Research Division
Federal Reserve Bank of St. Louis
Working Paper Series

The Unusual Behavior of the Federal Funds Rate and Treasury Yields: A Conundrum or an Instance of Goodhart's Law?

Daniel L. Thornton

Working Paper 2007-039D
http://research.stlouisfed.org/wp/2007/2007-039.pdf

September 2007
Revised August 2010

FEDERAL RESERVE BANK OF ST. LOUIS
Research Division
P.O. Box 442
St. Louis, MO 63166

The Unusual Behavior of the Federal Funds Rate and Treasury Yields: A Conundrum or an Instance of Goodhart's Law?

Daniel L. Thornton
Federal Reserve Bank of St. Louis
Phone (314) 444-8582
FAX (314) 444-8731
Email Address: thornton@stls.frb.org

August 2010

Abstract

In February 2005, Fed Chairman Alan Greenspan referred to the decline in long-term rates in the wake of the Fed increasing the target for the federal funds rate by 150 basis points as a "conundrum." Greenspan's remarks generated considerable interest and research. I document that the relationship between Treasury yields and the federal funds rate changed dramatically in the late 1980s, well in advance of Greenspan's observation. I hypothesize that the marked change in the relationship is a consequence of the Federal Open Market Committee switching from using the funds rate as an operating instrument to using the funds rate to implement monetary policy, i.e., change in the relationship is an instance of Goodhart's Law. Evidence from a variety of sources supports this hypothesis.

JEL Codes: E52, E43
Key Words: federal funds rate, federal funds target, Lucas critique, term structure

The views expressed here are the author's and do not necessarily reflect the views of the Board of Governors of the Federal Reserve System or the Federal Reserve Bank of St. Louis. I would like to thank Ben McCallum for insightful comments and Daniel J. McDonald, Aditya Gummadavelli, and Aaron Albert for valuable research assistance.

It is widely recognized that the relationship between the federal funds rate and long-term rates, such as the 10-year Treasury yield, changed around 2004. In his February 17, 2005, testimony before the Committee on Banking, Housing, and Urban Affairs of the U.S. Senate, 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. Greenspan termed this apparent aberrant behavior of Treasury yields relative to the funds rate a "conundrum."

Researchers have attempted to attribute the conundrum to a variety of factors with little success. Rather than focusing on the period that prompted Greenspan's observation, as previous research has done, I investigate the timing of the change in the relationship between the federal funds rate and the 10-year Treasury rate using data since the early 1980s. I find that there was a statistically significant change in the relationship between Treasury yields and the fund rate that occurred in the late 1980s and that there was no statistically significant change in the relationship before or after that date. The timing of the change coincides closely with the Federal Open Market Committee (FOMC) paying increased attention to the federal funds rate in the implementation of monetary policy that I have documented elsewhere (Thornton, 2006). I hypothesize that the marked change in the relationship occurred because the FOMC switched from using the funds rate as an operating instrument (i.e., a guide for conducting daily open market operations) to using it as a policy target (i.e., a target set to achieve specific policy objectives). That is, I hypothesize that the change in the relationship is an instance of Goodhart's Law: "any observed statistical regularity will tend to collapse once pressure is placed upon it for control purposes."[1]

This hypothesis is at odds with the conventional view of the monetary policy transmission mechanism. Modern analyses of the effectiveness of monetary policy are based on the expectations hypothesis of the term structure of interest rates (EH). The EH provides the link between the policy-determined overnight interest rate and longer-term interest rates that matter for economic decisionmaking. As an alternative to the EH, I offer a classical theory of interest rates and provide evidence from a variety of sources that is consistent with the classical theory and supports the hypothesis of the conundrum advanced here.

The remainder of the paper is divided into six sections. Section 2 presents the bond yield conundrum. Section 3 investigates when the change in the relationship occurred by investigating the relationship between the funds rate and the 10-year Treasury yield over the period from January 1983 through March 2007. This investigation reveals that the marked change in the relationship between these rates occurred in the late 1980s, far in advance of Greenspan's observation. Section 4 reviews previous attempts to account for the conundrum and possible alternative economic explanations for it. Section 5 presents the fund-rate-targeting hypothesis (FRTH), which hypothesizes that the change in the relationship occurred because the FOMC began targeting the funds rate for policy purposes. Section 6 presents documentary evidence that the FOMC switched from using the federal funds rate as an operational target to a

[1] 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.

policy target in the late 1980s. Section 7 tests several implications of the FRTH, and Section 8 concludes.

2.0 The Bond Yield Conundrum

The word conundrum was used by Alan Greenspan to describe the behavior of bond yields relative to the federal funds rate in testimony before the U.S. Senate Committee on Banking, Housing, and Urban Affairs on February 17, 2005, when he 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.[2]

Greenspan went on to argue that (i) only a portion of the decline in nominal forward rates could be attributed to a decline in long-run inflation expectations, (ii) suggestions that forward real rates had declined were inconsistent with the rise in stock prices and the narrowing of credit spreads over this period, and (iii) domestic explanations, such as weak credit demand and the eagerness of foreigners to lend in the U.S., were inconsistent with the fact that "bond yields and risk spreads have narrowed globally."[3] He also noted that, while a larger share of world savings was being lent across borders and that favorable inflation performance in a number of countries had likely reduced both

---

[2] Testimony of Chairman Alan Greenspan (2005).
[3] Testimony of Chairman Alan Greenspan (2005).

expectations of inflation and inflation risk premiums, "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*."[4]

Greenspan's discussion of long-term yields led some analysts to view the conundrum as purely a long-term-yield phenomenon. However, the 10-year yield in February 2005 was not unusually low by historical standards. Moreover, the behavior of any particular rate can be considered unusual only relative to the behavior of other rates. As Kuttner (2006) 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."[5] That yields in other countries also remained low about this time may not be particularly unusual given the predominant role of the U.S. in the world economy and the integration of financial markets internationally. This analysis focuses solely on the relationship among rates in the U.S.

3.0 When Did The Relationship between the Funds and Treasury Rates Change?

The conundrum is a change in the relationship between the federal funds rate and Treasury bond yields. While Greenspan noticed the change in the relationship shortly after the FOMC began increasing its target for the funds rate in June 2004, the change could have occurred earlier. What Greenspan noticed was a marked difference in the relationship between changes in the funds rate and changes in Treasury bond yields. Specifically, Treasury yields declined slightly

[4] Testimony of Chairman Alan Greenspan (2005), emphasis added.
[5] Kuttner (2006), p. 123.

despite a 150 basis point increase in the funds rate. Hence, a natural way to investigate when the relationship changed is to estimate the equation

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

This equation is estimated using monthly data over 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 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.

As an initial step, 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 period of the Greenspan conundrum. The estimates are presented in Figure 1. The data are plotted on the initial month of the sample. The estimates of β fluctuate in a relatively small range around 0.40 until the early 1990s, then decline. The estimates are negative for a period during the latter part of the sample. However, the estimate of $\bar{R}^2$ has been essentially zero since the mid-1990s, suggesting that the conundrum may have occurred well in advance of Greenspan's observation. Indeed, the relationship between the 10-year Treasury yield and the funds rate that characterized the 1980s and early 1990s appears to have essentially vanished sometime during the mid-1990s.

3.1 The Relationship at the Quarterly Frequency

In order to investigate the possibility that the 10-year yield may simply have responded more slowly to changes in the funds rate after the mid-1990s, Equation 1 is estimated using quarterly data. The sample period, 1983.Q1 through 2007.Q1, consists of 97 observations. When Equation 1 is estimated using the 46 observations from 1983.Q1 through 1994.Q2, the results are very similar to those obtained over a comparable period using monthly data. Specifically, the estimate of β is 0.569 with a t-statistic of 5.19 and $\bar{R}^2 = 0.366$.[6] When Equation 1 is estimated over the period 1994.Q3 through 2007.Q1, however, the estimate of β declines to 0.129 and is statistically insignificant with a t-statistic of 1.095. Moreover, as was the case with monthly data, the estimate of $\bar{R}^2$ is essentially zero (0.004). Hence, the marked deterioration in the relationship between the 10-year Treasury yield and the funds rate at the monthly frequency cannot be accounted for simply by a slower response of the long-term yield.[7]

3.2 When Did the Change Occur?

The results suggest that the conundrum occurred much earlier than 2005, when Greenspan first observed it. To more precisely date the beginning of the conundrum, Andrews' (1993) "supremum" method of identifying a single endogenous break point is used to determine the most likely date of a change. Specifically, Equation 1 is estimated over the first 45 months of the entire sample

---

[6] The standard errors are obtained using a heteroskedasticity-autocorrelation-consistent covariance matrix estimator.

[7] The results are essentially the same if the equation is estimated using monthly data with lags of the federal funds rate. Using contemporaneous funds rate and 2 lags, the estimate of $\bar{R}^2$ is 0.21 when estimated from January 1983 through June 1994 and essentially zero when estimated from July 1994 through March 2007. Moreover, the conclusion is essentially unchanged if the number of lags is increased to 5.

and the remaining 246 months and the likelihood ratio statistic for the hypothesis of no structural break is calculated. The procedure is repeated, adding one month to the 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 break point is given by the largest value (i.e., the supremum) of the likelihood ratio 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 likelihood ratio test statistic for all possible break dates is presented in Figure 2, along with the critical value for the 5.0 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 likelihood ratio test statistic occurred on May 1988. The likelihood ratio test statistic is over 25, much larger than even the 1-percent critical value of 18.58. The results indicate that a statistically significant break in the relationship between the 10-year Treasury yield and the federal funds rate occurred even earlier than the rolling regression estimates appear to suggest. While the supremum occurred in May 1988, there is another sharp spike in the likelihood ratio statistic in mid-1994, which coincides with the sharp drop in $\bar{R}^2$ using either monthly or quarterly data observed previously.

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 β is 0.48 with a t-statistic of 3.0 and the estimate of $\bar{R}^2$ is 0.21. When the equation is estimated over the period June 1988 through March 2007, the estimate of β is 0.18 with a t-statistic of 2.3; however, the estimate of $\bar{R}^2$ (0.02) suggests that there is essentially no relationship between changes in these rates.

3.3 Why Did the Change Go Unnoticed For So Long?

If the conundrum that Greenspan noticed in 2005 actually occurred in the late 1980s, it is reasonable to ask: Why did it take so long to notice such a marked change in the relationship? A possible answer is that the relationship was masked by a predominant downward trend in the levels of these rates over the period. Figure 3 shows the levels of the federal funds rate and 10-year Treasury yield over the sample period. These rates are dominated by a downward trend. The negative trend likely reflects a downward drift of inflation expectations and a reduction in inflation risk premium associated with the FOMC's evolution to (implicit) inflation targeting. It could also reflect a reduction in the real-rate risk premium associated with the Great Moderation (e.g., Bernanke, 2004). In any event, the existence of a common trend in rates could mask the change in the relationship, documented in Section 3, on the level of rates, hence, account for the fact that the marked change in the relationship noted above went unnoticed for so long.

