Anticipation of Monetary Policy and Open Market Operations*

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Central banking transparency is now a topic of great interest, but its impact on the implementation of monetary policy has not been studied. This paper documents that anticipated changes in the target federal funds rate complicate open market operations. We provide theoretical and empirical evidence on the behavior of banks and the Open Market Trading Desk. We find a significant shift in demand for funds ahead of expected target rate changes and that the Desk only incompletely accommodates this shift in demand. This anticipation effect, however, does not materially affect other markets.

JEL Codes: E5, E52, E58.

1. Introduction

Through time, the Federal Reserve has been perceived as becoming more open and transparent. For example, explicit announcements of changes in the target federal funds rate began in 1994. With predictable changes in monetary policy, financial markets move *before* the Federal Reserve, not just in reaction to it. Lange, Sack, and Whitesell (2003) find empirical evidence of an anticipation effect in

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the market for Treasury securities in the months prior to changes in monetary policy.

In this paper, we investigate whether a similar type of anticipation effect exists in the federal funds market, the overnight loans of balances on deposit at the Federal Reserve. The supply of balances in this market is influenced by the Open Market Trading Desk at the Federal Reserve Bank of New York in order to push trading in the market toward the target rate determined by the Federal Open Market Committee (FOMC). On the one hand, because this market is the most directly affected by monetary policy, one might think that an anticipation effect would more likely be present in this market. On the other hand, supply is controlled by the Desk to offset any rate pressures. As a result, deviations from the target could reflect constraints that the Desk faces in accomplishing its goal. Predictable changes in the target rate could therefore have implications for the conduct of open market operations. In addition, an anticipation effect is related to, but distinct from, changes in the funds rate that are a result of an announcement by the Federal Reserve. Demiralp and Jorda (2002) and Hanes (2005) analyze these so-called open-mouth operations by looking at the movement of the funds rate *after* a target change announcement, not prior to it.

In this paper, we look into why an anticipation effect in the federal funds market exists and what the broader implications are. We present evidence that the federal funds rate tends to move in the direction of an anticipated change in policy prior to that change. We estimate econometric models of the federal funds market at a daily frequency in the spirit of Hamilton (1997, 1998) and Carpenter and Demiralp (forthcoming) to filter out the systematic variation in the funds rate and to estimate the movement that is attributable solely to the anticipation effect. Turning from the price side to the quantity side, we present results on the supply of reserve balances that suggest that the Desk increases the supply of balances in response to the anticipation effect. The fact that federal funds trade away from the current target, however, suggests that the change in supply is not sufficient to achieve the target. Indeed, in its annual report for 2004, the Desk acknowledged that it has attempted to offset only partially a shift in demand, because fully offsetting the demand could lead to unwanted volatility in the federal funds market. We attempt to assess this rationale based on our results.

Because the anticipation effect is the result of a shift in demand, we present an optimizing, dynamic programming model of a representative bank's demand for daily reserve balances to explain the shift in demand.[1] The model indicates that demand is shifted by a finite amount, suggesting that a full offset to the shift in demand is possible. First, we discuss the open market operations that would be necessary to counteract this effect. We conclude that it is possible that fully offsetting the rise in rates before fully anticipated moves could result in a substantial decline in the funds rate relative to the target following the FOMC meeting in question. We then document that over the period studied, there has been no significant increase in volatility surrounding the meetings. Lastly, we show that there has been little spillover from the funds market to other financial markets.

2. Data and Econometric Evidence

To examine the anticipation effect, we turn to the market for Federal Reserve balances. Reserve requirements, based on banks' customers' reservable deposits, are satisfied either with vault cash or with balances at the Federal Reserve. These balances are called *required reserve balances.* In addition, banks may contract with the Federal Reserve to hold more balances to facilitate the clearing of transactions through their accounts. These balances are called *contractual clearing balances.* Holdings of required balances—the sum of required reserve balances and contractual clearing balances—are averaged over a fourteen-day period called a *maintenance period.* Any balances held beyond the required level are called *excess balances.* The market for balances is discussed in more detail in section 3.

We use business-day data from February 1994 through July 2005. The starting date reflects the Federal Reserve's adoption of a policy of announcing changes in the target federal funds rate. We specify an equation with the deviation of the effective federal funds rate from its target as the dependent variable, and we specify an equation with the level of daily excess reserves as the dependent variable. For each equation, we include a lagged dependent variable to capture the

[1] In this paper we frequently use the generic word "bank" to represent depository and other institutions with accounts at the Federal Reserve.

autoregressive behavior. We also include dummy variables for each day of the maintenance period to control for systematic variation in the variables; Carpenter and Demiralp (forthcoming) document an intra-maintenance-period pattern to the federal funds rate. We include the level of cumulative reserve balances to control for the fact that demand for balances has a maintenance-period-frequency component as well as a daily-frequency component. In an extreme example, on the last day of a maintenance period, one would expect demand to be lighter than usual if banks had already satisfied their balance requirements for the period. We include the error for the daily forecast of balances made by the Federal Reserve. Hamilton (1998) and Carpenter and Demiralp (forthcoming) use this variable to measure the liquidity effect in the funds market. We use it here to capture deviations in price and quantity that are due to unintentional changes in reserve balances. As shown later, our results for the liquidity effect are broadly consistent with previous work.

We also include separate dummy variables for "special pressure days"—specifically, the day after a holiday; quarter end; year end; first of the month; fifteenth of the month; month end; and settlement of Treasury two-, three-, five-, and ten-year notes, including Treasury inflation-protected securities.[2] These are days of increased payment flows through banks' reserve accounts and, as a result, represent days of increased uncertainty. Increased uncertainty should be associated with a greater demand for balances to avoid an overdraft. Finally, for the excess balances equation, we include carryover, broken down by bank size. Everything else remaining the same, a higher level of balances carried over from the previous maintenance period should induce banks to hold lower balances in the current maintenance period.

While the regressions include the control variables as well as the variables of interest, to ease exposition, we present the coefficients on these control variables first in table 1 before presenting the rest of the results from the model. Looking at the dummies for the days

[2]We exclude Treasury bill auctions, as these are regular weekly auctions and are thus captured by our daily dummy variables. The exceptions to this would be the handful of occasions when bill auctions were delayed due to debt limit constraints.

Table 1. Control Variables

Sample Period: January 26, 1994–July 13, 2005*

Variable	*(Deviation from Target)$_t$*		*(Daily ER)$_t$*	
	Coeff.	**s.e.**	**Coeff.**	**s.e.**
Lagged Dependent Variable	0.27	0.047	0.27	0.026
$D_{First\ Thursday}$	−0.00082	0.015	0.65	0.28
$D_{First\ Friday}$	−0.058	0.016	0.056	0.26
$D_{First\ Monday}$	0.0033	0.016	1.53	0.22
$D_{First\ Tuesday}$	−0.049	0.015	0.93	0.23
$D_{First\ Wednesday}$	−0.032	0.015	0.98	0.23
$D_{Second\ Thursday}$	0.00030	0.015	1.54	0.23
$D_{Second\ Friday}$	−0.064	0.015	1.66	0.22
$D_{Second\ Monday}$	0.026	0.016	4.13	0.27
$D_{Second\ Tuesday}$	−0.040	0.018	4.22	0.41
$D_{Second\ Wednesday}$	0.12	0.031	9.63	1.23
$Cumulative\ ER \times D_{First\ Friday}$	−0.011	0.0030	−0.082	0.069
$Cumulative\ ER \times D_{First\ Monday}$	−0.0083	0.0048	−0.089	0.069
$Cumulative\ ER \times D_{First\ Tuesday}$	−0.0082	0.0028	−0.35	0.073
$Cumulative\ ER \times D_{First\ Wednesday}$	−0.016	0.0041	−0.37	0.072
$Cumulative\ ER \times D_{Second\ Thursday}$	−0.017	0.0038	−0.70	0.074
$Cumulative\ ER \times D_{Second\ Friday}$	−0.013	0.0049	−1.0039	0.093
$Cumulative\ ER \times D_{Second\ Monday}$	−0.016	0.010	−1.79	0.24
$Cumulative\ ER \times D_{Second\ Tuesday}$	−0.040	0.011	−2.058	0.47
$Cumulative\ ER \times D_{Second\ Wednesday}$	−0.090	0.024	−4.11	1.22
$(Forecast\ Miss)_t$	−0.0095	0.0035	0.79	0.038
$D_{Month\ End}$	0.027	0.034	2.45	0.26
$D_{Month\ Start}$	0.012	0.021	1.60	0.22
$D_{Quarter\ End}$	0.28	0.0764	4.27	0.41
$D_{Quarter\ Start}$	0.17	0.081	2.54	0.42
$D_{Year\ End}$	−0.45	0.17	5.047	1.21
$D_{Year\ Start}$	0.25	0.11	1.94	0.81

(*continued*)

Table 1 (continued). Control Variables

Sample Period: January 26, 1994–July 13, 2005*

Variable	*(Deviation from Target)$_t$* Coeff.	s.e.	*(Daily ER)$_t$* Coeff.	s.e.
$D_{Mid\text{-}Month}$	0.09	0.012	2.31	0.20
$D_{Day\ Before\ Holiday}$	−0.02	0.017	0.10	0.19
$D_{Day\ After\ Holiday}$	−0.06	0.077	1.73	0.21
$D_{Treasury\ 2}$	0.11	0.041	−0.85	0.36
$D_{Treasury\ 3}$	0.065	0.032	−0.51	0.41
$D_{Treasury\ 5}$	0.098	0.045	1.47	0.39
$D_{Treasury\ 10}$	−0.045	0.016	−0.33	0.39
$(Required\ Operating\ Balances)_t$	0.00070	0.00059	−0.042	0.0085
Target	0.0014	0.0012	−0.13	0.023
$(Carry\text{-}in\_Large)_t$	—	—	−0.51	0.43
$(Carry\text{-}in\_Other)_t$	—	—	4.69	1.85
$(Carry\text{-}in\_Large)_t \times Anticipated\ \Delta \times D_{One\ Day\ Before\ a\ Tightening}$	—	—	−5.17	12.0080
$(Carry\text{-}in\_Large)_t \times Anticipated\ \Delta \times D_{One\ Day\ Before\ an\ Easing}$	—	—	−2.931	10.021

Note: Tables 1 and 2 report the results from the same regression but split the variables into two groups for exposition.
*Data for 2001 exclude September 11 through September 19.

of the maintenance period, we note that both Fridays have negative and statistically significant coefficients in the federal funds equation, as shown in the second and third columns. These results suggest that the funds rate consistently trades soft to the target on Fridays and indicate that the Desk typically provides more reserves on Fridays than are demanded at the target. Also of note is that the funds rate systematically trades firm to the target on the last day of the maintenance period. From the excess balances equation, shown in the last two columns, we can see that excess balances tend to start off low early in the period and gradually rise, peaking on settlement Wednesday.

