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## **Does the Fed Control Interest Rates?**

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## **Abstract**

To what extent does TF, the target Federal funds rate set by the Fed, influence other rates? There is lots of variation in rates unrelated to TF, and any effects of TF on rates dissipate quickly for longer maturities. For short rates, all the tests have interpretations in terms of: (i) a Fed that has the power to control rates and uses it, and (ii) a Fed that has little power over rates or chooses not to exercise its power. In the end, there is no conclusive evidence (here or elsewhere) on the role of the Fed versus market forces in the long-term path of interest rates.

The Federal funds rate, FF, is the interest rate on overnight loans of reserves among banks. The Fed can control FF, and arbitrage conditions link FF to the rate on other overnight loans of equivalent risk. The extent to which the Fed chooses to control overnight rates depends, however, on its willingness to vary the supply of reserves. Enforcing nontrivial changes in FF may require large changes in reserves that the Fed is not willing to accommodate. As a result, the Fed may passively let open market forces determine most of the variation in the level of FF and limit itself to small changes at the margin.

Concretely, the Fed funds rate starts near 12% at the beginning of my September 1982 to June 2012 sample period, ends near zero, and takes wide swings in between. How much of this impressive variation is due to the will of the Fed and how much is due to market forces? I offer tests but no unassailable conclusions, and this seems to be the state of the literature on this issue. Acknowledging this ambiguity is important, however, since recent research in monetary economics typically just assumes the Fed is the dominant force in FF and interprets evidence that FF leads real activity as evidence of Fed influence on real activity (e.g., Christiano, Eichenbaum, and Evans 2005). But if much of the variation in FF is passive adjustment to market forces, causation likely goes the other way. Specifically, if asset pricing is rational, forecasts of real activity are prime determinants of current asset prices and interest rates. This potential interpretation of evidence that asset prices and interest rates lead real activity is prominent in the early literature (Fama 1981, Harvey 1989, Stock and Watson 1989), but it fades from view in recent work on how monetary policy, embodied in the Fed funds rate, affects real activity.

The Fed potentially controls the overnight interest rate, but open market rates for longer maturities are important in the decisions of agents that affect real activity. Thus, another important issue centers on how policy with respect to the Fed funds rate plays out across the term structure. I take TF, the Fed's target for the Fed funds rate, as the concrete expression of its interest rate policy. Section I uses autocorrelations and plots of the spreads of rates over TF to show that open market rates (specifically, one-month commercial paper and Government bill and bond rates) take long-lasting swings away from TF, and the swings are larger in amplitude for longer maturities. This is consistent with long-standing evidence that much of the variation in interest rates beyond the shortest maturities is due to time-varying

expected term premiums in near-term returns rather than to forecasts of future short-term rates. (See, for example, Fama 1984, Fama and Bliss 1987, and the references therein.)

Section II uses autoregressions with error correction terms to document that the day-to-day variation in rates for maturities of a month or more has little or nothing to do with the Fed's target rate. This is consistent with a Fed that has little control of rates, but we shall see that it is also consistent with a powerful Fed whose predictable actions with respect to TF are built in advance into interest rates.

Though open market rates take long swings away from the target Fed funds rate, TF does track the long-term path of open market rates, especially short-term rates. Put differently, when cumulated, changes in TF trace out the long-term path of open market interest rates. Thus, judging the power of the Fed over rates largely depends on determining the extent to which changes in TF are due to active attempts by the Fed to control rates versus passive adjustment to market forces. The regressions in Section III show that when the Fed changes TF, it moves strongly toward existing short rates, especially the one-month commercial paper rate, CP. During the period after 1993, when the Fed announces changes in TF, the level of CP on the day before a change in TF captures 83% of the variance of changes in TF. This is consistent with a passive Fed that largely moves TF to line up with existing market rates, but it is also consistent with an active Fed that controls rates but whose actions with respect to rates are predicted by the market.

The last test (Section IV) is an event study. It shows that especially after 1993, short-term open market rates respond strongly to the unexpected part of a change in the target Fed funds rate. This is the best evidence that the Fed exercises some control of rates, but the evidence is tempered by (i) the fact that the responses of rates to unexpected changes in TF deteriorate quickly for longer maturities, and (ii) unexpected changes in TF are a small part (17%) of the variance of total changes. Moreover, skeptics can argue that the Fed is an informed agent with private information about how market forces will shape future open market rates, and it uses this information to change TF. It is then rational that rates respond to unexpected changes in TF even if the changes are not active attempts by the Fed to move rates.

The general message of the paper is that there is no conclusive evidence (here or elsewhere) on the role of the Fed versus market forces in the long-term path of market interest rates. For the period that starts with the lingering recession of 2008, however, a stronger conclusion is possible. During this period the Fed purchases massive amounts of long-term bonds and finances its purchases by issuing reserves. The reserves pay interest at or slightly above short-term open market rates, which means reserves are now just another form of riskless interest-bearing short-term debt. Section V argues that the decline in short rates to near zero after 2008, despite massive injections of interest-bearing short-term debt by the Fed (and other central banks) is a cautionary tale about how market forces can limit the power of central banks even with respect to the short rates that are supposed to be their special preserve.

### **I. Summary Statistics**

The tests focus on seven interest rates: FF, the Fed funds rate; TF, the target Fed funds rate set by the Fed; CP, the rate on 1-month high grade nonfinancial commercial paper; B3 and B6, three-month and six-month U. S. Treasury bill rates; G5 and G10, five-year and ten-year U.S. Government bond rates. The data are from the FRED website of the Federal Reserve Bank of St. Louis. The sample period is September 27, 1982, to June 28, 2012 (henceforth 1982-2012). The start date is the first available for data on the target funds rate, TF, which are from Thornton (2005) for the period prior to 1994. I take 1994, when the Fed starts announcing TF, as a natural break to define subperiods for the tests.

Rudebush (1995) and Romer and Romer (2004) argue that Fed funds rate targeting is the rule during almost all of my sample period. I interpret the target, TF, as the concrete expression of the Fed's interest rate policy.

For initial perspective, Table 1 Part A shows means and standard deviations of daily changes in the interest rates that change daily (all rates except the Fed's target, TF) and the spread of each rate over TF. Results are shown for 1982-2012 and for the subperiods that split at the beginning of 1994 (henceforth 1982-1993 and 1994-2012). The spreads are measured on the day preceding the changes.

Table 1 Part B shows autocorrelations for 20 daily lags (about a month of trading days). The subperiod autocorrelations are similar to those for the full sample, and only full-period results are shown.

Short-term interest rates are more variable before 1994 (Table 1 Part A). The decline in volatility thereafter is especially noticeable for the Fed funds rate, FF, but FF is always about four times more variable than other rates, probably because of special conditions in the market for reserves related to satisfying reserve requirements. Changes in FF are negatively autocorrelated for the first few lags. The autocorrelations of changes in other rates are positive for the first lag, and then random about zero thereafter. Because the sample size is huge (7,382 daily changes) many of the lower order autocorrelations are multiple standard errors from zero, but all seem minor in economic terms.

The spreads of interest rates over TF show how the rates for different maturities deviate from the Fed's target. The summary statistics for the spreads thus provide initial rough perspective on Fed control of rates. The standard deviations of the spreads are similar to or higher than those of changes in the Fed funds rates. The high volatility of the spreads largely reflects strong positive autocorrelation. The autocorrelations (Table 1 Part B) tend to decay for longer lags, but the decay is slower for longer-term rates. For example, the autocorrelations of FF-TF start at 0.53 and decline to 0.11 at the 20<sup>th</sup> lag. The autos of CP-TF start much higher, 0.94, and decay to 0.34 at the 20<sup>th</sup> lag. The autocorrelations of G5-TF and G10-TF start at 1.00 and are still around 0.95 at the 20<sup>th</sup> lag.

The slow decay of the autocorrelations of the spreads says that interest rates take long swings away from the Fed funds target rate and the swings are more persistent for longer-term rates. The plots of the spreads in Figure 1 provide additional perspective.

The means of the spreads for five-year and ten-year Government bonds are 1.13% and 1.61% respectively. If the Fed's target rate, TF, is the dominant force in the variation of G5 and G10, G5-TF and G10-TF should fluctuate closely about their means. Figure 1c shows, however, that the spreads are commonly far above or far below their means for long periods. This is not surprising since the autocorrelations of G5-TF and G10-TF show little tendency to decay (Table 1), and we see later that

Government bond rates do not respond much to TF and to unexpected changes in TF. In general, the results to come say that Fed actions with respect to its target rate have little effect on longer-term rates.

