspond to the empirical frequency of the distribution of target changes over the maintenance period.

The variable *EXPECT* denotes the expectation at the beginning of the maintenance period of a change in the target, rather than a one-day-ahead forecast. Therefore, this variable reflects the Fed's willingness to accommodate or profit from these movements in anticipation of a target change. Finally, the variable *SURPRISE* takes the value of zero except when the target is changed, in which case it measures the portion of a target change that was unexpected. This term will therefore capture the response of open market operations designed to enforce the new target level and will most closely correspond in interpretation to the traditional mechanism that characterizes the liquidity effect. Equation 4 implies that the sum of the *NEED*, *EXPECT*, and *SURPRISE* variables is equivalent to:

(5) $$(f_t - f^*_{m(t)-1}) + (\Delta f^*_t - \mathrm{E}_{m(t)-1}(\Delta f^*_{m(t)})) ,$$

which roughly corresponds to $f_t - f^*_t$: since the target is changed infrequently, the second term in parentheses is zero most of the time, except to capture the unexpected component of a target change.

The variables described in equation 4 require that we formulate forecasts of future target changes at a maintenance period frequency, rather than from one day to the next. Two options are available at this point. The first is to measure expectations directly from the federal funds futures market, as Kuttner (2001) does. However, this strategy proves inadequate for two reasons: 1) data on the futures market are not available before 1989, and 2) we want maintenance period forecast horizons, rather than daily forecasts: a target change in any day of the maintenance period will affect the average volume of reserves over the period, not just for that particular date.

Our second option is to use the forecasting models in Demiralp and Jordá (2000), which are based on the autoregressive conditional hazard (ACH) model. The ACH methodology allows us to produce forecasts at a maintenance period frequency starting with the April 25-May 9, 1984, period. The appendix provides a brief description of the ACH model along with the specifications we use to construct the forecasts. A more detailed discussion of the model is beyond the scope of this paper, but it can be found in Hamilton and Jordá (2000) and Demiralp and Jordá (2000).

Modeling Open Market Operations

The transformations of the variables described in the preceding sections allow us to analyze the determinants of each type of open market operation contained in the vector X_t. The Desk engages in open market operations approximately 60 percent of the time. However, even the most common type of open market operation is used only about 35 percent of the time. Consequently, estimation of the Desk's choice of operation cannot be done with conventional estimators since the dependent variable remains unchanged during most days in the sample. In addition, one could view a "sale" operation as a negative "purchase" operation, and thus lump operations together according to their maturity (a similar strategy is adopted in Feinman [1993]). We prefer to keep each type of operation separate to allow for the possibility of the Fed reacting asymmetrically.

Therefore, let x^*_{kt} denote the latent level of the k^{th} type of open market operation, which is an element of X_t, and let z_t contain three lags of all the elements of X_t.[11] If this latent index

x_{kt}^* were observable, it would be natural to specify its model as:

$$(6) \qquad x_{kt}^* = \alpha_t + \pi' z_t + \gamma_t^N NEED_{t-1} + \gamma_t^E EXPECT_{t-1} + \gamma_0^S SURPRISE_t + \gamma_1^S SURPRISE_{t-1} + \gamma_2^S SURPRISE_{t-2} + \gamma_3^S SURPRISE_{t-3} + \varepsilon_{kt},$$

where the coefficients on the *NEED* and *EXPECT* variables are allowed to vary according to the day of the maintenance period.[12] However, we do not in fact observe x_{kt}^*, but rather x_{kt}, whose values are determined by the following condition:

$$(7) \qquad x_{kt} = \begin{cases} 0 \text{ if } x_{kt}^* \le c_k \\ x_{kt}^* \text{ if } x_{kt}^* > c_k \end{cases}$$

Equation 7 makes it clear that the minimum size of an operation of the k^{th} type is c_k, otherwise the Fed does not engage in that operation and $x_{kt} = 0$. Equation 6 describes the latent process for the k^{th} type of open market operation, x_{kt}^*, as a function of reserve-need forecast errors, changes in the target, expectations of such target changes, and other open market operations conducted in previous days. From the econometric point of view, equations 6 and 7 constitute a truncated regression. Under the assumption that the errors are normally distributed, this model can be estimated as a standard Tobit model (see Maddala [1983]).[13]

The specification in equations 6 and 7 is quite flexible. In particular, the coefficient α_t modifies the threshold c_k so that the minimum size of the k^{th} operation is allowed to vary over the maintenance period. The inclusion of three lags of all the variables in X_t ensures that the effect of the explanatory variables is measured independently of any predictable response to previous open market operations, but it also serves to measure whether certain types of operations can be viewed as complements to or substitutes for the k^{th} type of operation. For example, in response to a reserve shortage, the Fed may react with a combination of overnight and temporary purchase operations, or it may delay any planned sale operations. The coefficient on the lag value of the variable *NEED* varies according to the day of the maintenance period to reflect the possibility that the Fed may be more reluctant to intervene on certain days of the period relative to others. A similar motivation justifies the variation in the coefficient on the variable *EXPECT*. Finally, note that the variable *SURPRISE* enters contemporaneously and with up to three lags to measure how quickly after the announcement the Fed needs to signal the new level with open market operations.[14] A strong liquidity effect would suggest that the parameters $\gamma_{i,\, i\, =\, 0,\, 1,\, \ldots,\, 3}^S$ are statistically significant and negative for open market purchase operations, and statistically significant and positive for open market sale operations. If these parameters are not statistically significant, we interpret this as evidence of the announcement effect.