Looking at the coefficients on cumulative excess, although many of the coefficients in the federal funds equation are statistically significant, they are only economically significant on the last two days, where an extra $1 billion of cumulative excess is associated with 4 and 9 basis points of softness, respectively. The negative coefficients in the excess balances equation suggest that the Desk recognizes the pressure that cumulative excess places on banks' demand for balances and works to offset the effect.

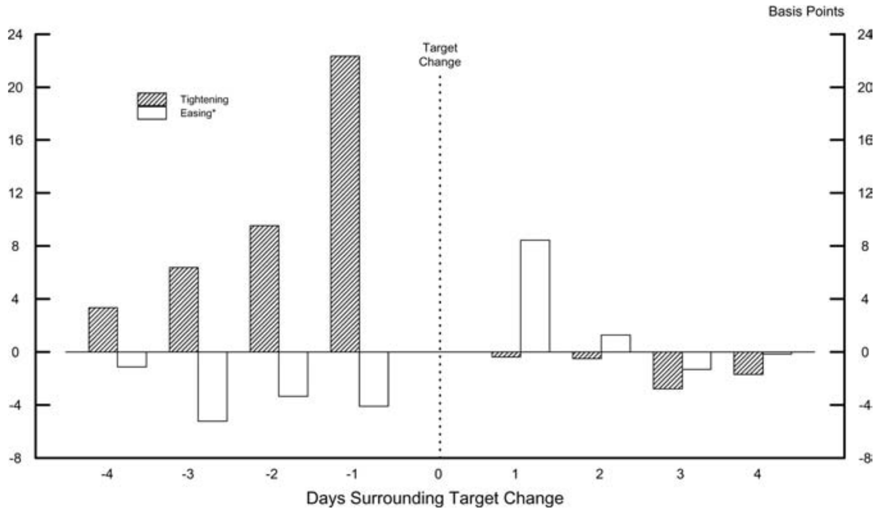
The carryover variable is negative for the large banks, indicating that these institutions act with the motivation to maximize profits and use their reserves efficiently. The coefficient is positive for small banks, confirming our understanding that these institutions do not closely manage their reserve positions. In order to test whether the banks boost their balances in the maintenance period before an anticipated rate hike in order to carry over the surplus, we interact lagged carryover balances with anticipated policy changes on the day before a target change for large banks. The coefficients are insignificant.

The coefficient on the forecast miss is consistent with results in Carpenter and Demiralp (forthcoming) for the funds rate equation. Essentially, this coefficient says that a $1 billion change in reserve balances changes the federal funds rate about 1 basis point. For the excess balances equation, the coefficient is slightly (but statistically significantly) less than unity. Hamilton (1997) suggests that these exogenous changes in reserve balances are partially offset by borrowing from the discount window, an interpretation consistent with a coefficient below 1. The other variables have similar, logical interpretations. On balance, these control variables should allow us to focus exclusively on the anticipation effect, feeling confident that we have accounted for other systematic variation in the dependent variables.

2.1 Measuring Anticipation

Figure 1 shows the deviation of the effective federal funds rate from the target rate on days leading up to policy changes at FOMC meetings over the period 1994 to 2004. As can be seen, on days prior to increases in the target, the funds rate was on average above the target rate, and on days prior to decreases in the target, the funds rate was below the target. While this evidence is suggestive, it does

Figure 1. Federal Funds Rate Deviations from Target Surrounding a Target Change (1994–2004)



*Data for 2001 exclude September 11 through September 19.

not control for whether or not the change in the target rate was expected—the crux of the anticipation effect.

To measure the degree of anticipation of changes in the target rate, we use a technique that generalizes the methodology proposed by Kuttner (2001) to measure expectations of the Federal Reserve's policy actions based on the price of federal funds futures contracts.[3] The key idea is that the spot-month rate for federal funds futures contracts on a particular day t reflects the expected average funds rate for that month, conditional on the information prevailing up to that date.[4] Based on this fact and knowing that the effective funds

[3]One ironic implication of the present paper is that a systematic anticipation effect should tend to get priced into futures contracts. As a result, the method for inferring anticipated changes is likely biased. Preliminary investigation of the phenomenon suggests that the bias is likely small, but future research should strive to make the estimation precise. In any event, this bias implies that we will understate any anticipation effect we find, so our general results should be unaffected.

[4]Naturally, this measure presumes that market participants are aware of the target and can observe the changes. If the market participants were unaware that the target had changed, expectations would not necessarily reflect the changes in the policy instrument.

rate as a monthly average is very close to the target rate (typically within a few basis points), the spot-month futures rate on any day k prior to a target change that is expected to occur on day t can be expressed as

$$\mathit{Spot\ Rate}_k = \frac{[(N_b \times \rho_{t-1}) + (N_a \times E_k(\rho_t)]}{N} + \mu_k, \quad k < t, \tag{1}$$

where ρ_t is the target funds rate on day t, E_k is the expectations operator based on information as of day k, and μ_k is a term that may represent the risk premium or day-of-month effects in the futures market. In an efficient market with risk-neutral investors, this term would be zero. N_b is the number of days before a target change, N_a is the number of days after a target change, and hence $N = N_b + N_a$ is the total number of days in a given month.

Assuming that the target change occurs on day t, the spot rate on day t is given by

$$\mathit{Spot\ Rate}_t = \frac{[(N_b \times \rho_{t-1}) + (N_a \times \rho_t)]}{N} + \mu_t. \tag{2}$$

The difference between the spot-month rates prior to and after the target change—i.e., equation (2) − equation (1)—gives us the policy surprise as of day k:

$$\begin{aligned} &\mathit{Spot\ Rate}_t - \mathit{Spot\ Rate}_k \\ &\quad = \Phi \underbrace{[\rho_t - E_k(\rho_t)]}_{\mathit{Unanticipated\ target\ change\ as\ of\ day\ k}}, \quad \text{where } \Phi = \left(\frac{N_a}{N}\right). \end{aligned} \tag{3}$$

Equation (3) is used to compute the policy surprise on any day k prior to a target change that takes place on day t (i.e., $k < t$), except for two cases:

1. Kuttner (2001) notes that the day-t targeting error and the revisions in the expectation of future targeting errors may be nontrivial at the end of the month. Consequently, if a target change occurs in the last three days of the month, the difference in one-month forward rates is used to derive the

policy surprise, since the one-month rate reflects the expected average funds rate for the next month:

$$(One\ Month\ Rate)_t - (One\ Month\ Rate)_k = \Phi \underbrace{[\rho_t - E_k(\rho_t)]}_{Unanticipated\ Policy\ Change\ as\ of\ day\ k},$$

$$\text{where } \Phi = \left(\frac{N}{N}\right) = 1.$$

2. If the number of days in the forecast horizon is equal to (or greater than) the day of the month in which the target is changed, we need to use the one-month forward rate from the *previous* month to assess the market's expectations on day k. For instance, if our goal is to derive the anticipated policy change five days prior to a policy meeting, and if the meeting occurs on the second day of the month, we need to look at the one-month forward rate on day $k = N - 3$ of the previous month and the spot rate on day 2 of the current month to compute the anticipated and unanticipated policy changes. That is,

$$(Spot\ Rate)_t - (One\ Month\ Rate)_k^{\text{Previous Month}} = \Phi \underbrace{[\rho_t - E_k(\rho_t)]}_{Unanticipated\ Policy\ Change\ as\ of\ day\ k}, \quad \text{where } \Phi = \frac{N_a}{N}.$$

This methodology allows us to estimate expectations of policy changes k days prior to a target change, which extends Kuttner's method of computing anticipated policy actions one day before the target change (i.e., $k = 1$).[5] This generalization provides us with an essential tool in testing the anticipation effect, because we can investigate how the funds rate responds to expectations as well as how the anticipated changes evolve in the days leading to a policy move.

[5] Following Kuttner (2001), we adjust for one timing mismatch on October 15, 1998, when the target change took place after the futures market had closed. In order to deal with this occurrence, we treat the data as if the target change took place on the next day.

2.2 Estimating the Anticipation Effect

Before we present the regression coefficients associated with the anticipation effect, it is informative to take a look at how the accuracy of policy expectations has evolved in time. Figure 2 displays the components of target changes that are unanticipated by the market for policy tightenings and easings, respectively.[6] Consistent with the improvements in the transparency of monetary policy actions, the component of target changes that surprised market participants declined gradually over time both for policy tightenings and policy easings.