We see later that the T-bill rates B3 and B6 respond to unexpected changes in the target Fed funds rate, TF, which is consistent with some Fed control of these rates. Figure 1b suggests, however, that the control is far from complete. Thus, the spreads B3-TF and B6-TF do not move as far from their respective means, -0.37% and -0.25%, as the Government bond spreads, but B3-TF and B6-TF are nevertheless rather far above or far below their means for years at a time. In short, the Fed may have some control of B3 and B6, but even bill rates take long swings away from the Fed's target rate, which suggests substantial variation beyond Fed control.

Finally, the autocorrelations of CP-TF decay more quickly than those of the spreads for T-bills and bonds, and we see later that the one-month commercial paper rate also shows a stronger response to unexpected changes in TF. These results suggest that CP is the open market rate most under Fed control. Figure 1a confirms that aside from occasional spikes, CP-TF is typically within 0.5% of its mean, 0.04%. Still, like other open market rates, CP-TF is often above or below its mean for years at a time, which again suggests sustained variation beyond the control of the Fed.

What market forces produce variation in rates beyond Fed control? One possibility is suggested by long-standing evidence that much of the variation in interest rates on T-bills and Government bonds is due to time-varying expected term premiums in near-term returns rather than to forecasts of future short-term rates. (See, for example, Fama 1984, Fama and Bliss 1987, and the references therein.) Whatever the explanation, Figure 1 and the autocorrelations of the spreads of rates over TF in Table 1, document sustained swings of open market rates (CP, B3, B6, G5, and G10) away from the Fed's target rate.

## **II. Autoregressions with Error Correction**

Table 2 shows regressions that measure the day-to day response of interest rates to the target Fed funds rate. The regressions explain the change in an interest rate  $R$  from day  $t-1$  to day  $t$ ,  $dR_t$ , with the previous day's spread of the rate over the Fed funds target,  $R_{t-1} - TF_{t-1}$ , and ten lagged changes in the rate,

$$(1) \quad dR_t = a + b(R_{t-1} - TF_{t-1}) + c_1 dR_{t-1} + \dots + c_{10} dR_{t-10} + e_t.$$

The lagged changes allow for predictability due to the time-series properties of changes in  $R$ , where  $R$  is one of the six rates in the sample. The variable that tests for movement of  $R$  toward the Fed's target,  $TF$ , is the error correction term,  $R_{t-1} - TF_{t-1}$ . If  $R_t$  moves toward  $TF_{t-1}$ , the slope  $b$  in (1) is negative; when  $R_{t-1}$  is above the target, the rate should fall. Table 2 also shows impulse response functions, given a 1% shock to  $R_t$ , with all explanatory variables in (1) set to zero before the shock. To save space, the table only shows results for the subperiods before and after the 1994 split.

The Fed funds rate moves strongly toward the target. The slope for  $FF_{t-1} - TF_{t-1}$  in the  $dFF_t$  regression for 1982-1993 is -0.37 ( $t = -12.12$ ), and the slope for 1994-2012 is similar, -0.44 ( $t = -19.54$ ). Thus, today's change in  $FF$  tends to absorb about 40% of the deviation of the lagged funds rate from the target rate. In contrast, other rates (which I call open market rates) show little tendency to move toward  $TF$  before or after the 1994 break. The slope for  $CP_{t-1} - TF_{t-1}$  in the  $dCP_t$  regression for 1982-1993 is the most extreme, -0.04. This trivial slope is -6.27 standard errors from zero, but this just says the slope is estimated precisely with the large samples of daily data. For other rates, the slopes on lagged spreads over  $TF$  are even closer to zero, and for 1994-2012, the slopes are slightly positive (the wrong sign).

In the Table 2 regressions for  $dCP_t$  and other open market rates, the slopes on lagged changes in a rate are close to zero, like the autocorrelations in Table 1. Thus, autocorrelation does not produce a lot of forecast power. In the regressions for  $dFF_t$ , the slopes on lagged changes tend to be negative and stronger than those for open market rates, so autocorrelation produces more predictability.

The impulse response functions summarize how the error correction and lagged dependent slopes interact to produce a post shock path for  $R$ . A 1% shock to  $FF$  largely disappears, that is,  $FF$  has moved just about fully back to the target  $TF$  within about five trading days. In contrast, for  $CP$  and other open market rates a 1% shock dissipates slowly at best. In the results for  $CP$  and  $B3$  for 1982-1993, near 90% of a shock remains in the level of the rate ten days later. In the 1982-1993 results for  $B6$ ,  $G5$ , and  $G10$ , just about all of a shock is still in the level of the rate ten days later. In the 1994-2012 results, reversion to



TF after a shock is special to the Fed funds rate FF. For other rates, including CP and B3, all of a shock remains in the level of the rate ten days later. This continues to be true 20 days later (in the impulse response functions from unreported regressions that use 20 rather than ten lags of  $dR$ ).

Evidence that the Fed funds rate, FF, moves quickly toward the target, TF, is commonly interpreted to imply that the Fed exercises substantial control of FF. This conclusion assumes that TF itself is determined actively by the Fed. Suppose instead that the Fed is passive and just sets TF to line up with open market rates. Daily changes in the Fed funds rate are about four times as variable as changes in other rates (Table 1). Much of this stronger variation in FF is probably due to transitory supply and demand conditions in the interbank market for reserves related to satisfying reserve requirements. Transitory variation in FF due to special conditions in the market for reserves can mean that FF moves strongly toward TF on a day-to-day basis, perhaps with a lot of help from the Fed via open market operations. If TF itself is set passively, however, the long-term path of FF, which closely tracks TF, is also determined by market conditions.

The fact that, unlike FF, open market rates show little tendency to move toward TF seems to say that the Fed has little or no control of open market rates. The results suggest instead that open market rates are driven by credit market conditions and the Fed is largely a powerless participant. There are, however, two potential reasons a powerful Fed may not show up in the results for open market rates in Table 2.

First, the estimates of regression (1) measure day-in-day-out effects; that is, they examine the behavior of open market rates on all days, not just days when the Fed actively tries to affect rates. It is reasonable that when the Fed judges that inflation and real activity require no action, it is passive and it lets rates move in response to market forces. It is thus possible that the Fed's power over rates is buried in the estimates of (1), which are dominated by days on which Fed policy is passive.

Second, suppose each open market rate,  $R$ , contains rational forecasts of the target Fed funds rate for the life of the rate. In this simple model,  $R_t$  does not respond to the spread  $R_{t-1} - TF_{t-1}$  because  $R_{t-1}$

already embeds all the relevant information about Fed policy available at time  $t-1$ . And there is evidence (Gürkaynak, Sack, and Swanson, 2007) that open market rates forecast FF (and thus TF).

This simple term structure model can explain why the slopes on the spread,  $R_{t-1} - TF_{t-1}$ , are close to zero in the estimates of (1) for open market rates, but it does not in itself imply that the Fed has much control of rates, for two reasons. First, the plots in Figure 1 and the autocorrelations of the spreads in Table 1 say that open market rates take protracted swings away from the Fed's target rate, and the regressions in Table 2 confirm that on a day-to-day basis open market rates do not respond to the spreads. Thus, even if negligible slopes on the spreads in Table 2 mean that interest rates already contain rational forecasts of future target Fed funds rates, this does not imply much Fed control of rates if lots of their variation has little to do with the Fed's target rate. Second, and perhaps more important, whether or not open market rates contain rational forecasts of TF says nothing about whether the Fed controls rates since it does not tell us whether TF itself is actively or passively determined.

Finally, banks issue and purchase open market securities. This surely puts pressure on the Fed funds rate to move in the direction of open market rates, and perhaps vice versa. To test for such effects, Table 3 shows  $dFF_t$  and  $dCP_t$  regressions like those in Table 2 but with  $FF_{t-1} - CP_{t-1}$  or  $CP_{t-1} - FF_{t-1}$ , the lagged spread between the Fed funds and commercial paper rates, as an additional explanatory variable. The estimates of these regressions say that the funds rate, FF, has two masters; it moves strongly toward the Fed's target, TF, but open market forces pull it toward CP. In contrast, the commercial paper rate, CP, does not move much toward either FF or TF.