Results

Table 2 summarizes the signs of the coefficients associated with the *NEED*, *EXPECT*, and *SURPRISE* variables across samples and for the regressions involving the purchase operations only.[15] The signs of the cross-correlations at different lags among the elements of x_t, also broken down by sample, are summarized in Table 3. In particular, ++/+ (--/-) indicates a positive (negative) parameter that is significant at the 95 percent/90 percent confidence level. A "." indicates a coefficient that is not statistically significant. Tables 4 and 5 contain the coefficient estimates and standard errors for the *SURPRISE* regressors for both purchase and sale operations.

Before we comment on the results, it is worth discussing some elements of the estimation. First, the coefficients associated with the variable *SURPRISE* are difficult to estimate for three reasons: 1) there are only 115 target changes in total relative to the 4,251 daily observations, 2) the Desk seems to have shifted its preferences somewhat over the type of operation it uses to support a target change, variation in reserve needs, or accommodation of expectations of a target change, and 3) some operations are rather infrequent (such as most "sale" operations), meaning that on most days in the sample these observations take the value zero. Despite these shortcomings, the "purchase" data (OB, TB, PB) contain a sufficient number of nonzero observations, thus allowing for reasonable coefficient estimates. The estimates from the "sale" data (OS, TS, PS) confirm the findings of the "purchase" data in the sense that the coefficient estimates typically have the opposite sign of those in the "purchase" equations.

The estimates for the first sample (April 25, 1984, to February 3, 1994) of "purchase" operations represent the canonical model of the federal funds market. Although outright transactions are more frequent (32 percent of the time), these do not appear to be linked to fluctuations in reserve needs. This finding substantiates the claim that permanent operations are used mostly for technical reasons. By contrast, overnight operations (OB), although less frequent (10 percent of the time), clearly respond to variations in the need in the direction of accommodating imbalances in the deviation of the federal funds rate from target. There appears to be little response to market expectations of a target change except for the first Friday in the maintenance period. The behavior of the *SURPRISE* variable is entirely consistent with a conventional liquidity effect: to drive the federal funds rate to its new target level, the Fed injects/drains liquidity as needed. In fact, although the lag 1 and lag 3 coefficients are not statistically significant, all the coefficients have a negative sign, further substantiating this claim.

Table 2
Signs of the Coefficients in the Tobit Regressions: Purchase Operations

	1984-94						1994-98						1998-00					
	Need			Expected			Need			Expected			Need			Expected		
Day	OB	TB	PB	OB	TB	PB	OB	TB	PB	OB	TB	PB	OB	TB	PB	OB	TB	PB
Thursday (1)	+	.	.	.	.	.	.	++	.	--	++	.	.	.	.	.	++	.
Friday (2)	++	.	.	.	++	.	++	.	.	.	.	.	--	.	.	++	++	.
Monday (3)	+	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Tuesday (4)	++	.	.	.	.	.	+	-	.	.	.	+	.	.	.	.	.	.
Wednesday (5)	.	++	.	.	.	.	++	.	.	--	.	.	.	.		.	.	-
Thursday (6)	++	.	.	.	.	.	.	.	.	-	.	+	.	.	.	.	.	.
Friday (7)	++	.	.	.	.	.	.	.	.	.	.	.	++	.	.	.	.	.
Monday (8)	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	-	.	.
Tuesday (9)	++	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.
Wednesday (10)	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Surprise: lag																		
0	--	-	.				+	.	.				.	.	.			
1	.	+	.				-	.	+				.	.	.			
2	--	.	.				.	.	.				.	.	.			
3	.	.	.				.	.	.				.	.	.			

Notes: ++/-- indicates a positive/negative coefficient significant at the 95 percent confidence level; +/- indicates a positive/negative coefficient significant at the 90 percent confidence level; . indicates a coefficient that is not statistically significant. OB is overnight purchase operations; TB is temporary purchase operations; PB is outright (permanent) purchase operations.

The dynamic correlations in Table 3 suggest a fair amount of smoothing in the manner in which operations occur. Purchase operations appear to complement each other in much the same way that sale operations are complementary (the signs of the boxes along the diagonal are positive and significant). By contrast, purchase and sale operations are typically substitutes for one another (the signs of the boxes in the off-diagonal terms are usually negative and significant).

What is the effect of the new policy of announcing the target? First, the portfolio of operations shifts from permanent operations toward more temporary operations. In particular, although permanent operations (PB) were used 32 percent of the time in the 1984-94 subsample, they were used only 11 percent and 17 percent of the time over the 1994-98 and 1998-00 subsamples, respectively. Conversely, overnight operations (OB), which took place 10 percent of the time in the 1984-94 subsample, were used 27 percent and 58 percent of the time during the 1994-98 and 1998-00 subsamples, respectively—a significant change.