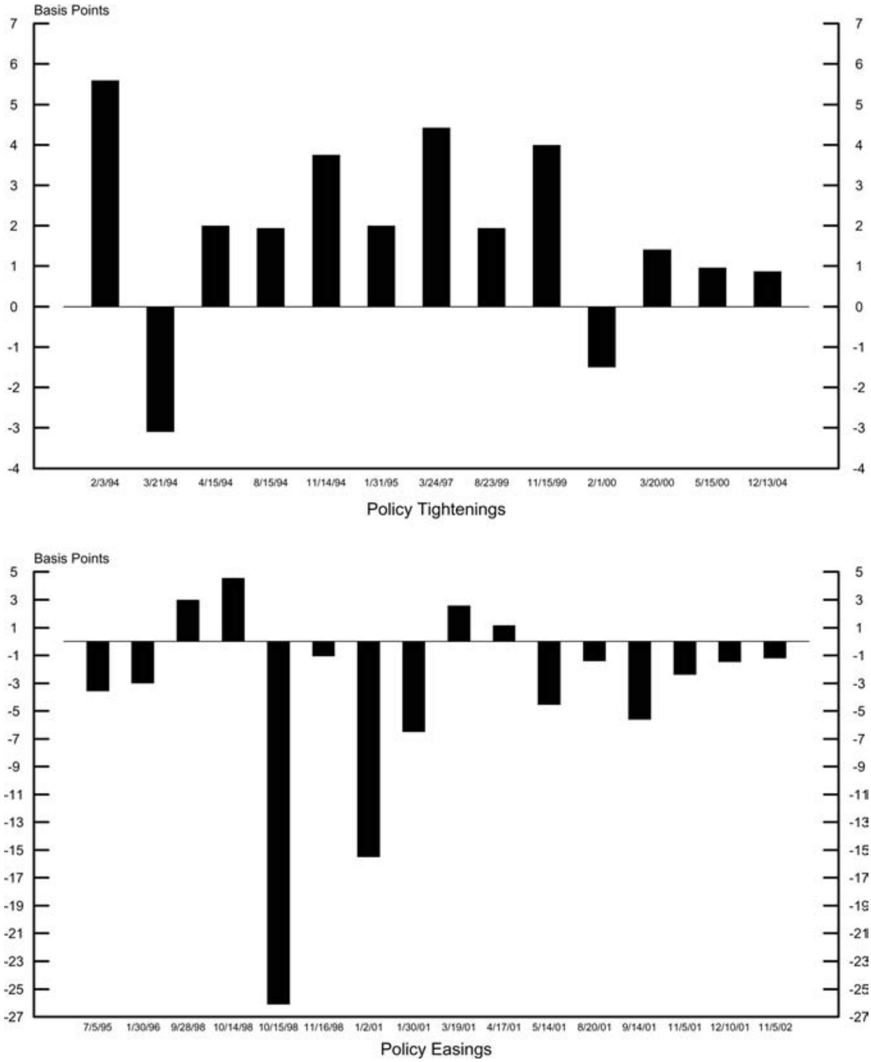
As noted above, we interacted the expected change in the federal funds rate with dummy variables for one through nine days before a policy change. To avoid conditioning our estimation on whether or not there was a policy change, a fact that is only known ex post,[7] we focus exclusively on anticipation of policy changes that took place at FOMC meetings.[8] Of course, during our sample period, there were intermeeting policy changes, but these moves were all surprises, and we do not believe that banks planned in advance for them. We do, however, want to allow for an asymmetry between an expected increase and an expected decrease. We interact the expected change in the funds rate with a dummy variable that denotes an upcoming FOMC meeting. To allow for the asymmetry, we create one dummy for meetings where there was either no change or an increase in the funds rate and another for meetings where there was either no change or a decrease in the funds rate. We assume, therefore, that the sign of an impending change in the target rate change is known by banks—an assumption we view as entirely plausible. Because some

[6]Unanticipated change is computed as the difference between the actual size of a target change and the anticipated change.

[7]We thank Jim Hamilton for pointing out our previous error in conditioning on information only knowable ex post.

[8]Prior to 1998, during the period of contemporaneous reserve accounting, reserve requirements and contractual clearing balances were calculated over a computation period that overlapped with all but the last two days of the maintenance period over which the requirements were to be satisfied. Since 1998, computation periods have ended prior to the beginning of the maintenance period. We interacted dummy variables for the lagged-accounting period with the anticipation variable to test whether or not this structural shift affects our results. We fail to reject that the coefficients are jointly equal to zero.

Figure 2. Unanticipated Target Changes on the Day before a Policy Action



of the observations that are multiple days prior to a policy move are in a previous maintenance period, we include in our estimation only those anticipations that are in the same maintenance period, within which the motivation to clear arbitrage opportunities is dominant.

Table 2. Anticipation Effect

Variable	*(Deviation from Target)$_t$* Coeff.	s.e.	*(Daily ER)$_t$* Coeff.	s.e.
$Anticipated\ \Delta \times D_{Nine\ Days\ Before\ a\ Tightening}$	0.055	0.054	1.33	0.88
$Anticipated\ \Delta \times D_{Eight\ Days\ Before\ a\ Tightening}$	0.056	0.058	0.050	0.57
$Anticipated\ \Delta \times D_{Seven\ Days\ Before\ a\ Tightening}$	0.014	0.044	1.23	0.58
$Anticipated\ \Delta \times D_{Six\ Days\ Before\ a\ Tightening}$	0.057	0.043	0.41	0.47
$Anticipated\ \Delta \times D_{Five\ Days\ Before\ a\ Tightening}$	0.028	0.044	0.31	0.34
$Anticipated\ \Delta \times D_{Four\ Days\ Before\ a\ Tightening}$	0.12	0.055	0.68	0.40
$Anticipated\ \Delta \times D_{Three\ Days\ Before\ a\ Tightening}$	0.29	0.060	1.26	0.34
$Anticipated\ \Delta \times D_{Two\ Days\ Before\ a\ Tightening}$	0.37	0.052	1.87	0.34
$Anticipated\ \Delta \times D_{One\ Day\ Before\ a\ Tightening}$	0.46	0.067	1.17	0.44
$Anticipated\ \Delta \times D_{Nine\ Days\ Before\ an\ Easing}$	0.078	0.083	1.45	1.0089
$Anticipated\ \Delta \times D_{Eight\ Days\ Before\ an\ Easing}$	0.11	0.13	0.38	0.53
$Anticipated\ \Delta \times D_{Seven\ Days\ Before\ an\ Easing}$	−0.066	0.19	−0.37	0.57
$Anticipated\ \Delta \times D_{Six\ Days\ Before\ an\ Easing}$	−0.11	0.11	−0.30	0.48
$Anticipated\ \Delta \times D_{Five\ Days\ Before\ an\ Easing}$	−0.0078	0.049	0.26	0.57
$Anticipated\ \Delta \times D_{Four\ Days\ Before\ an\ Easing}$	0.078	0.058	−0.57	0.46
$Anticipated\ \Delta \times D_{Three\ Days\ Before\ an\ Easing}$	0.017	0.059	−0.20	0.46
$Anticipated\ \Delta \times D_{Two\ Days\ Before\ an\ Easing}$	0.18	0.11	−0.34	0.56
$Anticipated\ \Delta \times D_{One\ Day\ Before\ an\ Easing}$	0.23	0.076	−0.055	0.74
$D_{Day\ of\ a\ Tightening}$	−0.18	0.048	0.42	0.57
$D_{Day\ of\ an\ Easing}$	0.089	0.029	−0.38	0.36
$D_{Day\ of\ a\ Tightening} \times Unanticipated\ \Delta$	−0.50	0.62	−5.40	7.60
$D_{Day\ of\ an\ Easing} \times Unanticipated\ \Delta$	0.43	0.56	5.22	2.97

Notes: Tables 1 and 2 report the results from the same regression but split the variables into two groups. For Daily ER regressions, the anticipated change variable is replaced with a dummy variable where $|Anticipated\ \Delta| > 0.125$.

The results shown are from the regression that had the control variables reported in table 1. As shown in the second and third columns of table 2, the results for the federal funds rate equation indicate a statistically significant anticipation effect in the funds market only for four days prior to a tightening and for two days prior to an easing.[9] The coefficients suggest that the funds rate moves in the direction of the anticipated change, but not fully. Prior to anticipated tightenings, the funds rate moves almost halfway—or about $12^1/_2$ basis points for an anticipated 25-basis-point policy move—to the anticipated new target on the day before the policy change and is elevated as many as three days prior. For anticipated easings, the effect is much more muted, although it is still statistically significant. This asymmetric effect will be confirmed in our theoretical model presented below. Because requirements are satisfied over a two-week period, there is an option value to waiting until the latter part of the period to satisfy these requirements. Given this pattern, which is reflected both in the data and in our model, there is less scope for banks to react to an anticipated easing by lowering balances further to take advantage of lower expected rates later in the period. Doing so would increase the probability of a costly overnight overdraft, and so the anticipation effect in this case is attenuated. For anticipated policy easings, the funds rate appears to move less than one-fourth of the way to the anticipated new target, or about 6 basis points for a 25-basis-point reduction in the target funds rate.

We do find some evidence that the Desk accommodates the increase in demand for reserve balances prior to an anticipated policy tightening—as indicated by the positive, statistically significant coefficients up to four days prior to a tightening, shown in the last two columns. Those results imply that over the four days before a fully anticipated increase in the target federal funds rate, the Desk provides between \$.75 and \$1.75 billion more in excess reserve each day than would be typical, holding all other things constant, for a total of about \$5 billion. Taking the results of the two equations together, however, we can infer that the increase in supply is not sufficient to fully offset the increased demand; the evidence is the funds rate trading firm to the target despite an increased provision of balances. These results imply that the Desk leans against the firmness but does not fully counteract it. Similarly, prior to anticipated policy

[9]For the excess balances equation, we replace the expected change with a dummy variable that equals 1 if the expected change is greater than $12^1/_2$ basis points; that is to say, better than even odds of at least a 25-basis-point change. This substitution is made because banks must decide if they think a change is coming or not, rather than acting on the size of the change, in order to shift balances.

easings, the Desk does not drain sufficient balances to offset fully the softness in the market, likely in an effort to avoid leaving the System with insufficient balances.