Table 3 suggests, not surprisingly, that in setting the Fed funds target rate, the Fed cannot ignore the pressure from open market rates. In other words, market forces constrain the Fed's actions in using the Fed funds rate to influence other rates.

### **III. What Moves TF?**

Open market rates take long swings away from the target Fed funds rate TF (Figure 1), and on a day-to-day basis, open market rates move little if at all toward TF (Table 2). Figure 2 shows, however,

that TF tracks the long-term swings in the six-month T-bill rate, B6, and the long-term variation in the levels of the two rates dwarfs the short-term swings of B6 away from TF (Figure 1a). Plots of TF that include other open market rates lead to similar conclusions. Thus, to judge how Fed power shows up in the history of open market rates, it is important to know how variation in TF splits between active attempts by the Fed to control the level of rates and passive responses to market conditions.

If the Fed sets TF passively, changes in TF move it toward existing levels of rates. To examine the relation between a change in TF and credit market conditions before the change, I estimate the regression,

$$(2) \quad TF_t - TF_{t-1} = a + b(R_{t-1} - TF_{t-1}) + e_t.$$

The sample of  $TF_t - TF_{t-1}$  is changes in TF for the days when the target changes, and  $R_{t-1}$  is an interest rate on the day preceding the change in TF on day  $t$ . The regression asks whether the change in the target, when it changes, is related to the deviation of the pre-change target from the pre-change level of an interest rate. The estimates of (2) for each of the six interest rates in the sample are in Table 4.

Table 4 says that interest rates predict changes in the Fed funds target, and the one-month commercial paper rate, CP, is an especially strong predictor. The slopes in (2) taper off for longer maturity instruments, but all rates show some forecast power. Thus, when the Fed changes the target funds rate, it moves TF in the direction of existing rates, especially CP.

In the Table 4 regression for the period beginning in 1994, the slope in the estimate of (2) for CP is near one (1.03,  $t = 17.13$ ). Thus, during the period when the Fed announces the target funds rate, the change in TF on average responds just about one-for-one to the deviation of the lagged CP rate from the lagged target rate. In the estimates of (2) for the preceding period, the slope in the regression for CP is lower, 0.46 ( $t = 6.14$ ). Thus, during 1982-1993 changes in the Fed funds target absorb less than half of the lagged spread of the commercial paper rate over the pre-change target. The weaker results for the earlier period may have something to do with the fact that TF and the dating of changes in TF are unknown and are inferred by Thornton (1995) from the behavior of FF.

The Table 4 evidence that short-term interest rates forecast changes in the Fed funds target rate is not news (Hamilton and Jorda 2002). For those who believe in a powerful Fed, the driving force is TF, the concrete expression of Fed interest rate policy, and the forecast power of short rates simply says that rates adjust in advance to predictable changes in the Fed's target rate. (See, for example, Taylor 2001.) The evidence is, however, also quite consistent with a passive Fed that changes TF in response to open market interest rates. There are, of course, scenarios in which both forces are at work, possibly to different extents at different times. The Fed may go passive and let the market dictate changes in TF when inflation and real activity are satisfactory, but turn active when it is dissatisfied with the path of inflation or real activity. This mixed story is also consistent with the evidence in Table 3 that the Fed funds rate moves toward both the open market commercial paper rate and the Fed's target rate.

In short, we know that the target Fed funds rate tracks the long-term swings in the level of interest rates, especially short rates, but we do not know the extent to which this reflects a powerful Fed that sets TF to control rates or a passive Fed that adjusts TF to line up with existing rates.

Acknowledging this uncertainty about the role of the Fed versus market forces in the path of TF is important since it casts a dark cloud over recent empirical work on the relation between monetary policy and real activity. The Fed's target rate, TF, is commonly interpreted as the concrete expression of monetary policy, and evidence that the Fed funds rate, FF (which closely tracks TF), leads real activity is interpreted as causation running from monetary policy to real activity (e.g., Christiano, Eichenbaum, and Evans 2005). This inference is based on the assumption that variation in TF and thus FF is closely controlled by the Fed. If much of the variation in TF and TF is instead passive adjustment to market forces, causation probably goes the other way; that is, with rational asset pricing, expectations of future real activity are a prime determinant of current asset prices and interest rates. This possibility is prominent in early work showing that stock returns and short-term interest rates lead real activity (Fama 1981, Harvey 1989, Stock and Watson 1989), but it fades from view in recent work on how monetary policy, embodied in the Fed funds rate, affects real activity.

#### IV. Event Study

Regression (2) leaves a fundamental ambiguity familiar from the discussion of regression (1). Do open market rates forecast changes in the Fed's target rate because the Fed passively adjusts TF to line up with existing market rates or because the market predicts how a powerful Fed will set TF to control rates? As a last attempt to bypass this problem, the final tests examine the response of rates to unexpected changes in TF. If the Fed uses TF to control interest rates, unexpected changes in TF should move open market rates.

To test this hypothesis, I examine current and future changes in rates in response to a proxy for unexpected changes in TF. For each of the six interest rates  $R$ , and using a proxy,  $F_{t-1}$ , for the rational forecast of the new target rate  $TF_t$  to be set on day  $t$ , I estimate the 11 univariate regressions,

$$(3) \quad dR_{t+lead} = a + b(TF_t - F_{t-1}) + e_{t+lead}, \quad lead = 0, 1, 2, \dots, 10.$$

Given a change in TF on day  $t$ , the 11 estimates of regression (3) measure the responses of the interest rate  $R$  on day  $t$  and the 10 subsequent days, using an error correction variable that is the difference between the new TF set on day  $t$  and a proxy for its expected value assessed on day  $t-1$ .

A simple proxy for  $F_{t-1}$  is the lagged target,  $TF_{t-1}$ , used, for example, by Cook and Hahn (1989) and Cochrane and Piazzesi (2002). The estimates of (2) say, however, that when TF changes, the change is in part predictable from past rates. This means the total change in TF is a noisy measure of the unexpected part of the change.

The estimates of (2) in Table 4 say that the lagged commercial paper rate is a better predictor of a new target Fed funds than any of the longer-maturity rates in the sample. This makes sense since, as predictors of  $TF_t$ , longer maturity rates are more contaminated by time-varying expected term premiums and longer-term forecasts of short rates. Table 4 also says that  $CP_{t-1}$  is a better predictor of a new  $TF_t$  than the lagged Fed funds rate,  $FF_{t-1}$ . This also makes sense since there is lots of transitory variation in FF due to special conditions in the market for reserves that is noise for predictions of a change in TF. I have confirmed that in the estimates of (3) to predict different open market rates, using  $CP_{t-1}$  as the proxy for

$F_{t-1}$  produces stronger slopes than the lagged values of any of the other rates. Thus, I use  $CP_{t-1}$  as the proxy for  $F_{t-1}$ . This can be viewed as data dredging to produce results in favor of Fed control of rates, but this seems appropriate, given my skepticism about a strong role for the Fed.

Kuttner (2001) uses predictions of the Fed funds rate from the Fed funds futures market as the proxy for the rational forecast of the target funds rate. This proxy requires complicated manipulation due to the fact that the futures contract covers the average daily effective Fed funds rate for a month. My simple approach produces results similar to his. (See also Gürkaynak, Sack, and Swanson 2007. Hamilton 2008 reviews this literature and provides a refinement of Kuttner's approach.)

The estimates of (3) are in Table 5. To keep the table manageable, it shows results for 1982-1993 and 1994-2012, but not for the full sample period. Table 5 stops at lead 4 in regression (3), but nothing is lost since the (unreported) estimates of the slope  $b$  in (3) say that the responses of interest rates to the proxy for unexpected changes in the target funds rate are concentrated on the day of the change in TF and one or two days thereafter.

The Fed funds rate, FF, gets special treatment in Table 5. The purpose of the Fed funds target rate, TF, is to signal that the Fed will use open market operations to move FF toward TF. Table 2 confirms that FF moves strongly toward TF on a day-to-day basis. Part B of Table 5 shows regressions that use  $TF_t - FF_{t-1}$ , the spread of a new TF set on day  $t$  over the lagged funds rate, to predict changes in FF. The purpose of these regressions is to examine the response of FF to a new TF. The response is quick and complete. When TF changes, current and future changes in FF move it to the new TF in about three days. This is true during 1982-1993 as well as 1994-2012, which is not surprising since the Fed always knows its target rate. In short, all the evidence says that the Fed funds rate moves quickly toward the target. Given this evidence, it seems redundant to examine how FF responds to the unexpected part of changes in the target rate.