Next, we consider the evidence reported in the two rightmost sections of Table 2. The pattern of responses to variations in reserve needs is similar to that in the first subsample. However, the response to expectations of a target change is somewhat mixed in the 1994-98 subsample (OB operations are negative and significant on Thursdays, although TB operations are significant and positive on the first day of the maintenance period), but it becomes noticeably more accommodating by the last subsample, typically in the form of TB operations early in the maintenance period. The pattern of coefficients for the *SURPRISE* variable seems to validate our notion that the Fed does not require open market operations to signal a new level for the federal funds rate. Tables 4 and 5 provide the specific coefficient estimates of the variable *SURPRISE* for the purchase and sale data regressions. In the 1994-98 subsample, the lag 0 coefficient is positive and marginally significant, suggesting accommodation rather than enforcement. The lag 1 coefficient is negative and marginally significant, suggesting that to some degree open market operations were required to achieve the new target level of the federal funds rate, once it was announced.

These results confirm some of the hypotheses advanced earlier and can be summarized as follows:

1. The announcement effect appears to be confirmed by the data, particularly for the 1998-00 subsample. However, caution is advised since the last two subsamples contain a

Table 3

Signs of the Lagged Coefficients of the Open Market Data in the Tobit Regressions by Subsample

	Lag 1						Lag 2						Lag 3					
	OB	TB	PB	OS	TS	PS	OB	TB	PB	OS	TS	PS	OB	TB	PB	OS	TS	PS
Sample 1: 1984-94																		
OB	++	++	.	-	.	.	+	.	.	.	.	.	.	+	.	.	.	-
TB	++	+	++	--	.	.	--	++	.	.	.	.	.	++	.	.	.	-
PB	.	+	++	-	--	.	.	++	++	--	--	.	.	.	++	--	--	.
OS	.	--	--	++	++	++	.	-	.	.	.	.	.	-	.	.	.	.
TS	.	.	.	.	++	.	.	.	.	.	++	.	.	.	.	.	++	.
PS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sample 2: 1994-98																		
OB	++	.	.	--	.	.	++	++	.	.	.	.	++	++	.	.	.	.
TB	++	.	.	-	.	.	.	.	.	.	.	.	.	.	.	.	.	.
PB	.	.	.	.	.	.	.	++	++	.	.	.	-	.	+	.	.	.
OS	.	--	.	++	.	.	.	.	.	.	.	.	.	.	.	.	+	.
TS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
PS	.	.	++	.	.	.	-	.	.	.	.	.	.	.	.	.	.	.
Sample 3: 1998-00																		
OB	.	.	-	-	.	++	.	.	.	.	.	.	.	.	-	.	.	.
TB	.	.	.	.	.	.	.	.	.	.	.	.	-	.	.	-	.	.
PB	.	.	.	.	.	.	.	.	++	.	.	.	.	.	+	.	.	+
OS	-	-	.	.	.	.	.	.	.	.	.	.	.	-	.	.	+	.
TS	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
PS	.	.	.	.	.	.	.	.	.	++	.	+	.	++	.	.	.	.

Notes: ++/-- indicates a positive coefficient significant at the 95 percent confidence level; +/- indicates a positive/negative coefficient significant at the 90 percent confidence level; . indicates a coefficient that is not statistically significant. OB is overnight purchase operations; TB is temporary purchase operations; PB is outright (permanent) purchase operations; OS is overnight sale operations; TS is temporary sale operations; PS is outright (permanent) sale operations.

smaller number of target changes, twenty between them, relative to the 1984-94 subsample, which contains ninety-five changes.

2. Expectations of a target change appear to be somewhat reinforced in the second subsample but mostly accommodated in the third subsample. In either case, the Fed's reaction appears to be circumscribed to the first days of the maintenance period.

3. The evidence strongly suggests that open market operations were used to enforce changes in the target during the first subsample, in a manner broadly consistent with the traditional liquidity effect.

4. Deviations of the federal funds rate from target are most persistent in the first subsample, which is consistent with the persistence observed in the size of each operation and suggests that the Fed required more pressure in the federal funds market to guide the federal funds accordingly. The degree of persistence in operations decreases in the second subsample and almost completely disappears in the third subsample. However, the persistence of federal funds rate deviations from target is lower for the second and third subsamples, suggesting that the Fed could exercise better control with fewer operations (Chart 2).

V. The Response of Term Rates

Our analysis thus far has investigated the behavior of the federal funds market in response to the Fed's practice of announcing rate changes (almost exclusively) after each FOMC

Table 4

Tobit Regressions for the Open Market Purchase Data

Coefficient Estimates for the *SURPRISE* Regressors

$$x^*_{kt} = \alpha_t + \pi' z_t + \gamma_t^N NEED_{t-1} + \gamma_t^E EXPECT_{t-1} + \gamma_0^s SURPRISE_t + \gamma_1^s SURPRISE_{t-1} + \gamma_2^s SURPRISE_{t-2} + \gamma_3^s SURPRISE_{t-3} + \varepsilon_{kt}$$