Inflation expectations and inflation and real-rate risk premiums are unobservable, so that any attempt to adjust rates using estimates of such factors is subject to considerable uncertainty. Consequently, the effect of such latent factors is accounted for by removing the common trends from the rates. Specifically, the latent factors are accounted for by estimating

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

where $i_t = ff$ or $T10$. The latent-factor-adjusted levels of the rates are given by estimates of ε_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. These restrictions are innocuous. The 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, there is no important or statistically significant difference in the persistent effect of latent factors on these rates over the sample period.

The latent-factor-adjusted federal funds and 10-year Treasury rates are presented in Figure 4.[8] The vertical line indicates May 1988. Consistent with the Andrews test results, there appears to be a marked change in the relationship between these latent-factor-adjusted rates that occurs around May 1988.[9] Prior to May 1988 the funds rate and the 10-year yield are highly correlated and follow relatively closely along essentially the same cycle. After May 1988 the funds rate and the 10-year yield move very differently, frequently having different cycles.

4.0 Previous Attempts to Resolve the Conundrum

This section reviews several attempts to resolve the conundrum and discusses possible economic explanations for the empirical failure of the EH, which might account for the conundrum.

4.1 Previous Attempts to Resolve the Conundrum

Kim and Wright (2005) investigate the bond yield conundrum by decomposing the term structure of nominal interest rates into the expected future short-term rate and

[8] Differences in the estimate of the intercepts for the trend equation is an estimate of the average relative risk premium, which is 147 basis points.

[9] 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.

the term premium using the three-factor, arbitrage-free, term structure model of Kim and Orphanides (2005). They find 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. While they do not identify the cause of the decline in the term premium, they conclude that the decline is due to “anything else that might affect the price of Treasury securities other than expected future monetary policy.”[10]

Rosenberg (2007) decomposed the decline in the term premium from updated estimates of Kim and Wright’s (2005) model into (a) changes in risk, (b) risk aversion, and (c) foreign demand. He finds that only about half of the reduction in the term premium can be accounted for by these factors, with most accounted for by a marked (but unexplained) reduction in risk aversion.

There are two reasons to doubt that the change in the relationship documented in Section 3 can be accounted for by a decline in the 10-year Treasury risk premium. First, the change in the relationship is a relatively high-frequency phenomenon, i.e., it is a marked change in the relationship between monthly changes in these rates, which would seem difficult to account for by either a secular or one-time decline in the risk premium. Second, a secular decline in the risk premium for long-term Treasuries could cause the trends in the funds rate and the 10-year Treasury yield to be markedly different, but as noted above, the trends are essentially identical. A one-time reduction in the risk premium should have little or no effect on the high-frequency relationship between these rates.

Rudebusch, Swanson, and Wu (2006) investigate the conundrum by estimating two macro-finance models of the term structure. Such models integrate

[10] Kim and Wright (2005), p. 7.

standard macroeconomic analyses with an affine model of the term structure. They consider two models: the VAR-based model of Bernanke, Reinhart, and Sack (2004) and the "New Keynesian" model of Rudebusch and Wu (2007). The Bernanke, Reinhart, and Sack model is estimated over the period January 1984 through December 2005. They compute the implications of the Rudebusch and Wu model for yields of all maturities through December 2005 based on parameters of the model estimated over the period January 1988 through December 2000.

They find that the models' residuals are relatively large during 2005 and conclude that "from the perspective of both models, the recent behavior of long-term Treasury yields does represent a conundrum."[11]

They then investigate possible explanations for the conundrum by regressing the residuals from these models on the implied volatility in the longer-term Treasury market, the implied volatility from Eurodollar options, the implied volatility from options on the S&P 500, the 8-quarter trailing standard deviation of the growth rate of real GDP, the 24-month trailing standard deviation of core PCE inflation, and the 12-month change in the custodial holdings by the New York Fed for all foreign official institutions, normalized by the total stock of Treasury debt held by the public. They find that over 50 percent of the residual is unexplained using the Bernanke, Reinhart, and Sack model and over 70 percent is unexplained using the Rudebusch and Wu model. The change in implied volatility of longer-term Treasury yields had the most explanatory power for the residuals of either model. Moreover, they indicate that increased foreign demand plays "little or no role" in explaining the conundrum.

[11] Rudebusch, Swanson, and Wu (2006), p. 100.

Smith and Taylor (2009) take a somewhat different approach. Specifically, they embed a model of the macro-economy consisting of a simple policy rule and an inflation equation that "describes how the interest affects inflation" into a standard affine term structure model. They do not estimate the model. Rather, they show analytically that "a monetary policy that reacts more aggressively against inflation implies that bond yields respond more aggressively to inflation as well."[12] They then estimate a Taylor-type rule using 1- to 5-year zero-coupon Treasury yields and find that the coefficient on inflation is much higher for all five yields after 1983. Noting that Bernanke's (2005) suggestion that long-term rates were low (relative to the funds rate) because of a global saving glut is inconsistent with the fact that the "world saving as a share of world GDP had actually fallen during this period," they suggest an alternative explanation; namely, that "the funds rate deviated significantly from what would have been predicted by the Fed's typical response as exemplified by the empirical estimates of the policy rule…for the sample period 1984.Q1 through 2006.Q4."[13] Re-estimating the policy rule over the period and including a multiplicative dummy variable on inflation for the period 2002.Q4 through 2000.Q5, they find that the coefficient on the multiplicative dummy is negative and highly statistically significant, "suggesting the possibility that the response coefficient on inflation dropped significantly during this period."[14] They conjecture that the decline in the response to inflation could account for Greenspan's conundrum. Specifically, they suggest that "a perception of a smaller response coefficient in the policy rule

[12] Smith and Taylor (2009), p. 910.
[13] Smith and Taylor (2009), p. 916.
[14] Smith and Taylor (2009), p. 916.

could have led market participants to expect smaller interest rate responses to inflation in the future, and therefore lower long-term interest rate responses."[15] They go on to note that "while the shift was temporary when viewed from the perspective of today, it would have been difficult to assess at the time whether the Federal Reserve would have returned to the typical rule followed during the post 1984.Q1 period."[16]

This explanation seems implausible. For one thing, for this explanation to be correct, 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 document, and believe the change to be permanent rather than temporary. That this actually occurred seems unlikely. While the Taylor-type rule framework has been evolving since the mid-1990s, there is little evidence that the FOMC actually implemented policy using a Taylor-type rule framework (e.g., Asso et al., 2010, and Meade and Thornton, 2010).

More fundamentally, the only way the hypothesis could be consistent with the EH is if there was a marked decline in the term premium associated with change in the Taylor rule or if market participants believed that the increases in the FOMC's funds rate target would be temporary. The latter seems improbable given that the funds rate target was being increased from a then historically low level and the well-documented persistence of changes in the FOMC's funds rate target.

---

[15] Smith and Taylor (2009), pp. 916-17.
[16] Smith and Taylor (2009), p. 917.

Finally, the Greenspan conundrum was motivated by the observation that long-term yields changed little despite the FOMC increasing its funds rate target by 150 basis points over a period of six months—an aggressive tightening of policy. Moreover, long-term yields continued to change little despite an additional 250-basis-point increase in the FOMC's funds rate target. Hence it seems unlikely that the 10-year Treasury yield would fail to respond to a 400-basis-point increase in the funds rate because market participants believed that the FOMC would respond less to inflation than it did previously.

4.2 Economic Explanations for the Empirical Failure of the EH

Because Greenspan's conundrum statement was essentially a statement about the failure of the EH, it is possible that it could be accounted for by economic theories of the failure of the EH. One such hypothesis, advanced by Fuhrer (1996), is similar to that suggested by Smith and Taylor (2009). Rather than observing a change in behavior of the Fed's reaction function and assuming that market participants believed the change to be permanent, Fuhrer hypothesizes that the EH fails because of unexpected changes in the policy rate. Specifically, Fuhrer (1996) showed that the pseudo 10-year Treasury yield based on the pure EH and expectations of the federal funds rate obtained from a four-variable VAR model—consisting of the federal funds rate, the inflation rate, the output gap, and the 10-year Treasury yield—deviated significantly from the actual 10-year yield. Noting that the constant-coefficient VAR implied fixed coefficients in the Fed's reaction function for setting the short-term interest rate, Fuhrer (1996) suggested that the failure of the EH could be due to the inability to predict the federal funds rate because of unexpected changes in policy. He then showed that there was a non-constant coefficient reaction function that could yield forecasts of the short-term rate such that the EH-consistent 10-year yield based on these forecasts more closely resembled the observed 10-year yield. Fuhrer's forecasts were based on the assumption that market participants had perfect knowledge of the reaction function, but that shifts in policymakers' reaction function were unpredictable.

Kozicki and Tinsley (2001, 2005) use an implication of Fuhrer's simulations—that the historical failure of the EH is due to the market participants' inability to predict changes in the process that generates the short-term rate—to account for the EH's failure. They do this by simulating two macro models. The models assume that policymakers determine their target for the short-term rate based on a Taylor-type rule and that market participants form expectations for the short-term rate based on policy rule. Markets participants are assumed to know the parameters of the policy rule. The models differ in only one respect. One model assumes that market participants know the Fed's inflation target with certainty. The other assumes that the inflation target is unknown and agents adjust their perception of the target based on a constant gain learning algorithm.

Not surprisingly, they find that conventional tests of the expectations hypothesis fare much better when the market knows the inflation target, i.e., when market participants can forecast the future short-term rate more accurately, but not very well when the target is unknown, i.e., short-term interest rate forecasts are less accurate. Based on their analysis, they conjecture that "empirical rejections [of the EH] might reflect incorrect assumptions about expectations formation rather than incorrect assumptions about the theoretical link between long rates and short rates."[17]

It is well known that the EH is directly linked to market participants' ability to predict the future short-term rate; however, it seems unlikely that the conundrum is a consequence of the unexpected shifts in the Fed's reaction function or increased uncertainty about the FOMC's inflation target. During the period when Greenspan first noticed the conundrum, the FOMC was using what is commonly referred to as "forward guidance." Specifically, the FOMC announced that would increase its funds rate target at a "measured pace." Consequently, knowledge of the future path of the funds rate target should have been at an all-time high.

Moreover, more was known about the FOMC's implicit inflation objective than any time previously. More generally, it is well documented that the period since the early 1980s is a period of continuously increasing Federal Reserve transparency. Hence, it is difficult to see how the change in the relationship between the funds rate and the 10-year Treasury yield documented in Section 3 could stem from greater monetary policy uncertainty.