Table 2 says that unlike FF, open market rates show little or no tendency to move toward TF on a day-to-day basis. We are thus especially interested in whether a different picture of the response of open market rates emerges when the sample is limited to days when TF changes. Table 5 Part A shows that

during 1994-2012, when the Fed announces changes in the target rate, open market rates respond to  $TF_t - CP_{t-1}$ , the proxy for the unexpected part of the change in TF. The responses decline with maturity. The commercial paper rate, CP, responds in full; that is, the sum of the slopes on  $TF_t - CP_{t-1}$  in (3) for leads 0, 1, and 2 in the three  $dCP_{t+lead}$  regressions for 1994-2012 is close to 1.0. The cumulative three-day response drops to 65% for three-month T-bills, 54% for six-month bills, and 21% and 9% for five-year and ten-year Government bonds.

During the earlier 1982-1993 period, the three-day response of the commercial paper rate to the proxy for unexpected changes in the target rate is weaker, 29% versus 108% for 1994-2012. T-bill responses are also lower in the earlier period, 24% versus 65% for B3 and 28% versus 45% for B6. Government bond responses are again weak during 1982-1993, but if anything, they are a bit stronger than during 1994-2012. The generally weaker responses of rates during 1982-1993 may in large part be a measurement error problem since the target rate and the dates of change in the target must be inferred from the behavior of the Fed funds rate, which is quite noisy prior to 1994.

The bottom line from the estimates of regression (3) is that the short-term open market rates, CP, B3, and B6, clearly respond to the estimates of the unexpected part of changes in the target Fed funds rate. The responses are stronger during 1994-2012, but the t-statistics for the 1982-1993 slopes say that the responses of the earlier period are also deep in the range of statistical reliability.

Table 5 is the best evidence for a Fed that exercises power at least over short rates. There is, however, a rejoinder. The response of short rates to unexpected changes in the Fed's target rate might just be a signaling effect. Rates adjust to unexpected changes in TF because the Fed is an informed agent with private information about the market forces that will determine future open market rates, and it uses this information passively to change TF. It is then rational that open market rates respond to unexpected changes in TF even if they do not represent active attempts by the Fed to move rates.

More important, viewed alone, the regression slopes in (3) for 1994-2012 in Table 5 give a misleading picture of Fed power. For example, the slopes say that during 1994-2012 the CP rate adjusts fully to the unexpected part of changes in TF. The regressions to explain changes in TF in Table 4 tell us,

however, that unexpected changes are a small part of total changes in TF. During 1994-2012, expected changes, measured as  $CP_{t-1} - TF_{t-1}$ , observed on day  $t-1$ , capture 83% of the variance of changes in TF from  $t-1$  to  $t$ , leaving only 17% for unexpected changes.

The quick decline with maturity in the responses of rates to unexpected changes in TF during 1994-2012 also illustrates the limitations of Fed power. Changes in TF are strongly correlated with past changes. The correlations of the changes for 1994-2012 start at 0.70 for the first lag and decline slowly to near zero at the sixth lag. The correlations for 1982-1993 are similar. During 1994-2012 changes in TF are on average almost four months apart. Given the positive correlation of successive changes in TF, an increase in TF means that TF is likely to increase further over the next year or so. Thus, if forecasts of TF are the sole force driving the response of rates (i.e., if the expectations hypothesis rules rates), the three-month and six-month bill rates, B3 and B6, should respond more to the unexpected part of changes in TF than the one-month commercial paper rate, CP. In fact, they respond much less (Table 5). This suggests that changes in the expected term premiums in B3 and B6 tend to offset the implications of unexpected changes in TF for the expected future short rates in B3 and B6.

## **V. New Game in Town**

In response to the lingering recession of 2008, the Fed's game plan changes. Its credit market interventions expand far beyond anything previously observed. In changing its game plan, the Fed changes the game and the old arguments about how Fed actions affect rates no longer apply. In the new game, the massive reserves issued to purchase longer-term debt put upward rather than downward pressure on short-term rates. The fact that short rates decline to near zero is then a clear example of variation in rates due to market forces beyond Fed control.

The conventional story for how Fed control of the monetary base affects interest rates centers on the opportunity cost of excess reserves. Historically, the Fed paid no interest on reserves, which means reserves have an opportunity cost to banks. When the Fed does an open market operation that pushes reserves beyond the quantity banks judge to be optimal, the opportunity cost of the excess reserves leads



banks to attempt to dispose of them by making loans and purchasing securities, which tends to push interest rates down.

In September 2008, the Fed's game plan changes. It starts issuing huge quantities of reserves to buy longer-term Government bonds and mortgage-backed securities, with the goal of lowering long-term interest rates to spur real activity (so-called Quantitative easing). The effects of Fed actions on long-term rates are studied by Krishnamurthy and Vissing-Jorgensen (2011), but the point I wish to make here is about how Fed actions affect short rates not long rates.

An important part of the Fed's new game plan is that in October 2008 it begins to pay interest on reserves at or slightly above the rate on open-market short-term riskless securities like Treasury bills. I infer that the Fed rightly judges that if massive new excess reserves have an opportunity cost, bank efforts to get rid of them are likely to produce high inflation. Whatever the reason, paying market interest on reserves means reserves no longer impose a cost on banks, and banks indeed largely respond to the reserves by holding them. At the end of 2012, excess reserves, which prior to September 2008 are almost always close to zero, are about \$1.5 trillion and rising, versus required reserves of \$112 billion. Other central banks adopt the same strategy, flooding the market with interest bearing reserves.

Paying market interest rates on reserves changes the game facing the Fed. Reserves are no longer "money" that has an opportunity cost (interest foregone). Instead, reserves are just another form of riskless interest-bearing short-term debt, and the Fed's actions with respect to reserves are subject to normal supply/demand effects. Specifically, when the Fed and other central banks increase the supply of short-term debt by issuing interest-bearing reserves to buy longer-term bonds, the interest rate on short-term debt should rise rather than fall.

In fact, short rates fall after the Fed executes its new game plan. The Fed funds rate and the one-month commercial paper rate fall from about 2% in September 2008 to near zero at the end of 2008 and thereafter. If my analysis is correct, this fall in riskless short rates (in the U.S. and around the world) occurs despite the actions of the Fed and other central banks in 2008 and thereafter, not because of them. Apparently, strong demand for short-term riskless debt, due to the uncertainty associated with a steep and

lingering recession, more than suffices to absorb the massive amounts of such debt issued by the Fed and other central banks. Whatever the explanation, the fact that short-term rates fall despite multiple trillions of new short-term interest-bearing central bank debt is an example of the limitations imposed by markets on the control of interest rates by central banks.

## **VI. Conclusions**

Does the Fed control interest rates? On the negative side of the ledger, the persistent strong positive autocorrelation of the spreads of open market rates over the Fed funds target rate in Table 1 and the plots of the spreads in Figure 1 say that open market short-term rates (CP, B3, and B6) and long-term rates (G5 and G10) take large sustained swings away from TF. This suggests that there is lots of variation in open market rates beyond Fed control.

The estimates of regression (1) in Table 2 say that open market rates show little or no tendency to move toward TF on a day-to-day basis. This is clear evidence that the day-to-day variation in open market rates has little to do with the Fed's target rate. This result is also consistent with the stronger hypothesis that the Fed has little control of open market rates.

The Fed funds rate, FF, converges quickly to the Fed's target, TF, on a day-to-day basis (Table 2) and in response to changes in TF (Table 5). Pushing FF toward TF does not in itself imply, however, that the Fed exercises much control of TF. A passive Fed might let market rates drive TF and use daily open market operations to ensure that FF, the rate it can control, does not get out of line. This passive Fed story is consistent with the evidence in Table 4 that when the Fed changes TF, it moves toward existing short-term open market rates, and it is consistent with the evidence in Table 3 that on a day-to-day basis the Fed funds rate moves toward CP as well as toward TF.