	Dependent Variables								
	OB			TB			PB		
	1984-94	1994-98	1998-00	1984-94	1994-98	1998-00	1984-94	1994-98	1998-00
γ_0^s	-28.58**	15.24*	1.94	-53.66*	21.15	-2.86	-14.40	30.69	7.73
	(11.43)	(8.75)	(11.51)	(29.53)	(68.18)	(116.51)	(9.26)	(33.98)	(47.59)
γ_1^s	-2.80	-21.42*	-8.03	72.78*	27.17	-126.67	15.20	66.78*	-19.06
	(14.70)	(11.66)	(11.88)	(38.42)	(50.74)	(131.86)	(10.83)	(39.02)	(54.39)
γ_2^s	-42.29**	-18.47	-7.51	5.28	-56.71	-93.72	2.13	42.45	4.11
	(14.56)	(17.64)	(13.39)	(35.11)	(59.00)	(79.92)	(11.02)	(38.61)	(38.59)
γ_3^s	-19.09	-24.12	-8.50	-12.63	-29.72	-167.15	-6.00	49.76	0.20
	(12.96)	(18.61)	(13.44)	(40.45)	(87.75)	(114.22)	(10.37)	(38.08)	(53.99)
Frequency (percent)	10.04	26.50	58.16	13.06	24.89	32.44	31.91	11.18	16.51

Notes: The equation is estimated for each type of purchase operation. The coefficient estimates correspond to the bottom part of Table 2. Frequency refers to the percentage of sample days on which the operation was used. OB is overnight purchase operations; TB is temporary purchase operations; PB is outright (permanent) purchase operations.

** Significant at the 95 percent confidence level.

* Significant at the 90 percent confidence level.

Table 5

Tobit Regressions for the Open Market Sale Data

Coefficient Estimates for the *SURPRISE* Regressors

$$x^*_{kt} = \alpha_t + \pi' z_t + \gamma_t^N NEED_{t-1} + \gamma_t^E EXPECT_{t-1} + \gamma_0^s SURPRISE_t + \gamma_1^s SURPRISE_{t-1} + \gamma_2^s SURPRISE_{t-2} + \gamma_3^s SURPRISE_{t-3} + \varepsilon_{kt}$$

	Dependent Variables								
	OS			TS			PS		
	1984-94	1994-98	1998-00	1984-94	1994-98	1998-00	1984-94	1994-98	1998-00
γ_0^s	31.44**	-25.02	27.44	-9.84	119.00	—	—	-8.07	517.66
	(14.41)	(52.34)	(75.33)	(31.54)	(999.99)			(73.76)	(999.99)
γ_1^s	10.86	7.74	9.40	-69.52**	-162.94*	—	—	-11.70	-130.07
	(10.51)	(141.49)	(37.14)	(31.88)	(85.35)			(92.35)	(171.78)
γ_2^s	3.15	4.05	0.89	-10.79	—	—	—	—	
	(10.22)	(21.55)	(25.86)	(32.74)					
γ_3^s	0.31	-76.75**	25.46*	57.13	—	—	—	—	
	(9.79)	(31.70)	(15.14)	(47.46)					
Frequency (percent)	5.33	4.33	4.80	3.22	1.44	0.00	0.00	1.69	2.96

Notes: The equation is estimated for each type of purchase operation. Frequency refers to the percentage of sample days on which the operation was used. OS is overnight sale operations; TS is temporary sale operations; PS is outright (permanent) sale operations.

** Significant at the 95 percent confidence level.

* Significant at the 90 percent confidence level.

meeting. In particular, we have argued that by providing a more regimented schedule in which to expect target changes, the Fed effectively signals its intentions and thus requires a smaller volume of open market operations. The questions we now consider are closely related to this scheduled-signaling mechanism. In particular, we explore the manner in which the scheduling of FOMC meetings coordinates the formation of expectations and the price-discovery process of term rates. Our results borrow heavily from Kuttner (2001).

It is important to begin by dissecting changes in the target into an expectational and a surprise component, because it is the surprise component that will ultimately affect term rates in a rational-expectations environment. Market expectations of changes in the target can be computed directly using data from the federal funds futures market. Specifically, Kuttner suggests that the surprise component of a target change can be constructed as:

(8) $$\tilde{\varepsilon}_t = \frac{m_s}{m_s - \tau}(f^0_{s,\tau} - f^0_{s,\tau-1})$$

for all but the first and last days of the month. $\tilde{\varepsilon}_t$ denotes the surprise component of a target change, m_s denotes the number of days in month *s*, τ is the day of the month in which the target is changed, and $f^0_{s,\tau}$ denotes the spot-month futures rate at date τ of month *s* over which the average effective overnight funds rate is computed to price the contract. The expected component of a target change can then be calculated as:

(9) $$E_{\tau-1}(\Delta f^*_\tau) = \Delta f^*_\tau - \tilde{\varepsilon}_\tau ,$$

where all the variables have been defined above and where we note that $\tilde{\varepsilon}_\tau = -E_{\tau-1}(\Delta f^*_\tau)$ whenever $\Delta f^*_\tau = 0$.[16]

A broad interpretation of the rational-expectations hypothesis would suggest that current term rates already incorporate expectations of future changes in the federal funds rate. Therefore, while at time *t* the forecast $E_t(\Delta f_{t+1}*)$ is likely to be an important explanatory factor, at time *t*+1 only the forecast error $\tilde{\varepsilon}_{t+1}$ should have any significant effect on term rates. More specifically, let ΔR_t denote a generic term rate, then a simple regression such as

(10) $$\Delta R_t = \alpha + \beta E_t(\Delta f^*_{t+1}) + u_t$$

or

(11) $$\Delta R_{t+1} = \alpha + \beta\tilde{\varepsilon}_{t+1} + v_{t+1}$$

would likely present a nonzero, significant β coefficient. However, how does the FOMC's schedule and the expectation that changes in the federal funds rate target are almost exclusively announced after FOMC meetings modify the predictions embodied in equations 10 and 11?