The tightening episode that began in June 2004 has been characterized as particularly well anticipated and predictable. As an extension, we test to see if the anticipation effect is different in this recent episode. Tables 3 and 4 present the same regressions but with dummy variables for the 2004 tightening episode interacted with our

Table 3. Control Variables

Sample Period: January 26, 1994–July 13, 2005*

	(Deviation from Target)$_t$		***(Daily ER)$_t$***	
Variable	**Coeff.**	**s.e.**	**Coeff.**	**s.e.**
Lagged Dependent Variable	0.27	0.047	0.27	0.026
$D_{First\ Thursday}$	−0.0033	0.016	0.59	0.28
$D_{First\ Friday}$	−0.061	0.016	0.0040	0.26
$D_{First\ Monday}$	0.0011	0.016	1.46	0.23
$D_{First\ Tuesday}$	−0.051	0.015	0.87	0.24
$D_{First\ Wednesday}$	−0.034	0.015	0.94	0.23
$D_{Second\ Thursday}$	−0.0014	0.015	1.49	0.23
$D_{Second\ Friday}$	−0.066	0.015	1.63	0.23
$D_{Second\ Monday}$	0.024	0.016	4.11	0.27
$D_{Second\ Tuesday}$	−0.041	0.018	4.18	0.41
$D_{Second\ Wednesday}$	0.12	0.031	9.58	1.23
Cumulative ER $\times D_{First\ Friday}$	−0.011	0.0030	−0.084	0.069
Cumulative ER $\times D_{First\ Monday}$	−0.0087	0.0048	−0.10	0.070
Cumulative ER $\times D_{First\ Tuesday}$	−0.0083	0.0028	−0.35	0.073
Cumulative ER $\times D_{First\ Wednesday}$	−0.016	0.0041	−0.37	0.072
Cumulative ER $\times D_{Second\ Thursday}$	−0.018	0.0038	−0.70	0.073
Cumulative ER $\times D_{Second\ Friday}$	−0.013	0.0050	−1.0070	0.093

(*continued*)

Table 3 (continued). Control Variables

Sample Period: January 26, 1994–July 13, 2005*

	(Deviation from Target)$_t$		*(Daily ER)$_t$*	
Variable	**Coeff.**	**s.e.**	**Coeff.**	**s.e.**
$Cumulative\ ER \times D_{Second\ Monday}$	−0.016	0.010	−1.80	0.25
$Cumulative\ ER \times D_{Second\ Tuesday}$	−0.040	0.011	−2.07	0.48
$Cumulative\ ER \times D_{Second\ Wednesday}$	−0.090	0.024	−4.10	1.22
$(Forecast\ Miss)_t$	−0.0094	0.0035	0.79	0.038
$D_{Month\ End}$	0.025	0.035	2.45	0.26
$D_{Month\ Start}$	0.013	0.021	1.58	0.22
$D_{Quarter\ End}$	0.28	0.077	4.27	0.41
$D_{Quarter\ Start}$	0.17	0.081	2.55	0.43
$D_{Year\ End}$	−0.45	0.17	5.051	1.21
$D_{Year\ Start}$	0.25	0.11	2.017	0.76
$D_{Mid\text{-}Month}$	0.091	0.012	2.33	0.20
$D_{Day\ Before\ Holiday}$	−0.020	0.017	0.11	0.19
$D_{Day\ After\ Holiday}$	−0.060	0.077	1.74	0.21
$D_{Treasury\ 2}$	0.11	0.041	−0.89	0.36
$D_{Treasury\ 3}$	0.067	0.032	−.44	0.40
$D_{Treasury\ 5}$	0.098	0.045	1.52	0.39
$D_{Treasury\ 10}$	−0.044	0.016	−.34	0.39
$(Required\ Operating\ Balances)_t$	0.00072	0.00057	−.041	0.0085
$Target$	0.0018	0.0013	−.13	0.024
$(Carry\text{-}in\_Large)_t$	—	—	−.54	0.43
$(Carry\text{-}in\_Other)_t$	—	—	4.67	1.85
$(Carry\text{-}in\_Large)_t \times Anticipated\ \Delta \times D_{One\ Day\ Before\ a\ Tightening}$	—	—	−.58	9.70
$(Carry\text{-}in\_Large)_t \times Anticipated\ \Delta \times D_{One\ Day\ Before\ an\ Easing}$	—	—	−.74	10.070

Note: Tables 3 and 4 report results from the same regression but split the variables into two groups.
*Data for 2001 exclude September 11 through September 19.

Table 4. Anticipation Effect

Variable	$(Deviation\ from\ Target)_t$		$(Daily\ ER)_t$	
	Coeff.	**s.e.**	**Coeff.**	**s.e.**
$Anticipated\ \Delta \times D_{Nine\ Days\ Before\ a\ Tightening}$	0.057	0.068	0.84	0.14
$Anticipated\ \Delta \times D_{Eight\ Days\ Before\ a\ Tightening}$	0.013	0.045	0.18	0.55
$Anticipated\ \Delta \times D_{Seven\ Days\ Before\ a\ Tightening}$	0.037	0.048	0.90	0.69
$Anticipated\ \Delta \times D_{Six\ Days\ Before\ a\ Tightening}$	0.034	0.042	0.80	0.53
$Anticipated\ \Delta \times D_{Five\ Days\ Before\ a\ Tightening}$	−0.026	0.039	0.38	0.46
$Anticipated\ \Delta \times D_{Four\ Days\ Before\ a\ Tightening}$	0.076	0.058	0.15	0.46
$Anticipated\ \Delta \times D_{Three\ Days\ Before\ a\ Tightening}$	0.21	0.067	0.78	0.30
$Anticipated\ \Delta \times D_{Two\ Days\ Before\ a\ Tightening}$	0.31	0.055	1.060	0.46
$Anticipated\ \Delta \times D_{One\ Day\ Before\ a\ Tightening}$	0.42	0.086	0.38	0.44
$Anticipated\ \Delta \times D_{Nine\ Days\ Before\ a\ Tightening} \times D_{2004}$	−0.0035	0.067	1.015	1.66
$Anticipated\ \Delta \times D_{Eight\ Days\ Before\ a\ Tightening} \times D_{2004}$	0.31	0.12	−0.50	1.60
$Anticipated\ \Delta \times D_{Seven\ Days\ Before\ a\ Tightening} \times D_{2004}$	−0.16	0.11	1.43	1.015
$Anticipated\ \Delta \times D_{Six\ Days\ Before\ a\ Tightening} \times D_{2004}$	0.17	0.061	−1.54	0.61
$Anticipated\ \Delta \times D_{Five\ Days\ Before\ a\ Tightening} \times D_{2004}$	0.26	0.048	−0.22	0.61
$Anticipated\ \Delta \times D_{Four\ Days\ Before\ a\ Tightening} \times D_{2004}$	0.18	0.096	1.45	0.65
$Anticipated\ \Delta \times D_{Three\ Days\ Before\ a\ Tightening} \times D_{2004}$	0.27	0.11	1.027	0.64
$Anticipated\ \Delta \times D_{Two\ Days\ Before\ a\ Tightening} \times D_{2004}$	0.19	0.12	1.74	0.53
$Anticipated\ \Delta \times D_{One\ Day\ Before\ a\ Tightening} \times D_{2004}$	0.11	0.11	1.87	0.76
$Anticipated\ \Delta \times D_{Nine\ Days\ Before\ an\ Easing}$	0.07	0.083	1.46	1.0053
$Anticipated\ \Delta \times D_{Eight\ Days\ Before\ an\ Easing}$	0.11	0.13	0.39	0.53
$Anticipated\ \Delta \times D_{Seven\ Days\ Before\ an\ Easing}$	−0.068	0.19	−0.35	0.56
$Anticipated\ \Delta \times D_{Six\ Days\ Before\ an\ Easing}$	−0.11	0.11	−0.28	0.49

(*continued*)

Table 4 (continued). Anticipation Effect

Variable	$(Deviation\ from\ Target)_t$		$(Daily\ ER)_t$	
	Coeff.	**s.e.**	**Coeff.**	**s.e.**
$Anticipated\ \Delta \times D_{Five\ Days\ Before\ an\ Easing}$	−0.0082	0.049	0.26	0.57
$Anticipated\ \Delta \times D_{Four\ Days\ Before\ an\ Easing}$	0.078	0.058	−0.57	0.46
$Anticipated\ \Delta \times D_{Three\ Days\ Before\ an\ Easing}$	0.016	0.060	−0.19	0.46
$Anticipated\ \Delta \times D_{Two\ Days\ Before\ an\ Easing}$	0.18	0.11	−0.34	0.56
$Anticipated\ \Delta \times D_{One\ Day\ Before\ an\ Easing}$	0.23	0.076	−0.060	0.74
$D_{Day\ of\ a\ Tightening}$	−0.18	0.048	0.42	0.57
$D_{Day\ of\ an\ Easing}$	0.089	0.029	−0.38	0.36
$D_{Day\ of\ a\ Tightening} \times Unanticipated\ \Delta$	−0.51	0.62	−5.60	7.63
$D_{Day\ of\ an\ Easing} \times Unanticipated\ \Delta$	0.43	0.57	5.24	2.99

Note: Tables 3 and 4 report results from the same regression but split the variables into two groups.
In ER regressions, the anticipation variable is replaced with a dummy variable where $|Anticipated\ \Delta| > 0.125$.

anticipation-effect variables. These results suggest that the anticipation effect was more pronounced during this tightening cycle. The regression that uses excess reserves as the dependent variable suggests that the Desk also provided somewhat more balances in this cycle as well. We read these results to indicate that the anticipation effect is a systematic phenomenon, but the particularly clearly signaled series of rate hikes beginning in 2004 amplified the effect.

One immediate question is whether or not the Desk could fully offset the increased demand for balances in advance of an anticipated tightening of policy. The answer to this counterfactual question, which we will consider in section 4, must be inferred based on the average deviation of the funds rate from the target and estimates of the liquidity effect. The factors affecting the demand for balances, however, are complicated and reflect both day-specific demand and demand for balances across the fourteen-day maintenance period. The next section describes demand for balances, following which we address the feasibility of completely offsetting the shift in demand and the potential ramifications.

3. The Demand for Balances and the Anticipation of Policy

The demand side of the federal funds market comes from banks' desire to hold balances at the Federal Reserve. Banks exchange their holdings of Federal Reserve balances in the federal funds market. Total demand for balances can be broken down into three components. First, the demand for required reserve balances—that is, funds on deposit at the Federal Reserve to satisfy reserve requirements—is a function of regulatory requirements imposed on banks by the Federal Reserve. The Federal Reserve requires that banks hold reserves, either on deposit at the Federal Reserve or as vault cash, related to the level of their customers' transactions deposits. In addition, banks with low levels of required reserve balances but with significant transactions hitting their Federal Reserve accounts may wish to hold contractual clearing balances with the Federal Reserve to help guard against overdrafts. Lastly, banks may wish to hold balances in addition to the required or contracted level—excess balances—because deficiencies on requirements and overnight overdrafts are penalized, and so holding excess balances serves as a buffer.[10] We will now discuss these components in further detail, which will provide the institutional background for the demand model developed in the appendix.