There is, however, a different interpretation of Tables 2, 3, and 4 that is consistent with an active Fed with lots of control of open market rates. Suppose the Fed's intentions with respect to TF are predictable. If the Fed controls interest rates, rates should adjust in advance to expected changes in TF. This logic can explain the Table 4 evidence that when the Fed changes TF, it moves toward existing short

rates, the Table 3 evidence that the Fed funds rate FF moves toward the commercial paper rate as well as toward TF, and the Table 2 evidence that on a day-to-day basis open market rates show little or no tendency to move toward the current Fed funds target rate. It cannot, however, explain the evidence in Table 2 that there is lots of day-to-day variation in open market rates that is unrelated to the Fed's target rate and the evidence in Table 1 and Figure 1 that open market rates take large long-lived swings away from the Fed's target rate.

A good way to test for Fed effects on open market interest rates is to examine the responses of rates to unexpected changes in the Fed's target rate. Table 5 confirms that short-term rates (the one-month commercial paper rate and three-month and six-month Treasury bill rates), respond to the unexpected part of changes in TF. Table 5 is the best evidence of Fed influence on rates, and event studies of this sort are center stage in the active Fed literature. But skeptics have a rejoinder. The response of short rates to unexpected changes in the Fed's target rate might be a signaling effect. Rates adjust to unexpected changes in TF because the Fed is viewed as an informed agent that sets TF to line up with its forecasts of how market forces will shape open market rates. In this scenario, unexpected changes in TF move open market rates even when the Fed does not attempt to control open market rates.

Even if the event study results in Table 5 are accepted as evidence of Fed power, they do not imply that the Fed has much control of rates, for three reasons. First, the responses of rates to unexpected changes in the Fed's target rate, TF, fall off quickly for bond maturities beyond a few months. Second, unexpected changes in TF account for a small fraction of the variance of changes in TF, and there is no unambiguous evidence on how much of the predictable part of changes in TF is active or passive. Third, there is lots of evidence in the term structure literature that much of the variation in interest rates is due to time-varying expected term premiums rather than to forecasts of future spot rates. This result is observed even for relatively short-term rates (for example, Fama 1984), and it is consistent with the large and protracted swings of short-term and long-term rates away from TF in Figure 1.

In sum, the evidence says that Fed actions with respect to its target rate TF have little effect on long-term interest rates, and there is substantial uncertainty about the extent of Fed control of short-term

rates. I think this conclusion is also implied by earlier work, but the problem typically goes unstated in the relevant studies, which generally interpret the evidence with a strong bias toward a powerful Fed.

Finally, for the period that starts with the lingering recession of 2008, a less ambiguous conclusion is possible. The decline in short rates after 2008, despite massive injections of interest bearing short-term debt (reserves) by the Fed and other central banks, is a cautionary tale about how market forces can limit the power of central banks even with respect to the short-term rates that are commonly taken to be their special preserve.

## References

- Cochrane, John H., and Monika Piazzesi, 2002, The Fed and Interest Rates – A High Frequency Identification, *American Economic Review* 92, 90-95.
- Cook, Timothy, and Thomas Hahn, 1989. The Effect of Changes in the Federal Funds Rate Target on Market Interest Rates in the 1970s. *Journal of Monetary Economics* 24, 331–351.
- Fama, Eugene F., 1984, The Information in the Term Structure, *Journal of Financial Economics*, 13, 509-528.
- Fama, Eugene F., 1981, Stock returns, real activity, inflation, and money, *American Economic Review* 71, 545-565.
- Fama, Eugene F. and Robert R. Bliss, 1987, The Information in Long-Maturity Forward Rates, *American Economic Review*, 77, 680-692.
- Hamilton, James D. and Oscar Jorda, 2002, A model of the Federal Funds Target Rate, *Journal of Political Economy*, 110, 1135-1167.
- Hamilton, James D., 2008, Assessing Monetary Policy Effects Using Daily Federal Funds Futures Contracts, *Review Federal Reserve Banks of St. Louis*, 90 (2) 110, 377-393.
- Harvey, Campbell R., 1989, Forecasts of Economic Growth from the Stocks and Bond Markets, *Financial Analysts Journal* September/October 1989, 38-45.
- Gürkaynak, Refet S., Brian P. Sack, and Eric T. Swanson, 2007, Market-Based Measures of Monetary Policy Expectations, *Journal of Business and Economic Statistics* 25, 201-212.
- Krishnamurthy, Arvind, and Annette Vissing-Jorgensen, 2011, The Effects of Quantitative Easing on Interest Rates: Channels and Implications for Policy, *Brookings Papers on Economic Activity*, Fall, 215-265.
- Kuttner, Kenneth N., 2001, Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures Market, *Journal of Monetary Economics* 47, 523-544.
- Romer, Christina D., and David H. Romer, 2004, A New Measure of Monetary Shocks: Derivation and Implications, *American Economic Review* 94, 1055-1084.
- Rudebush, Glen D., 1995, Federal Reserve Interest Rate Targeting, Rational Expectations, and the Term Structure, *Journal of Monetary Economics* 35, 245-274.
- Stock, James H., and Mark W. Watson, 1989, New indexes of coincident and leading economic indicators, *NBER Macroeconomics Manual* 4, 351-394.
- Taylor, John B., 2001, Expectations, Open Market Operations, and Changes in the Federal Funds Rate, *Review*, Federal Reserve Bank of St. Louis, 83 (2) July/August 2001, 33-47.
- Thornton, Daniel L., 2005, A New Federal Funds Rate Target Series: September 27, 1982 – December 31, 1993, Working Paper 2005-032A, Federal Reserve Bank of St. Louis.

**Table 1** – Summary statistics and autocorrelations for daily changes in the Fed funds rate (dFF) the one-month commercial paper rate (dCP), three-month and six-month Treasury bill rates (dB3 and dB6), and five-year and ten-year U.S Government bond rates (dG5 and dG10), measured on day t, and the lagged spread variables, FF-TF, CP-TF, B3-TF, B6-TF, G5-TF, and G10-TF, measured on day t-1, where TF is the target Fed funds rate. The data are from the FRED website of the Federal Reserve Bank of St. Louis. CP is FRED series DCP30 until 1997 and DCPN30 thereafter. The standard error of the autocorrelations under a null of zero is 0.0116.

Part A - Summary statistics												
	dFF	dCP	dB3	dB6	dG5	dG10	FF-TF	CP-TF	B3-TF	B6-TF	G5-TF	G10-TF
Summary statistics for 9/27/1982 - 6/28/2012, obs = 7382												
Mean	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.04	0.04	-0.37	-0.25	1.13	1.61
Std Dev	0.28	0.06	0.06	0.06	0.07	0.07	0.29	0.21	0.39	0.42	1.05	1.30
Summary statistics for 9/27/1982 - 12/31/1993, obs = 2812												
Mean	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.09	0.04	-0.55	-0.42	1.38	1.78
Std Dev	0.40	0.08	0.07	0.07	0.08	0.07	0.42	0.30	0.43	0.43	1.02	1.20
Summary statistics for 1/3/1994 - 6/28/2012, obs = 4570												
Mean	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	0.01	0.04	-0.25	-0.14	0.98	1.51
Std Dev	0.18	0.05	0.05	0.04	0.07	0.06	0.17	0.14	0.32	0.36	1.04	1.36
Part B - Autocorrelations for 9/27/1982 - 6/28/2012, obs = 7382, Standard Error is 0.0116												
lag	dFF	dCP	dB3	dB6	dG5	dG10	FF-TF	CP-TF	B3-TF	B6-TF	G5-TF	G10-TF
1	-0.20	0.11	0.11	0.09	0.06	0.05	0.53	0.94	0.98	0.99	1.00	1.00
2	-0.20	0.06	-0.06	-0.01	-0.01	-0.01	0.26	0.88	0.96	0.97	0.99	1.00
3	-0.04	-0.04	-0.06	-0.04	0.00	-0.00	0.17	0.83	0.94	0.96	0.99	0.99
4	-0.02	-0.01	-0.01	0.01	-0.02	-0.03	0.12	0.77	0.93	0.95	0.99	0.99
5	-0.01	-0.00	-0.01	0.01	-0.02	-0.02	0.09	0.73	0.91	0.93	0.98	0.99
6	-0.04	-0.01	-0.03	-0.01	-0.00	-0.01	0.07	0.68	0.90	0.92	0.98	0.99
7	-0.04	-0.03	0.01	0.01	0.04	0.04	0.09	0.64	0.88	0.91	0.98	0.99
8	0.06	0.01	-0.02	-0.04	-0.00	-0.00	0.15	0.61	0.87	0.90	0.98	0.98
9	0.00	0.03	0.01	0.01	0.01	-0.00	0.15	0.58	0.86	0.89	0.97	0.98
10	0.06	-0.01	0.04	0.04	0.01	0.02	0.15	0.54	0.85	0.89	0.97	0.98
11	-0.02	0.00	0.00	0.01	0.00	0.01	0.10	0.52	0.84	0.88	0.97	0.98
12	-0.03	-0.01	-0.03	-0.01	0.02	0.02	0.06	0.49	0.83	0.87	0.96	0.98
13	0.01	0.02	-0.01	0.00	0.00	0.00	0.06	0.47	0.82	0.86	0.96	0.98
14	0.01	0.01	0.04	0.05	0.03	0.03	0.04	0.45	0.81	0.86	0.96	0.97
15	-0.04	0.02	0.03	0.03	0.00	0.00	0.02	0.43	0.80	0.85	0.96	0.97
16	-0.03	0.01	-0.01	-0.00	-0.00	-0.00	0.04	0.41	0.80	0.84	0.95	0.97
17	0.01	-0.02	-0.04	-0.01	0.02	0.01	0.09	0.38	0.79	0.84	0.95	0.97
18	0.01	0.02	0.04	0.02	0.02	0.02	0.12	0.37	0.78	0.83	0.95	0.97
19	0.07	-0.00	0.08	0.04	-0.01	-0.01	0.15	0.35	0.78	0.83	0.95	0.96
20	-0.02	0.00	0.02	0.03	0.01	0.01	0.11	0.34	0.77	0.82	0.94	0.96