We argue that although expectations derived from the futures market from federal funds detect upcoming fluctuations in the federal funds rate, unless these fluctuations are associated with FOMC dates, they more likely represent technical and transitory deviations of the federal funds rate from target, rather than a new level for the target itself. Consequently, outside FOMC dates, these expectations based on futures markets are unlikely to have any significant effect on term rates.

To test this hypothesis, we use daily data on the repo (RP), three-month T-bill (TB3), and ten-year T-bond (TB10) rates over the May 18, 1989-August 14, 2000, period.[17] In particular, we consider estimating equation 10, but in such a way as to restrict the sample to meet the following criteria:

- $|E_t(\Delta f_{t+1}*)| > 0.125$ —that is, to eliminate noisy fluctuations in the futures market, we limit the sample to dates on which expectations of a change in the federal funds rate amounted to at least 0.125 percent in absolute value.
- $d_t^{FOMC} = 0$ (where $d_t^{FOMC} = 1$ if there is an FOMC meeting on day *t*, 0 otherwise)—that is, we exclude FOMC dates.
- $d_t^{CHANGE} = 0$ (where $d_t^{CHANGE} = 1$ if the target is changed in date *t*, 0 otherwise)—that is, we exclude dates on which the target was changed.

Imposing these restrictions reduces the sample to 184 observations. Table 6 reports the results of this experiment for ΔR_t = RP, TB3, and TB10. As the table illustrates, there is virtually no response of term rates to expectations of changes in the federal funds rate outside FOMC dates or dates on which the target is changed. The explained variation in all cases

Table 6

The Response of Term Rates to Expectations Outside FOMC Days

$$\Delta R_t = \alpha + \beta E_t(\Delta f^*_{t+1}) + u_t$$

ΔR_t	α	β	R^2
Repo rate	0.03*	-0.04**	0.04
	(0.01)	(0.02)	
Three-month T-bill	0.00	0.01**	0.02
	(0.00)	(0.00)	
Ten-year T- bond	0.00	0.01**	0.04
	(0.01)	(0.00)	

Notes: The sample is May 18, 1989, to August 14, 2000, excluding Federal Open Market Committee (FOMC) meetings, days on which the target was changed, and days for which $|E_{t-1}(\Delta f_t^*)| < 0.125$. The number of observations is 184. Standard errors are in parentheses. Term rates are measured in percentages.

*Significant at the 10 percent confidence level.
**Significant at the 5 percent confidence level.

remains below 4 percent, and although the coefficients are technically statistically significant, they are clearly indistinguishable from 0 by any reasonable economic metric. The results are virtually identical when the restriction $|E_t(\Delta f_{t+1}^*)| > 0.125$ is eliminated, allowing the sample to expand to 2,817 observations.

A natural complement to the previous experiment is to concentrate on dates on which the target was in fact changed and proceed to ask whether or not changes in the target executed outside FOMC meetings were more influential. According to the view that the FOMC schedule regiments expectations of when target changes are most likely to occur, a target change announced outside an FOMC meeting constitutes a rather unusual event (such an observation is borne out by the data, as we discussed above). We are also interested in examining what Kuttner labels "the timing hypothesis"—that is, whether the mere advancement or postponement of anticipated rate changes will have a smaller effect on term rates than actions that truly signify a directional change in the policy stance. In essence, this means that the forecast error $\tilde{\varepsilon}_t$ may, at times, represent having obtained the timing of a target change incorrectly, although that target change may have been widely expected to occur sometime in the near future.

A simple way to explore both of these issues simultaneously is to estimate a regression on a sample that contains only dates of a target change, similar in spirit to Cook and Hahn (1989) and Kuttner's equation 8. Consider the dummy variable d_τ^{FOMC}, which is described above, and then define an additional dummy variable, d_τ^{SWITCH}, which takes the value of 1 if the τ^{th} target change has the opposite sign of the $\tau - 1$ target change and is 0 otherwise. The choice of this variable definition is based on the observation—reported, for example, in Rudebusch (1995)—that the Fed typically changes the target in the same direction but only infrequently chooses to move the target in the opposite direction. Thus, the variable d_τ^{SWITCH} will help us identify the importance of the timing hypothesis, albeit admittedly in a crude way. With these considerations in mind, the regression we estimate is:

$$\begin{aligned}(12)\quad \Delta R_\tau = {} & \alpha_0 + \alpha_f d_\tau^{FOMC} + \alpha_s d_\tau^{SWITCH} + \beta_1^0 E_{\tau-1}(\Delta f_\tau^*) \\ & + \beta_1^f d_\tau^{FOMC} E_{\tau-1}(\Delta f_\tau^*) \\ & + \beta_1^s d_\tau^{SWITCH} E_{\tau-1}(\Delta f_\tau^*) \\ & + \beta_2^0 \tilde{\varepsilon}_\tau + \beta_2^f d_\tau^{FOMC} \tilde{\varepsilon}_\tau + \beta_2^s d_\tau^{SWITCH} \tilde{\varepsilon}_\tau + u_\tau ,\end{aligned}$$

where ΔR_τ = RP, TB3, and TB10. The results of this experiment are reported in Table 7. The discussion of the results centers on the β_2^i coefficients $(i = 0, f, s)$, which are the coefficients associated with the prediction errors and therefore whose estimates should be close to the value of 1. The β_1^i coefficients $(i = 0, f, s)$ are those associated with the expectational component of target changes and should therefore be statistically irrelevant according to the rational-expectations hypothesis. Generally speaking, this is in fact what we find.