3.1 Required Reserve Balances

Required reserves are a function of the level of reservable deposits at banks. Over a two-week computation period, the average level of deposits and the reserve requirement are calculated. Over the associated two-week maintenance period, which begins on a Thursday (seventeen days after the end of the computation period) and ends on a Wednesday, a bank must satisfy these requirements by holding reserves on deposit at the Federal Reserve or as vault cash. Balances held on a Friday are automatically also attributed to the following

[10]For a more complete discussion of the demand for reserve balances and the federal funds market, see Carpenter and Demiralp (forthcoming) and the references therein.

Saturday and Sunday. The requirement must be satisfied *on average* over the maintenance period, which means that, for purposes of reserve requirements, balances are perfectly substitutable across days of the maintenance period.

Because of the lag between the computation period and the maintenance period, reserve requirements are known with certainty in advance of the maintenance period.[11] Banks are allowed to carry over small excesses or deficiencies from one maintenance period to the next. Hence, a small deficiency in one period can be made up in the next period, and a small excess can be used in the subsequent period to fulfill requirements. However, banks can only carry over excesses or deficiencies for one maintenance period. Deficiencies in required reserve balances beyond carryover provisions are penalized at a rate of 1 percentage point (annual rate) above the primary credit rate (that is, the discount rate) in effect for borrowing from the Federal Reserve Bank on the first day of the calendar month in which the deficiency occurs.[12]

3.2 Contractual Clearing Balances

Contractual clearing balances facilitate clearing of transactions drawn on banks' Federal Reserve accounts, and their use was expanded with the Monetary Control Act in 1980 to help depository institutions with low required reserve balances limit the risk of overdrafts without having to hold large levels of excess balances. Banks must agree in advance of a maintenance period to hold a given level of contractual clearing balances, and—as with required reserve balances—this level must be met on a period-average basis. Beginning in January 2004, banks were allowed to adjust the level of contractual clearing balances each maintenance period, but the level may not be adjusted within a maintenance period. Contractual clearing balances differ from required reserves in an important way;

[11] In 1984, the Federal Reserve began "contemporaneous reserve accounting" in which the computation and maintenance period overlapped, and banks only knew their reserve requirement with certainty for the final two days of the maintenance period. In 1998, the Federal Reserve returned to "lagged reserve accounting."

[12] Prior to January 2003, reserve deficiency charges were calculated as 2 percentage points above the discount rate.

banks receive implicit interest on their holdings of contractual clearing balances, up to the contracted amount (plus a small allowance), in the form of credits to defray the cost of services—such as check clearing—provided by the Federal Reserve. Contractual clearing balances are subject to a clearing balance band of plus or minus the greater of $25,000 or 2 percent of the contracted level, giving the bank a bit of leeway in satisfying their requirements. Deficiencies beyond the clearing band up to 20 percent of the level of contractual clearing balances are assessed a penalty of 2 percent per annum, and deficiencies greater than 20 percent of contractual clearing balances are assessed a penalty of 4 percent per annum. Balances in a bank's account at the Federal Reserve are first applied to required reserve balances and subsequently used to satisfy contractual clearing balances.

3.3 Excess Balances

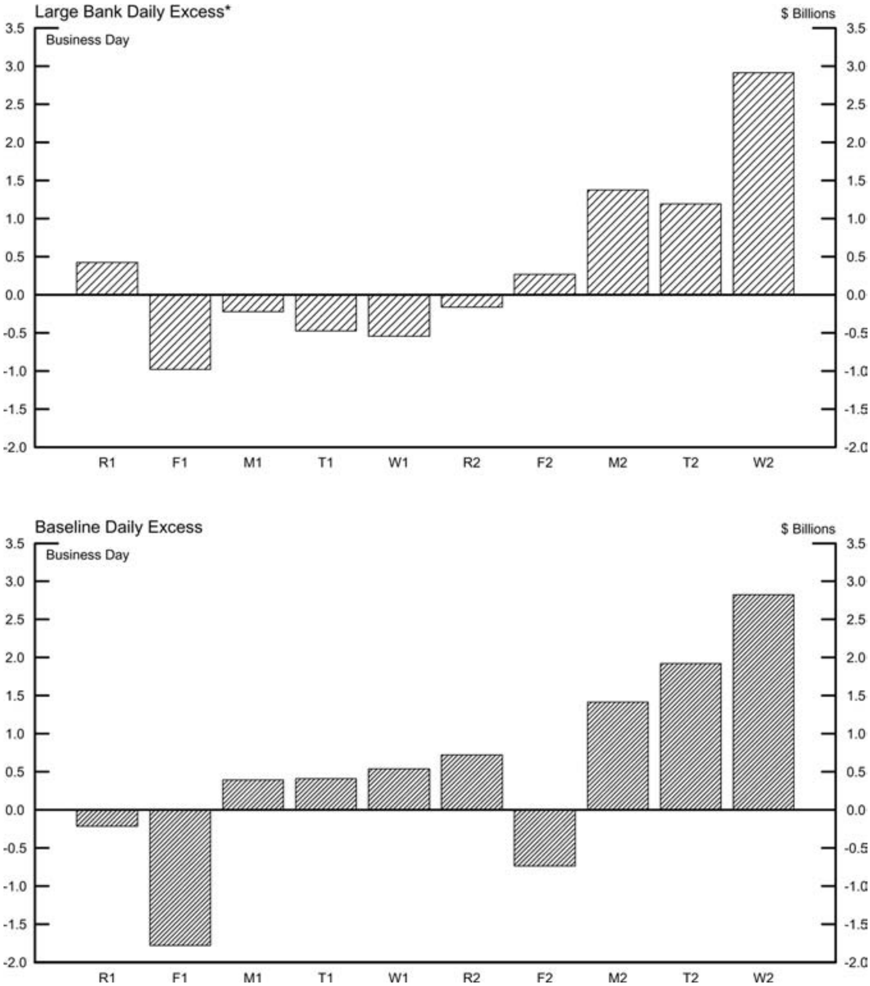
Any balances held in excess of those required to satisfy either of the above requirements are considered to be excess balances. Because these balances earn no return and do not satisfy any regulatory requirement, they have an opportunity cost of the prevailing federal funds rate. Large banks tend to manage their reserve accounts closely and typically end each maintenance period close to zero excess balances. Smaller banks, for which the dollar value of the opportunity cost may be relatively small, sometimes have excess balances, because the transactions cost of closely managing their accounts would be too high. That said, excess balances serve as a buffer against a possible costly overnight overdraft. Transactions that are settled late in the day on a bank's Federal Reserve account could unexpectedly drive the balance below zero; borrowing from the discount window is currently priced 1 percentage point over the target rate, and overnight overdrafts are assessed a fee of 4 percentage points (annual rate) above the target federal funds rate—more than a slap on the wrist. As a result, banks often demand greater levels of excess balances when flows in and out of their accounts are in greater volumes, and thus a greater uncertainty attends their end-of-day balance. From 1994 to 2004, total balances averaged about $20.8 billion, of which $11.7 billion were required reserve balances, $7.3 billion were contractual clearing balances, and $1.5 billion were excess balances. The lowest total balances were around $12 billion for a couple of days in 2000.

3.4 Demand for Balances and Policy Changes

As discussed above, figure 1 displays the average deviation of the federal funds rate from the target in the four days prior to and the four days following changes in the target federal funds rate since 1994. As the figure indicates, there is a clear, consistent pattern of funds rates firm relative to the target on days before increases in the target rate and funds rates soft to the target on days before decreases in the target rate. One of the simplest explanations for this phenomenon is intertemporal arbitrage. If banks expect the funds rate to be higher tomorrow, and funds are perfectly substitutable across days, there is an incentive to bid aggressively for the funds rate today in order to avoid borrowing funds when interest rates are expected to be high. Although Hamilton (1997) shows that there are systematic changes in the funds rate, and thus a strict martingale property does not exist in the federal funds rate, we could expect arbitrage to work at least partially in that direction.

The appendix presents in detail a dynamic-optimization model of daily reserve demand for a representative large bank, akin to that presented in Clouse and Dow (2002). The bank's objective is to minimize the expected cost of maintaining its reserve position subject to fees imposed for overdrafts, reserve deficiencies, and contractual clearing balance deficiencies. The bank must choose a target level for reserve balances each day before a random shock to its level of balances is realized. The top panel of figure 3 plots the pattern of daily excess for large banks averaged over maintenance periods from 1994 to present. The bottom panel plots the level of daily excess implied by the model when the federal funds rate is set equal to 2 percent each day. The intra-maintenance-period pattern is qualitatively similar, lending support to the descriptive power of the model. Of note is the fact that derived demand for excess balances is lower on Fridays but tends to increase through the maintenance period. The intuition is that on a Friday, the bank must pay three days of interest in borrowing reserve balances, but an overdraft on Friday is penalized for only one day's overdraft. As a result, on a relative basis, overdrafts are cheaper on Fridays than on other days,

Figure 3. Daily Excess Balances



*Large bank excess is calculated from 1994 to present.

and banks hold less excess as insurance. For the general uptrend, the intuition is as follows. Because holding excess funds is costly, banks would like to balance reducing excess against the expected cost of an overdraft and a deficiency. Banks want to avoid getting locked in to too large a cumulative reserve position early in the period, because there is limited scope to reduce balances on the last days of the maintenance period without incurring a high expected cost of an overdraft. Hence, they wait until late in the maintenance period to obtain more information about their remaining reserve need and then hold sufficient balances to meet their requirements. Recall that these day-of-the-maintenance-period shifts in demand for balances were incorporated into our empirical models.