**Table 2** – Estimates of regression (1) to explain the change in interest rate  $R$  on day  $t$ ,  $dR_t$ . The interest rates are the Fed funds rate (FF), the one-month commercial paper rate (CP), the three-month or six-month Treasury bill rate (B3 or B6), or the five-year or ten-year U.S Government bond rate (G5 or G10). The explanatory variables are (i) ten lags of  $dR_t$  and (ii) the lagged spread,  $R_{t-1} - TF_{t-1}$ , measured on day  $t-1$ , where  $TF_{t-1}$  is the Fed funds target rate. The table shows regression coefficients (Coef), t-statistics for the coefficients ( $t(\text{Coef})$ ) and regression  $R^2$ , adjusted for degrees of freedom. The impulse response functions in Part C show the cumulative change in  $R$  after a 1% shock to  $R$  on day  $t$ .

Part A: 9/27/1982 - 12/31/1993, obs = 2802												
	a	$R_{t-1} - TF_{t-1}$	$dR_{t-1}$	$dR_{t-2}$	$dR_{t-3}$	$dR_{t-4}$	$dR_{t-5}$	$dR_{t-6}$	$dR_{t-7}$	$dR_{t-8}$	$dR_{t-9}$	$dR_{t-10}$
$dFF, R^2 = 0.23$												
Coef	0.03	-0.37	-0.02	-0.15	-0.07	-0.07	-0.07	-0.07	-0.09	0.00	-0.01	0.05
$t(\text{Coef})$	4.13	-12.12	-0.72	-4.94	-2.22	-2.48	-2.66	-2.72	-3.81	0.19	-0.49	2.55
$dCP, R^2 = 0.06$												
Coef	0.00	-0.04	0.21	0.02	-0.04	0.02	0.03	0.01	-0.04	0.05	0.04	-0.03
$t(\text{Coef})$	0.09	-6.27	11.36	1.30	-2.26	1.18	1.43	0.49	-2.18	2.50	1.93	-1.39
$dB3, R^2 = 0.02$												
Coef	-0.01	-0.01	0.12	-0.01	-0.04	0.01	-0.00	-0.04	0.05	-0.02	-0.02	0.03
$t(\text{Coef})$	-3.33	-3.27	6.41	-0.51	-2.29	0.38	-0.16	-2.38	2.46	-1.32	-0.96	1.45
$dB6, R^2 = 0.01$												
Coef	-0.00	-0.01	0.11	-0.00	-0.04	0.02	0.01	-0.04	0.02	-0.03	-0.02	0.02
$t(\text{Coef})$	-2.23	-1.89	5.91	-0.13	-2.00	1.10	0.63	-2.40	1.28	-1.59	-1.18	1.03
$dG5, R^2 = 0.01$												
Coef	-0.00	-0.00	0.11	0.01	-0.01	-0.01	-0.01	-0.01	0.03	0.01	-0.01	0.01
$t(\text{Coef})$	-0.02	-0.81	5.62	0.57	-0.30	-0.75	-0.34	-0.64	1.78	0.38	-0.57	0.47
$dG10, R^2 = 0.01$												
Coef	0.00	-0.00	0.09	0.01	0.00	-0.03	-0.00	-0.03	0.04	0.01	-0.01	0.01
$t(\text{Coef})$	0.00	-0.75	4.60	0.26	0.26	-1.56	-0.11	-1.38	1.96	0.42	-0.46	0.45
Part B: 1/3/1994 - 6/28/2012, obs = 4560												
	a	$R_{t-1} - TF_{t-1}$	$dR_{t-1}$	$dR_{t-2}$	$dR_{t-3}$	$dR_{t-4}$	$dR_{t-5}$	$dR_{t-6}$	$dR_{t-7}$	$dR_{t-8}$	$dR_{t-9}$	$dR_{t-10}$
$dFF, R^2 = 0.27$												
Coef	0.00	-0.44	-0.13	-0.08	-0.06	-0.07	-0.04	-0.09	-0.07	-0.02	-0.04	0.05
$t(\text{Coef})$	1.03	-19.54	-5.70	-3.47	-2.64	-3.31	-2.35	-4.98	-3.91	-1.05	-2.41	3.81
$dCP, R^2 = 0.02$												
Coef	0.00	-0.02	-0.06	0.10	-0.00	0.02	0.03	0.03	0.05	-0.02	0.04	0.03
$t(\text{Coef})$	0.39	-3.44	-4.12	6.35	-0.17	1.54	2.03	1.72	3.63	-1.15	2.84	1.79
$dB3, R^2 = 0.04$												
Coef	0.00	0.01	0.12	-0.12	-0.06	-0.00	-0.01	-0.04	-0.00	-0.04	0.02	0.05
$t(\text{Coef})$	1.48	3.11	7.79	-7.93	-3.96	-0.24	-0.44	-2.76	-0.14	-2.40	1.36	3.10
$dB6, R^2 = 0.03$												
Coef	0.00	0.01	0.03	-0.07	-0.03	0.01	0.02	-0.00	-0.01	-0.08	0.06	0.07
$t(\text{Coef})$	1.45	5.63	2.24	-4.73	-2.17	0.41	1.04	-0.20	-0.45	-5.10	3.69	4.41
$dG5, R^2 = 0.00$												
Coef	-0.00	0.00	0.01	-0.05	0.00	-0.03	-0.03	-0.01	0.03	-0.01	0.01	0.01
$t(\text{Coef})$	-1.34	0.87	0.70	-3.29	0.30	-2.29	-1.90	-0.44	2.06	-0.98	0.86	0.86

dG10,  $R^2 = 0.00$   
 Coef      -0.00    0.00    0.02   -0.03   -0.01   -0.03   -0.03   -0.01    0.03   -0.02    0.00    0.03  
 t(Coef)   -0.72    0.06    1.21   -2.25   -0.57   -2.30   -1.82   -0.45    2.35   -1.39    0.16    2.10

