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# Greenspan's Conundrum and the Fed's Ability to Affect Long-Term Yields

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## ***Abstract***

In February 2005 Federal Reserve Chairman Alan Greenspan noticed that the 10-year Treasury yields failed to increase despite a 150-basis-point increase in the federal funds rate as a “conundrum.” This paper shows that the connection between the 10-year yield and the federal funds rate was severed in the late 1980s, well in advance of Greenspan’s observation. The paper hypothesize that the change occurred because the Federal Open Market Committee switched from using the federal funds rate as an operating instrument to using it to implement monetary policy and presents evidence from a variety of sources supporting the hypothesis. The analysis has implications for central banks’ interest rate policies.

**JEL Codes:** E52, E43

**Key Words:** federal funds rate, federal funds target, Lucas critique, term structure

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## 1.0 Introduction

In his February 17, 2005, testimony before the Committee on Banking, Housing, and Urban Affairs of the U.S. Senate, Federal Reserve Chairman Alan Greenspan observed that long-term rates had trended lower despite the 150-basis-point rise in the Federal Open Market Committee's (FOMC's) target for the federal funds rate. Rejecting a variety of possible explanations for the behavior as implausible he called it a "conundrum." Previous research has attempted to explain the conundrum with little success. However, all of this research focused on the mid-2000s and on the behavior of the 10-year Treasury yield. This research departs from this approach by considering the possibility that change in the relationship may have occurred prior to Greenspan first noticed it. Instead, the change in the relationship between the federal funds rate and the 10-year Treasury yield is dated using Andrews' (1993) test for structural change. The test indicates that the relationship between Treasury yields and the funds rate changed in the late 1980s, well in advance of Greenspan's observation. Based on previous research, I hypothesize that the change in the relationship between the funds rate and the 10-year Treasury yield when the FOMC began using the funds rate as a *policy* target rather than an *operating* target as it had previously. Hence, the change in the relationship between the 10-year Treasury yield and the funds rate is an instance of Goodhart's Law, which states that "any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes."<sup>1</sup> A variety of documentary and statistical evidence is presented in support of the hypothesis. Moreover, the hypothesis is confirmed for the Bank of England and the Reserve Bank of New Zealand.

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<sup>1</sup> See Goodhart (1975). Chrystal and Mizen (2003) argue that Goodhart's law and the far more influential Lucas critique are essentially the same. I have chosen to focus on Goodhart's law because, from its origin, it has been narrowly associated with monetary policy, while the Lucas critique is broader in scope.

The paper is divided into six sections. Section 2 presents the bond yield conundrum and previous attempts to explain it. Section 3 dates the change in the relationship between the 10-year Treasury yield and the funds rate using Andrews' (1993) structural break test. A hypothesis for the structural break in the relationship between the 10-year Treasury yield and the funds rate is presented in Section 4. Section 5 presents documentary evidence supporting the hypothesis and Section 6 presents a variety of statistical tests of the hypothesis. Section 7 concludes.

## **2.0 The Bond Yield Conundrum**

In testimony before the U.S. Senate Committee on Banking, Housing, and Urban Affairs on February 17, 2005, Alan Greenspan observed that

long-term interest rates have trended lower in recent months even as the Federal Reserve has raised the level of the target federal funds rate by 150 basis points. This development contrasts with most experience, which suggests that, other things being equal, increasing short-term interest rates are normally accompanied by a rise in longer-term yields. The simple mathematics of the yield curve governs the relationship between short- and long-term interest rates. Ten-year yields, for example, can be thought of as an average of ten consecutive one-year forward rates. A rise in the first-year forward rate, which correlates closely with the federal funds rate, would increase the yield on ten-year U.S. Treasury notes even if the more-distant forward rates remain unchanged.<sup>2</sup>

Considering a variety of possible explanation for his observation, including the world saving glut, he concluded that “none of this is new and hence it is difficult to attribute the long-term interest rate declines of the last nine months to glacially increasing globalization. For the moment, the broadly unanticipated behavior of world bond markets remains a *conundrum*.”<sup>3</sup>

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<sup>2</sup> Testimony of Chairman Alan Greenspan (2005).

<sup>3</sup> Testimony of Chairman Alan Greenspan (2005), emphasis added.

Greenspan's comment led some analysts to view the conundrum as purely an issue about the behavior of long-term-yields. Consequently, most previous research has focused solely on the behavior of the 10-year Treasury yield. Kim and Wright (2005) investigate the conundrum by decomposing the term structure of nominal Treasury yields into the expected future short-term rate and the term premium using the three-factor, arbitrage-free, term structure model of Kim and Orphanides (2005).<sup>4</sup> Their analysis suggests that most of the decline in long-term interest rates from June 29, 2004, through July 20, 2005, was due to a decline in the term premium. They do not determine why the term premium declined but suggest that it is due to "anything else that might affect the price of Treasury securities other than expected future monetary policy."<sup>5</sup>

Rosenberg (2007) decomposed the decline in the term premium from Kim and Wright's (2005) model into (a) changes in risk, (b) risk aversion, and (c) foreign demand. He finds that most of the decline in the term premium is accounted for by a marked—but unexplained—reduction in risk aversion.

Rudebusch, Swanson, and Wu (2006) investigate the conundrum using two macro-finance models of the term structure, the VAR-based model of Bernanke, Reinhart, and Sack (2004) (BRS) and the "New Keynesian" model of Rudebusch and Wu (2007) (RW). The BRS model is estimated over the period January 1984 through December 2005. They find that the models' residuals are relatively large during 2005 which they note is consistent with Greenspan's conundrum. However, various attempts to explain the enigmatic behavior of the

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<sup>4</sup> Also see Backus and Wright (2007).

<sup>5</sup> Kim and Wright (2005), p. 7.

10-year yield are largely unsuccessful. They find that over 50 percent of the residuals from the BRS model and over 70 percent of the residuals from the RW model are unexplained.

Smith and Taylor (2009) embed a simple macro model consisting of a Taylor rule and an inflation equation into a standard affine term structure model. They find that there was a decline in the response coefficient to inflation in the Taylor rule could account for Greenspan's conundrum, suggesting that "a perception of a smaller response coefficient in the policy rule could have led market participants to expect smaller interest rate responses to inflation in the future, and therefore lower long-term interest rate responses."<sup>6</sup>

This explanation is implausible. Market participants would have had to know (or believe) that the FOMC was following a specific Taylor rule, observe the change that Smith and Taylor (2009) document, and believe the change to be permanent rather than temporary; all of which seem unlikely.<sup>7</sup>

Bernanke's (2005) advanced the global saving glut hypothesis to explain the conundrum. Bernanke (2005) suggested that the significant increase in the supply of saving globally could account for the "relatively low level of long-term interest rates." Smith and Taylor (2009) reject this hypothesis, noting that "world saving as a share of world GDP had actually fallen during this period."<sup>8</sup>

Bernanke's (2005) hypothesis also is problematic in that it implies that foreign investors had a strong preference for the long end of the yield curve. The

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<sup>6</sup> Smith and Taylor (2009), pp. 916-17.

<sup>7</sup> While the Taylor rule framework has been evolving since the mid-1990s, there is little or no evidence of rule like behavior by the FOMC or that it implemented policy using a specific policy rule (e.g., Asso et al., 2010, and Meade and Thornton, 2012).

<sup>8</sup> Smith and Taylor (2009), p. 916.

3-month T-bill rate rose in lockstep with the funds rate and the yield curve inverted by July 2006.

### **3.0 When Did the Change Occur?**

The previous research has focused on the behavior of the 10-year Treasury yield; however, as Kuttner (2006) has noted, “what is unusual about the 2004-05 episode is that bond yields remained relatively unchanged, despite the Fed’s campaign to raise interest rates.”<sup>9</sup> Indeed, over the entire period from June 2004 through July 2006, the 10-year Treasury yield increased by about 30 basis points despite a 400-basis-point increase in the funds rate target—an outcome that is not easily explained by a smaller response of the funds rate to inflation.

Furthermore, while Greenspan first noticed the 10-year Treasury yield failed to increase when the FOMC began increasing its funds rate target in June 2004, the relationship between changes in the funds rate and changes in the 10-year Treasury yield could have occurred earlier. A natural way to investigate when the change occurred is to test of a break in the relationship by estimating the equation

$$(1) \quad \Delta T10_t = \alpha + \beta \Delta ff_t + \eta_t,$$

where  $\Delta T10$  and  $\Delta ff$  denote the change in the 10-year Treasury yield and the change in the federal funds rate, respectively. This is done using monthly data the period January 1983 through March 2007. The beginning of the period was chosen because Thornton (2006) shows that the FOMC began paying increased attention to the federal funds rate in its policy deliberations in late 1982. The

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<sup>9</sup> Kuttner (2006), p. 123.

starting date also coincides with the onset of the great moderation (e.g., McConnell and Perez Quiros, 2000). The end of the period was chosen so the results would not be affected by the financial market crisis that began in the summer of 2007.

Equation 1 is estimated using a 33-month rolling-window regression. The window size is equal to the number of months from July 2004 to March 2007. The estimates, plotted on the initial month of the sample, are presented in Figure 1. Estimates of  $\beta$  fluctuate in a relatively small range around 0.40 until the early 1990s, then decline, and are negative for a period during the latter part of the sample. The estimate of  $\bar{R}^2$ , however, falls to essentially zero in the mid-1990s and remains there, suggesting that the relationship between the 10-year Treasury yield and the funds rate occurred well in advance of Greenspan's conundrum statement.<sup>10</sup>

### 3.1 Dating the Change

This section dates the change in the relationship between changes in the 10-year Treasury yield and the federal funds rate using Andrews' (1993) "supremum" test for identifying a single endogenous break point. Specifically, Equation 1 is estimated over the first 45 months of the sample and the remaining 246 months, and the likelihood ratio(LR) statistic for the hypothesis of no structural break is calculated. The procedure is repeated, adding one month to the

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<sup>10</sup> The results are essentially the same using quarterly data. The estimate of  $\beta$  for the full sample period is 0.4 and highly statistically significant, with an  $\bar{R}^2$  of 0.2. However, when the equation is estimated using the 46 observations from 1983.Q1 through 1994.Q2, the estimate of  $\beta$  declines to 0.08 and is not statistically significant and the estimate of  $\bar{R}^2$  is zero. Moreover, the results are essentially the same if the equation is estimated using monthly data with lags of the federal funds rate.



first period and deleting one month from the second period until there are 246 months in the first period and 45 months in the second. The most likely breakpoint is given by the largest value of the 291 LR statistics. Following the suggestion of Diebold and Chen (1996), a bootstrap approximation to the finite sample distribution of the test statistic is used to test the null hypothesis of no break.

The LR statistic for all possible break dates is presented in Figure 2, along with the critical value for the 5 percent significance level obtained from 10,000 replications of the sample data under the null hypothesis using a sample size of 291 observations. The supremum of the LR statistic occurs at May 1988. The LR statistic is over 25, much larger than the 1 percent critical value of 18.58. The results indicate that a statistically significant break in the relationship between changes in the 10-year Treasury yield and changes in the federal funds rate occurred earlier than the rolling regression estimates suggest. While the supremum occurred at May 1988, there is another sharp spike in the likelihood ratio statistic in mid-1994, which coincides with the sharp drop in the estimate of  $\bar{R}^2$  using monthly and quarterly data.

The May 1988 break date is supported by estimates of Equation 1 over the two periods. When the equation is estimated over the period from January 1983 through May 1988, the estimate of  $\beta$  is 0.48 with a  $t$ -statistic of 3.0 and  $\bar{R}^2$  is 0.21. When the equation is estimated over the period June 1988 through March 2007, the estimate of  $\beta$  is 0.18 with a  $t$ -statistic of 2.3; however, the estimate of

$\bar{R}^2$  is just 2 percent, suggesting that there is essentially no relationship between changes in the rates.

#### **4.3 Why Did the Change Go Unnoticed for So Long?**

The evidence suggests that the relationship between changes in the 10-year Treasury yield and changes in the federal funds rate that occurred in the late 1980s. Why did the change go unnoticed for so long? Figure 3, which shows the levels of the two rates over the sample period, suggests that the change in the relationship could have been masked by the downward trend in the levels of the rates. The negative trend in the rates is likely occurred for several reasons, such as, a downward drift of inflation expectations associated with the FOMC's evolution to inflation targeting. It could also reflect a reduction in the real rate risk premium associated with the Great Moderation (e.g., Bernanke, 2004) or a decline in the inflation risk premium (Ang et al., 2008).

In any event, the existence of a common trend could account for the fact that the marked change in the relationship went unnoticed for so long. By the early to mid-2000s the 10-year yield had stabilized. Consequently, when the FOMC began increasing the funds rate target, the marked change in the relationship between the 10-year yield and the funds rate that occurred in the late 1980s was visible.

This possibility is investigated by removing the common trend from both rates. Ideally, one would remove the effects of a decline in inflation expectations, and inflation and real rate risk premiums from the rates. However, proxies for these latent variables are model specific and can vary significantly from model to model. Consequently, adjustments to the level of rates using model-based estimates of these latent variable are subject to considerable uncertainty. Because

these latent factors should affect all of the rates similarly, the effect of these latent variables should be similar and consequently identified by a common trend.

Hence, a simple, model-free, and reasonable way to remove the effect of these latent variables on each rate is to estimate the equation

$$(2) \quad i_t = \delta_0 + \delta_1^i trend + \delta_2^i trend^2 + \varepsilon_t^i,$$

where  $i_t = ff$  or  $T10$ . The latent-factor-adjusted levels of the rates are given by estimates of  $\varepsilon_t^i$ .

The two equations are estimated over the entire sample period with the cross-equation restrictions  $\delta_1^i = \delta_1^j$  and  $\delta_2^i = \delta_2^j$  imposed. The restrictions are innocuous: Chi-square statistics for the test of the hypotheses  $\delta_1^i = \delta_1^j$  and  $\delta_2^i = \delta_2^j$  are 0.50 and 0.09, respectively. Hence, the persistent effect of latent factors on these rates appears to be identical over the sample period. In any event, the qualitative conclusions are the same if these restrictions are not imposed.

The latent-factor-adjusted federal funds and 10-year Treasury rates are presented in Figure 4.<sup>11</sup> The vertical line indicates May 1988. Consistent with the Andrews test results, there appears to be a marked change in the relationship between the levels of the 10-year Treasury yield and the federal funds rate that occurs around May 1988.<sup>12</sup> Prior to May 1988 the funds rate and the 10-year yield are highly correlated and cycle similarly. After May 1988 the funds rate and the 10-year Treasury yield move very differently, frequently with different cycles.

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<sup>11</sup> The difference in the estimate of the intercepts for the two trend equations is an estimate of the average relative risk premium, which is 147 basis points.

<sup>12</sup> The timing of the change is confirmed by Andrews' test. The supremum of the test occurs at April 1987; however, the test statistic is relatively flat between April 1987 and May 1988.

#### **4.0 What Caused the Relationship to Change?**

The results in the previous section indicate that something happened in the late 1980s that produced a marked change in the relationship between changes in the 10-year Treasury yield and changes in the federal funds rate. This section proposes a hypothesis of what caused the change. The theory of the term structure that dominates the finance and monetary policy literature is the expectations hypothesis (EH)—the hypothesis that the long-term yield is equal to the average of a default-risk-equivalent short-term rate over the term of the long-term asset plus a constant term premium. Consequently, the fact that the 10-year Treasury yield is independent of changes in the federal funds rate is a rejection of the EH. Hence, this section begins with an analysis of why the EH cannot account for the change in the relationship documented in the previous section and offers an alternative theory of the term structure.

#### **4.1 An Alternative Theory of the Term Structure**

In order to be consistent with the EH, the marked change in the relationship between changes in the funds rate and changes in the 10-year yield would have to be due to a marked deterioration in markets' ability to predict the federal funds rate because of unexpected changes in policy (Fuhrer, 1996; and Kozicki and Tinsley, 2001, 2005). This explanation is inconsistent with the fact that the FOMC increasingly transparent about its policy intentions since at least 1994 when the FOMC began announcing policy actions. The FOMC also became increasingly transparent about its inflation target in 2003 (Thornton, 2007) and began using “forward guidance” in 2004. Consequently, knowledge of the future

path of the FOMC's funds rate target high by the early 1990s and the path of the funds rate target more predictable than ever.

Some might argue that the change in the relationship documented above is consistent with the EH, and merely reflects the fact that the term premium is time varying. However, “time-varying term premium” and “failure of the EH” are just different ways of saying the same thing. The time-varying-term-premium explanation has validity if and only if there is a credible and empirically verifiable hypothesis that can account for the discrepancy between the observed long-term rate and that implied by the EH. Hence, in order to account for the persistent change in the relationship noted above, the term premium would not only have to be time varying but its data generating process would have to be changing frequently as well.

Despite the fact that it has been massively rejected using a wide variety of interest rates, sample periods, monetary policy regimes, etc. (Campbell and Shiller, 1991; Bekaert and Hodrick, 2001; Thornton, 2005; Kool and Thornton, 2004; Sarno, Thornton, and Valente, 2007, and references therein), the EH remains the dominant finance and monetary policy paradigm.<sup>13</sup> Fuhrer (1996) notes that the “tendency to fall back on the paradigm [the EH] is so strong because candidates to replace it are so weak.”<sup>14</sup> Given the inconsistency between the change in the relationship noted above and the EH this section offers the

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<sup>13</sup> The empirical failure of the EH does not necessarily imply that markets are not forward looking. For example, Guidolin and Thornton (2012) show that empirical failure of the EH is likely due to short-term interest rates being essentially impossible to predict beyond their current level. Hence, the failure of the EH is consistent with evidence is that neither market participants nor central bankers can predict the future path of short-term rates beyond a few months (e.g., Andersson and Hofmann, 2010; Goodhart and Lim, 2008; and Rudebusch, 2007, and Kool and Thornton, 2012).

<sup>14</sup> Fuhrer (1996), p. 1183.

classical theory (e.g., Humphrey, 1983ab) as an alternative. The classical economists believed that “the” interest rate (which can be thought of as the level of the structure of interest rates) was a long-term real rate determined by economic fundamentals, such as productivity, thrift, the rate of time preference, the marginal efficiency of capital, etc. “The” interest rate was unobservable. Observed real long-term rate could deviate from “the” rate for a variety of reasons; however, arbitrage would keep the observed long-term rate from deviating too far from the unobservable rate for too long. The two rates would be equal in equilibrium. Consistent with the classical theory, the equilibrium real long-term rate is commonly estimate as the average of the observed long-term real rate over a long period of time.