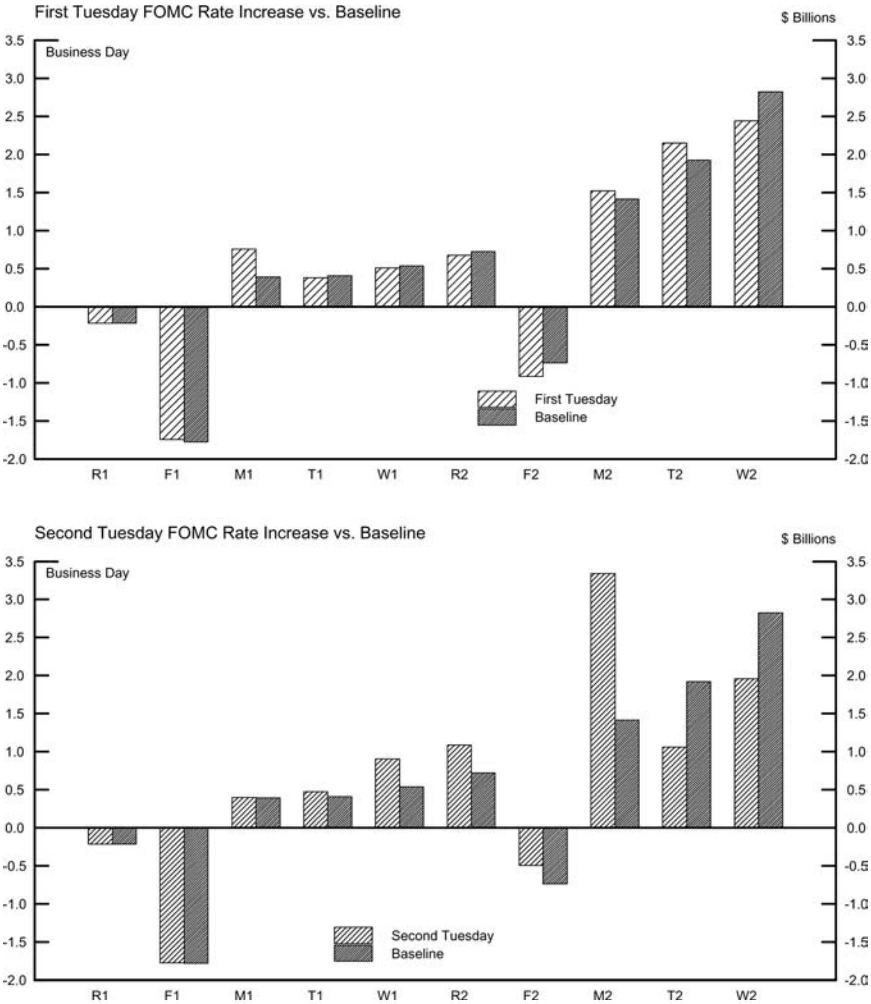
Next, we simulate maintenance periods in which banks correctly anticipate that the federal funds rate will be raised from 2 percent to $2^1/_4$ percent on the first or the second Tuesday of the maintenance period.[13] Figure 4 plots the results. Demand for balances in each case is shifted earlier in time relative to the baseline. Banks want to hold more of their reserve balances when funds are cheap and less when funds are more costly. This result may seem obvious, but it is important to note that demand is not shifted so much that there is zero demand on days after the rate increase. In particular, the same tension exists between holding funds early in the period and the possibility of getting locked in to an overly high level of excess balances.

We also simulate maintenance periods in which the federal funds rate is lowered 25 basis points from $2^1/_4$ percent to 2 percent, again on the first or the second Tuesday of the maintenance period. Figure 5 shows the results, and the pattern is reversed qualitatively. The optimal strategy is for a bank to run leaner balances early in the maintenance period in order to fulfill its requirements after the funds rate is lower. The anticipation effect is not symmetric, however, for increases and decreases in the funds rate. Given that the optimal strategy with no expected change in the funds rate is for banks to carry fewer reserves early in the period, an anticipated decrease in the funds rate reinforces the baseline case, whereas an anticipated increase in the funds rate works against the bank's typical strategy. Indeed, as we have already seen earlier in the empirical results, an anticipated decline in the funds rate creates less of a change from the optimal program under an unchanged funds rate than does an anticipated increase.

As was stated before, this model is only one of demand for reserve balances, and our results in this section suggest that demand should be shifted if the funds rate is expected to change. By combining these results from our empirical findings on both quantity and price

[13]Typically, FOMC meetings and announced changes to the target fall on Tuesdays.

Figure 4. Daily Excess Balances

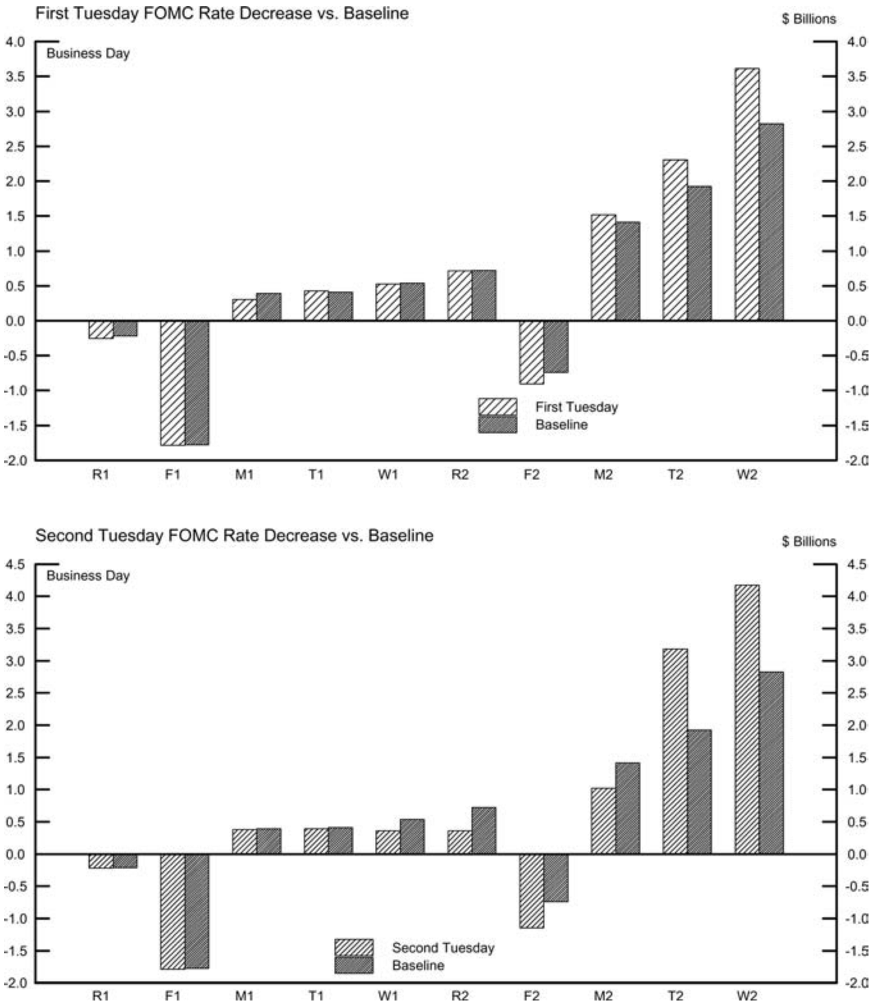


in the previous section, we can make inferences about supply and demand together.

4. Implications of the Anticipation Effect

We now explore the strategy of the Desk of only partially offsetting the anticipation effect. Our theoretical model suggests an interior solution for the portion of demand for balances that is shifted prior

Figure 5. Daily Excess Balances



to the anticipated change; that is to say that a finite quantity of balances should be able to satisfy this demand on the days before the policy tightening. The intuition is fairly simple. Demand for balances comprises day-specific demand to cover payments in and out of a bank's Federal Reserve account and maintenance-period demand to cover reserve requirements and contractual clearing balance requirements. If a large amount of balances are provided before the policy decision, the quantity of balances demanded following the target change would fall, perhaps dramatically. As a result, either the quantity supplied would outstrip the quantity demanded and federal funds would trade far below the target rate, or banks would have extremely lean balances and run a higher risk of overdraft or discount window borrowing, leading to higher volatility in the market.

Our regression results provide a means to analyze this question. Although the results are not immune to the Lucas critique, at face value they do provide support for the Desk's stated intent of only partially accommodating demand prior to changes in order to avoid a substantial drain afterward that might lead to volatility. As first explored by Hamilton (1997) and Carpenter and Demiralp (forthcoming), the coefficient on the error of the forecast of balances used for open market operations is an estimate of the liquidity effect. In our results, an extra \$1 billion results in a 1-basis-point reduction in the federal funds rate. A 25-basis-point increase that is fully anticipated is associated with four days of positive deviations from the target of 3, $7^{1}/_{4}$, $9^{1}/_{4}$, and $11^{1}/_{2}$ basis points, respectively. Using our estimate of the liquidity effect, these four days would require a total of almost \$31 billion of excess reserves in addition to the \$5 billion that we estimate is typically provided and in addition to any excess that would normally be provided, like the pattern shown in figure 3. It is the draining of these extra balances that is the difficulty mentioned in the Desk's annual report. It is possible that a large draining operation would leave balances at such a low level that demand becomes very inelastic. As a result, a minor error in forecasting that causes a deviation of supply from the quantity demand at the target could result in a large movement in the funds rate.

If the FOMC meeting takes place on the first Tuesday of the maintenance period, the bulk of the maintenance-period demand for balances will have been satisfied with the extra provision of balances early in the period. On days following the FOMC meeting, therefore, the primary demand for balances is the day-specific demand. The intertemporal substitutability of maintenance-period demand tends to smooth the funds rate—unfulfilled demand on one day can be met the next, and the funds rate need not move appreciably. Day-specific demand, by definition, cannot be spread across days, and thus the funds rate should be more sensitive to mismatches of supply and demand. Day-specific demand is driven by daily transaction needs and is therefore much more volatile relative to requirement-related demand—the component that can be substituted across the days of a maintenance period. Indeed, Carpenter and Demiralp (forthcoming) show that relatively small changes in the supply of balances have little effect on the funds rate precisely because of the typically intertemporal substitutability. By supplying the majority of the maintenance-period demand for balances early in a maintenance period, on days subsequent to an FOMC meeting, the funds rate would be more sensitive to forecast misses on the days following the meeting.