Table 2 -- continued

Part C: Impulse response functions for a 1% shock to the interest rate R on day t											
	t	t+1	t+2	t+3	t+4	t+5	t+6	t+7	t+8	t+9	t+10
9/27/1982 - 12/31/1993											
dFF	1.00	0.64	0.29	0.21	0.17	0.13	0.10	0.07	0.15	0.16	0.19
dCP	1.00	1.18	1.20	1.12	1.08	1.06	1.04	0.95	0.94	0.94	0.90
dB3	1.00	1.10	1.09	1.02	1.00	0.98	0.92	0.93	0.90	0.87	0.87
dB6	1.00	1.10	1.10	1.05	1.05	1.06	1.00	1.01	0.97	0.94	0.94
dG5	1.00	1.11	1.13	1.12	1.11	1.09	1.08	1.11	1.12	1.11	1.12
dG10	1.00	1.09	1.10	1.10	1.07	1.07	1.04	1.07	1.08	1.07	1.08
1/3/1994 - 6/28/2012											
dFF	1.00	0.44	0.25	0.15	0.08	0.07	-0.00	0.01	0.06	0.03	0.12
dCP	1.00	0.92	1.00	0.97	0.98	0.99	0.99	1.03	0.98	1.02	1.01
dB3	1.00	1.13	1.03	0.96	0.96	0.98	0.95	0.95	0.93	0.96	1.03
dB6	1.00	1.05	0.99	0.97	0.99	1.02	1.03	1.03	0.97	1.03	1.12
dG5	1.00	1.01	0.96	0.96	0.93	0.90	0.89	0.93	0.91	0.92	0.94
dG10	1.00	1.02	0.98	0.97	0.94	0.91	0.90	0.94	0.92	0.92	0.95



**Table 3** - Autoregressions for changes in the Fed funds and one-month commercial paper rate,  $dFF_t$  and  $dCP_t$ , with error correction terms  $FF_{t-1}-TF_{t-1}$  (labeled FF-TF) and  $FF_{t-1}-CP_{t-1}$  (FF-CP) or  $CP_{t-1}-TF_{t-1}$  (CP-TF) and  $CP_{t-1}-FF_{t-1}$  (CP-FF), where  $TF_{t-1}$  is the Fed funds target rate and  $a$  is the regression intercept. The table shows regression coefficients (Coef), t-statistics for the coefficients ( $t(\text{Coef})$ ) and regression  $R^2$ , adjusted for degrees of freedom.

Part A: dFF <sub>t</sub>													
	a	FF-TF	FF-CP	dFF <sub>t-1</sub>	dFF <sub>t-2</sub>	dFF <sub>t-3</sub>	dFF <sub>t-4</sub>	dFF <sub>t-5</sub>	dFF <sub>t-6</sub>	dFF <sub>t-7</sub>	dFF <sub>t-8</sub>	dFF <sub>t-9</sub>	dFF <sub>t-10</sub>
9/27/1982 - 12/31/1993, obs = 2802, R2 = 0.24													
Coef	0.03	-0.28	-0.16	0.02	-0.12	-0.04	-0.05	-0.06	-0.06	-0.09	0.01	-0.01	0.05
t(Coef)	4.21	-8.46	-6.91	0.63	-3.96	-1.48	-1.92	-2.26	-2.46	-3.65	0.31	-0.36	2.58
1/3/1994 - 6/28/2012, obs = 4560, R2 = 0.28													
Coef	-0.00	-0.35	-0.14	-0.09	-0.05	-0.04	-0.05	-0.04	-0.09	-0.07	-0.02	-0.04	0.05
t(Coef)	-1.17	-14.19	-8.34	-4.02	-2.24	-1.72	-2.64	-1.89	-4.72	-3.86	-1.15	-2.57	3.62

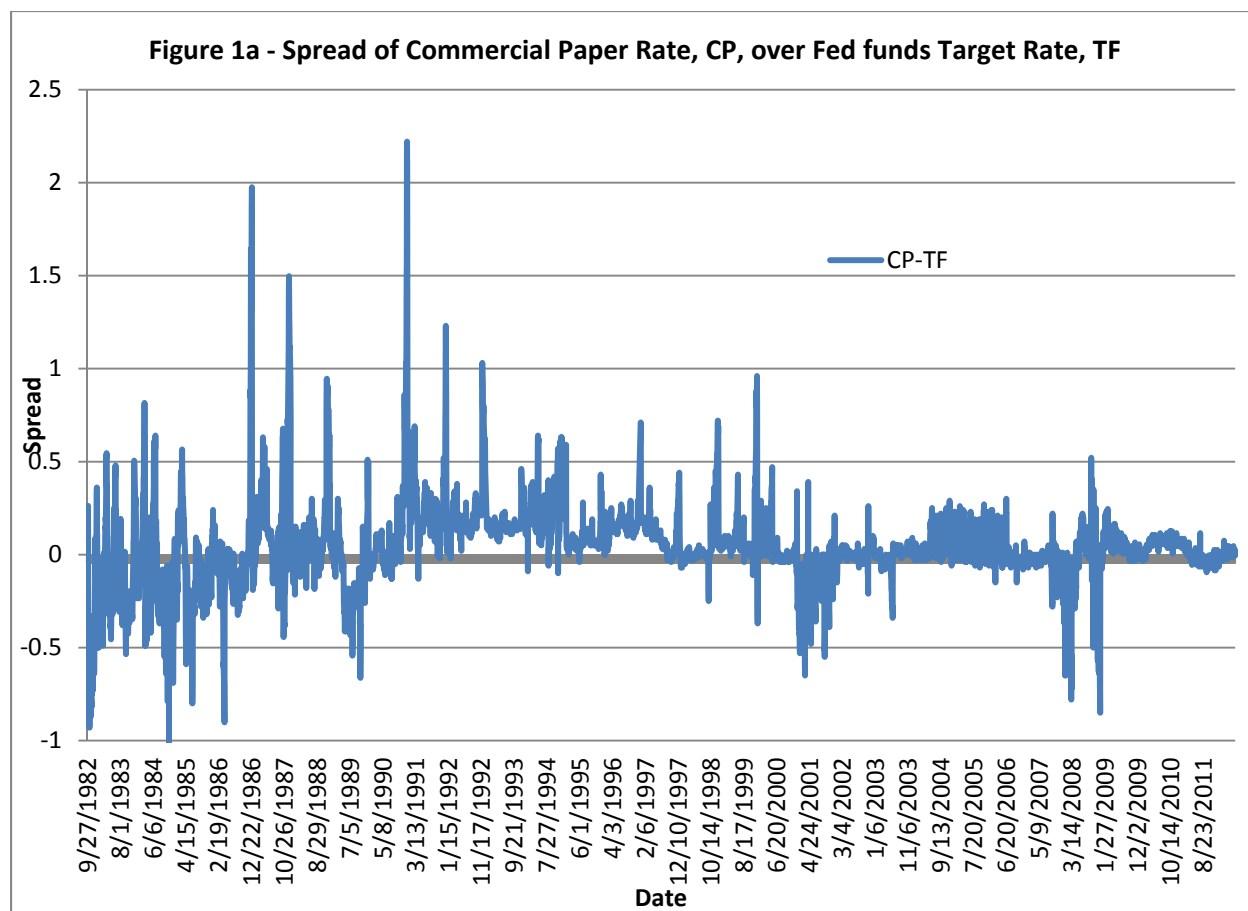
Part B: dCP <sub>t</sub>													
	a	CP-TF	CP-FF	dCP <sub>t-1</sub>	dCP <sub>t-2</sub>	dCP <sub>t-3</sub>	dCP <sub>t-4</sub>	dCP <sub>t-5</sub>	dCP <sub>t-6</sub>	dCP <sub>t-7</sub>	dCP <sub>t-8</sub>	dCP <sub>t-9</sub>	dCP <sub>t-10</sub>
9/27/1982 - 12/31/1993, obs = 2802, R2 = 0.07													
Coef	0.00	-0.05	0.02	0.23	0.03	-0.04	0.02	0.03	0.01	-0.04	0.05	0.04	-0.02
t(Coef)	1.13	-7.81	5.10	12.19	1.61	-2.18	1.13	1.49	0.79	-2.00	2.51	2.12	-1.21
1/3/1994 - 6/28/2012, obs = 4560, R2 = 0.03													
Coef	0.00	-0.00	-0.02	-0.07	0.09	-0.01	0.02	0.03	0.03	0.05	-0.02	0.04	0.03
t(Coef)	0.32	-0.12	-5.72	-4.69	5.78	-0.66	1.31	1.96	1.70	3.52	-1.24	2.81	1.74