As noted in Section 3, the conundrum is more obvious when the effects of latent factors that commonly affect rates are removed and that the change in the relationship occurs at the monthly and quarterly frequencies. Uncertainty about the FOMC's inflation target could be an explanation of the change documented in Section 3 only if market participants believed the FOMC changed its inflation target frequently and in either direction, which seems implausible. Finally, these

[17] Kozicki and Tinsely (2005), p. 444.

explanations rest on the FOMC following a fixed policy rule since the early 1980s, which as noted above, appears unlikely.

5.0 The Funds Rate Targeting Explanation for the Conundrum

This section proposes the FRTH to account for the conundrum documented in the Section 3. This hypothesis requires a different theory of the term structure of interest rates than the EH, which dominates the modern monetary policy literature. Hence, the analysis begins with the discussion of the conventional theory of the yield curve and an alternative classical theory.

5.1 The Conventional Theory of the Treasury Yield Curve

Modern macro-finance sees Treasury bond yields as being determined in accordance with the EH. Specifically, Treasury yields are determined by the market participants' expectation for the short-term rate over the term of the long-term asset plus a constant risk premium. Indeed, Greenspan's conundrum statement is essentially an observation that long-term yields did not behave in a manner consistent with the EH: Treasury yields failed to increase despite a significant increase in the FOMC's target for the funds rate. According to the EH, this could have occurred only if a) the Fed's actions were anticipated, b) the increase in the target was expected to be temporary, or c) there was a marked change in the term premium. None of these seems likely. Treasury yields did not increase significantly in advance of the Fed's actions. It is unlikely that market participants would have anticipated a rapid and significant reversal of the funds rate target. Moreover, there is no creditable argument for why the term premium should have changed quickly and dramatically and, as noted above, it is difficult to see how a change in the risk premium could account for the changes document in Section 3.

The EH has been rejected using a wide variety of interest rates, sample periods, monetary policy regimes, etc. (e.g., Campbell and Shiller, 1991; Bekaert and Hodrick, 2001; Thornton, 2005; Thornton and Kool, 2004; Sarno, Thornton, and Valente, 2007, and references therein). As Kozicki and Tinsely (2005) note, the widespread empirical failure of the EH need not imply a rejection of the idea that long-term investors are forward looking. Indeed, Guidolin and Thornton (2010) suggest that failure of the EH is likely due to the fact that it is nearly impossible to predict short-term interest rates beyond their current level, rather than because of a fundamental flaw in the theory or well-known econometric problems associated with commonly used tests of the EH. Consistent with Guidolin and Thornton's (2010) findings, Andersson and Hofmann (2009), Goodhart and Lim (2008), and Rudebusch (2007) show that neither central bankers nor markets participants are able to predict the future path of the central bank's policy rate beyond a few months.

5.2 An Alternative (Classical) Theory of the Term Structure

The EH remains the dominant paradigm for the monetary policy transmission mechanism because, as Fuhrer (1996) suggests, the "tendency to fall back on the paradigm [the EH] is so strong because candidates to replace it are so weak."[18] Hence, I propose what I believe is essentially a classical theory of the term structure (e.g., Humphrey 1983a,b). The classical theory presented here is not necessarily inconsistent with the EH, if the empirical failure of the EH is a

[18] Fuhrer (1996), p. 1183.

consequence of market participants' inability to forecast short-term rates appreciably beyond their current level (e.g., Guidolin and Thornton, 2010, and references therein). The EH is relevant for monetary policy only if market participants can make reasonably good predictions of the future short-term rate.

Classical economists generally believed that the structure of interest rates was anchored at the long-end of the term structure rather than at the short-end of the term structure as implied by the EH. "The" interest rate in classical analyses was an unobservable long-term rate, which was determined by basic economic forces—productivity, thrift, the rate of time preference, the marginal efficiency of capital, etc. In the short-run, observed long-term rates could deviate from the unobservable long-term rate determined by economic fundamentals for a variety of reasons. However, arbitrage would keep long-term rates from deviating too far from the fundamental rate for too long.

Classical economists did not have a specific theory of the structure of rates. Short-term interest rates were thought to be determined by current economic and financial market conditions; however, arbitrage would keep short-term rates from deviating from long-term rates over the long run. For example, if short-term rates deviate too far above (below) the long-term real rate, investors would have an incentive to lend (borrow) short and borrow (lend) long, causing short-term rates to rise (fall) and long-term rates to fall (rise). Within limits of differences in market participants' expectations for economic fundamentals, current conditions in financial markets, investors' tolerance for interest rate risks, etc., the relationship between long-term and short-term rates could vary over time.

The supply of credit, primarily determined by saving and changes in the stock of high-powered money, was thought to be relatively inelastic in the short run. 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. Given the inelastic supply of credit, long-term rates would tend to rise relative to short-term rates, i.e., the yield curve would tend to become steeper. During periods of weak investment opportunities, long-term rates would decline, pushing the entire rate structure lower. Given the relative inelasticity of credit supply, however, long-term rates would tend to fall relative to short-term rates so the yield curve would tend to flatten. If investment opportunities were particular weak (such as during and leading up to recession), the yield curve could invert. Inversions of the yield curve would be relatively rare, however, because investors were assumed to be risk adverse, i.e., the rate of time preference was assumed to be positive: All other things the same, investors require a term or risk premium for investing longer-term.

5.3 The Funds-Rate-Targeting Hypothesis

This section shows how, given the classical theory of the term structure and efficiency of financial markets, a shift to funds rate targeting for policy purposes could alter the relationship between the funds rate and Treasury yields. To see how, assume that the equilibrium federal funds rate (ff) and the 10-year Treasury yield ($T10$) are represented by

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

where r_t denote the natural real rate of interest, i.e., the classical unobservable long-term real rate, and π_t^e and $\pi_t^{e'}$ allows for the possibility that the expected rate of inflation relevant for the federal funds rate and the 10-year Treasury yield might be different. rp_t^{ff} and rp_t^{T10} denote non-zero risk premiums that are unique to each rate. Because Treasuries are void of default risk, rp_t^{T10} reflects a market-risk premium to compensate lenders for lending long. The overnight federal funds rate is essentially void of market risk, so rp_t^{ff} represents a default-risk premium. μ_t and μ_t' reflect potential premiums or discounts that are due to 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."

Given Equation (3), changes in interest rates will reflect the response of rates to changes in the economic fundamentals and shocks to factors that are unique to the markets, i.e.,

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

where ΔF_t is the change in economic fundamentals, e.g., changes in the natural rate of interest, changes in inflation expectations, or changes in the inflation or real risk premiums. The terms ε_t^{ff} and ε_t^{T10} are zero-mean, constant variance shocks to the factors that are unique to the particular rate. These shocks are uncorrelated with each other and with changes in economic fundamentals. The coefficients θ and ψ reflect the fact that different rates are likely to respond differently to economic fundamentals.

With both rates free to respond to news, the correlation between changes in the federal funds and 10-year rates is given by

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

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 non-zero correlation is a consequence of the fact that both rates respond to economic fundamentals at the same time.[19] The correlation will be positive if both θ and ψ have the same sign and negative if their signs are opposite. Given the fact that interest rates are positively related to the real rate, inflation expectations, etc., it is not surprising to see that changes in interest rates across the term structure tend to be positively correlated even at the daily frequency.

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

$$(6) \qquad ff_t = ff_t^{T} + \zeta_t,$$

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

[19] 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.

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

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

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

where $\sigma^2_{\Delta ff^T}$ denotes the variance of changes in the funds rate target.[20] Note that this correlation is zero if the $Cov(\Delta F_t, \Delta ff_t^T) = 0$. This covariance will be zero if the FOMC does not adjust its funds rate target quickly to changes in the economic fundamentals that the 10-yield responds to.

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, to June 30, 2004. Moreover, it is common for the funds rate target to be constant for a period of a month or more. Indeed, since 1994 there were only 7 occasions when the FOMC changed the target between regularly scheduled FOMC meetings. Indeed, the more slowly the FOMC adjusts the target to news and the less frequently it changes its target, the more likely the correlation will be small, perhaps zero.

[20] This assumes that control shocks are uncorrelated with changes in economic fundamentals.

6.0 Funds Rate Targeting in the 1970 and 1980

The previous section advanced the FRTH of the conundrum, first noticed by Greenspan (2005), but documented here to have occurred in the late 1980s. It is well known, however, that the Fed targeted the federal funds rate from the mid to the late 1970s (e.g., Cook and Hahn, 1989; and Rudebusch, 1995). Hence, if the change in the relationship between the funds rate and the 10-year yield documented above is a consequence of funds rate targeting, the natural question is: Why was the relationship not changed in the 1970s? The answer to this question comes from the distinction between using the funds rate as an “operating target” and using it as a “policy target.” Specifically, the FOMC used the federal funds rate in the 1970s much differently than it does today.

6.1 Funds Rate Targeting in the 1970s

It is important to remember that in the early 1970s there was no wide-spread acceptance of the view that monetary policy 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 important, 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 period 1970-79 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.[21]

The funds rate was used by the Trading Desk of the Federal Reserve Bank of New York (hereafter, Desk) as a guide for conducting daily open market operations. The target was not set to achieve specific FOMC policy objectives. If the funds rate began trading high relative to expectations, i.e., "the target," 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.

The FOMC's "official funds rate objective," as the FOMC then referred to its funds rate target, was adjusted frequently. Figure 5 shows the daily funds rate and Rudebusch's (1995a,b) funds rate target over the period September 13, 1974, through September 19, 1979. Rudebusch reports 99 adjustments to the funds rate objective—an average of an adjustment every 2.5 weeks. This is hardly the behavior one would expect if the funds rate target were being used to implement monetary policy as it is today. Moreover, many of the changes in the funds rate target that Rudebusch reports were made by the Desk, not the FOMC. Indeed, the FOMC's funds rate target was stated as a range of 50 to 75 basis points, not as a specific rate.[22]

Finally, despite frequent target adjustments, differences of the funds rate from the funds rate objective were relatively large. The average absolute monthly

---

[21] Meulendyke (1998), pp. 44-45.

[22] See the annual review of the FOMC published in the Federal Reserve Bank of St. Louis *Review* from 1975 through 1979.

difference of the funds rate from the funds rate objective was 13 basis points, with a standard deviation of 28 basis points during the 1973-79 period.

Because the funds rate was permitted to deviate significantly from the mid-point of the target range and adjustments to the funds rate objective were frequent, the funds rate effectively responded to news about economic fundamentals in much the same way as other market rates. Consequently, there is no reason to see a marked change in the relationship between the funds rate and the 10-year Treasury yield as a result of "funds rate targeting" during this period.