Moreover, it seems plausible that there may be some rough lower bound on the absolute level of balances needed for the funds market to function smoothly; however, estimating this bound is problematic. For maintenance periods with an FOMC meeting on the first Tuesday, there are six remaining days over which balances could be drained, for an average of almost $5 billion to be drained each day. For maintenance periods with required balances of less than $18 billion, such open market operations would leave the market with a level of total balances at the lower end of the range observed in our sample. Of course, it is impossible to know with certainty if the Desk could overcome the anticipation effect, given the current data and the fact that our results are implicitly conditioned on the current operating environment. Nevertheless, plausible measures of the size of the operations needed to offset the anticipation effect—and therefore a possible need to drain those balances later—suggest that the argument made in the annual report has merit.

Part of that rationale is a desire to avoid undue volatility in the funds market. Table 5 presents some of the coefficients from a regression of the intraday standard deviation of the federal funds rate on a specification identical to that in the federal funds rate equation.[14] None of the coefficients is positive and statistically significant, a fact that suggests that the Desk's current strategy avoids adding intraday volatility given the pressures of anticipation effect. Indeed, the only statistically significant coefficient is negative in sign, suggesting *less* volatility the day before an anticipated policy move.

[14]Intraday standard deviation is a volume-weighted measure of standard deviation, based on total brokered funds rate transactions on a given day.

Table 5. Intraday Volatility

Variable	Coeff.	s.e.
$Anticipated\ \Delta \times D_{Nine\ Days\ Before\ a\ Tightening}$	−0.12	0.12
$Anticipated\ \Delta \times D_{Eight\ Days\ Before\ a\ Tightening}$	−0.059	0.039
$Anticipated\ \Delta \times D_{Seven\ Days\ Before\ a\ Tightening}$	−0.062	0.041
$Anticipated\ \Delta \times D_{Six\ Days\ Before\ a\ Tightening}$	−0.056	0.051
$Anticipated\ \Delta \times D_{Five\ Days\ Before\ a\ Tightening}$	−0.051	0.052
$Anticipated\ \Delta \times D_{Four\ Days\ Before\ a\ Tightening}$	−0.039	0.053
$Anticipated\ \Delta \times D_{Three\ Days\ Before\ a\ Tightening}$	−0.057	0.079
$Anticipated\ \Delta \times D_{Two\ Days\ Before\ a\ Tightening}$	−0.025	0.044
$Anticipated\ \Delta \times D_{One\ Day\ Before\ a\ Tightening}$	0.049	0.086
$Anticipated\ \Delta \times D_{Nine\ Days\ Before\ an\ Easing}$	−0.059	0.074
$Anticipated\ \Delta \times D_{Eight\ Days\ Before\ an\ Easing}$	−0.20	0.20
$Anticipated\ \Delta \times D_{Seven\ Days\ Before\ an\ Easing}$	−0.39	0.31
$Anticipated\ \Delta \times D_{Six\ Days\ Before\ an\ Easing}$	0.029	0.064
$Anticipated\ \Delta \times D_{Five\ Days\ Before\ an\ Easing}$	−0.064	0.058
$Anticipated\ \Delta \times D_{Four\ Days\ Before\ an\ Easing}$	−0.081	0.086
$Anticipated\ \Delta \times D_{Three\ Days\ Before\ an\ Easing}$	−0.097	0.056
$Anticipated\ \Delta \times D_{Two\ Days\ Before\ an\ Easing}$	−0.19	0.12
$Anticipated\ \Delta \times D_{One\ Day\ Before\ an\ Easing}$	−0.13	0.068
$D_{Day\ of\ a\ Tightening}$	−0.014	0.047
$D_{Day\ of\ an\ Easing}$	0.00068	0.046
$D_{Day\ of\ a\ Tightening} \times Unanticipated\ \Delta$	1.10	0.79
$D_{Day\ of\ an\ Easing} \times Unanticipated\ \Delta$	−0.93	0.32

Having established that an anticipation effect exists in the federal funds market, we may ask whether or not this effect spills over to other financial markets. Market rates can be influenced both by current interest rates and expected future rates. Appealing to the expectations hypothesis of the term structure, one might think of long rates as being the average of expected future short rates plus a possible term premium or risk premium. If this assumption is valid, we would expect to see the largest impact (if any) of the anticipation effect on other overnight rates and a diminishing impact for longer-dated yields, because the effect of the anticipation effect on short rates is confined to a few days prior to each target rate change. The rest of the expected path of short rates is unchanged. In particular, if the market assumes a reaction function for the Federal Reserve, news about the economy could signal innovations to expected future policy moves. In fact, Lange, Sack, and Whitesell (2003) do present strong evidence of an improvement in the ability of financial markets to predict future changes in policy by the FOMC. In this section, however, we try to find out whether the existence of an anticipation effect in the funds market per se has any impact on broader financial markets, independent of the effects of policy anticipation on these rates. In order to capture those changes in interest rates that are purely due to the anticipation effect in the federal funds market, we estimate an autoregressive specification for each interest rate, because the lagged dependent variable is expected to capture any movements that are due to other financial market developments. Furthermore, we regress each rate on announcement surprises about the producer price index, the unemployment rate, the consumer price index, and GDP. Market expectations for each release are estimated by the median market forecast as compiled and published by Money Market Services the Friday before each release. The surprise component of each data release is computed as the actual released value less the market expectation. Lastly, we included the fitted value of the anticipation effect from our previous estimation. The general empirical specification is of the following form:

$$\begin{aligned} y_t = {} & \sum_{i=1}^{5} \xi_i y_{t-i} + \sum_{i=1}^{5} \gamma_i PPI_{t-i} + \sum_{i=1}^{5} \delta_i Unemp_{t-i} + \sum_{i=1}^{5} \alpha_i CPI_{t-i} \\ & + \sum_{i=1}^{5} \beta_i GDP_{t-i} + \sum_{i=1}^{5} \phi_i D^B D_{t+i}^{Tight} Anticipated\ \Delta \\ & + \sum_{i=1}^{5} \phi_i D^B D_{t+i}^{Ease} Anticipated\ \Delta + \varepsilon_t, \end{aligned} \tag{4}$$

where y_t is the change in the interest rate measure at time t, and *PPI* , *Unemp, CPI,* and *GDP* are the surprise terms associated with these announcements.

Table 6 shows the results of several regressions in which we attempt to quantify the impact of an anticipation effect in the funds market prior to policy tightenings on a selection of other financial market variables. The first row gives the results for the overnight Treasury repurchase agreement (RP) rate—a close substitute for federal funds, because banks can meet balance requirements also by overnight RPs. For the three days prior to an anticipated tightening—the days when the anticipation effect is the strongest—the estimated spillover to the RP market is statistically significant. The point estimate suggests that almost three-quarters of the firmness in the federal funds market shows up in the RP market. Further out the yield curve, however, the effect is much attenuated. We interpret these results as suggesting that the anticipation effect in the funds market has almost no effect on other financial markets. Table 7 presents similar results for anticipated policy easings. There appears to be a bit of evidence that yields on Treasury bills up to three months may be affected by the anticipation effect in the funds market but only for one day. Similarly, for the longer-dated yields, there is some evidence that the anticipation effect triggers a Fisher-type response by flattening out the yield curve on the day before a policy action. In terms of effecting volatility in financial markets, anticipated easings tend to reduce implied volatilities of ten-year and thirty-year bonds in the two days prior to the target cut.

5. Conclusions

The anticipation effect in the federal funds market has been a topic of growing interest over the last decade as the Federal Reserve has become more transparent in its policy decisions. In this paper, we document evidence of the anticipation effect in the funds market since 1994. This effect became more pronounced over time and received particular media attention prior to the policy tightenings starting in the second half of 2004, consistent with the improvements in the Federal Reserve's communications policy and the public's expectations of policy actions.

Table 6. Implications of Anticipation Effect in Other Financial Markets prior to Policy Tightenings

Dependent Variable	One Day prior to a Tightening		Two Days prior to a Tightening		Three Days prior to a Tightening		Four Days prior to a Tightening	
	Coeff.	**s.e.**	**Coeff.**	**s.e.**	**Coeff.**	**s.e.**	**Coeff.**	**s.e.**
RP	0.74	0.19	0.76	0.24	0.47	0.19	0.040	0.58
T-Bill (One-month)	0.12	0.12	−0.22	0.28	0.56	0.20	0.18	0.56
T-Bill (Three-month)	0.095	0.089	0.058	0.19	0.068	0.14	0.22	0.41
T-Bill (Six-month)	0.076	0.051	0.22	0.093	0.011	0.087	0.060	0.25
T-Note (One-year)	0.044	0.043	0.18	0.12	−0.00075	0.11	0.014	0.29
T-Note (Two-year)	0.0015	0.048	0.10	0.15	−0.017	0.15	−0.17	0.33
T-Note (Five-year)	−0.086	0.052	0.088	0.15	−0.093	0.15	−0.30	0.29
T-Note (Ten-year)	−0.15	0.053	0.15	0.13	−0.14	0.14	−0.60	0.24
T-Bond (Thirty-year)	−0.12	0.044	0.081	0.11	−0.11	0.16	−0.54	0.24
Implied Volatility (Eurodollar)	−0.15	0.59	−0.38	1.320	−2.22	1.41	−0.31	3.36
Implied Volatility (10-yr T-Note)	−0.49	0.25	0.65	0.36	−0.67	0.37	0.068	0.77
Implied Volatility (30-yr T-Bond)	0.018	0.31	0.61	0.50	−0.76	0.43	−0.13	1.77

Table 7. Implications of Anticipation Effect in Other Financial Markets prior to Policy Easings

Dependent Variable	One Day prior to an Easing		Two Days prior to an Easing	
	Coeff.	**s.e.**	**Coeff.**	**s.e.**
RP	0.0025	0.16	−0.085	0.50
T-Bill (One-month)	0.75	0.32	0.74	0.48
T-Bill (Three-month)	0.75	0.32	0.28	0.30
T-Bill (Six-month)	0.14	0.17	0.090	0.19
T-Note (One-year)	0.098	0.18	−0.054	0.21
T-Note (Two-year)	0.12	0.18	−0.24	0.26
T-Note (Five-year)	0.14	0.18	−0.40	0.33
T-Note (Ten-year)	0.16	0.18	−0.42	0.35
T-Bond (Thirty-year)	0.18	0.17	−0.39	0.28
Implied Volatility (Eurodollar)	−0.011	3.55	2.97	4.33
Implied Volatility (10-yr T-Note)	−0.0094	0.49	−2.52	0.88
Implied Volatility (30-yr T-Bond)	−1.35	0.61	−2.27	0.98

The theoretical model developed in this paper confirms the intuition that banks have an incentive to shift their holdings of reserve balances to the days when funding is expected to be cheaper. The results from the econometric equations suggest that demand does indeed shift as predicted in theory, but supply does not shift to the same extent. As a result, the funds rate moves in the direction of the anticipated change. Furthermore, this anticipation effect is significantly larger in the post-2004 period, which gave rise to the media attention mentioned above.