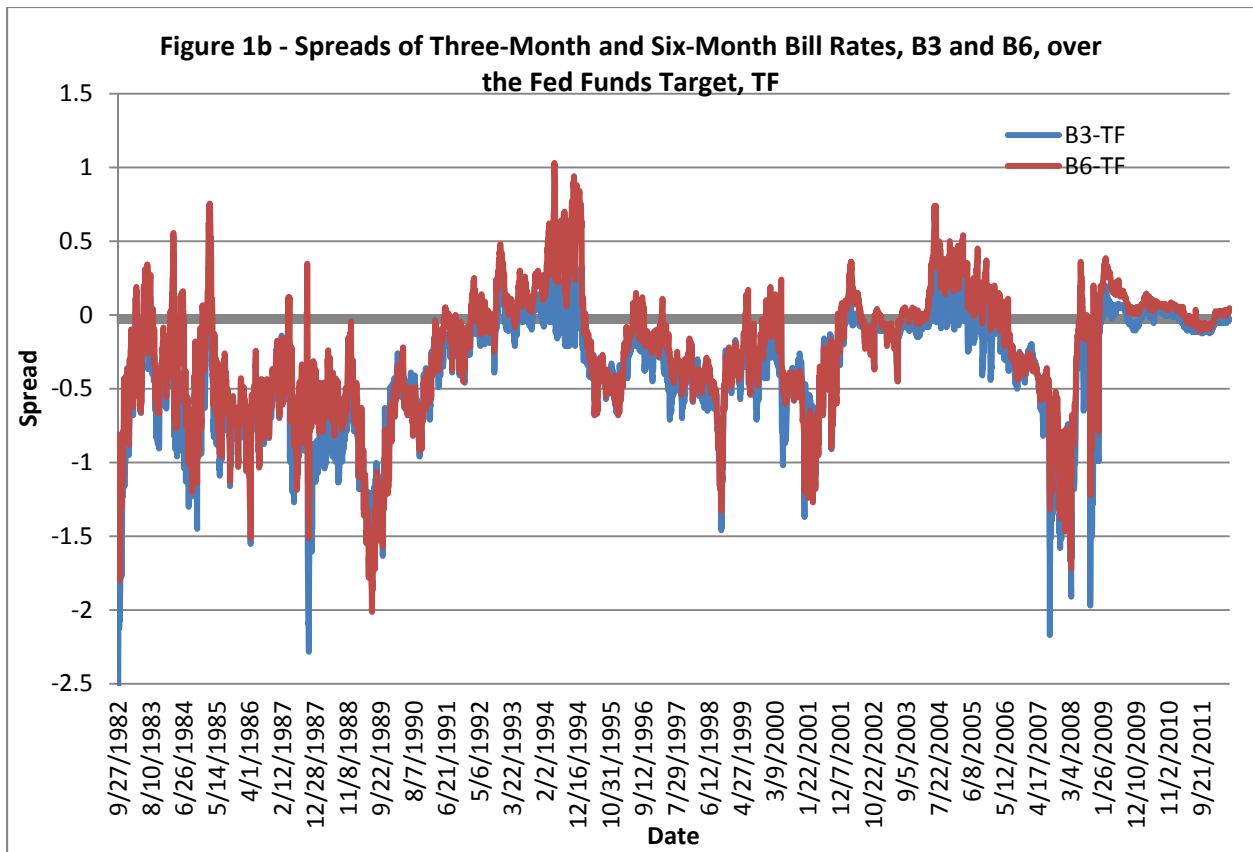
**Table 4** –Univariate regressions that predict changes in the target Fed funds rate, TF, with the difference between the level of TF and the level of an interest rate R on the day preceding the change. The interest rates R are the Fed funds rate (FF), the one-month commercial paper rate (CP), the three-month or six-month Treasury bill rate (B3 or B6), or the five-year or ten-year U.S. Government bond rate (G5 or G10). The table shows the regression slopes, b, their t-statistics, t(b), and the regression  $R^2$  (R Sq), adjusted for degrees of freedom. The regression intercepts are not shown. The sample period ends on 12/16/2008, the date of the last change in TF.

Ind	FF-TF	CP-TF	B3-TF	B6-TF	G5-TF	G10-TF
Period is 9/27/1982 - 12/16/2008, obs for changes in target is 153						
b	0.24	0.66	0.40	0.41	0.13	0.09
t(b)	4.56	11.87	10.29	12.42	5.77	4.02
R Sq	0.11	0.48	0.41	0.50	0.18	0.09
Period is 9/27/1982 - 12/31/1993, obs for changes in target is 93						
b	0.17	0.46	0.27	0.34	0.08	0.06
t(b)	3.22	6.14	4.67	5.87	2.73	2.09
R Sq	0.09	0.29	0.18	0.27	0.07	0.04
Period is 1/3/1994 - 12/16/2008, obs for changes in target is 60						
b	0.56	1.03	0.59	0.52	0.21	0.13
t(b)	4.09	17.13	14.59	16.58	6.17	3.77
R Sq	0.21	0.83	0.78	0.82	0.39	0.18

**Table 5** – Part A shows univariate regressions to predict contemporaneous and four future changes in  $dR_{t+lead}$  with  $TF_t - CP_{t-1}$  for days  $t$  when  $TF_t$  changes. The interest rate  $R$  is the commercial paper rate (CP), the three-month or the six-month Treasury bill rate (B3 or B6), or the five-year or ten-year U.S. Government bond rate (G5 or G10). Part B shows regressions to predict contemporaneous and four future changes in the Fed funds rate, FF, with  $TF_t - FF_{t-1}$  for days  $t$  when  $TF_t$  changes. The table shows regression slope coefficients (b), t-statistics for the slopes (t(b)) and regression  $R^2$  (R Sq), adjusted for degrees of freedom. The regression intercepts are not shown. The last change in TF is on 12/16/2008. There are 93 changes in  $TF_t$  in the regressions for 9/27/1982 - 12/31/1993, and there are 60 changes during 1/3/1994 - 12/16/2008.

Lead	9/27/1982 - 12/31/1993					1/3/1994 - 12/16/2008				
	0	1	2	3	4	0	1	2	3	4
Part A										
Predict $dCP_{t+lead}$ with $TF_t - CP_{t-1}$										
b	0.17	0.11	0.01	-0.02	-0.06	0.26	0.66	0.16	0.05	0.02
t(b)	5.55	3.72	0.34	-0.88	-1.88	3.45	11.11	2.90	1.40	0.64
R Sq	0.24	0.12	-0.01	-0.00	0.03	0.16	0.67	0.11	0.02	-0.01
Predict $dB3_{t+lead}$ with $TF_t - CP_{t-1}$										
b	0.16	0.05	0.03	0.02	-0.02	0.33	0.18	0.14	-0.00	-0.06
t(b)	5.27	1.67	1.18	0.85	-0.66	4.53	2.27	2.04	-0.01	-1.64
R Sq	0.23	0.02	0.00	-0.00	-0.01	0.25	0.07	0.05	-0.02	0.03
Predict $dB6_{t+lead}$ with $TF_t - CP_{t-1}$										
b	0.19	0.05	0.04	0.00	-0.01	0.30	0.13	0.11	-0.00	0.03
t(b)	6.19	1.68	1.65	0.17	-0.30	4.75	2.24	1.91	-0.02	0.68
R Sq	0.29	0.02	0.02	-0.01	-0.01	0.27	0.06	0.04	-0.02	-0.01
Predict $dG5_{t+lead}$ with $TF_t - CP_{t-1}$										
b	0.12	0.08	0.03	-0.01	-0.03	0.11	0.05	0.05	0.03	0.04
t(b)	3.26	2.83	1.31	-0.46	-0.78	1.33	0.79	0.79	0.49	0.99
R Sq	0.09	0.07	0.01	-0.01	-0.00	0.01	-0.01	-0.01	-0.01	-0.00
Predict $dG10_{t+lead}$ with $TF_t - CP_{t-1}$										
b	0.07	0.08	0.04	-0.01	-0.03	0.02	0.03	0.02	0.01	0.04
t(b)	2.26	3.00	1.65	-0.28	-0.97	0.25	0.40	0.35	0.17	0.94
R Sq	0.04	0.08	0.02	-0.01	-0.00	-0.02	-0.01	-0.02	-0.02	-0.00
Part B										
Predict $dFF_{t+lead}$ with $TF_t - FF_{t-1}$										
b	0.67	0.14	0.16	0.06	-0.05	0.59	0.42	0.09	-0.01	-0.03
t(b)	9.92	2.49	3.23	1.15	-0.64	7.76	4.26	1.12	-0.13	-0.38
R Sq	0.51	0.05	0.09	0.00	-0.01	0.50	0.23	0.00	-0.02	-0.01





**Figure 1c - Spreads of Five-Year and Ten-Year Government Bond Rates, G5 and G10, over Fed Funds Target, TF**