The classical economists did not have a specific theory of the term structure of interest rates. Short-term real rates were thought to be determined by current economic and financial market conditions. Arbitrage kept the observed real short-term rate from deviating too far from the observed real long-term rate over time. Within limits of differences in market participants’ expectations of economic fundamentals, current financial market conditions, investors’ tolerance for interest rate risks, etc., the relationship between long-term and short-term rates could vary considerably over time.

Classical economists believed that the supply of credit—primarily determined by saving and changes in the stock of high-powered money—was relatively inelastic in the short run. Consequently, during periods of economic expansion when the expected return to investment in real capital was high, long-

term rates would rise, causing the entire structure of rates to shift up. With an inelastic supply of credit, long-term rates would tend to rise relative to short-term rates, that is, the yield curve would tend to become steeper—reflecting the increased demand for long-term relative to short-term credit. During periods of weak investment opportunities, long-term rates would decline, pushing the entire rate structure lower, and the yield curve would tend to flatten. If investment opportunities were particularly weak (such as leading up to and during recessions), the yield curve could invert. Inversions of the yield curve would be relatively rare because risk-averse investors require a risk (or term) premium for lending long term.

The classical theory and the EH differ fundamentally. The classical theory assumes that the interest rate structure is anchored by the long-term rate. The EH assumes that rate structure is anchored by the short-term rate, as long-term rates are determined by the market participant's expectation of the future short-term rate.

## **4.2 The Funds Rate Targeting Hypothesis**

This section hypothesizes the marked change in the relationship between changes in the 10-year Treasury yield and changes in the funds rate occurred because the FOMC began using the federal funds rate as a policy instrument: The change occurred when the FOMC switched from using the funds rate as an indicator of the stance of policy to a variable that it controlled to implement policy. That is, the FOMC began using the funds rate as it would if it were

following a policy rule, such as a Taylor rule. I call this the funds rate targeting hypothesis (FRTH).

The analysis begins by demonstrating how such a change can generate a change in the relationship between the 10-year Treasury yield and the funds rate similar to the one observed in the data. To see how, consider the heuristic model of the federal funds rate and the 10-year Treasury yield,

$$(3) \quad \begin{aligned} ff_t &= r_t + \pi_t^e + rp_t^{ff} + \mu_t \\ T10_t &= r_t + \pi_t^{e'} + rp_t^{T10} + \mu'_t, \end{aligned}$$

where  $r_t$  denotes the classical unobservable long-term real rate;  $\pi_t^e$  and  $\pi_t^{e'}$  are the expected rates of inflation relevant for the federal funds rate and the 10-year Treasury yield, respectively; and  $rp_t^{ff}$  and  $rp_t^{T10}$  are nonzero risk premiums unique to each rate. Treasuries are free of default risk, so  $rp_t^{T10}$  reflects a market-risk premium to compensate lenders for lending long. The federal funds rate is free from market risk, so  $rp_t^{ff}$  represents a default-risk premium. The variables  $\mu_t$  and  $\mu'_t$  reflect potential premiums or discounts that may exist because of unique characteristics of the particular market. For example, only institutions that hold deposits with the Federal Reserve can participate directly in the federal funds market. Likewise, the price of 10-year Treasuries may reflect a discount because they are “on the run.”

Assume that the FOMC is not using the funds rate to implement policy. Consequently, both rates will respond to changes in the economic fundamentals, as well as shocks to factors that are unique to each market. That is,



$$(4) \quad \begin{aligned} \Delta f_t &= \theta \Delta F_t + \varepsilon_t^{ff} \\ \Delta T10_t &= \psi \Delta F_t + \varepsilon_t^{T10}, \end{aligned}$$

where  $\Delta F_t$  is the change in economic fundamentals and  $\varepsilon_t^{ff}$  and  $\varepsilon_t^{T10}$  are zero-mean, constant variance shocks to the factors that are particular to each rate. These shocks are uncorrelated with each other and with changes in economic fundamentals. The coefficients  $\theta$  and  $\psi$  reflect the fact the rates are likely to respond differently to economic fundamentals.

Given these assumptions, the correlation between changes in the federal funds and 10-year rates is given by

$$(5) \quad \rho = \frac{\theta \psi \sigma_{\Delta F}^2}{(\theta^2 \sigma_{\Delta F}^2 + \sigma_{\varepsilon^{ff}}^2)^{1/2} (\psi^2 \sigma_{\Delta F}^2 + \sigma_{\varepsilon^{T10}}^2)^{1/2}} \neq 0,$$

where  $\sigma_{\Delta F}^2$ ,  $\sigma_{\varepsilon^{ff}}^2$ , and  $\sigma_{\varepsilon^{T10}}^2$  denote the variances of changes in economic fundamentals and rate-specific shocks, respectively. The nonzero correlation is a consequence of the fact that both rates respond to economic fundamentals at the same time.<sup>15</sup> The correlation will be positive if both  $\theta$  and  $\psi$  have the same sign and negative if their signs are opposite. The directional response of various interest rates to a wide variety of shocks is likely to be the same. Consequently, it is not surprising that changes in interest rates across the term structure tend to be positively correlated, even at very high frequencies

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<sup>15</sup> The correlation would be zero if and only if rates responded to different fundamentals (e.g., the funds rate responds only to changes in the natural rate, while the 10-year yield responds only to changes in expected inflation).

Now assume instead that the FOMC targets the funds rate for policy purposes and that the funds rate remains close to the target level. In this case, the funds rate will be given by

$$(6) \quad ff_t = ff_t^T + \zeta_t,$$

where  $ff_t^T$  denotes the FOMC's target for the funds rate and  $\zeta_t$  denotes the control error. Given this assumption, changes in the funds rate and the 10-year yield can be expressed as

$$(7) \quad \begin{aligned} \Delta ff_t &= \Delta ff_t^T + \Delta \zeta_t \\ \Delta T10_t &= \psi \Delta F_t + \varepsilon_t^{T10}. \end{aligned}$$

The correlation between changes in the 10-year yield and the funds rate is now given by

$$(8) \quad \rho = \frac{\psi \text{Cov}(\Delta F_t, \Delta ff_t^T)}{(\sigma_{\Delta ff^T}^2 + \sigma_{\zeta}^2)^{1/2} (\psi^2 \sigma_{\Delta F}^2 + \sigma_{\varepsilon^{T10}}^2)^{1/2}},$$

where  $\sigma_{\Delta ff^T}^2$  denotes the variance of changes in the funds rate target.<sup>16</sup> Note that this correlation is zero if  $\text{Cov}(\Delta F_t, \Delta ff_t^T) = 0$ . This covariance will be zero if the FOMC does not adjust its funds rate target quickly to changes in the economic fundamentals that influence the 10-year yield.

Market rates respond to news each day. In contrast, if the FOMC is targeting the funds rate for policy purposes, the target will be adjusted relatively infrequently. For example, the funds rate target was maintained at 3.0 percent from September 4, 1992, until February 4, 1994, and at 1.0 percent from June 25, 2003, through June 30, 2004. Moreover, it is common for the funds rate target to

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<sup>16</sup> This assumes that control shocks are uncorrelated with changes in economic fundamentals.

be unchanged for a period of months and it is seldom changed between meetings. The less frequently the target is changed, the more likely the correlation will be small, perhaps zero.

## **5.0 Documentary Evidence of the FRTH**

If the FRTH is correct, there should be evidence that the FOMC began using the funds rate as a policy target about the time that the change in the relationship between the 10-year Treasury yield and the funds rate occurred. This section reviews the FOMC's monetary policy using FOMC transcripts and other documents.

### **6.1 Funds Rate Targeting in the 1970s**

It is often suggested that the Fed “targeted” the federal funds rate from the mid-to-late 1970s (e.g., Cook and Hahn, 1989; and Rudebusch, 1995ab). Hence, the natural question is: Why did the change in the relationship not occur in the 1970s? The answer is found in the distinction between an operating target and a policy target. The FOMC was using the funds rate as an operating target in the 1970s. During most of the 1970s there was no widespread acceptance of the view that central banks could control long-run inflation as there is today. For a variety of reasons, policymakers believed that the Fed's ability to control inflation was limited (e.g., Nelson, 2005; Romer and Romer, 2002; and Thornton, 2010). More importantly, the FOMC was attempting to manipulate aggregate demand by affecting the growth rate of monetary aggregates, not by setting a target for the funds rate. Meulendyke (1998) describes the Fed's funds rate operating procedure during the 1970-79 period this way:

The techniques for setting and pursuing money targets developed gradually during the decade, with frequent experimentation and modification of procedures taking place in the first few years of the 1970s. Nonetheless, until October 1979 the framework used by the FOMC for guiding open market operations generally included setting a monetary objective and encouraging the Federal funds rate to move gradually up or down if money was exceeding or falling short of the objective. The Federal funds rate, as an indicator of money market conditions, became the primary guide to day-to-day open market operations, and free reserves took a secondary role.<sup>17</sup>

The FOMC had a tolerance range for the funds rate that ranged between 50 and 150 basis points. The tolerance range was adjusted at FOMC meetings.<sup>18</sup> The Trading Desk of the Federal Reserve Bank of New York (hereafter, Desk) used the funds rate as an indicator of conditions in the reserve market to guide open market operations. The midpoint of the tolerance range was not set to achieve specific FOMC policy objectives. In conducting daily open market operations, the Desk sought to keep the funds rate in a narrower range of about 25 basis. If the funds rate began trading high relative to expectations the Desk would inject reserves: If it was low relative to expectations, reserves were drained. If the funds rate was persistently high or low relative to expectations, the “target” was adjusted up or down.

Rudebusch (1995ab) used the Desk’s funds rate operating objective to create a daily funds rate “target.” The target, which was inferred from the weekly report of the Desk, is shown in Figure 5. Consistent with the idea that the Desk used the funds rate as an operating objective, Rudebusch’s (1995ab) target was adjusted frequently, 99 times during the period September 1974 to September

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<sup>17</sup> Meulendyke (1998), pp. 44-45.

<sup>18</sup> See the annual review of the FOMC published in the Federal Reserve Bank of St. Louis *Review* from 1975 through 1979.

1979—an average of an adjustment every 2.5 weeks. The FOMC’s tolerance range was also adjusted frequently, about once every 35 days. Such frequent adjustments are inconsistent with using the funds rate as a policy target. Moreover, despite the frequent adjustments, differences of the funds rate from Rudebusch’s (1995ab) target were relatively large. The average absolute monthly difference of the funds rate from the funds rate objective was 13 basis points, with a standard deviation of 28 basis points.<sup>19</sup>

The frequent adjustments to the funds rate operating target and the fact that the funds rate deviate significantly from the midpoint of the target ranges, suggest that the funds rate was responding to news about economic fundamentals in much the same way as other market rates. Consequently, there should be no marked change in the relationship between changes in the funds rate and changes in the 10-year Treasury yield during this period. Nevertheless, to test whether the relationship between the funds rate and the 10-year yield occurred before the late 1980s, the Andrews’ (1993) test was applied to a regression of the change in the 10-year Treasury yield on the change in the funds rate using monthly data from January 1974 through March 2007. Consistent with the above analysis, the test indicates a statistically significant break at May 1988. There is no indication of a break in the relationship during the 1970s or in the late 1970s when the FOMC led by Chairman Volcker put greater emphasis on monetary aggregates in the implementation of monetary policy.

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<sup>19</sup> The average absolute difference between the funds rate and the midpoint of the FOMC’s tolerance range was 22 basis points and the standard deviation of the difference was 37 basis points.

## **5.2 Funds Rate Targeting in the 1980s**

Officially, the FOMC replaced its nonborrowed reserves operating procedure with a borrowed reserves operating procedure when it deemphasized M1 in its monetary policy deliberations in October 1982. However, Thornton (2006) shows that, unofficially, the operating objective was the overnight federal funds rate. Initially, the FOMC using the funds rate in much the same way as it had during the 1974-1979 period. For policy purposes, the FOMC continued to focus on monetary aggregates (primarily M2 and, to a lesser extent, M3).

The FOMC shifted from using the funds rate as an operating target to using it as a policy target as policymakers became increasingly skeptical of the usefulness of monetary aggregates for policy purposes. There are numerous discussions of this skepticism in the FOMC transcripts. One of the most interesting occurred at the February 10, 1988, meeting when Greenspan noted that “there has been more data mining with the monetary aggregates in the last two years than I’ve seen with any other set of data in my whole life. And whenever you get to that, you know that there’s nothing there. We can expand away or we can contract, but I don’t think it matters.”<sup>20</sup>

Thornton (2006) documents that discussions of the extent to which the Committee was targeting the funds rate and the desirability of doing so occurred frequently in 1988. Moreover, Committee members became increasingly open about the extent to which they were focusing on the funds rate in their policy deliberations.

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<sup>20</sup> FOMC Transcript, February 10, 1988, p. 44.

The transcripts of FOMC meetings make it clear that the funds rate was being used as a policy target by early 1988. For example, on May 9, 1988, the funds rate objective was increased from 6.75 percent to 7.0 immediately following a May 6, 1988, conference call. There is no transcript of this conference call; however, the discussion at the May 17, 1988, FOMC meeting indicates that the increase was in response to concerns about inflation.<sup>21</sup> Chairman Greenspan opened the policy discussion at the May 17, 1988 meeting by noting that

at this particular stage in the cycle, if we are running into the type of acceleration and inflationary process which is at the forefront of our concerns...I don't think there is any question that the next move that we have to make is on the upside. And the only question, basically, is whether we do it now or we do it before the next FOMC meeting on the basis of certain contingencies.<sup>22</sup>

Rather than mentioning the funds rate, most FOMC participants continued to use the code suggesting incremental changes in the borrowing assumption; however, others were more candid. For example, concerned about small incremental moves in the funds rate target in the current environment, President Melzer noted:

at some point we're going to have to step out in front of this situation if everything we've heard today is correct. And that's going to take something more on the order of alternative C. The timing issue has been talked about. I would guess...that if you [Chairman Greenspan] had the benefit of all this discussion you might have moved it a full 50 basis points [referring to the 25-basis-point increase in the funds rate target on May 9], and we wouldn't get into two increments of 25 basis points.<sup>23</sup>

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<sup>21</sup> It is interesting to note that Poole, Rasche, and Thornton (2002), who examined the *Credit Market* column of the *Wall Street Journal* two days before and after changes in the Fed's funds rate objective to determine whether the market was aware that the Fed was targeting the funds rate or that the funds rate target had changed, found that "the first time in the 1980s that market participants knew that policy action occurred was May 9, 1988, when the Desk injected fewer reserves than analysts expected. This action sparked speculation that the Fed was increasing its fight against inflation, and market analysts concluded that the action would cause the funds rate to trade at 7 percent or slightly higher" (Poole, Rasche, and Thornton, 2002, p. 73).

<sup>22</sup> FOMC Transcript, May 17, 1988, p. 1. There is no available transcript for the first part of this meeting.

<sup>23</sup> FOMC Transcript, May 17, 1988, p. 10.

Greenspan summarized the Committee's views:

there seems to be a consensus for alternative B and asymmetrical language, with a fairly strong willingness—desire, if I can put it that way—to give instructions to the Chairman and the Desk to move before the next period. I would interpret that to mean that, unless we see events which clearly are contrary to the general consensus of the outlook as one hears it today, it's almost an automatic increase. There is a strong, and I think convincing, case that is being made that we should not, under any conditions, allow ourselves to get behind the power curve on this question.<sup>24</sup>

Greenspan increased the funds rate target from 7.0 to 7.25 percent on May 25.

Fears of accelerating inflation prompted the FOMC to increase the funds rate target another 250 basis points by February 24, 1989.

This shift toward using the funds rate as a policy target also corresponds well with the Asso, Kahn, and Leeson's (2010) documentation of the increased interest among Fed policymakers in the Taylor rule in the mid-1990s and the trend toward using a short-term interest rate to implement policy decisions in other central banks.

The change in the FOMC's use of the funds rate is further evidenced by the behavior of the funds rate target during the first half of 1989. Short-term market rates, such as the 3-month T-bill rate, peaked in late March 1989 and began to fall. Nevertheless, concerned about inflation, the FOMC made a small, 6.25-basis-point increase in the funds rate target on May 17, 1989. More importantly, the FOMC did not reduce the funds rate target despite a sharp drop in other rates. For example, between March 27 and June 6, 1989 (the date of the FOMC's first 25-basis-point cut in the funds rate target), the 3-month T-bill rate declined 96 basis points and the 10-year Treasury yield declined 112 basis points.

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<sup>24</sup> FOMC Transcript, May 17, 1988, p. 10.



At the conference call on June 5, 1989, Greenspan announced that he was requesting the Desk to adjust the borrowing objective to bring the funds rate down 25 basis points. In response to one Committee member's concern about the "urgency" of the move given uncertainty about inflation and the strength of the economy, Greenspan responded that his "major concerns are (a) the money supply data and (b) evidence that is emerging that the commodity price inflation is beginning to subdue."<sup>25</sup> Consistent with Greenspan's concern, Thornton (2004) notes that

total reserves decreased by \$0.89 billion during the period from February to May. This is the largest three-month decline in total reserves in the entire period from January 1959 to March 1995. This is remarkable because consecutive monthly decreases in reserves are uncommon owing to the need to increase the monetary base to meet the growing demand for currency. The effect of these actions on banks was direct and substantial. M1—which had been growing at about a 3.5% rate during the previous year—declined by \$11 billion between February and June 1989.<sup>26</sup>

The behavior of reserves and M1 also suggests that the FOMC was using the funds rate as a policy target. To maintain the target in the face of declining interest rates, the Fed had to drain a significant amount of reserves, which produced a correspondingly large decline in M1. Concerned about the effects of such an atypical decline in M1 on the real economy, Greenspan opted to adjust the funds rate target, but only when the effect of the Fed's restrictive actions on the monetary aggregates became sufficiently large.

In contrast, when questioned at the February 10, 1988, FOMC meeting about why he reduced the funds rate target by 25 basis points on January 28,

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<sup>25</sup> Transcript FOMC conference call (1989), p. 3.

<sup>26</sup> Thornton (2004), p. 494.

1988, Greenspan noted that he did so in part because “the markets were coming down on their own at that particular time—clearly trying to seek a somewhat lower market rate level,” i.e., there was an endogenous response to a change in market interest rates.<sup>27</sup>

The marked change in the Committee’s emphasis on the funds rate is further evidenced in the monthly average difference in the daily funds rate from the funds rate target present in Figure 6. The vertical line denotes May 1988. Beginning about that time, the FOMC appears to increase its control over the funds rate. The average absolute difference between the funds rate and the funds rate objective during the 65 months between January 1983 and May 1988 is 16 basis points—about the same as during the 1970s. Moreover, the funds rate objective was adjusted frequently—36 times, an average of once every 1.8 months. In contrast, the average absolute difference during the 68 months from June 1988 through January 1994 was just 7 basis points. The target was also adjusted less frequently—30 times, an average of once every 2.25 months. After the FOMC began the practice of announcing policy actions in February 1994, the absolute difference became even smaller and target changes became less frequent. The absolute average difference from February 1994 through March 2007 was just 2.6 basis points, and there were 49 target changes, an average of one every 3.25 months.