The parametrization of equation 12 measures the response of term rates to surprise changes in the target announced at an FOMC meeting as the coefficient sum $\hat{\beta}_2^0 + \hat{\beta}_2^f$. This response takes on the values 0.20 (0.86), 0.62 (0.32), and -0.23 (0.32) for the RP, TB3, and TB10 rates, respectively (standard errors are in parentheses). These values are not particularly close to the canonical value of 1 (especially for the TB10 rate). However, if we instead consider the same response when the target change is announced outside an FOMC meeting (that is, looking at $\hat{\beta}_2^0$ in isolation), we notice that the values uniformly increase to 0.54 (0.31), 0.73 (0.11), and 0.44 (0.11) for RP, TB3, and TB10, respectively (standard errors are in parentheses). These values are closer to 1 and highlight the "specialness" of FOMC meeting days.

In addition to providing these results, equation 12 also allows us to investigate the validity of Kuttner's timing hypothesis. Thus, the response of term rates to surprise target changes that correspond to a shift in the direction of previous changes can be measured as the sum of the coefficients $\hat{\beta}_2^0 + \hat{\beta}_2^f + \hat{\beta}_2^s$. For RP, TB3, and TB10, these coefficient estimates (and their standard errors) are, respectively, 0.19 (1.47), 1.08 (0.55), and 1.48 (0.55), which strongly suggest (except for the repo rate) that the timing hypothesis is important. Finally, we consider the extreme case of a target change that corresponds to a shift in direction, which is made outside an FOMC meeting. This corresponds to the strongest signal that the Fed could send and can be measured by the coefficient sum $\hat{\beta}_2^0 + \hat{\beta}_2^s$. The estimates of this type of response for RP, TB3, and TB10 (and their standard errors) are, respectively, 0.52 (1.73), 1.19 (0.64), and 2.15 (0.65).

Overall, these results are consistent with the rational-expectations hypothesis and the view that the FOMC schedule imposes a specific timetable upon which to expect decisions that will affect the level of the federal funds rate target. As the maturity of the term rate considered increases, we find that the response to unusual events (such as a target change announced outside an FOMC meeting that constitutes a reversal in the direction of previous changes) also becomes stronger. The timing hypothesis advanced by Kuttner appears to be well supported by the data. By contrast, the response to target changes that take place at FOMC meetings is weaker as long as these changes follow the same general direction of previous changes.

Table 7

The Response of Term Rates When the Target Is Changed

$$\Delta R_\tau = \alpha_0 + \alpha_f d_\tau^{FOMC} + \alpha_s d_\tau^{SWITCH} + \beta_1^0 E_{\tau-1}(\Delta f_\tau^*) + \beta_1^f d_\tau^{FOMC} E_{\tau-1}(\Delta f_\tau^*) + \beta_1^s d_\tau^{SWITCH} E_{\tau-1}(\Delta f_\tau^*)$$
$$+ \beta_2^0 \tilde{\varepsilon}_\tau + \beta_2^f d_\tau^{FOMC} \tilde{\varepsilon}_\tau + \beta_2^s d_\tau^{SWITCH} \tilde{\varepsilon}_\tau + u_\tau$$

		ΔR_t = Repo	ΔR_t = Three-Month T-Bill	ΔR_t = Ten-Year T-Bond
Intercept	α_0	0.02	0.03	0.07**
		(0.07)	(0.03)	(0.03)
	α_f	-0.04	-0.06	-0.11**
		(0.10)	(0.04)	(0.04)
	α_s	0.04	0.00	0.01
		(0.10)	(0.04)	(0.04)
Response to expectations	β_1^0	0.16	0.23*	0.33**
		(0.33)	(0.12)	(0.12)
	β_1^f	0.16	-0.11	-0.32*
		(0.44)	(0.16)	(0.16)
	β_1^s	-0.20	-0.01	0.03
		(0.42)	(0.16)	(0.16)
Response to surprises	β_2^0	0.54*	0.74**	0.44**
		(0.31)	(0.11)	(0.11)
	β_2^f	-0.34	-0.12	-0.67*
		(0.91)	(0.34)	(0.34)
	β_2^s	-0.01	0.46	1.71**
		(1.71)	(0.63)	(0.64)
	R^2	0.23	0.70	0.42

Responses to the surprise component	Repo	Three-Month	Ten-Year
Timing of target change			
At FOMC: $\beta_2^0 + \beta_2^f$	0.20	0.62*	-0.23
	(0.86)	(0.32)	(0.32)
Outside FOMC: β_2^0	0.54*	0.73**	0.44**
	(0.31)	(0.11)	(0.11)
At FOMC + SWITCH: $\beta_2^0 + \beta_2^{3f} + \beta_2^s$	0.19	1.08**	1.48**
	(1.47)	(0.55)	(0.55)
Outside FOMC + SWITCH: $\beta_2^0 + \beta_2^s$	0.53	1.19*	2.15**
	(1.73)	(0.64)	(0.65)

Notes: The sample is May 18, 1989, to August 14, 2000; only target changes have been included. The number of observations is 45. Standard errors are in parentheses. Term rates are measured in percentages.