Nevertheless, to test whether the relationship between the funds rate and the 10-year yield occurred even earlier, 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 and, importantly, even in the late 1970s when the FOMC greater emphasis on monetary aggregates in the implementation of monetary policy.

6.2 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 "targeted" the funds rate in much the same way as it did during the pre-October 1979 period. For policy, the FOMC continued to focus on monetary aggregates (primarily M2 and, to a lesser extent, M3). The funds rate was used as an operating objective, similar to how it was used in the mid- to late 1970s. In discussing the FOMC's practice from "1983 to the late 1980s," Meulendyke (1998) notes, the Committee adjusted its operating objective up or down, "whenever money seemed to be deviating significantly from the desired growth path."[23]

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. For example, at the February 10, 1988, meeting, 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."[24]

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 and Committee members became increasingly open about the extent to which they were focusing on the funds rate in their policy deliberations.

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

[23] Meulendyke (1998), p. 53.
[24] FOMC Transcript, February 10, 1988, p. 44.

call; however, the discussion at the May 17, 1988, FOMC meeting indicates that the increase was in response to concerns about inflation.[25] 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.[26]

Most FOMC participants continued to use the code of 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 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.[27]

Greenspan summarized the Committee's views by stating

> 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

---

[25] 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.

[26] FOMC Transcript, May 17, 1988, p. 1. There is no available transcript for the first part of this meeting.

[27] FOMC Transcript, May 17, 1988, p. 10.

> 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.[28]

Consistent with this statement, 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 et al. (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 its target for the funds rate 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.[29]

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

[28] FOMC Transcript, May 17, 1988, p. 10.
[29] For a more detailed analysis of this period see Thornton (2004).

"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."[30] 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.[31]

The behavior of reserves and M1 is consistent with the idea 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, 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

[30] Transcript FOMC Conference Call (1989), p. 3.
[31] Thornton (2004), p. 494.

lower market rate level."[32] In this case, the change in the target was essentially an endogenous response to a change in interest rates.

The marked change in the Committee's emphasis on the funds rate is 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 May 1988, 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 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.

7.0 Evidence of the FTRH

The previous section documents that the FOMC began using the funds rate to implement monetary policy in the late 1980s, about the time of the marked change in the relationship between the funds rate and the 10-year Treasury yield occurred. This section provides empirical evidence from a variety of sources that

[32] FOMC Transcript, February 10, 1988, p. 50.

supports the hypothesis that the change in the FOMC's use of the funds rate accounts for the change in the relationship between these rates.

7.1 The Relationships of the Federal Funds and 10-Year Yield and Other 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 also be a noticeable effect on the relationship between the federal funds rate and other Treasury rates as well. Moreover, given that arbitrage is stronger the closer the term to maturity of two assets, the FRTH suggests that there should be a noticeable change in the relationship between the rate on 10-year Treasuries and shorter-term Treasury rates as well.

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 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 non-zero 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 Figures 7 are statistically significant and to get an estimate of the date the changes 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% 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 $T1$. For Treasury rates with maturities of a year or less the supremum occurs in the early 2000s, about the time when the FOMC reduced it funds rate target to what was then a historically low level and kept it there for a year. The 5-year yield has a local peak at May 1988; however, the slightly higher surpremum occurs at July 1989.

The Andrews break point 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. As with the federal funds rate, there is a statistically significant break in the relationship between the 10-year yield and the 3-month T-bill rate that occurs at May 1988. The other rates have local extremums at or near May 1988; however, there is no statistically significant break for $tb6$ or $T1$ even at the 10 percent significance level. There is also a local peak for $T5$ at June 1988, but the statistically significant break occurs near the period when the funds rate target was extremely low for an extended period of time.

The above evidence is even stronger when all the rates are adjusted for the effect of the latent factors. This is done by estimating Equation (2) for all six rates and imposing the cross-equation restrictions $\delta_1^i = \delta_1^j$ and $\delta_2^i = \delta_2^j$, for all i and j. 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. Hence, 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.[33]

The four panels of Figure 11 plot the latent-factor-adjusted levels of $tb3$, $tb6$, $T1$, and $T5$ 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 12-month 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 in the

[33] As before, the results are nearly identical if the restrictions are not imposed.

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 before and after 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 the greatest the larger the shorter the term to maturity. Indeed, the effect on the relationship with the 5-year yield is relatively modest, and consistent with results of Andrews' test reported above, the relationship appears to be most different beginning about 2002.

7.2 Temporal Ordering and the FRTH

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 for all possible pairs of the six latent-factor-adjusted interest rates for the period before and after May 1988. The latent-factor-adjusted rates are used 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.

The complete set of results is presented in Appendix A; however, 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 or lower before and after May 1988. With one exception, the Granger causality tests indicate unidirectional temporal ordering from each of Treasury rates to the federal funds rate both 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 nine of the 25 lag specifications considered after May 1988. The fact that there is unidirectional temporal ordering before May 1988 suggests that the funds rate was somewhat slow to adjust news even when FOMC was using it as an operational guide for open market operations before 1988. 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 to implement policy.

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.

The results change markedly after May 1988, however. After May 1988, there is strong evidence of unidirectional temporal ordering from longer-term Treasury rates to shorter-term Treasury rates, which is consistent with the classical notion 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 short-term Treasury rate is rejected for all or most of the 25 lag specifications considered, and the null hypothesis that the shorter-term Treasury rate does not Granger-cause the longer-term Treasury rate is either never rejected or rejected for a much smaller number of the lag lengths considered.

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 when the FOMC was not using the funds rate to implement policy.

7.3 The FRTH and the Effect of Target Changes

If the FRTH is correct, the relationship between the 10-year Treasury yield and other Treasury rates should be also be affected by FOMC funds rate target changes. 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) $$\Delta T10_t = \alpha + \beta^{\Delta ff^*} \Delta j_t D^{\Delta ff^*} + \beta^{no\Delta ff^*} \Delta j_t D^{no\Delta ff^*} + \eta_t,$$

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 elsewhere, and $D^{no\Delta ff^*} = 1 - D^{\Delta ff}$. 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 during the month when the target was changed.

Equation 9 is estimated over the sample periods January 1983–May 1988 and June 1988 through March 2007. The results for the first period are presented in Panel A of Table 2. Consistent with 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.

The results are very different after May 1988, however. 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 is not rejected. This suggests that the relationships between monthly changes in these Treasury rates and changes in the 10-year Treasury yield changed after May 1988 only during months when the target was changed.[34] The null hypothesis is

---

[34] Table 3 reports the test of equality of the estimate of $\beta^{no\Delta ff^*}$ for the second sample period with the estimate of β from the equation, $\Delta T10_t = \alpha + \beta \Delta i_t + \varepsilon_t$ .estimated over the first sample period. However,

rejected, however, for the 5-year rate. Consistent with the Andrew test in Section 5.3; however, the relationship between the 5- and 10-year yields changed significantly during the latter part of the second period.

7.4 The FRTH and the Effect of Policy Actions

If the change in the relationship between the funds rate and Treasury rates is the consequence of the FOMC targeting the funds rate, we should expect to see the relationships among rates affected most when the funds rate target 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 for the funds rate despite marked declines in long-term and short-term rates.

The second 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 and despite this fact, inflation had been declining and low. Greenspan attributed what appeared to be aberrant behavior of inflation relative to output growth to a rise in productivity. The Committee delayed policy actions even though Board of Governors' staff forecasts, which were repeatedly wrong, were for rising inflation (e.g., Meade and Thronton, 2010). 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 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.

The third occurred in 2001 when the FOMC reduced its funds rate target aggressively relative to long-term Treasury rates 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 that it could be very 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. The figure shows that there was a marked decline in the correlation between the federal funds rate and each of the Treasury rates during each of these three episodes.[35]

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 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 in the relationship between the 5- and 10-year occurred when the sample includes the period when the FOMC maintained the funds rate target at 1.0 for about a year.

7.5 The FRTH and the FOMC's Reaction Function

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

[35] The data are plotted on the first month in the sample.

its target for the funds rate. Most theoretical models have FOMC setting the funds rate target in accordance with a Taylor-type rule. It is doubtful that the FOMC followed such a rule or even adopted rule-like behavior (e.g., Asso et al., 2010, and Meade and Thornton, 2010). Moreover, empirical Taylor rules do not fit the data very well unless they include the lagged federal funds rate, which is characterized as representing policy inertia (Woodford, 1999, 2003). However, there is little empirical (e.g., Rudebusch, 2002, 2006, 2007) or documentary (e.g., Asso et al., 2010) evidence that monetary policy was inertial during this period.

While the FOMC has likely never followed a Taylor-type rule per se, there is little doubt that policymakers believed that they should adjust their policy rate lower to promote output growth and raise it to slow output growth and/or reduce inflation (e.g., Meade and Thornton, 2010). Hence, the approach taken here is to estimate the simple policy reaction function of the form,

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

where $i\dot{p}_t$ denotes the monthly growth rate of industrial production and Δur_t denotes the monthly change in the unemployment rate.[36] To ensure that Equation (10) is a policy reaction function rather than simply capturing reduced-form relationship between interest rates and these macro-variables, Equation (10) is also estimated with $\Delta T10$ as the dependent variable. If the equation simply reflects a reduced-form relationship between interest rates and these variables, the

[36] 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.

relationships of the funds rate and the 10-year Treasury yield with these variables should be similar.

Equation (10) is estimated using monthly data for periods before and after May 1988. The estimates for periods before and after May 1988 are presented in the top section of Table 3. There is a very weak relationship between changes in the funds rate and these macro-variables before 1988. Moreover, the relationship of the changes in the funds rate to these variables is nearly identical to that of changes in the 10-year Treasury yield.

The results changed markedly after May 1988, however. After May 1988 the macro-variables account for more than 25 percent of the variation of changes in the funds rate. However, as before May 1988, these variables account for essentially none of the variation of changes in the 10-year yield. These findings are consistent with the idea the FOMC was targeting the funds rate for economic stabilization purposes after May 1988 but not before.

This conclusion is enhanced by estimating Equation (10) over two periods when the FOMC was aggressively changing the funds rate target for policy purposes. The first 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."[37] 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," while Governor Angell and

[37] Federal Reserve Press Release, November 16, 1990, pp. 16 & 17.

Presidents Boykin and Hoskins dissented because "they were opposed to the easing of reserve conditions contemplated by the majority."[38] 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 in 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 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.[39]

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 this period, reported in the bottom section of Table 3, show that estimates of θ_1 and θ_2 are highly statistically significant with the expected signs. Moreover, the estimate of $\bar{R}^2$ indicates that these variables account for nearly half of the variation of changes in the funds rate.