## **6.0 Empirical Tests of the FRTH**

The previous section provided documentary evidence that the FOMC began using the funds rate to implement monetary policy in the late 1980s, about

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<sup>27</sup> FOMC Transcript, February 10, 1988, p. 50.

the time of the marked change in the relationship between the funds rate and the 10-year Treasury yield. The FRTH is empirically tested in a variety of ways in this section.

### **6.1 The Relationships of the Federal Funds and Other Treasury Rates**

If the change in the relationship between the federal funds rate and the 10-year yield is a consequence of the FRTH, there should be a noticeable effect on the relationship between the federal funds rate and other Treasury rates as well. There should also be a change in the relationship between the 10-year Treasury yield and other Treasury rates, especially shorter-term rates that are likely to be more closely linked to the funds rate through arbitrage.

Figure 7 presents estimates of  $\bar{R}^2$  from 33-month rolling regressions of changes in each of five Treasury rates, the 3- and 6-month T-bill rates (*tb3* and *tb6*) and the 1, 5, and 10-year Treasury yields (*T1*, *T5*, and *T10*) on changes in the federal funds rate. The estimates are plotted on the first month in the sample. As expected, there is a noticeable decline in the estimates of  $\bar{R}^2$  in the early 1990s for each of the five Treasury rates. Estimates of  $\bar{R}^2$  for 5- and 10-year Treasury yields behave similarly, both remaining at zero after the early 1990s. The estimates for the other Treasury rates also decline dramatically and become much more variable.

Figure 8 shows the estimates of  $\bar{R}^2$  from regressions of changes in the 10-year yield on each of the other Treasury rates. The funds rate is included for comparison. There is no obvious change in the relationships with the 10-year Treasury yield until the late 1990s. The estimates of  $\bar{R}^2$  cycle around a nonzero

average level until the late 1990s, when all of the estimates decline briefly and subsequently rise. The estimates for *tb3* and *tb6* go to zero for a period at the beginning of 2000, but become positive toward the end of the sample period. The estimates for *T1* and *T5* never become negative. Indeed, the relationship between the 5- and 10-year Treasury yields is the least affected.

To investigate whether the changes noted in Figure 7 are statistically significant and to date when it- occurred, Andrews' (1993) test is applied to regressions of changes in each of the Treasury rates on changes in the funds rate. As before, the sample period is January 1983 through March 2007 and the truncation is set at 45 observations.

The Andrews test results for *tb3*, *tb6*, *T1*, and *T5* are presented in the four panels of Figure 9, along with the corresponding bootstrapped 5 percent critical value of the test under the null hypothesis. All of the tests indicated that there was a statistically significant change in the relationship with the federal funds rate that occurred at or slightly before May 1988. However, the supremum for the test occurs later, in the early 2000s, for *tb3*, *tb6*, and *T1*, about the time when the FOMC reduced its funds rate target to what was then a historically low level and kept it there for a year. For the 5-year yield, the supremum occurs at July 1989; however, there is a local peak at May 1988.

The Andrews breakpoint test was also applied to regressions of the change in the 10-year Treasury yield on the change in each of the other Treasury rates. These test results are reported in Figure 10. There is a statistically significant break in the relationship between the 10-year yield and the 3-month T-bill rate at

May 1988. The other rates have local extremums at or near May 1988; however, none is statistically significant. There is a statistically significant break between the 5- and 10-year Treasury yields that occurred at November 2002, when the FOMC reduced the target 50 basis points to 2 percent.

## 6.2 Common Trends and the Level of Rates

All of the Treasury rates trended down over the sample period. To see the effect of the change in the relationship between the 10-year yield and the funds rate on the levels of these rates, the common trend is removed by estimating Equation (2) for all six rates. The cross-equation restrictions  $\delta_1^i = \delta_1^j$  and  $\delta_2^i = \delta_2^j$ , for all  $i$  and  $j$  are imposed, but these restrictions are innocuous. The chi-square statistics for the tests of the hypotheses  $\delta_1^i = \delta_1^j$  and  $\delta_2^i = \delta_2^j$  are 1.78 and 0.25, respectively, neither is significant at conventional significance levels. Consequently, there appears to be no important or statistically significant difference in the persistent effect of latent factors on any of the six interest rates over this sample period.<sup>28</sup>

The four panels of Figure 11 plot the latent-factor-adjusted levels of  $tb3$ ,  $tb6$ ,  $T1$ , and  $T5$ , along with the latent-factor-adjusted federal funds rate. The vertical line denotes May 1988. Panel A shows no obvious break in the relationship with the 3-month T-bill rate. There is more evidence of a break in the relationship with the 6- and 1-year T-bill rates shown in panels B and C. Specifically, the tendency of the contemporaneous correspondence of peaks and troughs in the rates prior to May 1988 is replaced by a tendency of turning points

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<sup>28</sup> The results are nearly identical if the restrictions are not imposed.

in the Treasury rates to precede turning points in the funds rate. Panel D presents the latent-factor-adjusted 5-year Treasury and funds rates. This figure is very similar to Figure 4 and shows a marked change in the behavior of these rates at May 1988.

The four panels of Figure 12 present the latent-factor-adjusted 10-year Treasury yield with each of the other latent-factor-adjusted Treasury rates. The panels show a marked departure of the behavior of the 10-year yield and other rates after May 1988, with the effect being larger the shorter the term to maturity. The effect on the relationship with the 5-year yield is relatively modest. Consistent with results of Andrews' test reported above, the relationship appears to change in 2002.

### **6.3 Granger Causality**

The FRTH is based on the assumption that when the Fed is not targeting the funds rate, all rates should respond to news simultaneously. However, when the FOMC is using the funds rate to implement policy, the funds rate will respond more slowly and, hence, lag changes in market rates. Moreover, given the strength of arbitrage between the funds rate and other short-term rates, the FRTH suggests that temporal ordering of shorter-term and longer-term Treasury rates could also be affected.

These implications of the FRTH are investigated using a Granger causality test of temporal ordering. Granger causality tests were performed the latent-factor-adjusted interest rates because the common response to the latent factors will bias the test toward no Granger causality. Also, given the sensitivity of the

test to lag specification used (e.g., Thornton and Batten, 1985), the tests are performed using all possible combinations of lags from 2 to 6.

To conserve space, Table 1 presents the number of times out of the 25 lag combinations that the null hypothesis was rejected at the 5 percent significance level (the complete set of results is presented in Appendix A). The tests are performed for the periods before and after May 1988. With one exception, the Granger causality tests indicate unidirectional temporal ordering from each of the Treasury rates to the federal funds rate before and after May 1988. The exception is for the 3-month T-bill rate, where the hypothesis that the funds rate does not Granger-cause the 3-month T-bill rate was rejected at the 5 percent level for 9 of the 25 lag specifications considered after May 1988. The fact that there is unidirectional temporal ordering before May 1988 is consistent with the classical interest rate theory. Of course, it could also be a consequence of the FOMC adjusting the funds rate objective slowly in response to news even when it was using the funds rate as an operational guide for open market operations.

While not evident from Table 1, qualitatively the evidence of unidirectional causality from Treasury rates to the funds rate is much stronger after May 1988, suggesting an even slower adjustment of the funds rate when the FOMC was using the funds rate as a policy target. Consistent with the classical theory of the term structure, there is no evidence of unidirectional causality between any pair of Treasury rates before May 1988. All of the latent-factor-adjusted Treasury rates respond simultaneously to news.

After May 1988 there is evidence of unidirectional temporal ordering from longer-term Treasury rates to shorter-term Treasury rates. This is consistent with the classical belief that the structure of rates is anchored at the long end of the term structure. The hypothesis that the longer-term Treasury rate does not Granger-cause the shorter-term Treasury rate is rejected for all or most of the 25 lag specifications considered. In contrast, the null hypothesis that the shorter-term Treasury rate does not Granger-cause the longer-term Treasury rate is either never rejected or rejected much less frequently.

These findings are consistent with the FRTH. When changes in economic fundamentals drive longer-term rates higher (or lower), the movement in shorter-term Treasury rates is impeded by arbitrage, which causes shorter-term Treasury rates to adjust more slowly than they would if the FOMC was not using the funds rate as a policy target.

#### **6.4 The Effect of Target Changes**

If the FRTH is correct, the relationship between the 10-year Treasury yield and other Treasury rates also should be most affected when the funds rate target is changed. At other times the Treasury rates are more likely to respond similarly to changes in economic fundamentals. To test whether the relationships between changes in the 10-year yield and changes in other Treasury rates are affected by target changes, the equation

$$(9) \quad \Delta T10_t = \alpha + \beta^{\Delta ff^*} \Delta j_t D^{\Delta ff^*} + \beta^{no\Delta ff^*} \Delta j_t D^{no\Delta ff^*} + \eta_t,$$

is estimated for the four other Treasury rates.  $D^{\Delta ff^*}$  denotes a dummy variable that is equal to 1 during months when the funds rate target was changed and zero



otherwise.  $D^{no\Delta ff^*} = 1 - D^{\Delta ff^*}$ . Because the data are monthly,  $D^{\Delta ff^*}$  is 1 for the month following a target change when the change occurred during the last three business days of the month. Otherwise, it is one for the month when the target was changed.

Equation 9 is estimated over two sample periods: January 1983–May 1988 and June 1988–March 2007. The results for the first period are presented in panel A of Table 2. The results support the FRTH. The estimates of  $\beta^{\Delta ff^*}$  and  $\beta^{no\Delta ff^*}$  are similar for each of the four rates before May 1988. Indeed, the null hypothesis of equality is not rejected at any reasonable significance level. However, the results are very different after May 1988, when the estimates of  $\beta^{\Delta ff^*}$  are smaller than the estimates of  $\beta^{no\Delta ff^*}$ . Indeed, the null hypothesis of equality is rejected for all four rates at the 5 percent significance level or lower. Also, for the 3-month, 6-month, and 1-year rates, the hypothesis that the estimate of  $\beta^{no\Delta ff^*}$  in the second sample is equal to the estimate of  $\beta^{no\Delta ff^*}$  in the first sample period is not rejected. Hence, the relationships between changes in the 10-year Treasury yield and other Treasury rates changed after May 1988, but only during months when the FOMC adjusted its policy target.<sup>29</sup>

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<sup>29</sup> Table 3 reports the test of equality of the estimate of  $\beta^{no\Delta ff^*}$  for the second sample period with the estimate of  $\beta$  from the equation,  $\Delta T10_t = \alpha + \beta \Delta i_t + \varepsilon_t$ , estimated over the first sample period. However, the qualitative conclusions are identical if the hypothesis that the estimate of  $\beta^{no\Delta ff^*}$  for the first sample period is equal to the estimate of  $\beta^{no\Delta ff^*}$  for the second sample period.

## **6.5 The Effect of Policy Actions on the Funds Rate**

If the change in the relationship between the funds rate and Treasury rates is the consequence of the FOMC targeting the funds rate, the relationship should be affected most when the funds rate is behaving unusually because of policy considerations. There are three episodes of interest. The first is in the late 1980s, when as noted previously, the FOMC was slow to adjust its funds rate target despite marked declines in long-term and short-term rates.

The second episode occurred in the mid-to-late 1990s, when the FOMC kept the funds rate target essentially unchanged even as long-term rates declined significantly. Economic growth was strong, but despite this fact inflation relatively low and declining. Greenspan attributed the apparent aberrant behavior of inflation relative to output growth to an increase in productivity. The Committee delayed policy actions even though the forecasts of staff of the Board of Governors, which were repeatedly wrong, predicted rising inflation (e.g., Meade and Thornton, 2012). With economic growth strong and inflation subdued, policymakers were content to leave the funds rate target essentially unchanged during this period (e.g., Wheelock, 1999).

The third episode occurred in 2001. The FOMC reduced its funds rate target aggressively and maintained the target at the then historically low level of 1.0 percent from late June 2003 to late June 2004. With inflation expectations well anchored by the FOMC's implicit inflation objective, the FOMC believed it could be more aggressive in its efforts to increase employment following the 2001 recession.

Evidence that the relationship between the Treasury rates and the funds rate changed more during these periods is presented in Figure 13, which plots the 24-month rolling correlation between the latent-factor-adjusted federal funds rate and each of the latent-factor-adjusted Treasury rates plotted on the first month of the sample. The figure shows a marked decline in the correlation between the federal funds rate and each of the Treasury rates during these three episodes.<sup>30</sup>

There is also a marked decline in the correlation between the latent-factor-adjusted 10-year Treasury yield and each of the rates during these three periods. This is shown in Figure 14, which plots the 24-month rolling correlation of each of the latent-factor-adjusted rates with the latent-factor-adjusted 10-year Treasury yield. Consistent with the Andrews' test results noted previously, the most noticeable change was in the relationship between the 5- and 10-year yields which occurred when the sample includes the period when the FOMC maintained the funds rate target at 1.0 percent for more than a year.

## **6.6 The FOMC's Reaction Function**

Stopped If the FRTH is correct, there should be a marked change in the relationship between the funds rate and variables that the FOMC might respond to in setting its target for the funds rate. Most monetary policy models assume that policymakers implement policy using a Taylor-type policy rule. It is doubtful that the FOMC has ever followed such a rule or exhibited rule-like behavior (e.g., Asso et al., 2010, and Meade and Thornton, 2012). Indeed, empirical Taylor rules do not fit the data very well unless they include the lagged federal funds rate,

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<sup>30</sup> The results for 2003-2004 period are broadly consistent with Swanson and Williams' (2012) that the 3 and 6-month T-bill rates responded very differently to economic news during this period, while longer-term rates did not.

which is characterized as representing policy inertia (Woodford, 1999, 2003).

However, there is little empirical (e.g., Rudebusch, 2002, 2006, 2007) or documentary evidence (e.g., Asso et al., 2010) that monetary policy was inertial during this period.

Although the FOMC has likely never followed a policy rule per se, there is little doubt that policymakers believed that they should reduce the policy rate to promote output growth and raise it to slow output growth and/or reduce inflation (e.g., Meade and Thornton, 2012). Consequently, there should be a marked improvement in the relationship between changes in the federal funds rate and economic variables that policymakers would likely respond to after May 1988. This implication of the FRTH is investigated by estimating the following equation for periods before and after May 1988:

$$(10) \quad \Delta ff_t = \theta_0 + \theta_1 \dot{ip}_t + \theta_2 \Delta ur_t + \xi_t^i,$$

where  $\dot{ip}_t$  denotes the monthly growth rate of industrial production and  $\Delta ur_t$  denotes the monthly change in the unemployment rate.<sup>31</sup> To ensure that estimates of the equation are not simply reflecting a reduced form relationship, the equation is also estimated with  $\Delta T10$  as the dependent variable.

Estimates for periods before and after May 1988 are presented in Table 3. There is a very weak relationship between changes in the funds rate or the 10-year yield and the macrovariables before 1988. After May 1988, the macrovariables account for more than 25 percent of the variation of changes in the funds rate but,

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<sup>31</sup> The inflation rate or the inflation rate less the implied inflation target of 2.0 percent was initially included. The coefficients were negative, but never statistically significant at any reasonable significance level and, hence, not included here.

essentially none of the variation of the 10-year yield. These results are consistent with the hypothesis that the FOMC was using the funds rate as a policy instrument after May 1988 but not before.

This implication is enhanced by estimating the equation over two periods when the FOMC was aggressively changing the funds rate target for policy purposes. The first period begins in late October 1990. At its October 2, 1990, meeting the FOMC noted that “economic activity expanded at a slow pace in the third quarter...however, data available thus far provide only limited evidence of a retarding effect [of a large increase in oil prices] on production and aggregate spending.”<sup>32</sup> The FOMC voted, with four dissents, to keep the funds rate target unchanged. The FOMC’s Record of Policy Actions, notes that Governor Seger dissented “because she favored an immediate easing;” Governor Angell and Presidents Boykin and Hoskins dissented because “they were opposed to the easing of reserve conditions contemplated by the majority.”<sup>33</sup> Consistent with the discussion of the October meeting, the funds rate target was reduced by 25 basis points on October 29 in an intermeeting move and by another 25 basis points at the November 13, 1990 meeting. While there is no information about what motivated the October target change, the FOMC’s policy directive from the November meeting makes it clear that the action was taken in response to weakening economic activity, reflected in the growth rate of industrial production. Specifically, the directive noted that

The information reviewed at this meeting suggests a weakening in economic activity. Total nonfarm payroll employment declined further in

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<sup>32</sup> Federal Reserve Press Release, November 16, 1990, pp. 16 & 17.

<sup>33</sup> Record of Policy Actions of the Federal Open Market Committee, October 2, 1990, p. 18.

October, reflecting sizable job losses in manufacturing and construction; the civilian unemployment rate held steady at 5.7 percent. Industrial production declined sharply in October after rising moderately during the summer.<sup>34</sup>

The funds rate target was decreased from 8 percent to 3 percent from October 1990 to September 1992. The Committee maintained the target at 3 percent until February 1994 when it began increasing the target. The target was raised by 300 basis points from February 1994 to February 1995.

Estimates of Equation (10) for the period December 1990–February 1995, reported in the bottom section of Table 3, show that estimates of  $\theta_1$  and  $\theta_2$  are highly statistically significant with the expected signs. Moreover, these variables account for nearly half of the variation of changes in the funds rate. As before, these variables account for essentially none of the variation in the 10-year Treasury yield.

The second period begins on January 3, 2001, when the Committee made a 50-basis-point intermeeting cut in the funds rate target. The FOMC noted that “these actions were taken in light of further weakening of sales and production, and in the context of lower consumer confidence.”<sup>35</sup> The FOMC acted aggressively, cutting the target by 200 basis points by mid-May. The funds rate was further reduced over time to the then historically low of 1.0 percent on June 25, 2003. In announcing the last cut, the FOMC stated its belief that “an accommodative stance of monetary policy, coupled with still robust underlying growth in productivity, is providing important ongoing support to economic

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<sup>34</sup> Federal Reserve Press Release, December 21, 1990, pp. 13-14.

<sup>35</sup> Federal Reserve Press Release, January 3, 2001.

activity.”<sup>36</sup> The target was maintained at 1.0 percent until late June 2004, when the FOMC made the first of 17 consecutive 25-basis-point increases in the target, the last coming on June 29, 2006.

Estimates of Equation (10) over the period February 2001-June 2006 shows that changes in the federal funds rate are positively and significantly related to the growth of industrial production and negatively, though not significantly, related to the unemployment rate. Importantly, the equation accounts for more than 50 percent of the variation of changes in the funds rate, but almost none of the variation in the 10-year Treasury yield.