*Significant at the 10 percent confidence level.
**Significant at the 5 percent confidence level.

VI. Conclusion

After keeping the federal funds rate unchanged since September 4, 1992, the FOMC, at its February 1994 meeting, decided to modify the federal funds rate target. To ensure that this policy decision was communicated clearly to the markets, the FOMC disclosed it by way of public announcement. Thus, what began as an experiment has now become part of the Federal Reserve's tradition—one now shared by numerous central banks. One of the practical implications of this policy is the announcement effect: the ability to control the federal funds rate with little or no immediate action by the Trading

Desk. The market's understanding and expectation of how the Fed operates has also molded the behavior of market rates at different maturities.

The daily conduct of open market operations is a complex process: it is influenced by a large variety of technical factors that are often unrelated to monetary policy per se. In addition, a number of procedural changes have characterized the reserves market and the manner in which the Desk manages reserve needs. These difficulties notwithstanding, the analysis based on the pattern and choice of open market operations confirms the belief that the Desk is able to communicate a new level for the federal funds rate with a smaller volume of interventions than was characteristic prior to 1994. Traders are placing increased credibility in the Desk's commitment to maintain the federal funds rate on target, which is underscored by the clarity of the regular announcement of FOMC outcomes.

Ultimately, the goals of monetary policy require the Federal Reserve to be successful in guiding the market's expectations of future policy moves, and thus the goals require that some synchronicity exists in longer maturity rate movements. The evidence we have provided on this front is consistent with the view that expectations are updated with the FOMC calendar. Long-term rates appear to react strongly when the Fed initiates policy moves in a new direction in a manner consistent with the timing hypothesis, but they remain quiescent afterward. Shorter term rates track the Fed's policy moves more closely, as one would expect from their maturity, but they react less strongly to unusual events.

Open Market Operations

The Trading Desk of the Federal Reserve Bank of New York manages open market operations. There are two types of operations, depending on the duration of the operation. If the reserve need or surplus is expected to be persistent, the Trading Desk may conduct *permanent operations* through outright purchases or sales of securities. Outright purchases or sales of Treasury debt (that is, Treasury bills or Treasury coupon securities) are permanent operations that generally are executed in the market when the estimated need or surplus is expected to be large and to extend a few periods into the future (these variations in need are mostly associated with increases in the demand for currency). Typically, the Desk does not address small reserve shortages or excesses of brief duration with outright operations, which entail greater execution costs and can be affected by market price changes.

Alternatively, if staff projections indicate a short-lived need to add or drain reserves, the Desk undertakes *temporary operations*. Temporary operations are repurchase agreements (RPs) or matched sale-purchase (MSP) transactions. Note that a purchase adds to reserves in the banking system, whereas a sale drains them. In overseeing bank reserves, the Manager of the Trading Desk finds it helpful to put reserves in or take them out in large volumes for one day to a few days at a time. RPs and MSPs are temporary transactions that enable the Desk to respond quickly when reserves fall short of desired levels or prove to be in excess. Temporary operations are particularly useful in dealing with the uncertainties present in the reserves market (see Meulendyke [1998, Chapter 7]).

According to Feinman (1993), in the pre-1994 regime, the Federal Reserve signaled the strongest protest of a policy easing by using overnight RP transactions. Meanwhile, term RPs reflected a much weaker rate protest. Edwards (1997) notes that term repurchase agreements were considered more technical and did not aim to signal target changes. Term RPs usually are designed to leave reserve shortages of moderate size to be addressed with additional RPs (Hilton 1999).

It is important to note that there has been an increasing tendency over the past decade for the Desk to have to add reserves (see the discussion below). This is because the Desk does not want to drain reserves during periods in which low operating balances might lead to late-day firmness in the money market (see Cohen [1996]) and because of the Desk's response to an increasing demand for currency over time. Consequently, because the portfolio has been expanding in recent years, MSPs have been used less frequently than RPs (see Meulendyke [1998, Chapter 7]).

The Autoregressive Conditional Hazard Model

This methodology is explained in detail in Hamilton and Jordá (2000) and Demiralp and Jordá (2000). For brevity, we describe only the salient features. Details about the estimates and the forecasts themselves are available from us upon request.

The autoregressive conditional hazard (ACH) model seeks to answer the question, what is the probability that during the next maintenance period the target will be changed, conditional on information available today? Denote with $x_t = 1$ if the target is changed during the maintenance period t and $x_t = 0$ otherwise. Then, the conditional probability of a target change is a discrete-time hazard that can be modeled as the following ACH(p,q):

(A1) $$P(x_t = 1|\Omega_t) = h_t = [1 + exp(\lambda_t)]^{-1}$$

$$\lambda_t = \omega + \sum_{j=1} \theta_j u_{w_j(t-1)} + \sum_{j=1} \beta_j \lambda_{w_j(t-1)} + \delta' z_{t-1} ,$$

where ω is a constant term, $w_j(t-1)$ is an index that records the j^{th} most recent target change as of time $(t-1)$, $U_{w_{j(t-1)}}$ therefore denotes the duration between the j^{th} two most recent target changes as of date $t-1$, and z_{t-1} is a vector of exogenous variables. The specification in equation A1 is dynamic in a manner similar to conventional ARMA and ARCH models and ensures that the probability h_t is between 0 and 1. The likelihood associated with equation A1 is:

(A2) $$L(\Pi) = \sum_{t=1} \{x_t \log(h_t) + (1-x_t)\log(1-h_t)\} ,$$

which can be maximized by conventional numerical techniques.