[38] Record of Policy Actions of the Federal Open Market Committee, October 2, 1990, p. 18.
[39] Federal Reserve Press Release, December 21, 1990, pp. 13-14.

Consistent with the reaction function interpretation, these variables account for essentially none of the variation of changes in the 10-year Treasury yield.

The second period begins on January 3, 2001, when the FOMC 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…"[40] 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 historical 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 activity."[41] 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 through June 2006, presented in the lower panel of Table 3, show that change in the federal rate is 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.

---

[40] Federal Reserve Press Release, January 3, 2001.
[41] Federal Reserve Press Release, June 25, 2003.

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. These results also provide strong support for the FTRH.

8.0 Conclusions

In February 2005, then-Chairman Alan Greenspan pointed out that Treasury yields changed little despite a 150-basis-point increase in the FOMC's target for the federal funds. Dismissing several possible explanations, he called the uncharacteristic behavior a conundrum. This paper investigated the conundrum by examining the behavior of changes in the federal funds rate and changes in the 10-year Treasury yield since the early 1980s. This examination showed that the percent of variation in the 10-year yield that could be accounted for by the behavior of the funds rate declined dramatically from about 30 percent to zero around 1994 and remained at essentially zero thereafter. Further analysis established a single break in the relationship between these rates that occurred in the late 1980s—specifically, May 1988—well in advance of Greenspan's observation.

Finding alternative explanations for the marked change in the relationship between the funds rate and the Treasury yield lacking, I proposed an alternative hypothesis. Specifically, I hypothesize that the change in the relationship occurred because the FOMC began using the funds rate to implement policy in the late 1980s, rather than simply using the funds rate to guide daily open market operations as it had done in the mid-to-late 1970s and early 1980s. Documentary and empirical evidence is presented that supports the claim that the FOMC began using the funds rate to implement monetary policy in the late 1980s. Several implications of the hypothesis are tested and evidence consist with the hypothesis is presented.

The hypothesis offered here appears to be at odds with the conventional theory of the monetary policy transmission mechanism, which sees the Fed as affecting aggregate spending by affecting long-term rates through its control over the overnight policy rate, via the expectations hypothesis. This is not necessarily the case, however. The usefulness of the expectations hypothesis depends critically on the extent to which market participants can predict the future level of short-term rates. Evidence presented by Guidolin and Thornton (2010), Goodhart and Lim (2008), Rudebusch (2007), Andersson and Hofmann (2010), and others, however, indicates that short-term rates are very difficult to predict significantly beyond their current level. Hence, while the theoretical underpinnings of the expectations hypothesis may be correct, its practical application for monetary policy may be limited. Indeed, the recent focus of central banks (e.g., New Zealand, Norway, Sweden, and the U.S.) on "forward guidance" is motivated by a desire to have a larger effect on longer-term rates by making the future path of the policy rate more predictable.

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.

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.

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 meetings of the Eastern Economic Association, Washington, DC, February 20, 2004; 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 Econometric*s, *70*, 221-41.

Federal Open Market Committee Transcript, May 17, 1988.

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, dp612

Guidolin, M. and D.L. Thornton. 2010, “Predicting Short-Term Rates and the Expectations Hypothesis,” Federal Reserve Bank of St. Louis Working Paper 2110-013A.

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.

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.

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. 2010, "The Phillips Curve and US Monetary Policy: What the FOMC Transcripts Tell Us," Federal Reserve Bank of St. Louis Working Paper 2010-017A.

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* (April 1995a), 245-74.

Rudebusch, G.D. 1995b, "Erratum," *Journal of Monetary Economics* (December 1995b), 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', FRBSF *Economic Letter*, no. 2007-03, (January 26).

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 Economic*," 56, 907-17.

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: Frequency Results for Granger Causality Test					
	ff	*tb*3	*tb*6	*T*1	*T*5
January 1983 – May 1988					
hypothesis	The column rate does not Granger cause the row rate				
*tb*3	0				
*tb*6	0	0			
*T*1	0	0	0		
*T*5	0	0	0	0	
*T*10	0	0	0	0	0
hypothesis	The row rate does not Granger cause the column rate				
*tb*3	25				
*tb*6	25	0			
*T*1	25	0	0		
*T*5	25	0	0	0	
*T*10	25	0	0	0	0
June 1988 – March 2007					
hypothesis	The column rate does not Granger cause the row rate				
*tb*3	9				
*tb*6	0	8			
*T*1	0	0	0		
*T*5	0	4	7	9	
*T*10	0	0	0	0	3
hypothesis	The row rate does not Granger cause the column rate				
*tb*3	25				
*tb*6	25	25			
*T*1	25	25	19		
*T*5	25	8	15	24	
*T*10	25	10	16	25	20

Table 2: Results of the regression							
Panel A: January 1983--May 1988							
	α	$\beta^{\Delta ff^*}$	$\beta^{no\Delta ff^*}$	$\overline{R}^2$	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 the null hypothesis that $\beta^{\Delta ff^*} = \beta^{no\Delta ff^*}$ within the sample period. Test 2 is a Chi-square test the null hypothesis that the estimate of $\beta^{no\Delta ff^*}$ in the June 1988 – March 2007 is equal the estimate of the relationship for the January 1983 – May 1988 sample period.

Table 3: Estimates of the Policy Reaction Function				
Dependent Variable	Δff	$\Delta T10$	Δff	$\Delta T10$
	January 1983 – May 1988		June 1988 – March 2007	
θ_0	-0.116 (0.043)	-0.121 (0.085)	-0.098 (0.000)	-0.017 (0.452)
θ_1	0.014 (0.193)	0.018 (0.112)	0.033 (0.000)	-0.001 (0.796)
θ_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	
θ_0	-0.159 (0.004)	-0.045 (0.325)	-0.061 ()0.054)	0.012 (0.718)
θ_1	0.045 (0.001)	0.010 (0.364)	0.054 (0.001)	-0.011 (0.297)
θ_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

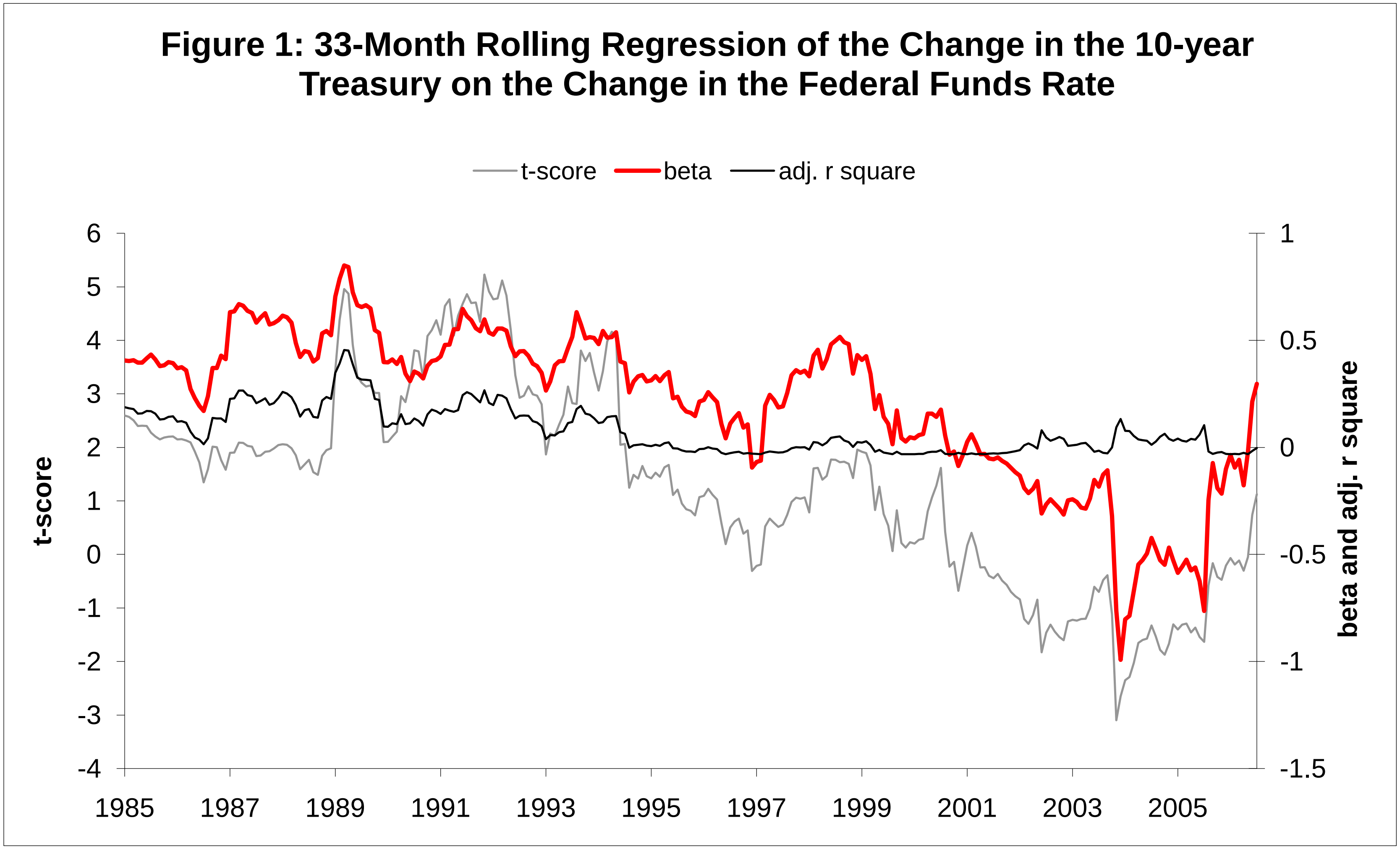


Figure 1: 33-Month Rolling Regression of the Change in the 10-year Treasury on the Change in the Federal Funds Rate
t-score
beta
adj. r square
6
5
4
3
2
1
0
-1
-2
-3
-4
1
0.5
0
-0.5
-1
-1.5
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
t-score
beta and adj. r square