These results support the conclusion obtained from the FOMC transcripts—namely, that the FOMC was targeting the funds rate and changing the target in response to changes in economic activity in furtherance of its economic stabilization objective, i.e., these results support the FRTH.

## **6.7 Other Central Banks**

If the FRTH is correct, there should be a similar change in the relationship between the policy rate and long-term yields when other central banks began using a short-term rate as the policy instrument. This section presents evidence for the Bank of England (BoE) and the Reserve Bank of New Zealand (RBNZ). These banks are chosen because the data are readily available and the dates of when they began using the short-term rate as a policy target are well documented.

Like the Federal Reserve, the BoE was targeting monetary aggregates until the late 1970s. Finding that monetary aggregates were increasingly less reliable guides for output and inflation, the BoE shifted its emphasis to “a broad

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<sup>36</sup> Federal Reserve Press Release, June 25, 2003.

range of economic indicators.”<sup>37</sup> Changes in the stance of monetary policy were accompanied by changes in the BoE’s official policy rate (i.e., the bank lending rate). The BoE increased the emphasis on its policy rate in conducting monetary policy over time. Unlike the Fed, the BoE had an exchange rate target, which constrained monetary policy. Policy was further constrained in 1990 when the United Kingdom entered the European Exchange Rate Mechanism (ERM). In 1992 the BoE noted that “differences in economic conditions across Europe created tensions between setting the interest rate to maintain the exchange rate and that required for the domestic economy.” The United Kingdom withdrew from the ERM in September 1992 and the BoE began using the policy rate to implement policy.

The FRTH suggests that there should have been a marked change in the relationship between changes in the 10-year yield on gilts and changes in the policy rate about this time. Figure 15 shows the estimates of  $\bar{R}^2$  from a 50-month rolling regression of the change in the 10-year yield on sovereign debt and changes in the policy rate from January 1972 through June 2007. The data are plotted on the first month in the sample; the vertical line denotes October 1992. The BoE’s experience is consistent with the FRTH. The relatively strong and statistically significant relationship between changes in the 10-year yield and changes in the BoE’s policy rate vanished beginning September 1992.

Until the mid-to-late 1990s the RBNZ used an eclectic approach to implementing monetary policy (Huxford and Reddell, 1996). In March 1997 the

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<sup>37</sup> See the Bank of England website (<http://www.bankofengland.co.uk/education/Pages/targettwopointzero/mpframework/monetarypolicyinuk.aspx>) for a discussion of the evolution of policy over time.



RBNZ made a proposal to implement policy by targeting the overnight cash rate. This policy was implemented in March 1999. If the FRTH is correct there should be a marked change in the relationship between the 10-year yield on government securities and the cash rate at about this time.

Figure 16 shows the estimates of  $\bar{R}^2$  from a 50-month rolling regression of the change in the 10-year government bond yield and the change in the overnight cash rate for the period January 1986 - May 2012. The data are plotted on the first observation in the sample and the vertical line denotes March 1999. There is a relatively weak and variable relationship between changes in the 10-year yield and changes in the cash rate prior to March 1999. Nevertheless, the estimate of  $\bar{R}^2$  drops to zero a few months before March 1999. The estimate of  $R^2$  increases dramatically around Lehman Bros.' bankruptcy announcement, but then falls back to zero. The sharp rise is associated with Lehman Bros.' announcement when the 10-year yield and the cash rate responded similarly for a few months. This is illustrated in Figure 17 which shows the change in the 10-year yield and the change in the cash rate from March 1999 through May 2012. The two rates moved independently except for the 5 months from September 2008 through January 2009, when the rates move together. When the equation is estimated over the entire period March 1999 through May 2012 the relationship is relatively weak. The estimate of  $\beta$  is 0.13 with a  $t$ -statistic of 1.25 and  $R^2$  of 0.015. The relationship is much weaker, however, the September 2008-January 2009 observations are deleted; the estimates of  $\beta$  and  $\bar{R}^2$  are  $-0.05$  and  $-0.003$ , respectively. Hence, the RBNZ's experience is also consistent with the FRTH:

There was a weak but statistically significant relationship between the 10-year government yield and the cash rate that vanished when the RBNZ began using the cash rate as its policy instrument.

## **7.0 Conclusions**

In February 2005 Alan Greenspan observed that the 10-year Treasury yield had declined somewhat despite the fact that the FOMC had increased its target for the funds rate by 150 basis points. Moreover, the 10-year yield remained essentially unchanged little despite the fact the FOMC increased the funds rate target by an additional 250 basis points. This paper investigates why the 10-year Treasury yield change little despite a 400 basis point increase in the funds rate by analyzing the relationship between changes in the 10-year Treasury yield and changes in the funds rate since the early 1980s. The results of this investigation are surprising: There was a relatively strong and statistically significant relationship between changes in the 10-year yield and changes in the funds rate in the early 1980s that vanished by the late 1980s. The fact that changes in the 10-year yield and changes in the funds rate were uncorrelated went unnoticed for nearly two decades for so long. The failure to notice the marked change in the relationship between the 10-year yield and the funds rate appears to be due to the fact that the levels of the rates had common trends. When the common trend is removed from the levels of the rates, the change that occurred in the late 1980s is clearly visible in the detrended levels of the rates.

I hypothesize that the change in the relationship between the funds rate and the 10-year yield occurred when the FOMC began using the funds rate to

implement policy in the late 1980s. The use of the federal funds rate as a policy instrument caused the funds rate to be determined by monetary policy consideration and not by economic fundamentals as before. The 10-year Treasury yield was unaffected by this change and continued to be determined by economic fundamentals. Hence, the relationship between changes in the 10-year Treasury yield and changes in the federal funds rate vanished. This hypothesis is supported by a variety of documentary and empirical evidence, including the experiences of the BoE and the Reserve Bank of New Zealand.

This paper shows that the marked improvement in the Fed's control over the federal funds rate since the late 1980s has not been accompanied by an improvement in its ability to affect longer-term yields as the EH and modern macroeconomic theory (Woodford, 1999, 2003) suggests. Indeed, the evidence supports the classical theory, which hypothesizes that real long-term yields are determined by economic fundamentals independent of monetary policy. The paper's findings and the classical theory of interest are consistent with lack of empirical support for central banks' forward guidance policies (Goodhart and Lim, 2008; Rudebusch, 2007; Andersson and Hofmann, 2010; and Kool and Thornton, 2012) and by Swanson and Williams' (2012) finding that the response of yields on Treasuries with maturities of 2 years or longer to macroeconomic news did not change after the FOMC adopted a zero interest rate policy.

The major implication of this research is that the Fed's interest rate policy may be much less effective than previously thought. This implication appears to

be borne out by the Fed's monetary policy experience since the beginning of the financial crisis.

## References

- Andersson, M. and B. Hofmann. 2010, "Gauging the Effectiveness of Central Bank Forward Guidance," in *Twenty Years of Inflation Targeting*, Cambridge University Press, Cambridge, U.K.
- Andrews, D.W.K. 1993, "Testing for Parameter Instability and Structural Change with Unknown Change Points," *Econometrica* 61, 821-56.
- Ang, A., G. Bekaert, M. Wei. (2008), "The Term Structure of Real Rates and Expected Inflation," *Journal of Finance*, 63(2), 797-849.
- Asso, P.F., G.A. Kahn, and R. Leeson. 2010, "The Taylor Rule and the Practice of Central Banking," Federal Reserve Bank of Kansas City Working paper No. 10-05.
- Backus, D.K., and J.H. Wright. 2007, "Cracking the Conundrum," *Brookings Papers on Economic Activity*, (1), 293-329.
- Bekaert, G., and R.J. Hodrick. 2001, "Expectations Hypotheses Tests," *Journal of Finance*, 56, 1357-94.
- Bernanke, Ben S. 2004, "The Great Moderation." Presented at the meeting of the Eastern Economic Association, Washington, DC, February 20, 2004; [www.federalreserve.gov/Boarddocs/Speeches/2004/20040220/default.htm](http://www.federalreserve.gov/Boarddocs/Speeches/2004/20040220/default.htm)
- Bernanke, B.S. 2005, "The Global Saving Glut and the U.S. Current Account Deficit," Homer Jones Lecture, Federal Reserve Bank of St. Louis, St. Louis, Missouri, April 14, 2005, <http://www.federalreserve.gov/boarddocs/speeches/2005/20050414/default.htm>.
- Bernanke, B.S., V.R. Reinhart, and B.P. Sack. 2004, "Monetary Policy Alternatives at the Zero Bound: An Empirical Assessment," *Brookings Papers on Economic Activity*, 1-78.
- Campbell, J.Y., and R.J. Shiller. 1991, "Yield Spreads and Interest Rate Movements; A Bird's Eye View," *Review of Economic Studies*, 58, 495-514.
- Chrystal, K.A. and P.D. Mizen. 2003, "Goodhart's Law: Its Origins, Meaning and Implications for Monetary Policy," in *Central Banking, Monetary Theory and Practice, Essays in Honour of Charles Goodhart*, Volume 1, Paul Mizen, ed., Edward Elgar.

- Cook, T., and T. Hahn. (1989). "The Effect of Changes in the Federal Funds Rate Target on Market Interest Rates in the 1970s," *Journal of Monetary Economics*, 24(3), pp. 331-51.
- Diebold, F. and C. Chen. 1996, "Testing Structural Stability With Endogenous Breakpoint: A Size Comparison Of Analytic And Bootstrap Procedures." *Journal of Econometrics*, 70, 221-41.
- Federal Open Market Committee Transcript, February 10, 1988.
- Federal Open Market Committee Transcript, May 17, 1988.
- Federal Reserve *Press Release*, November 16, 1990.
- Federal Reserve *Press Release*, December 21, 1990.
- Federal Reserve *Press Release*, January 3, 2001.
- Federal Reserve *Press Release*, June 25, 2003.
- Fuhrer, J.C. 1996, "Monetary Policy Shifts and Long-Term Interest Rates. *The Quarterly Journal of Economics*, 111, 1183–1209.
- Goodhart, C.A.E. 1975, "Monetary Relationships: A View from Threadneedle Street," in *Paper in Monetary Economics*, Volume 1, Reserve Bank of Australia.
- Goodhart, C.A.E., and W.B. Lim. 2008, "Interest Rate Forecasts: A Pathology, Financial Market Group Discussion Papers, dp 612.
- Guidolin, M. and D.L. Thornton. 2012, "Predicting Short-Term Rates and the Expectations Hypothesis," Federal Reserve Bank of St. Louis Working Paper 2110-013A, revised 2012.
- Humphrey, Thomas M. 1983a, "The Early History of the Real/Nominal Interest Rate Relationship." Federal Reserve Bank of Richmond *Economic Review*, 2-10.
- Humphrey, Thomas M. 1983b, "Can the Central Bank Peg Real Interest Rates? A Survey of Classical and Neoclassical Opinion." Federal Reserve Bank of Richmond *Economic Review*, 12-21.
- Huxford, J., and R. Reddell. 1996, "Implementing Monetary Policy in New Zealand," *Reserve Bank Bulletin*, 59(4), 309-22.

- Kim, D.H. and A. Orphanides. 2005, "Term Structure Estimation with Survey Data on Interest Rate Forecasts," Board of Governors of the Federal Reserve, Finance and Economics Discussion Series, 2005-48.
- Kim, D.H. and J.H. Wright. 2005, "An Arbitrage-Free Three-Factor Term Structure Model and Recent Behavior of Long-Term Yields and Distant-Horizon Forward Rates," Finance and Economics Discussion Series, 2005-33, Board of Governors of the Federal Reserve.
- Kool, C.J.M., and D.L. Thornton. 2012, "How Effective is Central Bank Forward Guidance?" unpublished manuscript.
- Kool, C.J.M., and D.L. Thornton. 2004, "A Note On The Expectations Hypothesis At The Founding Of The Fed," *Journal of Banking and Finance*, 28(12), 3055-68.
- Kozicki, S. and P.A. Tinsley. 2001, "Shifting endpoints in the term structure of interest rates," *Journal of Monetary Economics*, 47, 613-52.
- Kozicki, S. and P.A. Tinsley. 2005, "What Do You Expect? Imperfect Policy Credibility and Tests of the Expectations Hypothesis," *Journal of Monetary Economics*, 52, 421-47.
- Kuttner, K.N. 2006, "The Bond Yield 'Conundrum' from a Macro-Finance Perspective: Comment," *Monetary and Economic Studies*, Special Edition, December, Bank of Japan, 120-27.
- McConnell, M. and G. Perez Quiros. 2000, "Output Fluctuations in the United States: What Has Changed Since the Early 1980s?" *American Economic Review*, 90, 1464-76.
- Meade, E.E., and D.L. Thornton. 2012, "The Phillips Curve and US Monetary Policy: What the FOMC Transcripts Tell Us," *Oxford Economic Papers*, 64, 197-216
- Meulendyke, A-M. 1998, *U.S. Monetary Policy & Financial Markets*, Federal Reserve Bank of New York.
- Nelson, E. 2005, "The Great Inflation of the Seventies: What Really Happened?" *B.E. Journal of Macroeconomics: Advances in Macroeconomics*, 5, Iss.1, Article 3.
- Poole, W., R.H. Rasche, and D.L. Thornton. 2002, "Market Anticipations of Monetary Policy Actions," *Federal Reserve Bank of St. Louis Review*, 84, 65-94.

- Romer, C.D., and D. Romer. 2002, “The Evolution of Economic Understanding and Postwar Stabilization Policy Perspective,” in *Rethinking Stabilization Policy*, a Symposium Sponsored by the Federal Reserve Bank of Kansas City, August 29-31, 2002.
- Rosenburg, J. 2007, “Interpreting the Decline in Long-Term Interest Rates,” Internal memo, Board of Governors of the Federal Reserve.
- Rudebusch, G.D. 1995a, “Federal Reserve Interest Rate Targeting, Rational Expectations, and the Term Structure,” *Journal of Monetary Economics*, 245-74.
- Rudebusch, G.D. 1995b, “Erratum,” *Journal of Monetary Economics*, 679.
- Rudebusch, G.D., 2002, “Term Structure Evidence on Interest Rate Smoothing and Monetary Policy Inertia,” *Journal of Monetary Economics*, 49, 1161-1187.
- Rudebusch, G.D., 2006, “Monetary Policy Inertia: Fact or Fiction?” *International Journal of Central Banking*, 2, 85-135.
- Rudebusch, G.D. 2007, ‘Monetary Policy Inertia and Recent Fed Actions’, Federal Reserve Bank of San Francisco *Economic Letter*, No. 2007-03.
- Rudebusch, G.D. and T. Wu. 2007, “Recent Shifts in Term Structure Behavior from a No-arbitrage and Macro-Finance Perspective,” *Journal of Money, Credit, and Banking*, 39(2), 395-422.
- Rudebusch, G.D., E.T. Swanson, and T. Wu. 2006, “The Bond Yield ‘Conundrum’ from a Macro-Finance Perspective,” *Monetary and Economic Studies*, Special Edition, December, Bank of Japan, 83-109.
- Sarno, L., D.L. Thornton, and G. Valente. 2007, “The Empirical Failure of the Expectations Hypothesis of the Term Structure of Bond Yields,” *Journal of Financial and Quantitative Analysis*, 42(1), 81-100.
- Smith, J. M. and J.B. Taylor. 2009, “The Term Structure of Policy Rules,” *Journal of Monetary Economics*, 56, 907-17.
- Swanson, E.T., and J.C. Williams. 2012, “Measuring the Effect of the Zero Lower Bound on Medium- and Longer-Term Interest Rates” unpublished manuscript, Federal Reserve Bank of San Francisco.
- Testimony of Chairman Alan Greenspan. 2005, Federal Reserve Board’s Semiannual Monetary Policy Report to the Congress, Before the Committee on Banking, Housing, and Urban Affairs, U.S. Senate, February 16, 2005.



- <http://www.federalreserve.gov/Boarddocs/hh/2005/february/testimony.htm>
- Thornton, D.L. 2010, "The Evolution to Inflation Targeting in the U.S.: How Did We Get Here and Where Do We Need to Go?" in *Twenty Years of Inflation Targeting*, Cambridge University Press, Cambridge, U.K.
- Thornton, D.L. 2007, "The Lower and Upper Bounds of the Federal Open Market Committee's Long-Run Inflation Objective," *Federal Reserve Bank of St. Louis Review*, 89, 183-93.
- Thornton, D.L. 2006, "When Did the FOMC Begin Targeting the Federal Funds Rate? What the Verbatim Transcripts Tell Us," *Journal of Money, Credit, and Banking*, 38, 2039-71.
- Thornton, D.L. 2005, "Tests of the Expectations Hypothesis: Resolving the Anomalies When the Short-Term Rate Is the Federal Funds Rate," *Journal of Banking and Finance*, 29, 2541-56.
- Thornton, D.L. 2004, "The Fed and Short-term Interest Rates: Is It Open Market Operations, Open Mouth Operations or Interest Rate Smoothing," *Journal of Banking and Finance*, 28, 475-98.
- Thornton, D.L., and C.J.M. Kool. 2004, "A Note on the Expectations Hypothesis at the Founding of the Fed," *Journal of Banking and Finance*, 28, 3055-68.
- Thornton, D.L., and D.S. Batten. 1985, "Lag Length Selection and Tests of Granger Causality Between Money and Income," *Journal of Money, Credit and Banking*, 17, 164-78.
- Transcript of FOMC Conference Call. 1989, "Federal Open Market Committee Conference Call, May 31, 1989;" <http://www.federalreserve.gov/monetarypolicy/files/FOMC19890531confcall.pdf>.
- Wheelock, D.C. 1999, "The FOMC in 1998: Can It Get Any Better Than This?" *Federal Reserve Bank of St. Louis Review*, 81, 11-22.
- Woodford, M. 1999, "Optimal Monetary Policy Inertia," *The Manchester School*, 67 (special supplement), 1-35.
- Woodford, M. 2003, *Interest and Prices: Foundations of a Theory of Monetary Policy*, Princeton University Press, Princeton, N.J.

Table 1: Estimates of Equation (1) Using Quarterly Data: 1983Q1 - 2007Q1			
Coef.	1983Q1 - 2007Q1	1983Q1 - 1994Q4	1995Q1 - 2007Q1
$\alpha$	-0.045 (0.05)	-0.010 (0.08)	-0.065 (0.06)
$\beta$	0.400* (0.08)	0.573* (0.10)	0.081 (0.08)
$\bar{R}^2$	0.197	0.384	0.000

\* indicates statistical significance at the 5 percent level or lower. HAC standard errors in parentheses.