Forecasting Target Changes Using the ACH

The ACH produces forecasts of when the target will be changed next, which can be easily combined with forecasts of the expected magnitude of the target change when it occurs. Due to the discrete nature of target changes, which typically come in increments of 25 basis points, we model this process with an ordered response model with normal errors (ordered probit model, or OP). The ACH and the OP are then estimated over two samples at a maintenance period frequency: April 25, 1984, to February 2, 1994, and February 16, 1994, to August 23, 2000. The first sample was modeled with an ACH(1,1) that included as exogenous variables whether or not the Federal Open Market Committee (FOMC) met during the current and previous maintenance periods, as well as the most recently available information on consumer price index inflation. The corresponding OP contained as regressors the size of the previous target change, the spread between the target and the one-year T-bond, the spread between the target and the discount rate, and the ratio of nonborrowed reserves to lagged total reserves. The second sample required an ACH(1,1) that included the same FOMC variable from the first sample, the absolute value of the spread between the ten-year T-bond and the federal funds rate, and the duration since the last change in the prime rate. The companion OP model included as regressors the value of the most recent target change, the spread between the six-month T-bill and the ten-year T-bond, and the spread between the target and the prime rate.

Endnotes

1. However, Demiralp and Jordá (2000) argue that perhaps as early as mid-November 1989, there was little if any ambiguity about decoding changes in the federal funds rate target based on the pattern of open market operations that followed the meeting. Their evidence consists mainly of the fact that the prime rate typically was adjusted within a day or two of an unannounced federal funds rate target change.

2. See Anderson and Raasche (2000).

3. The actual policy change date is July 1998. However, because there is a thirty-day lag between the computation period and the maintenance period, the first maintenance period that effectively reflected the new policy was August 13-26, 1998. We note that the Fed had experimented with lagged reserve accounting in the past, but prior to the beginning of our sample.

4. For a more detailed model of the demand for reserves, see Clouse and Dow (2000) and Bartolini, Bertola, and Prati (2000).

5. Hamilton (1997) uses open market data to estimate the liquidity effect by carefully calculating the effect on the federal funds rate of surprises in the Treasury balance. The requisite that this surprise component be measured as accurately as possible required him to be extremely detailed in modeling all the sources of "seasonality" relating to the Treasury balance and the other components of the Fed's balance sheet—in essence, he is trying to capture the manner in which the Fed constructs its forecasts. However, because the variable of interest, $(f_{t-1} - f_{t-1}^*)$, is directly observable rather than computed, we can dispense with such complications.

6. Specifically, $\alpha_t = \sum_{j=1}^{10} \alpha_j d_t^j$, $\rho_{it} = \sum_{j=1}^{10} \rho_i^j d_t^j$ for $i = 1, 2$ and where $d_t^j = 1$ if observation *t* belongs to the j^{th} day of the maintenance period for $j = 1, 2, \ldots, 10$ (since we only need to consider business days); and is 0 otherwise.

7. For a more in-depth investigation of the behavior of the federal funds rate and the interbank market, see Bartolini, Bertola, and Prati (2000) and Furfine (2000).

8. The appendix describes how the Federal Reserve Bank of New York's Trading Desk actually implements open market operations.

9. Note that an overnight transaction executed on a Friday is not reversed until Monday and therefore its effect on the maintenance period's average volume of reserves is that of a three-day transaction.

10. Note that the normalization eliminates the unit of measurement in favor of expressing liquidity as a fraction of the volume of reserves in the previous maintenance period.

11. That is, $z_t = (x_{PB,t-1}, x_{TB,t-1}, \ldots, x_{OS,t-1}, \ldots, x_{PB,t-3}, x_{TB,t-3}, \ldots, x_{OS,t-3})'$.

12. Specifically, $\alpha_t = \sum_{j=1}^{10} \alpha_j d_t^j$, $\gamma_t^N = \sum_{j=1}^{10} \gamma_j^N d_t^j$ and $\gamma_t^E = \sum_{j=1}^{10} \gamma_j^E d_t^j$, where $d_t^j = 1$ if observation *t* belongs to the j^{th} day of the maintenance period, and is zero otherwise (note: $j = 1, 2, \ldots, 10$).

13. In particular, denoting with ϕ_t and Φ_t the normal density and the distribution function, respectively, of observation *t*, the log likelihood can be expressed as: $\log L = \sum \log(1 - \Phi_t) + \sum \log \phi_t$, where the first summation is over all the observations in which $x_{kt} = 0$ and the second summation is over the remaining observations.

14. Note that, unlike some of the previous regressors, this variable is zero for every day in the sample except when the target is changed.

15. Due to the low frequency with which "sale" operations are used (typically less than 5 percent of the time), we have omitted those operations from Table 2 to simplify the exposition. The results of the sale operations support the same conclusions supported by the purchase data, but they typically involve far fewer observations and therefore are less reliable; in some instances, we were unable to estimate the model because of an insufficient number of observations.

16. For a detailed discussion of the author's methodology, see Kuttner (2001).

17. May 18, 1989, is the earliest date for which we have reliable data on the federal funds futures market, which was established in 1988.

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