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

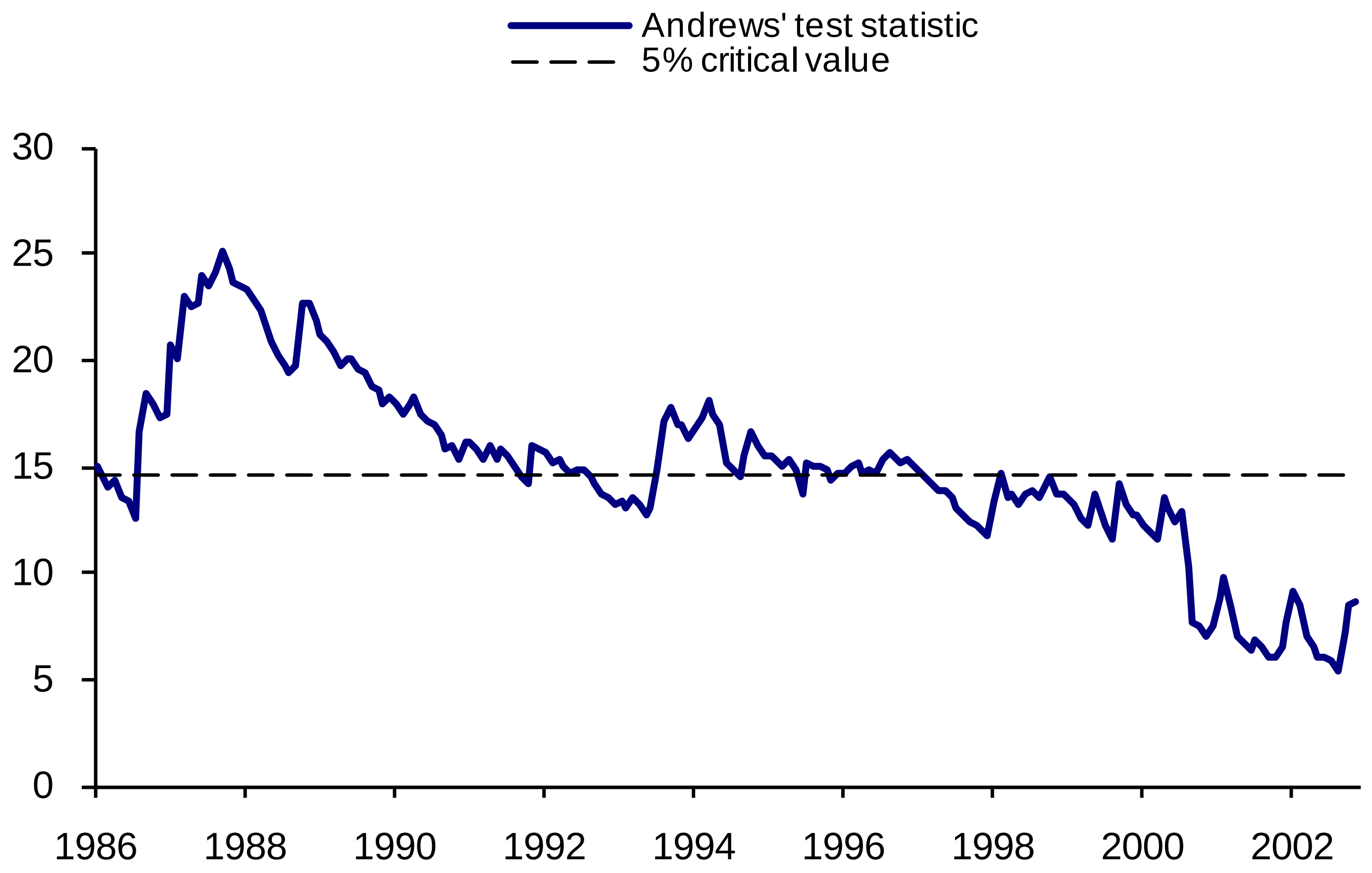
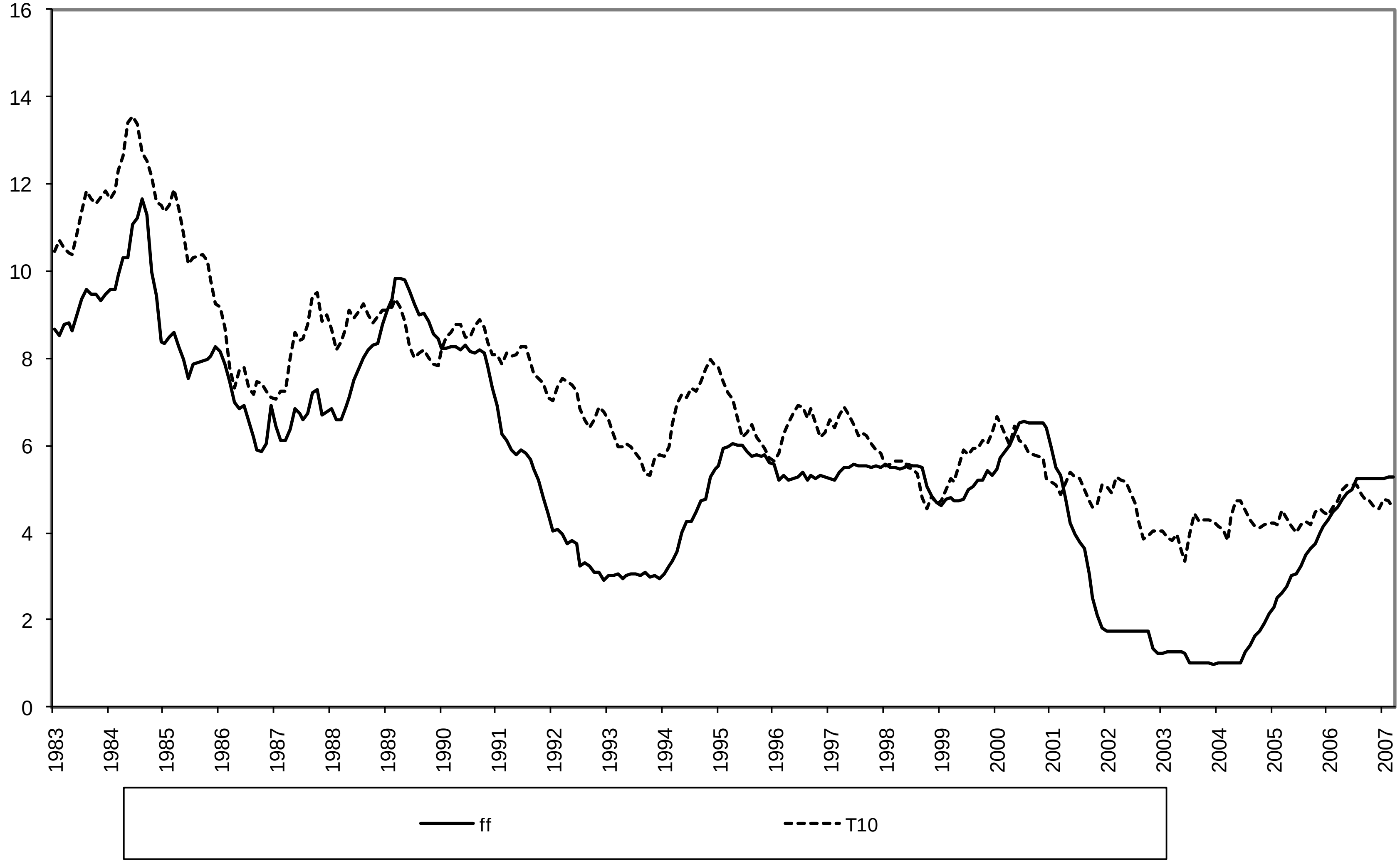


Figure 3: The Federal Funds and 10-Year Treasury Rates, January 1983 - March 2007



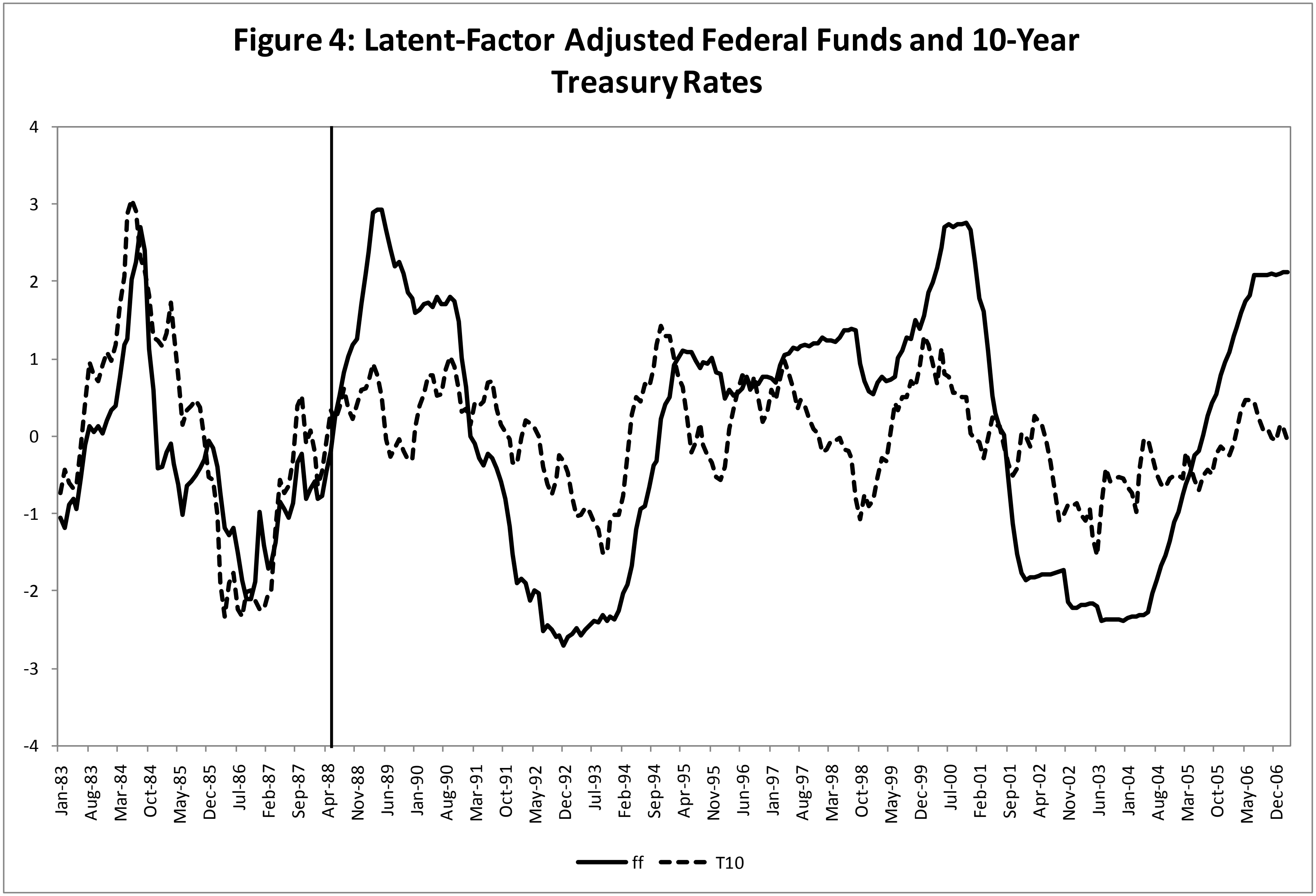


Figure 4: Latent-Factor Adjusted Federal Funds and 10-Year Treasury Rates
4
3
2
1
0
-1
-2
-3
-4
Jan-83
Aug-83
Mar-84
Oct-84
May-85
Dec-85
Jul-86
Feb-87
Sep-87
Apr-88
Nov-88
Jun-89
Jan-90
Aug-90
Mar-91
Oct-91
May-92
Dec-92
Jul-93
Feb-94
Sep-94
Apr-95
Nov-95
Jun-96
Jan-97
Aug-97
Mar-98
Oct-98
May-99
Dec-99
Jul-00
Feb-01
Sep-01
Apr-02
Nov-02
Jun-03
Jan-04
Aug-04
Mar-05
Oct-05
May-06
Dec-06
ff
T10