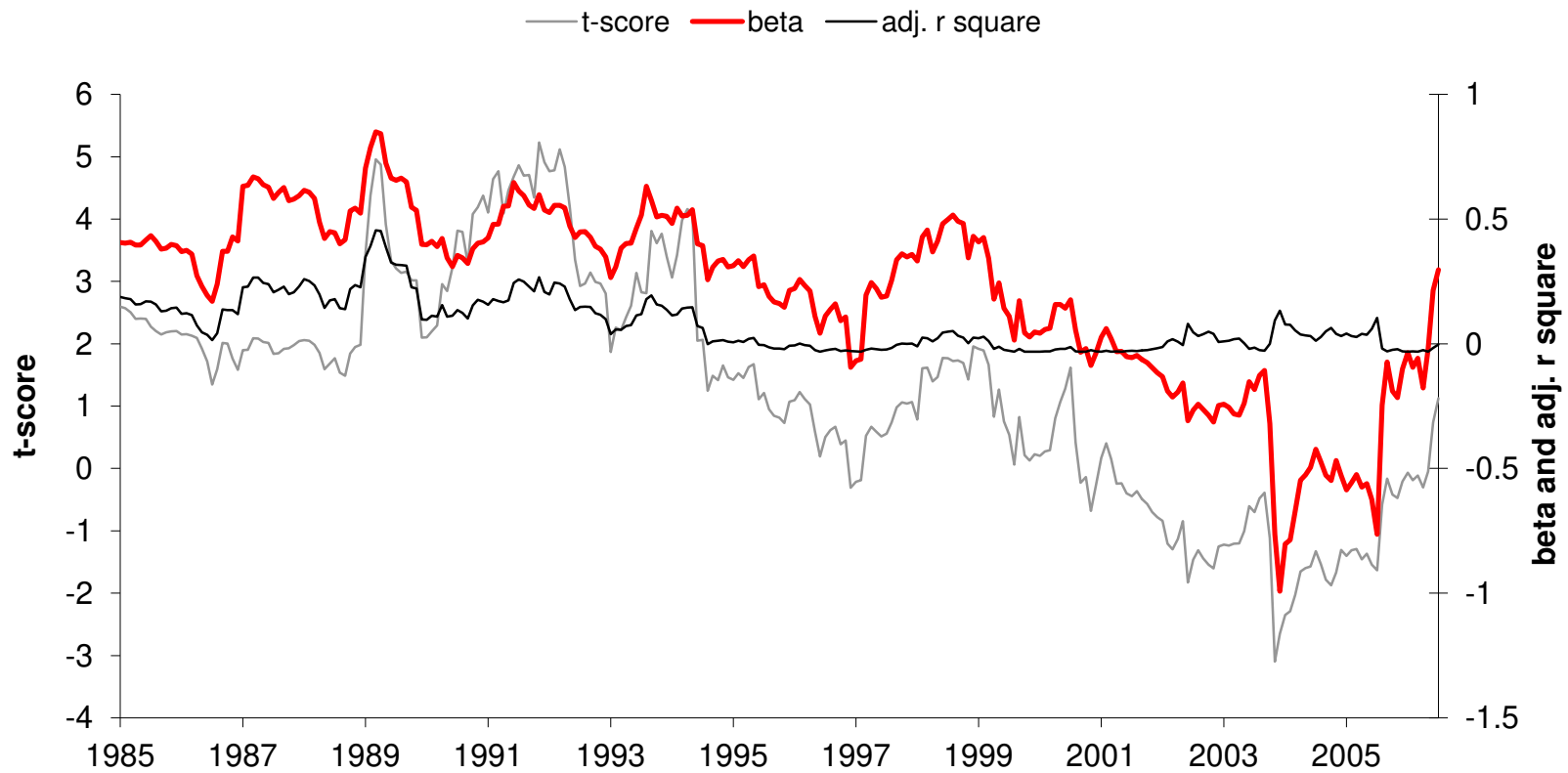
Table 2: Frequency Results for Granger Causality Test					
	<i>ff</i>	<i>tb3</i>	<i>tb6</i>	<i>T1</i>	<i>T5</i>
January 1983 – May 1988					
hypothesis	The column rate does not Granger cause the row rate				
<i>tb3</i>	0				
<i>tb6</i>	0	0			
<i>T1</i>	0	0	0		
<i>T5</i>	0	0	0	0	
<i>T10</i>	0	0	0	0	0
hypothesis	The row rate does not Granger cause the column rate				
<i>tb3</i>	25				
<i>tb6</i>	25	0			
<i>T1</i>	25	0	0		
<i>T5</i>	25	0	0	0	
<i>T10</i>	25	0	0	0	0
June 1988 – March 2007					
hypothesis	The column rate does not Granger cause the row rate				
<i>tb3</i>	9				
<i>tb6</i>	0	8			
<i>T1</i>	0	0	0		
<i>T5</i>	0	4	7	9	
<i>T10</i>	0	0	0	0	3
hypothesis	The row rate does not Granger cause the column rate				
<i>tb3</i>	25				
<i>tb6</i>	25	25			
<i>T1</i>	25	25	19		
<i>T5</i>	25	8	15	24	
<i>T10</i>	25	10	16	25	20

Table 3: Estimates of Equation 9							
Panel A: January 1983--May 1988							
	$\alpha$	$\beta^{\Delta ff^*}$	$\beta^{no\Delta ff^*}$	$\overline{R}^2$	s.e.	Test 1	Test 2
$\Delta tb3$	-0.0011 (0.9760)	0.7243 (0.0000)	0.6268 (0.0205)	0.3702	0.2989	0.1101 (0.7400)	
$\Delta tb6$	-0.0058 (0.8518)	0.7627 (0.0000)	0.8699 (0.0000)	0.5917	0.2407	0.2998 (0.5840)	
$\Delta T1$	-0.0049 (0.8407)	0.8221 (0.0000)	0.8795 (0.0000)	0.7452	0.1901	0.1706 (0.6796)	
$\Delta T5$	-0.0002 (0.9819)	0.9185 (0.0000)	0.9906 (0.0000)	0.9699	0.0654	2.5344 (0.1114)	
Panel B: June 1988--March 2007							
$\Delta tb3$	-0.0203 (0.1360)	0.3788 (0.0000)	0.6772 (0.0000)	0.1785	0.2025	3.8497 (0.0498)	0.0490 (0.8250)
$\Delta tb6$	-0.0206 (0.0865)	0.4508 (0.0000)	0.9618 (0.0000)	0.3625	0.1784	16.6507 (0.0000)	2.6399 (0.1056)
$\Delta T1$	-0.0173 (0.0906)	0.5210 (0.0000)	0.9472 (0.0000)	0.5353	0.1523	21.7755 (0.0000)	2.2813 (0.1324)
$\Delta T5$	-0.0048 (0.2247)	0.7956 (0.0000)	0.8914 (0.0000)	0.9286	0.0597	8.9015 (0.0028)	5.8566 (0.0163)

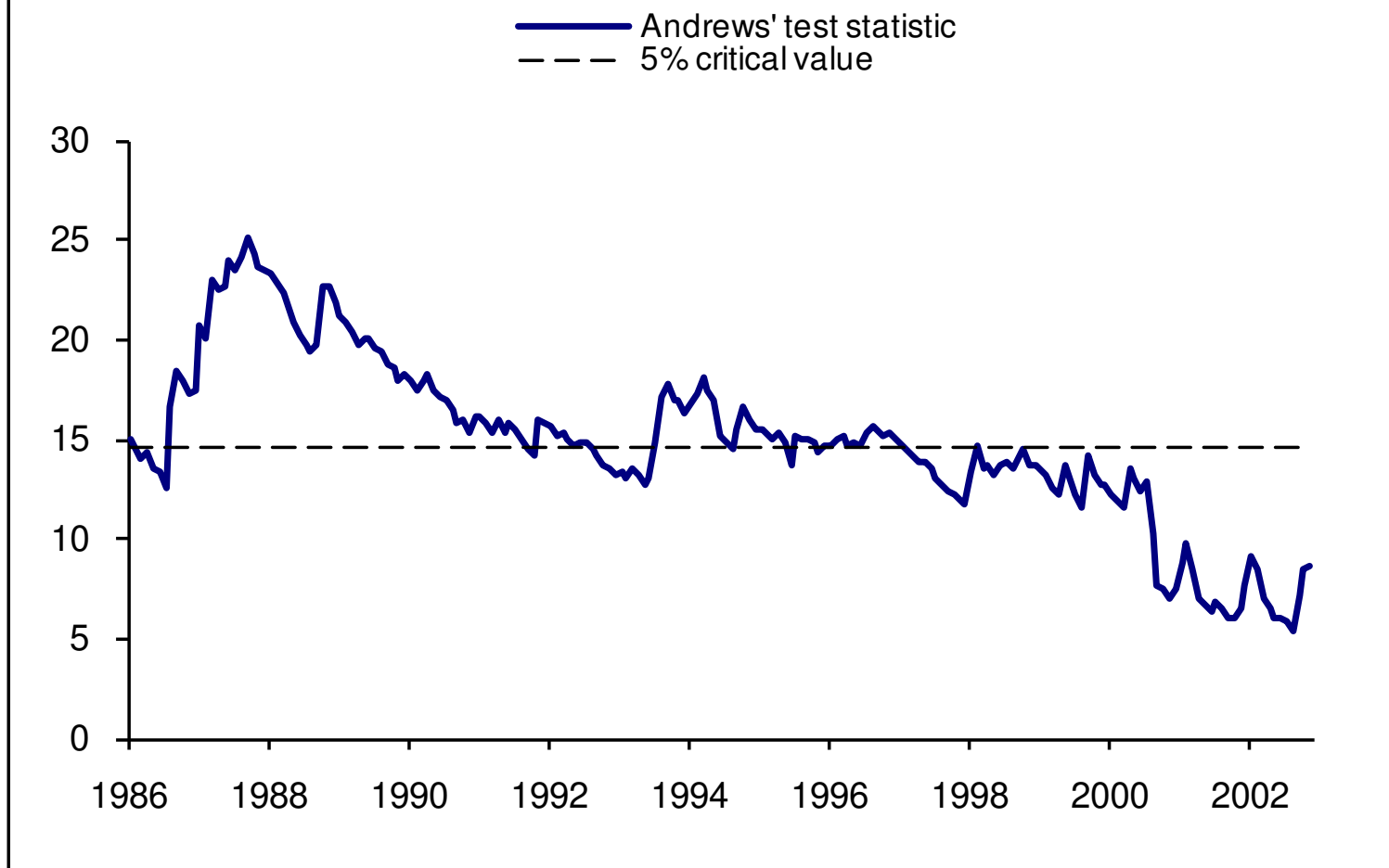
Test 1 is a chi-square test of the null hypothesis that  $\beta^{\Delta ff^*} = \beta^{no\Delta ff^*}$  within the sample period. Test 2 is a chi-square test of the null hypothesis that the estimate of  $\beta^{no\Delta ff^*}$  in the June 1988 – March 2007 is equal to the estimate of the relationship for the January 1983 – May 1988 sample period.

Table 4: Estimates of the Policy Reaction Function				
Dependent Variable	$\Delta ff$	$\Delta T10$	$\Delta ff$	$\Delta T10$
	January 1983 – May 1988		June 1988 – March 2007	
$\theta_0$	-0.116 (0.043)	-0.121 (0.085)	-0.098 (0.000)	-0.017 (0.452)
$\theta_1$	0.014 (0.193)	0.018 (0.112)	0.033 (0.000)	-0.001 (0.796)
$\theta_2$	-0.379 (0.084)	-0.317 (0.131)	-0.173 (0.060)	-0.119 (0.333)
$\bar{R}^2$	0.040	0.040	0.271	-0.004
	December 1990 – February 1995		February 2001 – June 2006	
$\theta_0$	-0.159 (0.004)	-0.045 (0.325)	-0.061 (0.054)	0.012 (0.718)
$\theta_1$	0.045 (0.001)	0.010 (0.364)	0.054 (0.001)	-0.011 (0.297)
$\theta_2$	-0.427 (0.037)	-0.161 (0.459)	-0.088 (0.741)	-0.553 (0.071)
$\bar{R}^2$	0.446	-0.007	0.516	0.037

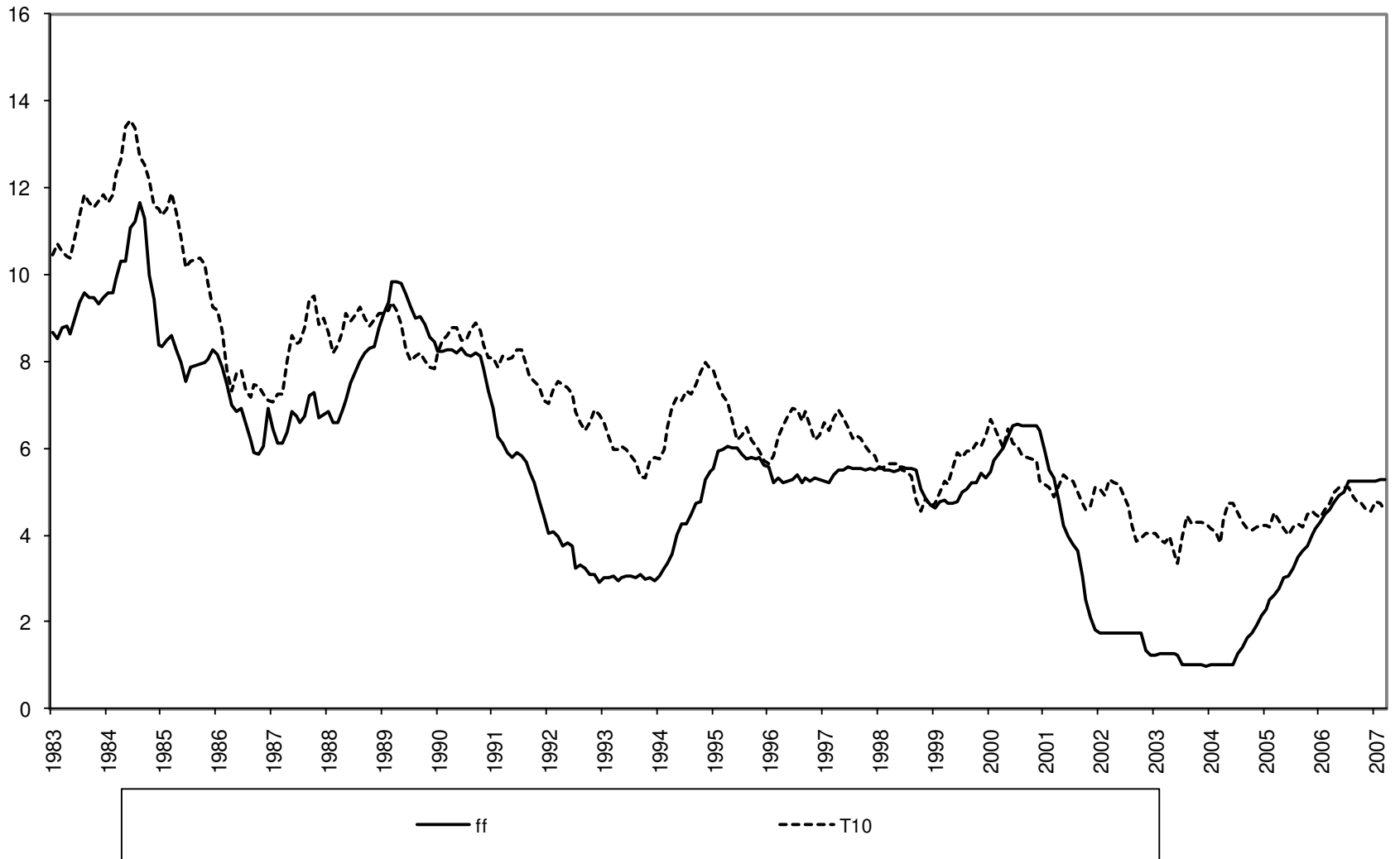
**Figure 1: 33-Month Rolling Regression of the Change in the 10-year Treasury on the Change in the Federal Funds Rate**



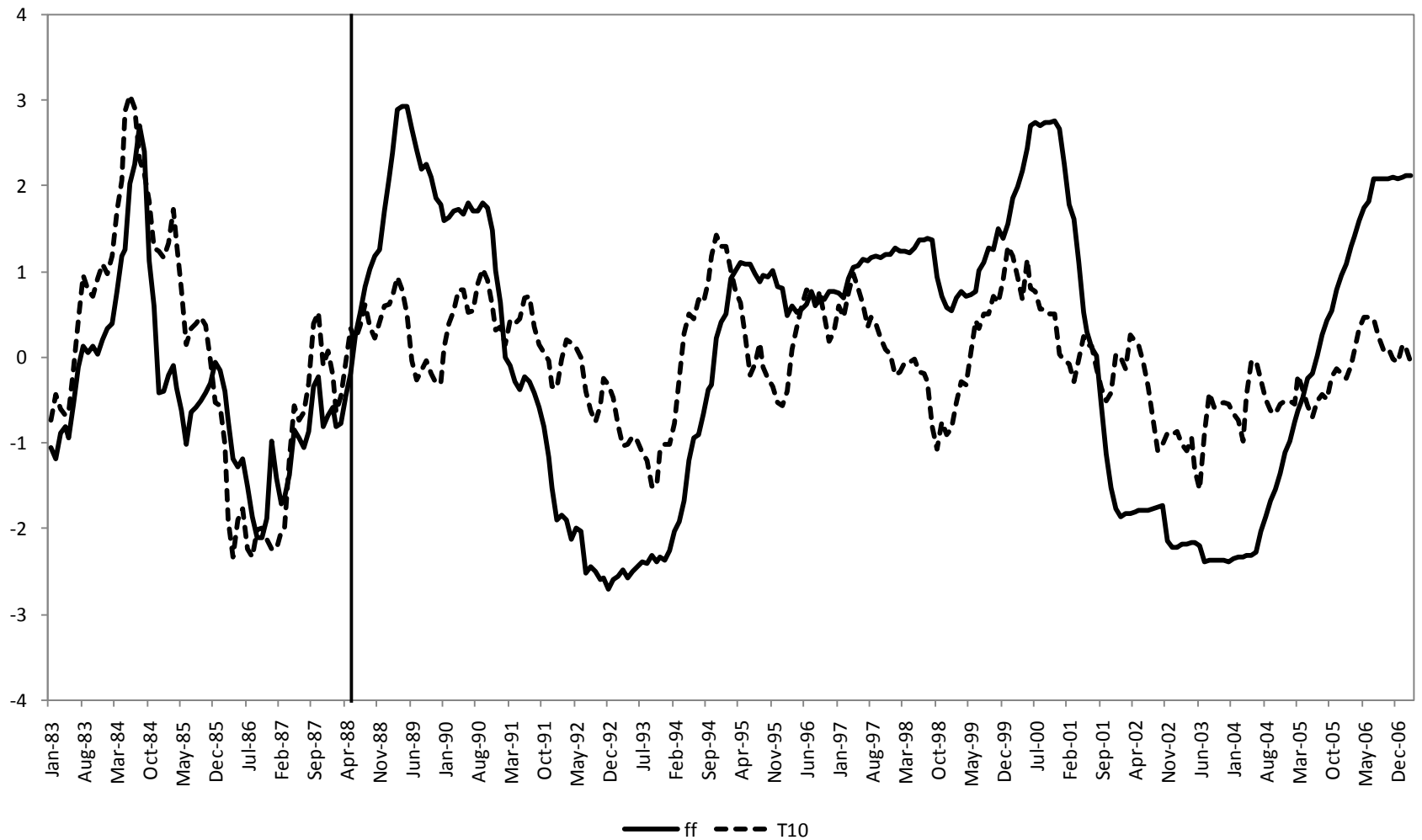
**Figure 2: Andrews' Break Point Test of 10-year Treasury on the Federal Funds Rate**