A natural question would be whether or not this effect can be effectively counteracted by the Open Market Trading Desk. Because a change in the target for the federal funds rate requires a decision by the Federal Open Market Committee, a plausible goal for the Desk would be to maintain the old target until the new one is announced. A definitive answer is impossible, given the fact that our results are estimated over a period that is characterized by only partial accommodation of the increased demand. Nevertheless, we find that offsetting the anticipation effect is likely possible but would require extremely large open market operations, potentially leaving the market with a level of balances at which demand is quite inelastic. Indeed, even if the Desk were able to force trading to the target, the rationale stated by the Open Market Trading Desk—only partially accommodating the increased demand to avoid volatility later—remains a plausible characterization of the market. If the supply of balances were increased in advance of an anticipated tightening, it is likely that the only demand for balances in the days following the tightening would be the day-specific demand to clear payments. This demand is much less elastic with respect to price than period-average demand, because it cannot be substituted across days. As a result, the funds rate could become quite sensitive to small errors in supply provision, and the market could become volatile. Our results suggest no such increased volatility, which we interpret as support for the Desk's current strategy.

The existence of an anticipation effect in the funds market also has implications for the traditional view of the monetary transmission mechanism. The conventional view relies on the liquidity effect to explain how open market operations affect the overnight rate; increased supply lowers the funds rate, and decreased supply raises the funds rate. The phenomenon referred to as "open-mouth operations" following Guthrie and Wright (2000) suggests that the Federal Reserve can affect the funds rate merely through statements. Prior to announcing changes in the target rate (i.e., prior to February 1994), changes in the target rate were sometimes signaled to the market by the use of certain types of open market operations. The empirical evidence shown in this paper suggests that the Desk does not need to implement open market operations to signal target changes, and indeed the funds rate moves toward the new target even before the announcement of the policy move and prior to the implementation of open market operations associated with the new target in the post-1994 era. Nevertheless, both the anticipation effect studied here and open-mouth operations rely on the credibility of the Desk to *maintain* the funds rate. That is to say, market participants must believe that supply and demand will subsequently be aligned at the target rate. Hence, while the existence of an anticipation effect implies funds rate movements independent of changes in the balances prior to a policy move, it necessitates a strong liquidity effect on other days, as documented in Carpenter and Demiralp (forthcoming).

The anticipation effect is clearly important in the federal funds market. The evidence presented above, however, suggests that the marginal impact of the anticipation effect in the funds market on broader markets is minimal. To be sure, with increased transparency of monetary policy, markets have begun to price in changes that are well anticipated. We test to see whether, over and above this effect, the anticipation of policy changes in the funds market spills over to other markets. We conclude that, in line with the expectations hypothesis of the term structure, the effect is minimal outside of overnight markets.

Appendix. Theoretical Model of the Demand for Balances

Specifically, consider the following objective function at the business-day frequency:[15]

$$\min_{x_t^*} E\left\{\left(\sum_{t=1}^{10}(od_t + x_t ff_t\right) + rd + ccbd - cbe\right\}, \tag{5}$$

where E is the expectations operator. The bank is attempting to minimize the expected cost of its reserve account, which comprises overdraft fees, od_t; the cost of borrowing funds in the market,[16] $x_t ff_t$ (where x_t is the bank's closing balances and ff_t is the prevailing federal funds rate); deficiency fees for required reserves, rd; and deficiency fees for contractual clearing balances, $ccbd$; but is reduced by earnings on contractual clearing balances, cbe. The bank is assumed to choose a target closing balance x_t^* that is subject to a stochastic shock, so that

$$x_t = x_t^* + \varepsilon_t$$
$$\varepsilon_t : N(0, \sigma_\varepsilon^2).$$

[15] As noted in Stigum (1990), the bulk of the transactions in the federal funds market are overnight.

[16] Without loss of generality, the cost of funds could also be considered the opportunity cost of not lending out funds the bank has into the market.

The cost of overdrafts is defined as

$$od_t = \min[x_t, 0] * \phi_{od}, \tag{6}$$

where ϕ_{od} is the overdraft fee. The cost of reserve requirement deficiencies is computed on a period-average basis as a function of required reserve balances (RR), so we write

$$rd = \max\left[RR - \sum_1^{10} x_t^* \omega, 0\right] * \phi_{rd} \tag{7}$$

$$\omega = \begin{cases} 3 & \textit{if } t = 2, 7 \\ 1 & \textit{otherwise} \end{cases},$$

which says that Fridays count three times and ϕ_{rd} is the reserve deficiency fee. The cost of deficiencies for contractual clearing balances can be written as

$$ccbd = \begin{cases} 0 \\ \quad \textit{if } CCB - \left(\sum_1^{10} x_t^* \omega - RR\right) \leq 0 \\ CCB - \left(RR - \sum_1^{10} x_t^* \omega\right) * \phi_{cbd}^1 \\ \quad \textit{if } 0 < CCB - \left(\sum_1^{10} x_t^* \omega - RR\right) \leq .2CCB \\ CCB - \left(RR - \sum_1^{10} x_t^* \omega\right) * \phi_{cbd}^2 \\ \quad \textit{if } -.2 * CCB < CCB - \left(\sum_1^{10} x_t^* \omega - RR\right) \end{cases} \tag{8}$$

where ϕ_{cbd}^1 and ϕ_{cbd}^2 are contractual clearing balance deficiency fees.

The above expression combines the maintenance-period-average nature of contractual clearing balances with the nonlinear fee structure attached to deficiencies. Finally, earnings credits reduce the cost of the reserve position by

$$cbe = \left(RR - \sum_{t=1}^{10} x_t\right) * ecr, \tag{9}$$

where ecr is the earnings credit rate.

Taken together, these equations define a stochastic, nonlinear, finite dynamic programming problem with ten periods where the choice variable is the target closing balance on each of the ten business days of the maintenance period. The model abstracts from uncertainty about the federal funds rate, carryover provisions, and the clearing balance allowance. Funds rate determination is overlooked for now, as this is only a model of demand; supply of balances will be discussed below. Although the carryover provisions can be important (see Clouse and Dow 2002), the fundamental story is unchanged, and including carryover would introduce a significant increase in computational complexity.[17] The clearing balance allowance is a minor omission that is of little relevance.

Solving the model allows us to examine the implied demand for excess balances on a daily basis throughout the maintenance period. Although excess balances are strictly defined only for a maintenance period as a whole, the concept of daily excess is useful. Daily excess can be defined as the level of balances on a day less one-fourteenth the level of required balances—that is, what excess would be if requirements were defined daily instead of biweekly. We simulate our model using 2 percent as the target (and therefore expected) federal funds rate. Based on the actual rules for Federal Reserve balances, overdraft fees are 4 percent; reserve deficiencies are penalized at 1 percentage point over the primary credit rate, which is 1 percentage point over the target rate, for a deficiency fee of 4 percent. Contractual clearing balance deficiencies up to 20 percent of the clearing balance are penalized at 2 percent, and deficiencies over 20 percent of the clearing balances are penalized at 4 percent. We chose reserve requirements to be $10 billion and contractual clearing balances to be $10 billion to roughly replicate the aggregate funds market. We chose the variance of the stochastic shock so that the level of excess balances for a two-week reserve maintenance period was $1.5 billion, essentially calibrating the model to the actual data.

The model is solved as follows. The state variable is defined as the cumulative position to date; that is, the sum of end-of-day balances. This variable is used in the final period to calculate whether or not period-average balance requirements are fulfilled. Accordingly, a grid for the state variable is constructed. The model is solved recursively,

[17] Our results in the empirical section suggest that the abstraction from carryover does not have a significant impact on the implications derived from the model.

beginning with the last day of the maintenance period. For each value of the state variable—here equal to the position-to-date at the end of the ninth day—an optimal choice for the tenth day's target closing balance is chosen. This value is selected by evaluating a grid for the choice variable at each possible value. The stochastic shock to end-of-day balances is simulated by a ten-point discrete approximation to a normal distribution. The maintenance-period cost of each value of the choice variable can thus be computed in expected value for each value of the state variable. Thus, we find a mapping between the state variable coming into the last day and the optimal choice *conditional on the state variable.*

We can assign an expected cost to each value of the state variable at the end of day 9. Assuming that an optimal choice will be made, we can step back to the optimal choice for day 9. For each grid value of the state variable at the end of day 8, we can search to find the optimal choice for day 9. Each possible value of the choice variable will imply, in expected value, a particular value of the state variable at the end of day 9 and, thus, from our previous computation, an expected cost for the maintenance period as a whole. That is to say, the optimal choice on day 9 is conditional on both the value of the state variable at the end of day 8 and the expected cost associated with the expected value of the state variable at the end of day 9 that is determined by the choice on day 9. This logic is recursed back to the first day. For each day, then, we have an optimal choice of a target end-of-day balance that is assigned to each grid value of the state variable. To simulate a maintenance period, we begin on day 1, assume the state variable is equal to 0, take the optimal choice of target end-of-day balance for a state variable of 0, and add a draw from a random normal variable. We then compute the end-of-day position for day 1 (that is, the realized balance) and proceed to day 2, taking this end-of-day balance as our new value for the state variable. We select the optimal target balance in day 2 and proceed forward to the end of the maintenance period.

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