Figure 5: The FOMC's Federal Funds Rate Objective and the Federal Funds Rate

(September 13, 1974 - September 19, 1979)

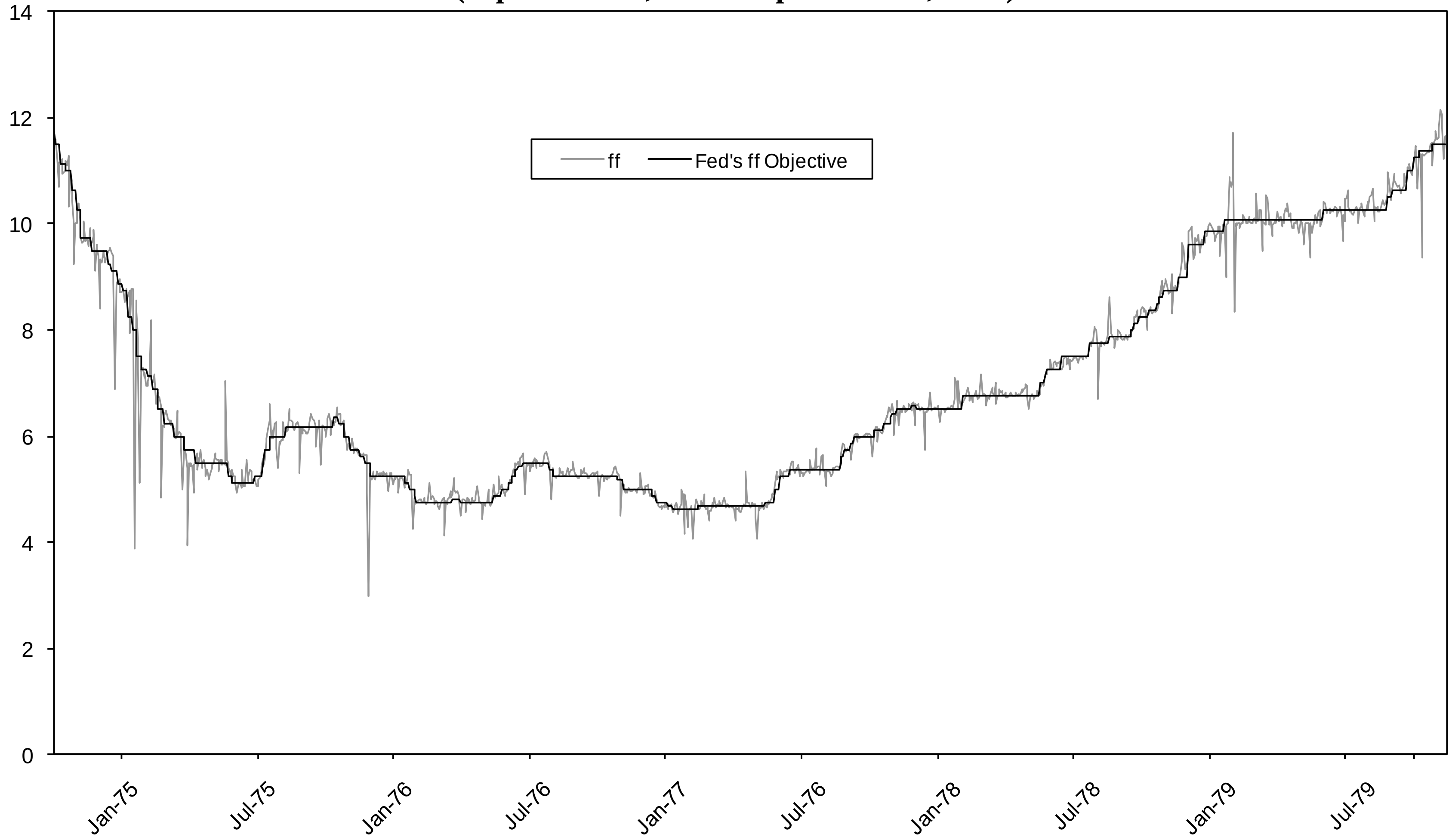


Figure 6: Average Difference Between the Federal funds Rate and the FOMC's Funds Rate Target
(January 1983 - March 2007)

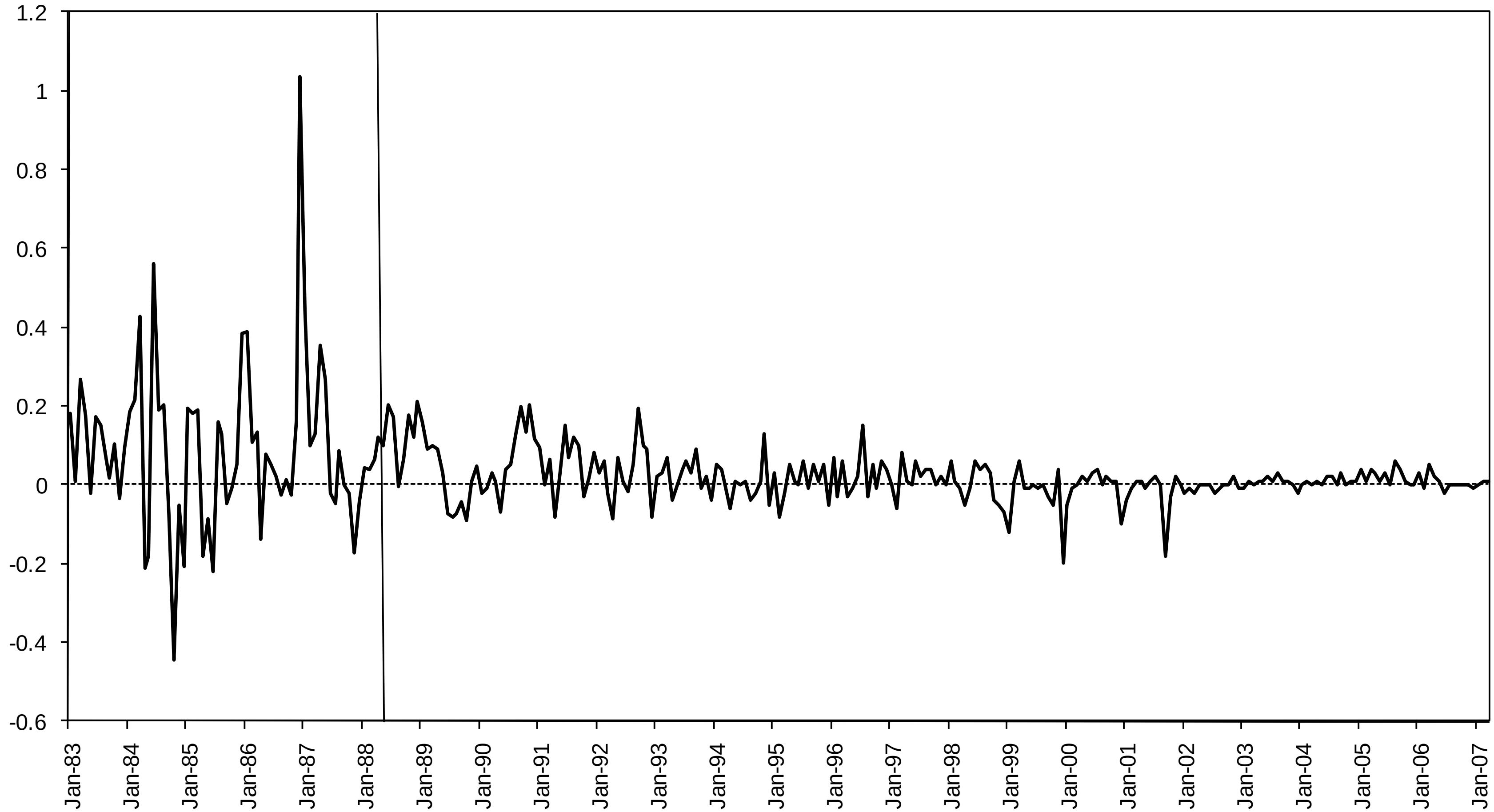


Figure 7: 33-Month Adj-Rsquares from Rolling Regressions of the Change in Various Rate on Changes in the Funds Rate