**Figure 3: The Federal Funds and 10-Year Treasury Rates,  
January 1983 - March 2007**

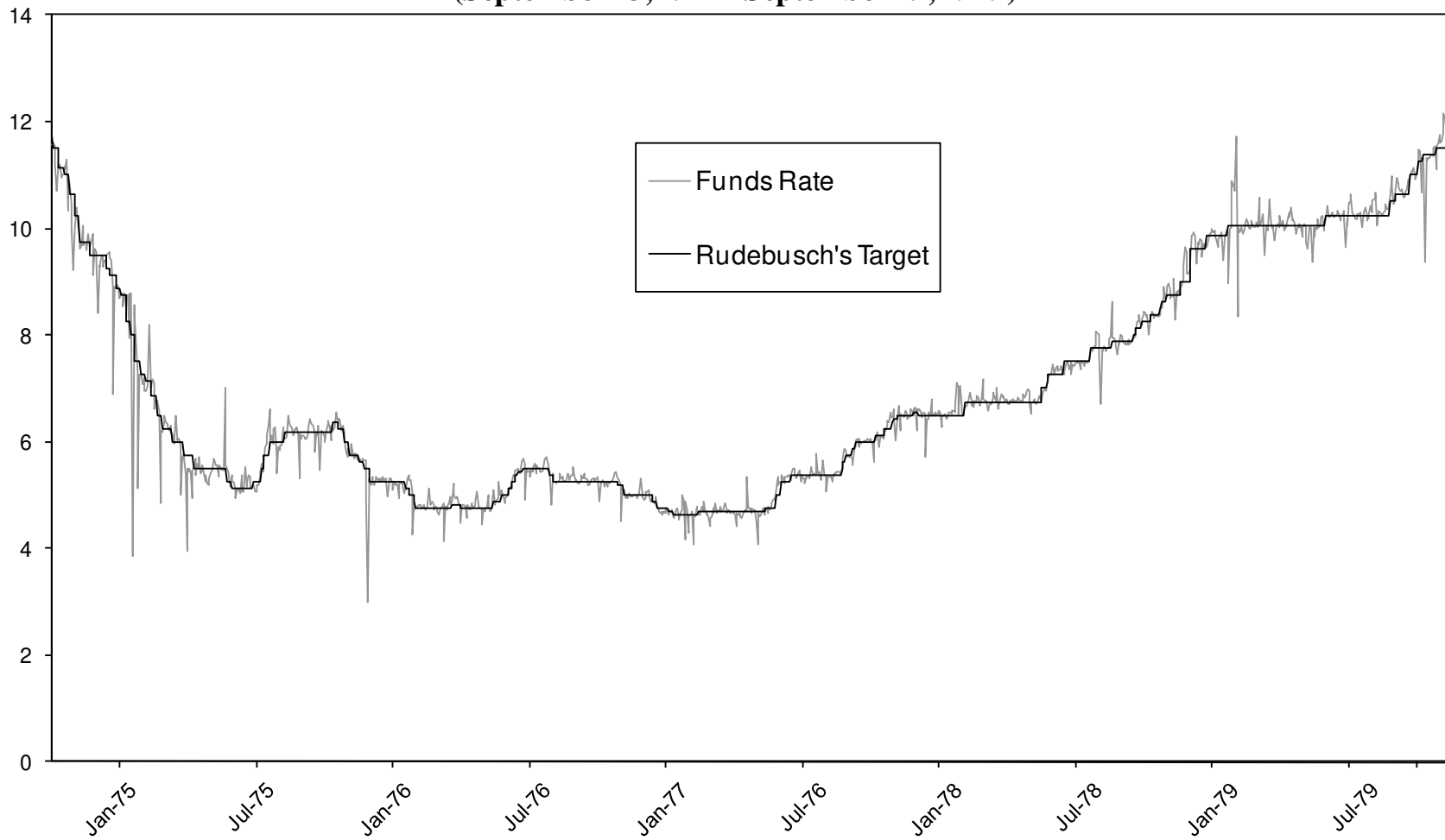


**Figure 4: Latent-Factor Adjusted Federal Funds and 10-Year Treasury Rates**

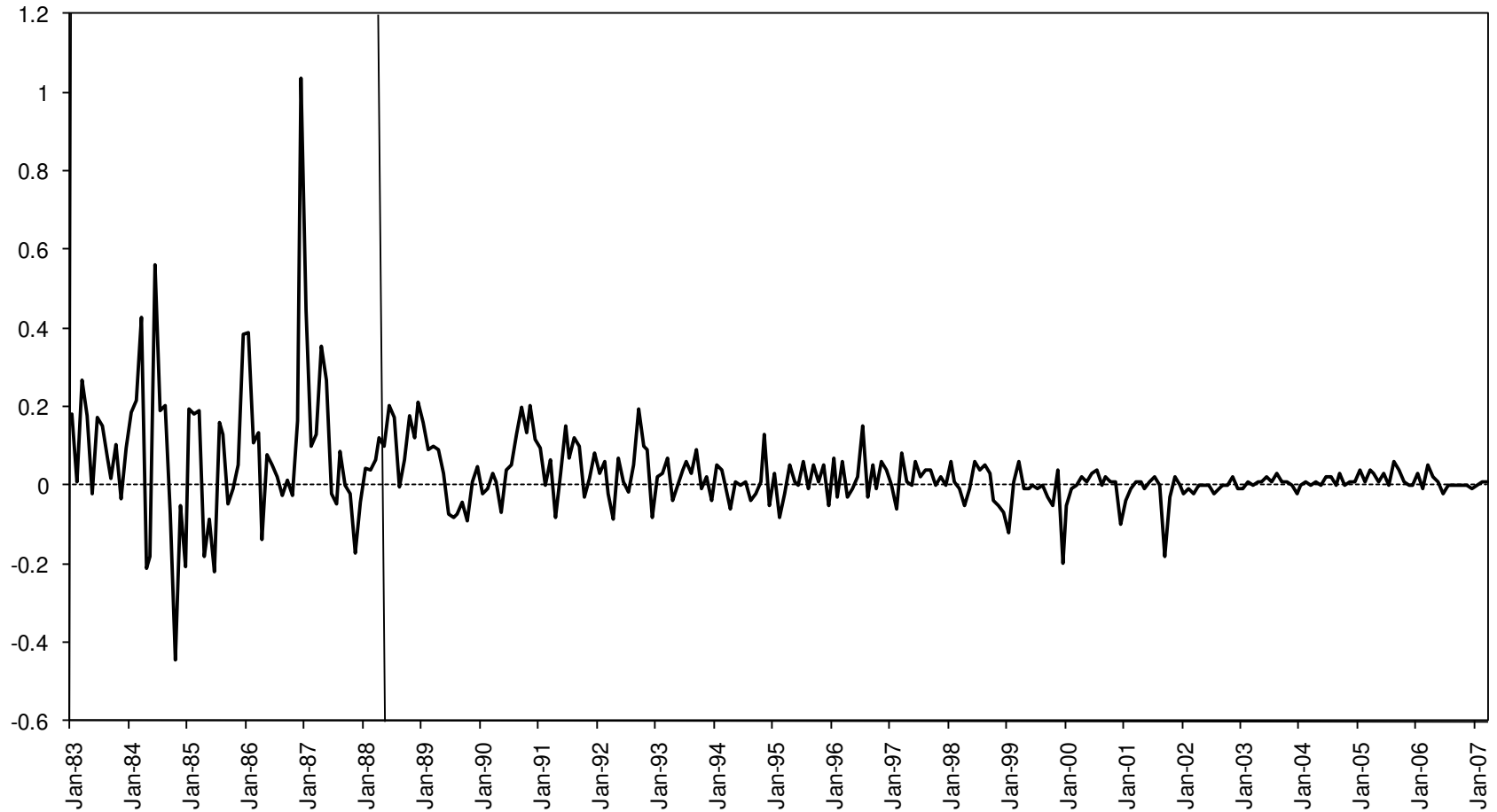




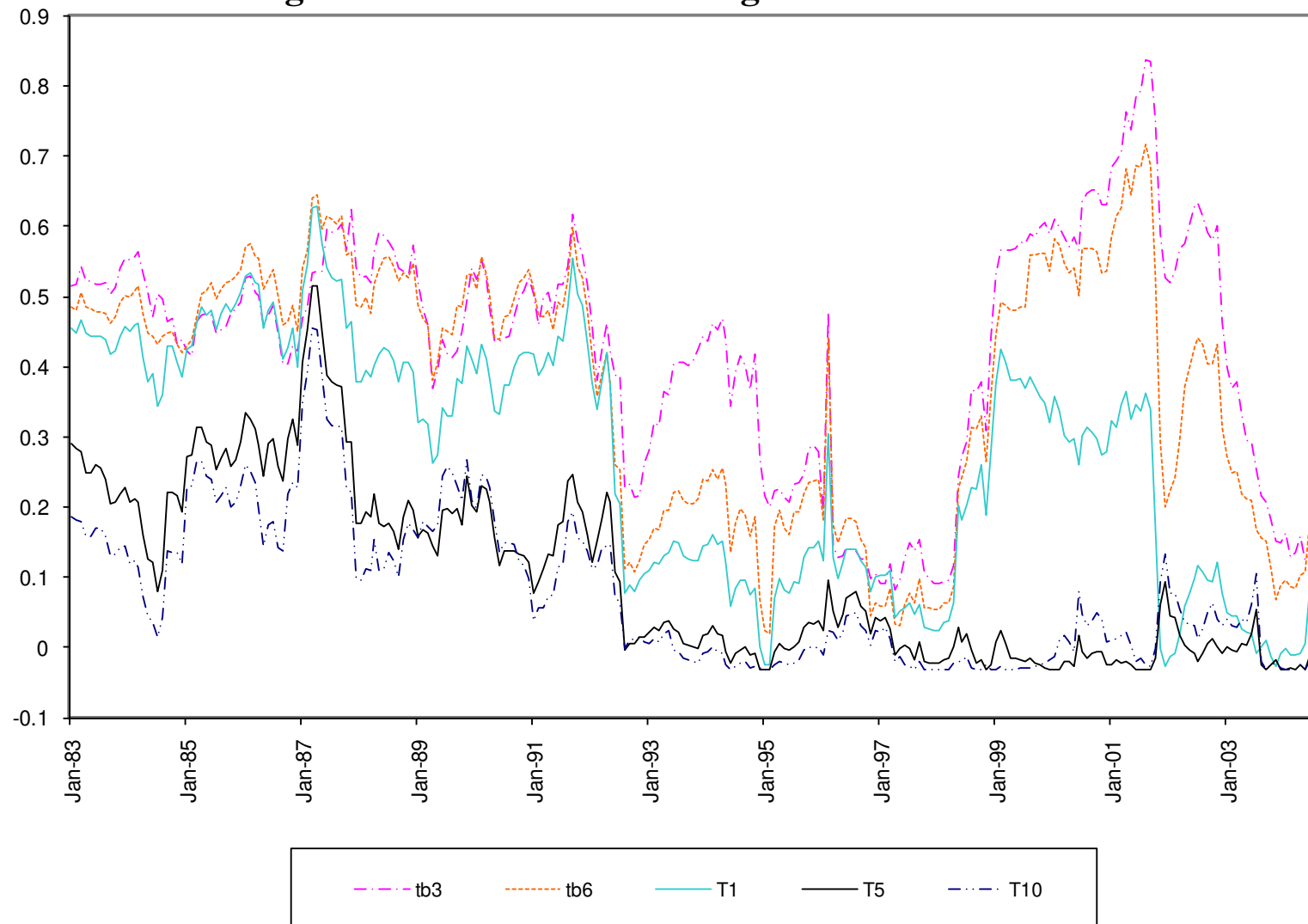
**Figure 5: Rudebusch's Funds Rate Target and  
the Federal Funds Rate**  
(September 13, 1974 - September 19, 1979)



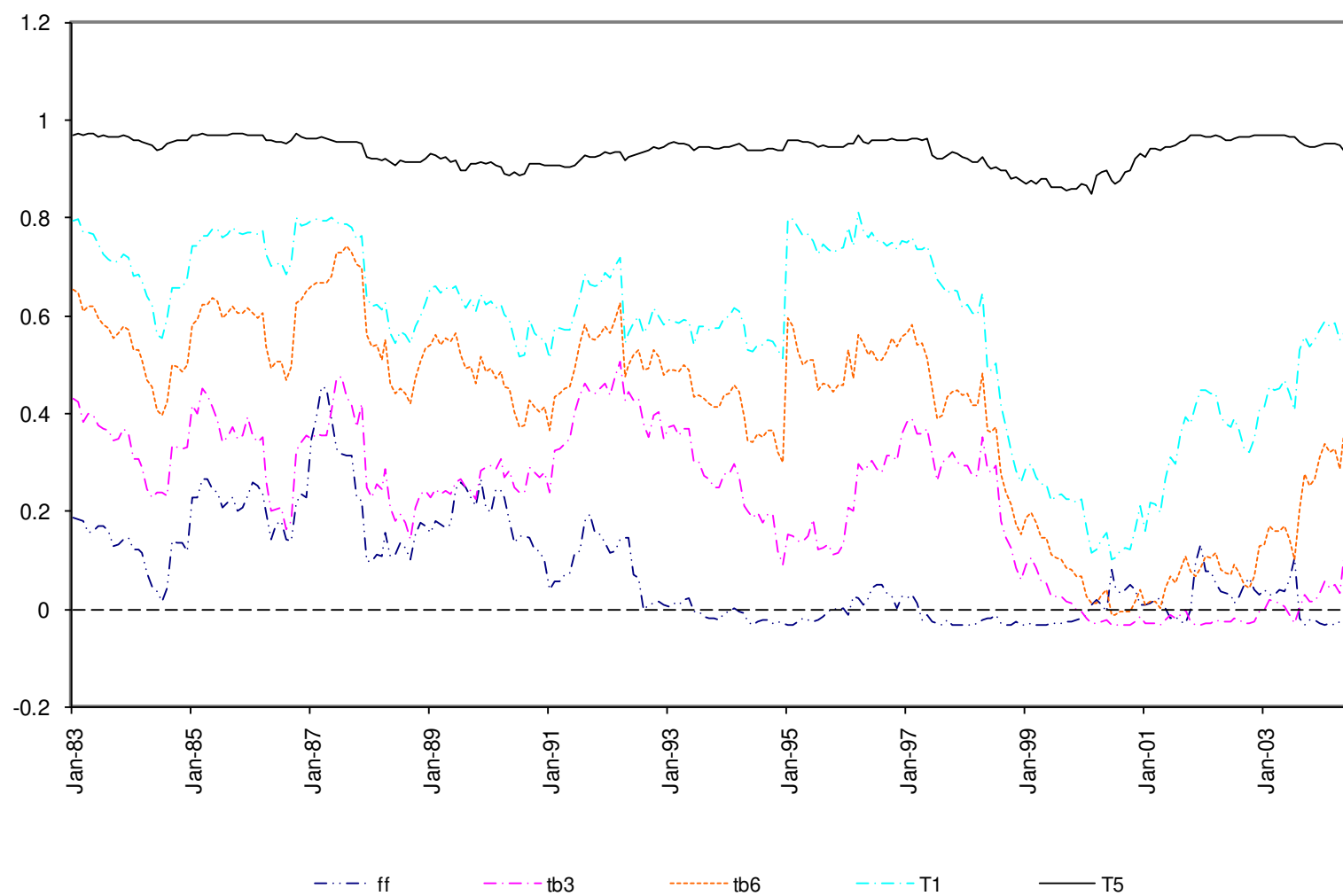
**Figure 6: Average Difference Between the Federal funds Rate and the  
FOMC's Funds Rate Target  
(January 1983 - March 2007)**



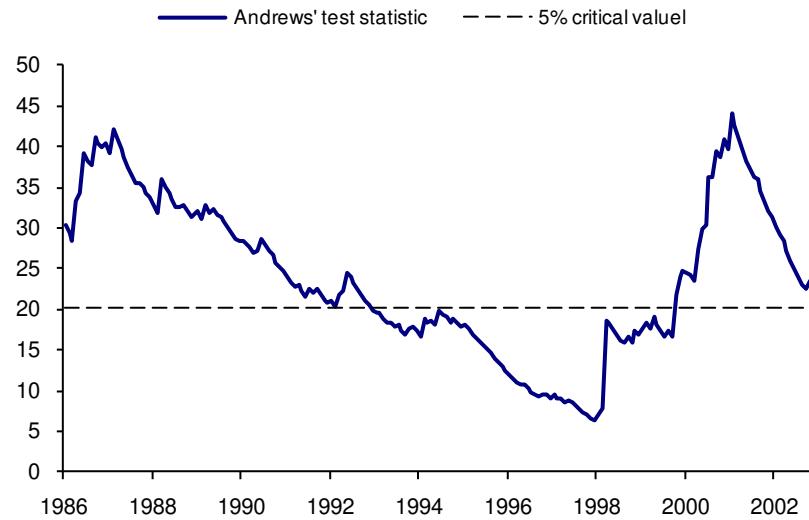
**Figure 7: 33-Month Adj-Rsquares from Rolling Regressions of the Change in Various Rate on Changes in the Funds Rate**



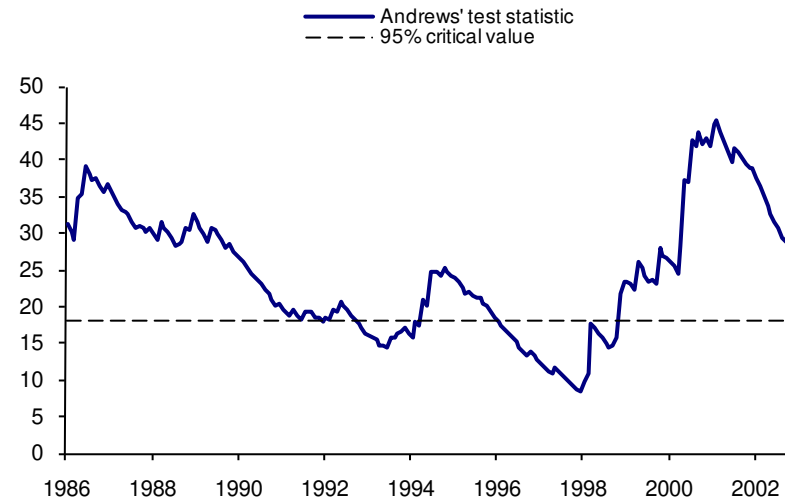
**Figure 8: 33-Month Rolling Adj-Rsquares of Regressions of the Change in the 10-Year Yield on Changes in Various Rates**



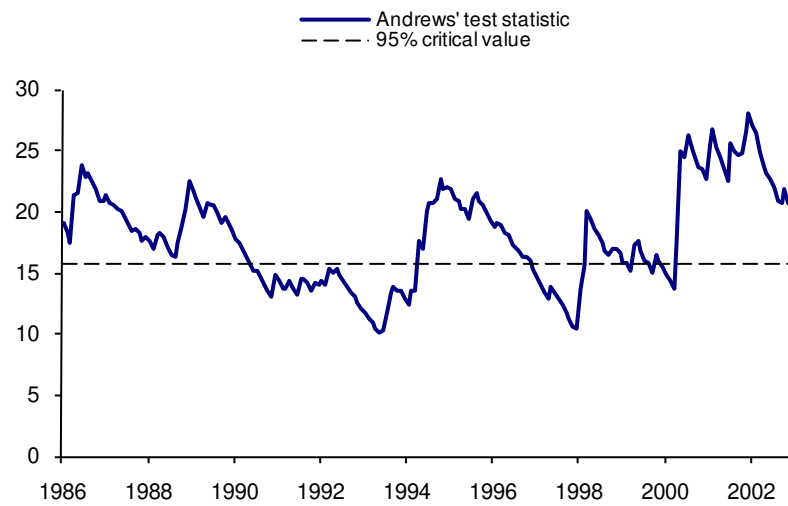
**Figure 9, Panel A: Andrews Break Point Test of 3-month TB on the Federal Funds Rate**



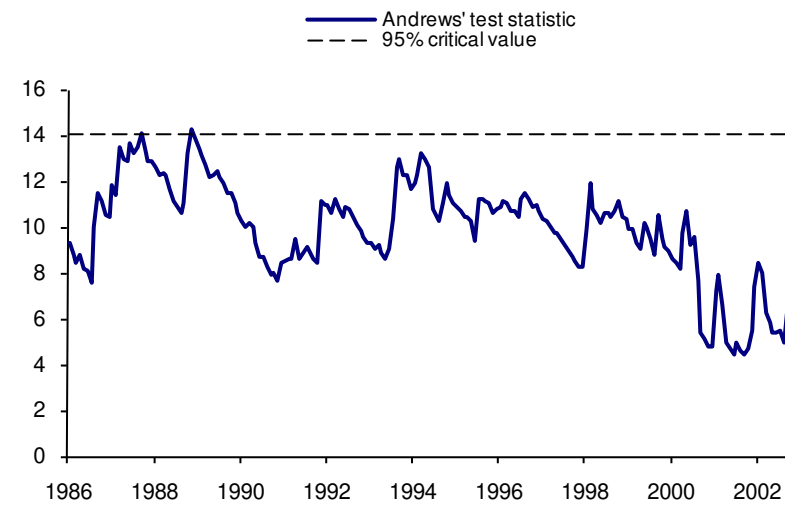
**Figure 9, Panel B: Andrews Break Point Test of 6-month TB on the Federal Funds Rate**



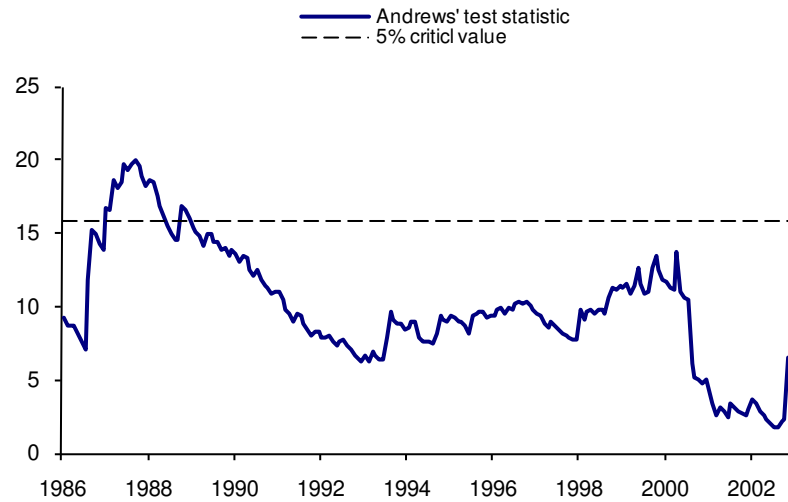
**Figure 9, Panel C: Andrews Break Point Test of 1-year Treasury on the Federal Funds Rate**



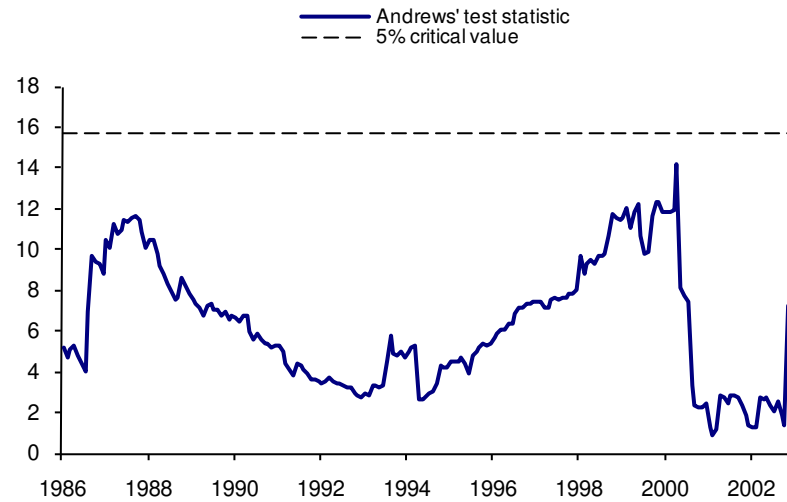
**Figure 9, Panel D: Andrews Break Point Test of 5-year Treasury on the Federal Funds Rate**



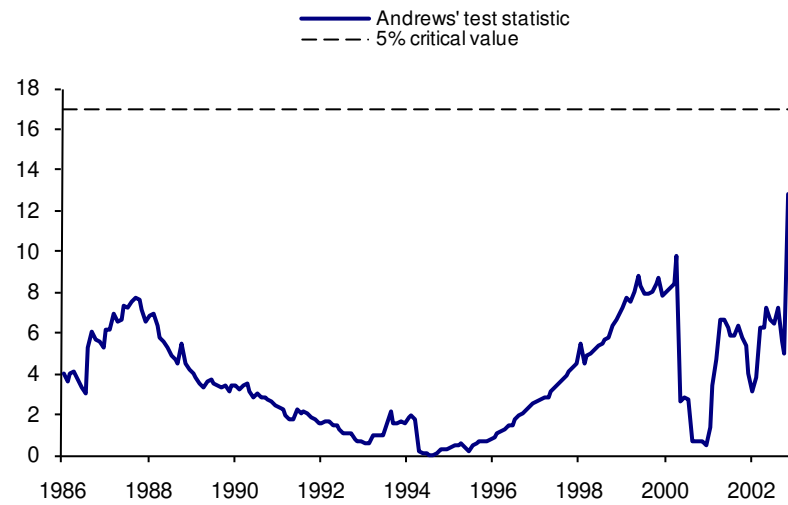
**Figure 10, Panel A: Andrews Break Point Test of 10-year Treasury on the 3-month TB**



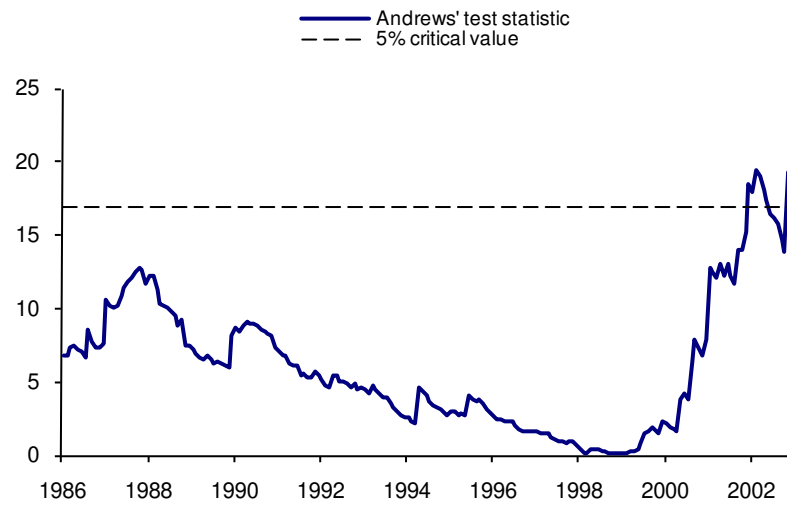
**Figure 10, Panel B: Andrews Break Point Test of 10-year Treasury on the 6-month TB**



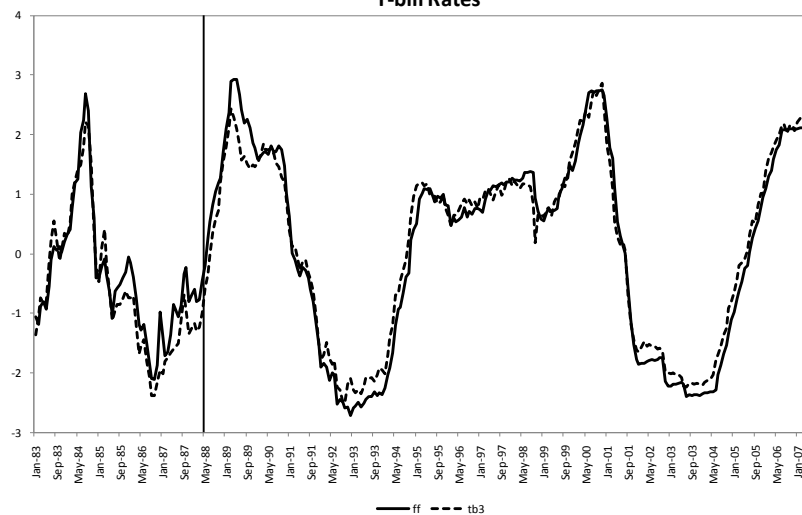
**Figure 10, Panel C: Andrews Break Point Test of 10-year Treasury on the 1-year Treasury**



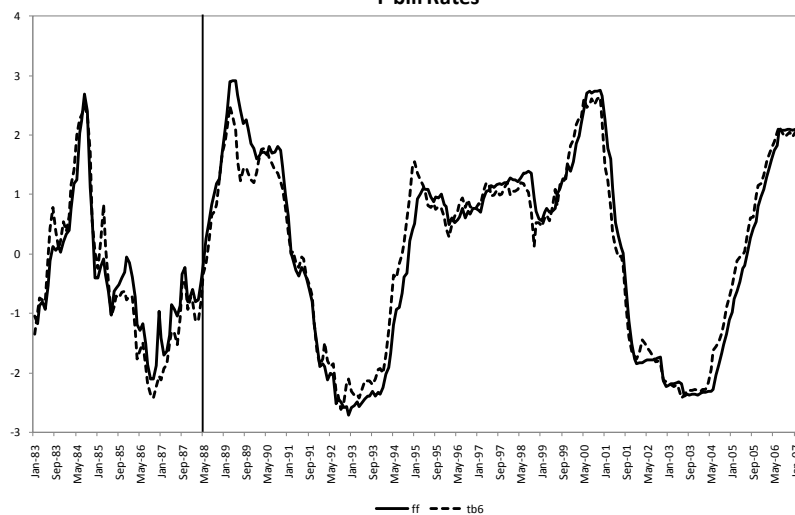
**Figure 10, Panel D: Andrews Break Point Test of 10-year Treasury on the 5-year Treasury**



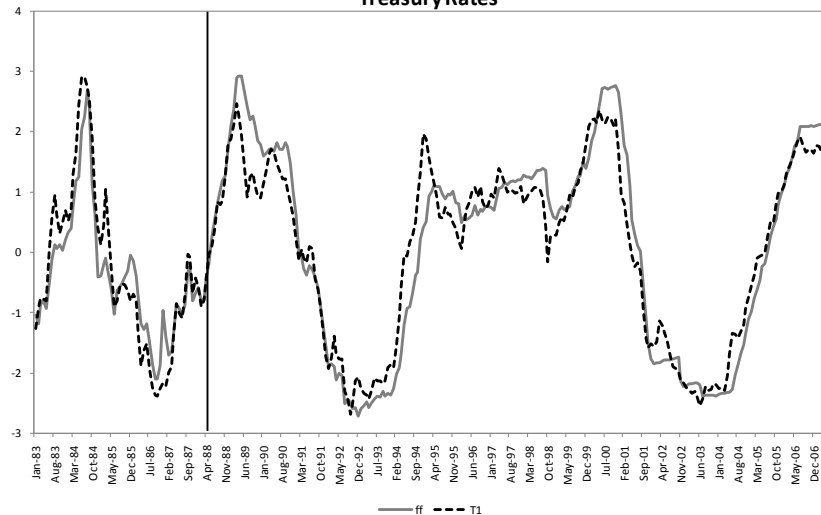
**Figure 11, Panel A: Latent-Factor Adjusted Federal Funds and 3-Month T-bill Rates**



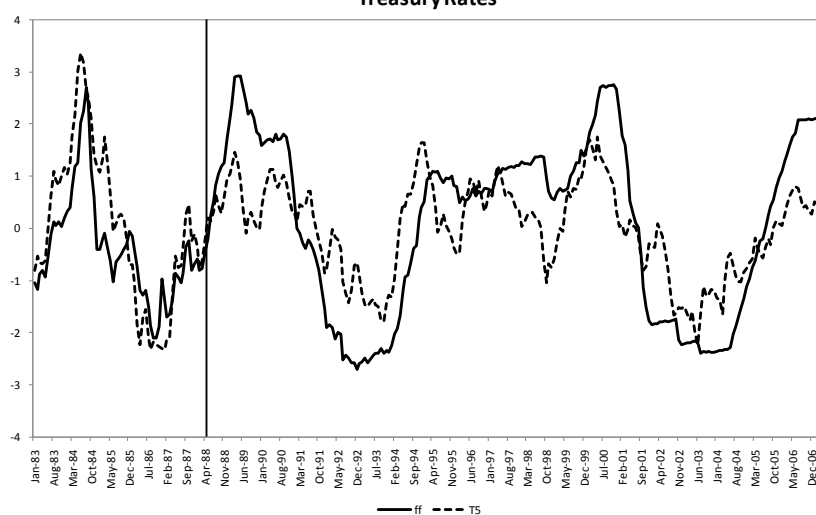
**Figure 11, Panel B: Latent-Factor Adjusted Federal Funds and 6-Month T-bill Rates**



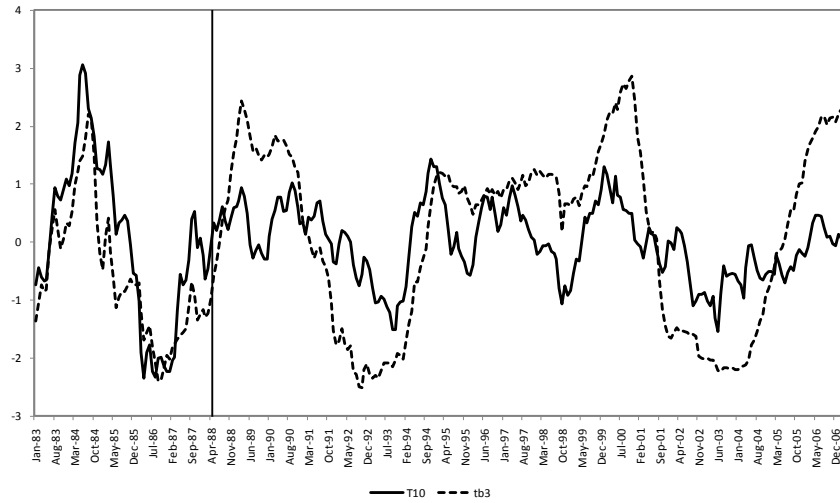
**Figure 11, Panel C: Latent-Factor Adjusted Federal Funds and 1-Year Treasury Rates**



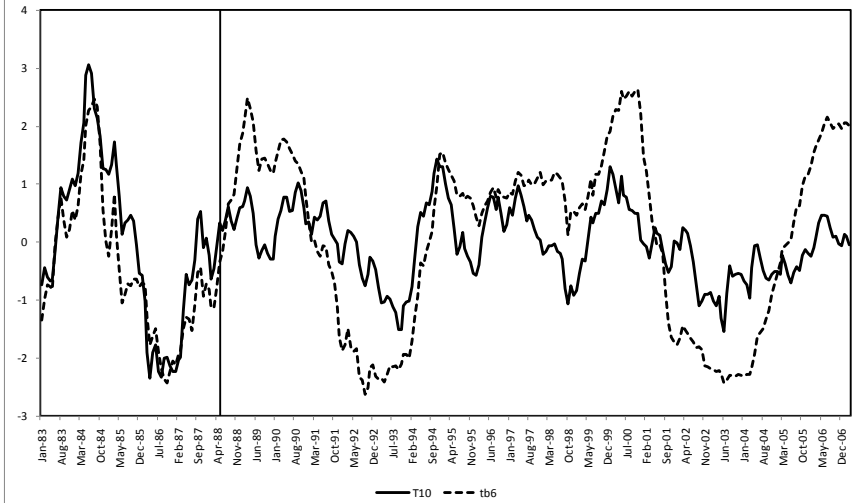
**Figure 11, Panel D: Latent-Factor Adjusted Federal Funds and 5-Year Treasury Rates**



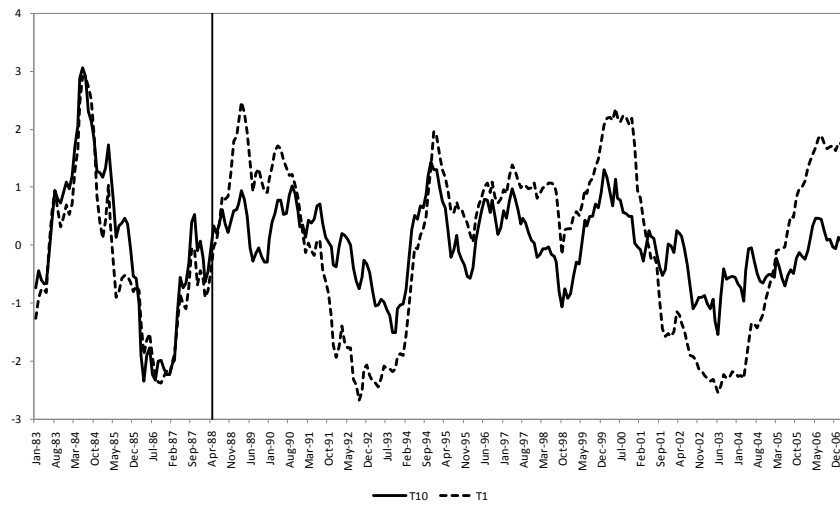
**Figure 12, Panel A: Latent-Factor Adjusted 10-Year Treasury and 3-Month T-Bill Rates**



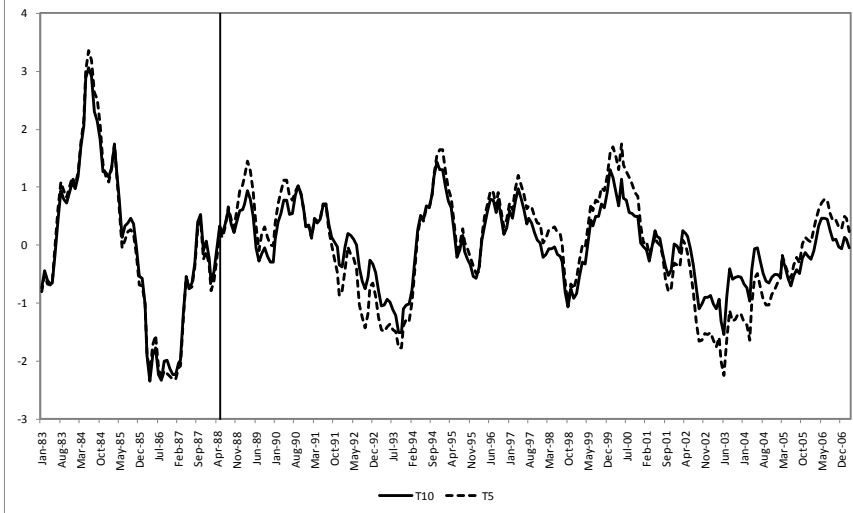
**Figure 12, Panel B: Latent-Factor Adjusted 10-Year Treasury and 6-Month T-Bill Rates**



**Figure 12, Panel C: Latent-Factor Adjusted 10-Year and 1-Year Treasury Rates**

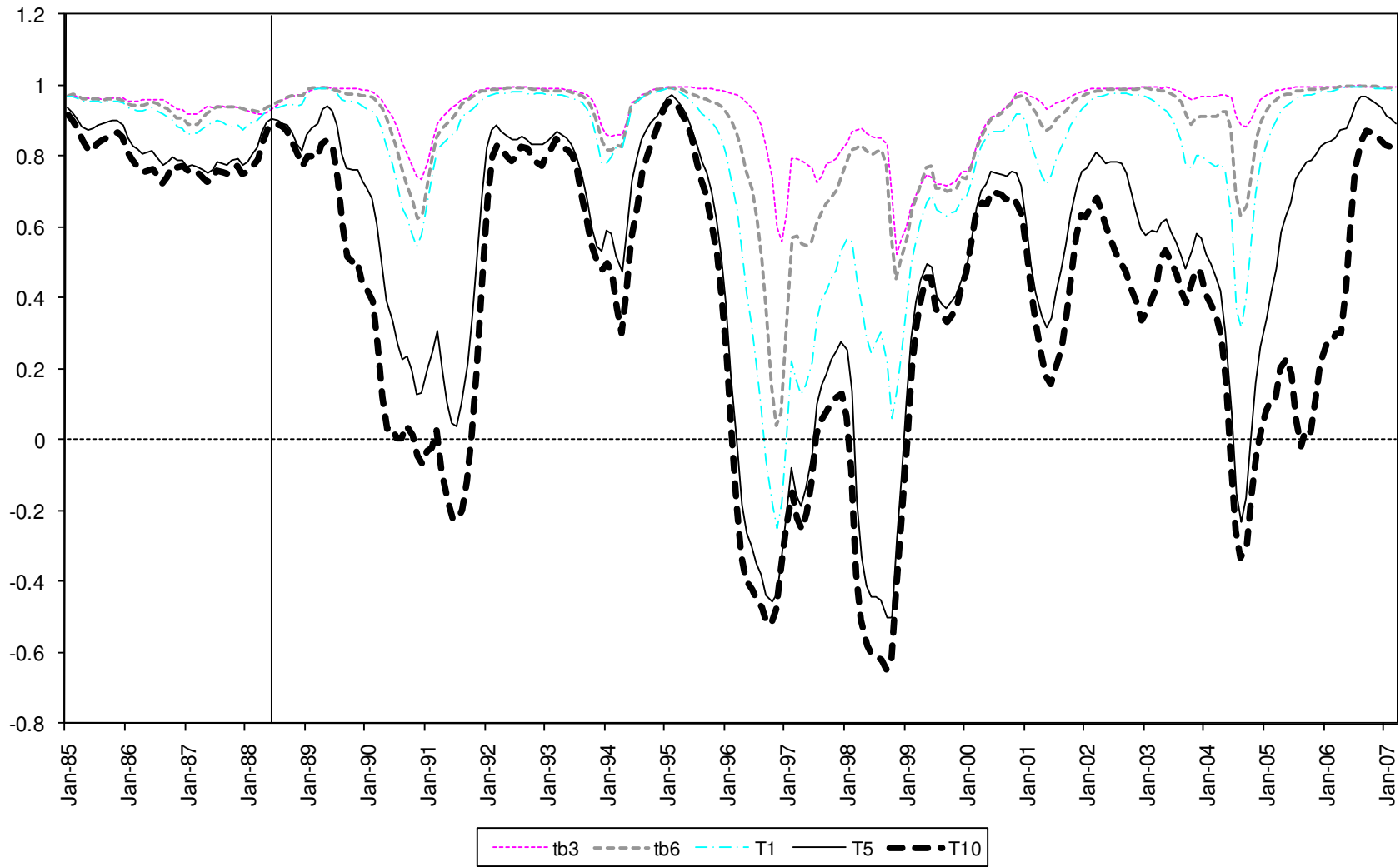


**Figure 12, Panel D: Latent-Factor Adjusted 10-Year and 5-Year Treasury Rates**

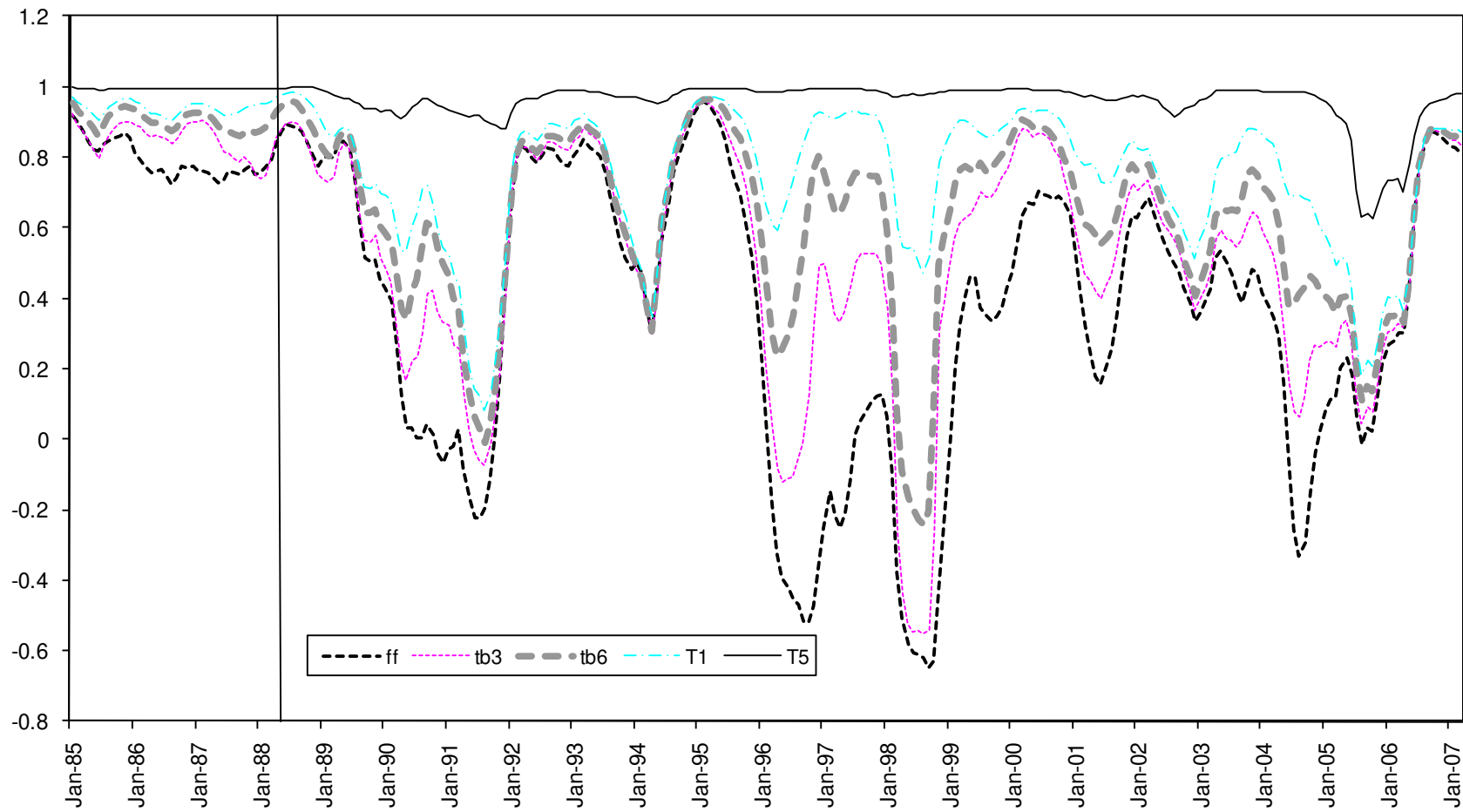




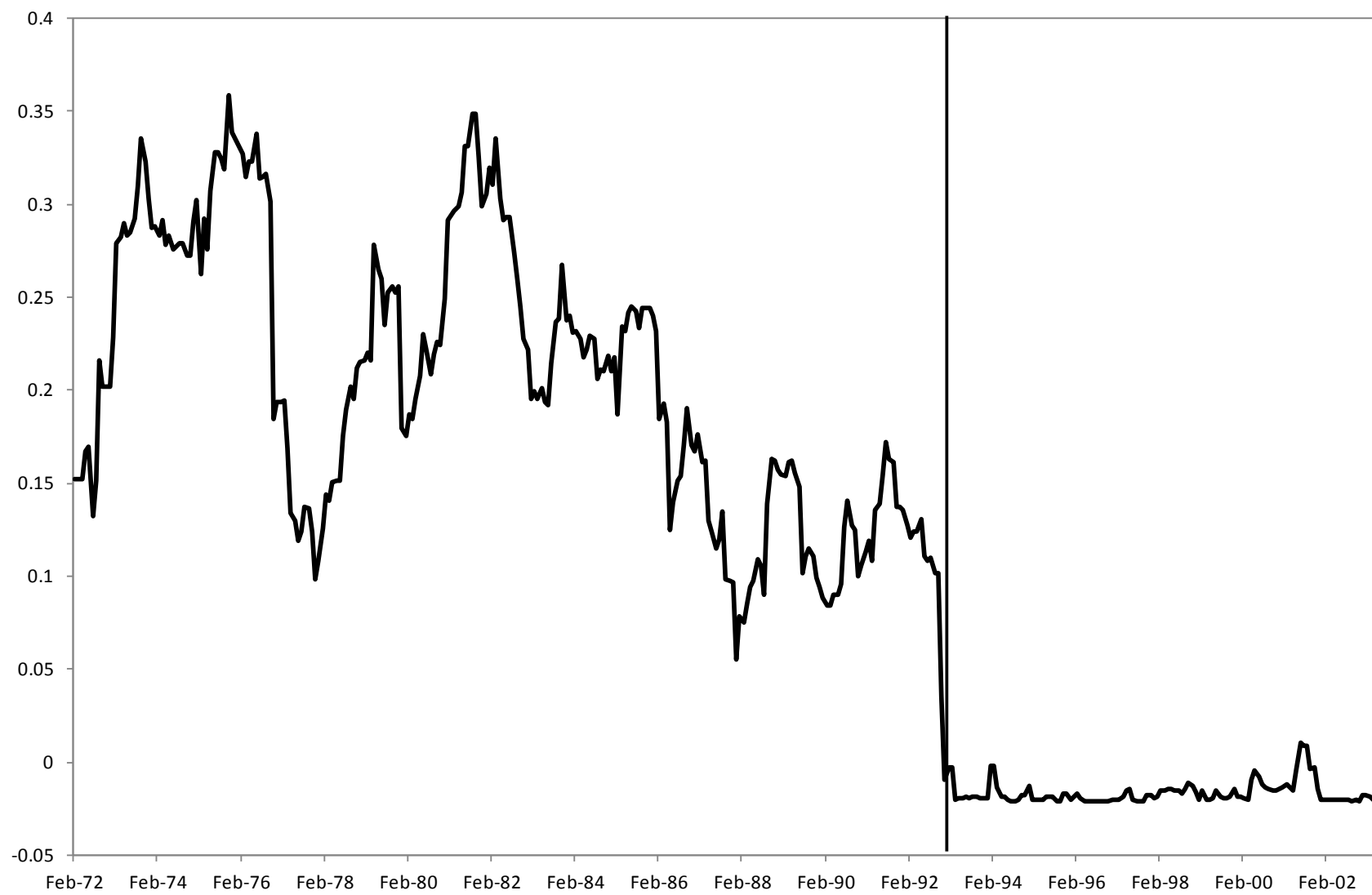
**Figure 13: 24-Month Rolling Correlation of the Latent-Factor-Adjusted Treasury and Federal Funds Rates**



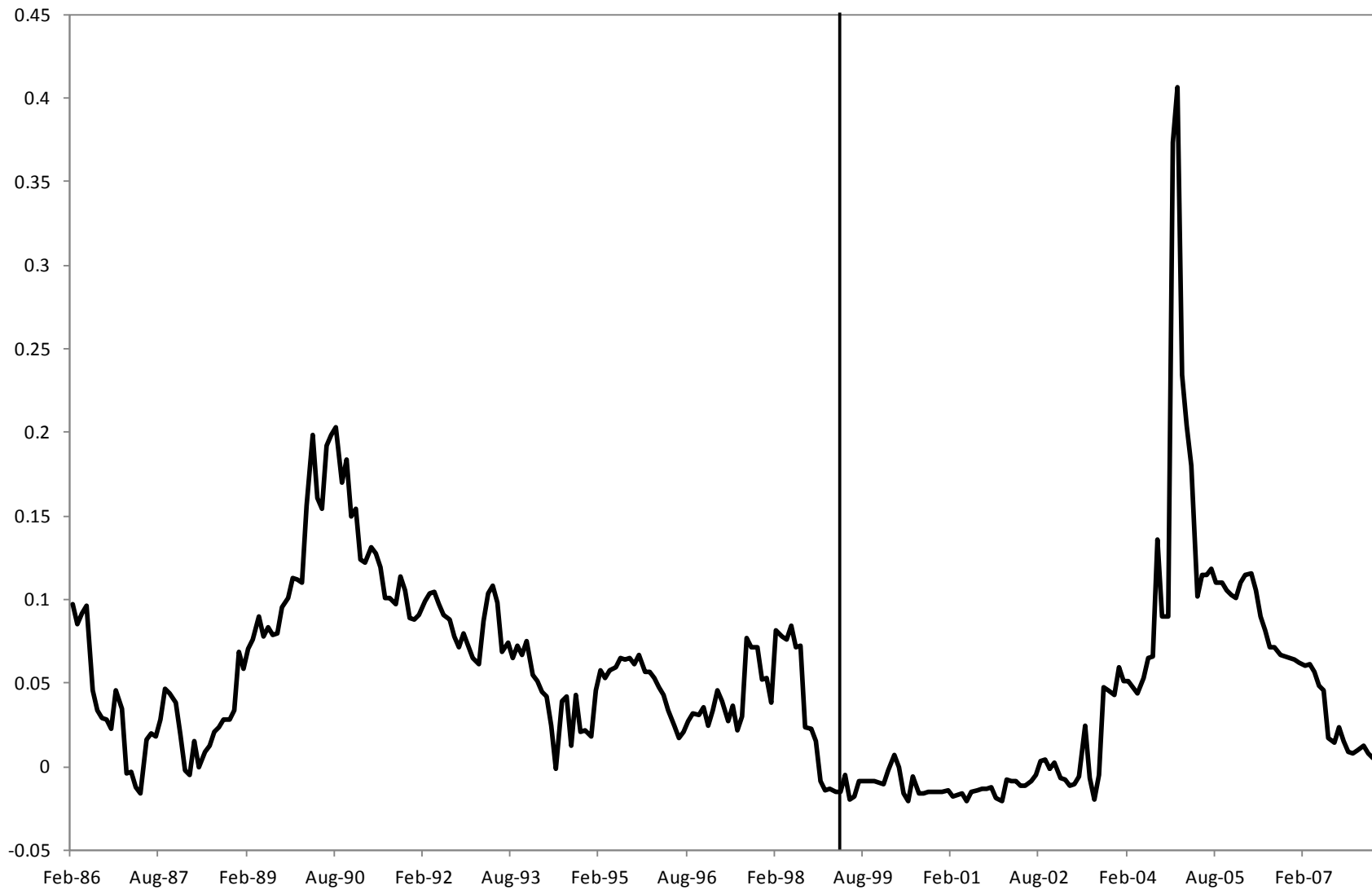
**Figure 14: 24-Month Rolling Correlation of the Latent-Factor-Adjusted  
10-Year Yield and Other Rates**



**Figure 15: 50-Month Rolling Adj-Rsquares of Regression of the Change  
in 10-Year Yield on the Change in the BoE's Policy Rate**



**Figure 16: 50-Month Rolling R-square for Changes in New Zealand's 10-Year Yield on Changes in the Cash Rate**



**Figure 17: The New Zealand 10-Year and Cash Rates,  
March 1999 - May 2012**