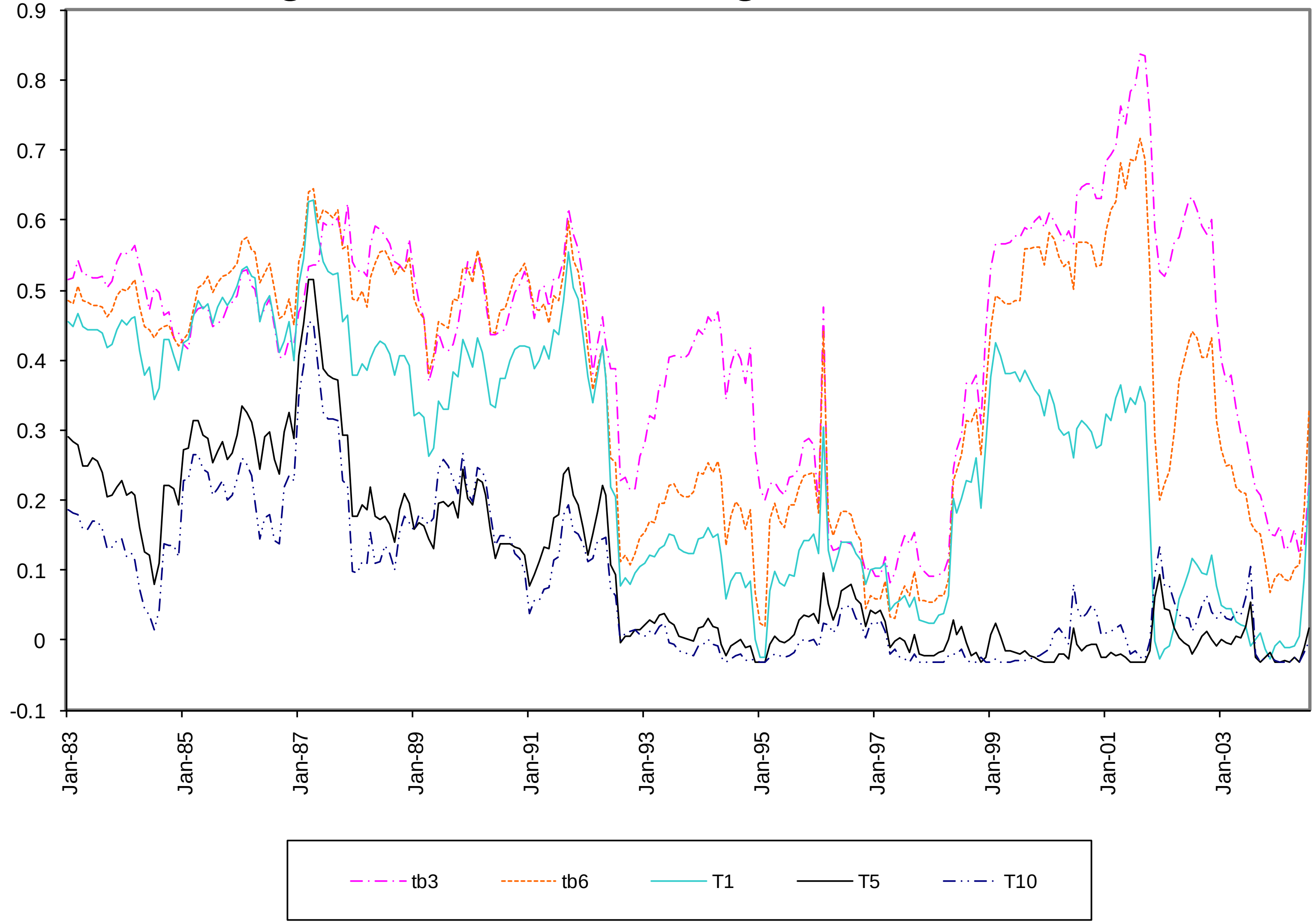


Figure 8: 33-Month Rolling Adj-Rsquares of Regressions of the Change in the 10-Year Yield on Changes in Various Rates

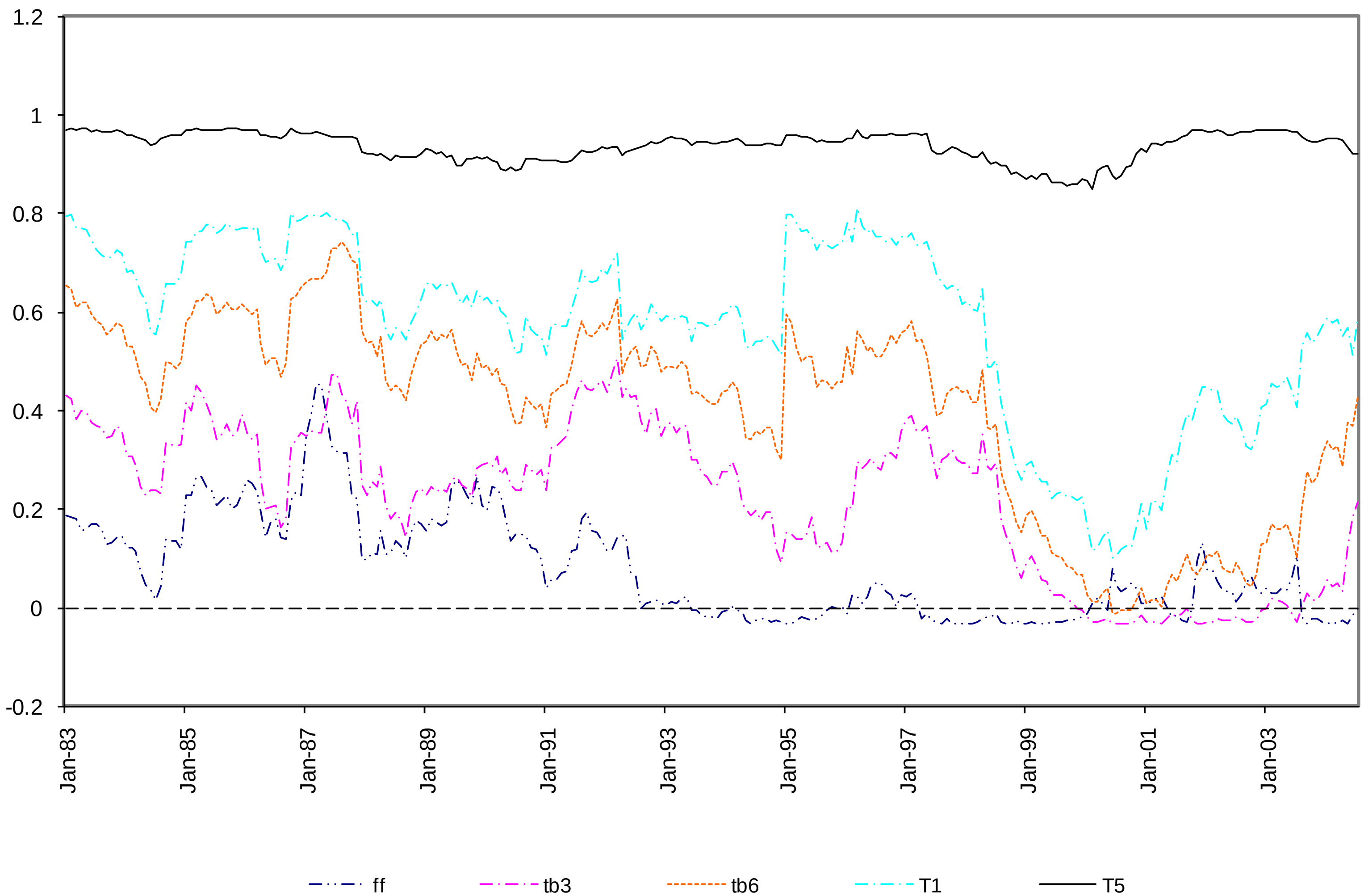


Figure 9, Panel A: Andrews Break Point Test of 3-month TB on the Federal Funds Rate

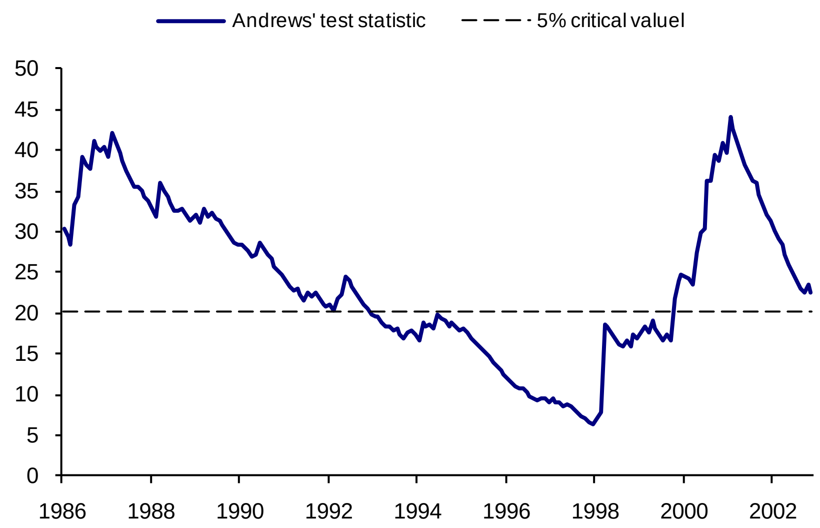


Figure 9, Panel B: Andrews Break Point Test of 6-month TB on the Federal Funds Rate

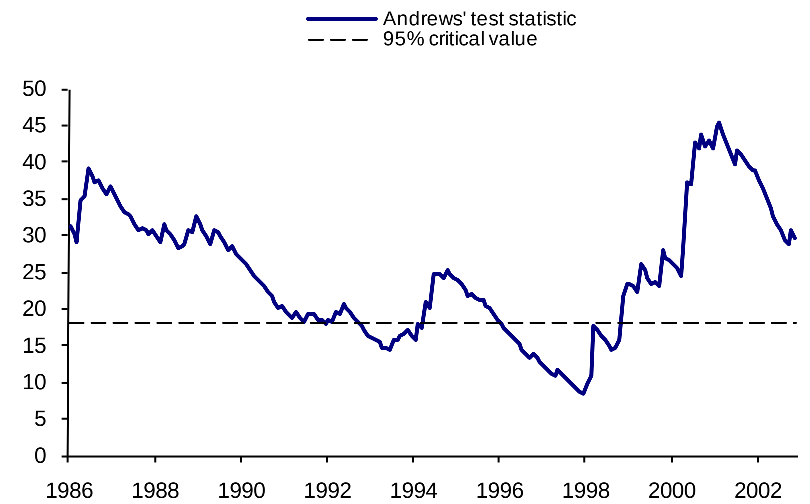


Figure 9, Panel C: Andrews Break Point Test of 1-year Treasury on the Federal Funds Rate

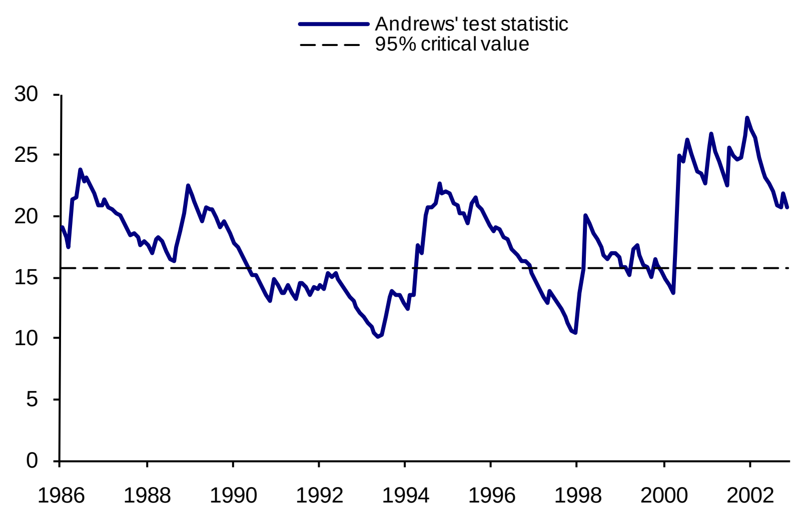


Figure 9, Panel D: Andrews Break Point Test of 5-year Treasury on the Federal Funds Rate

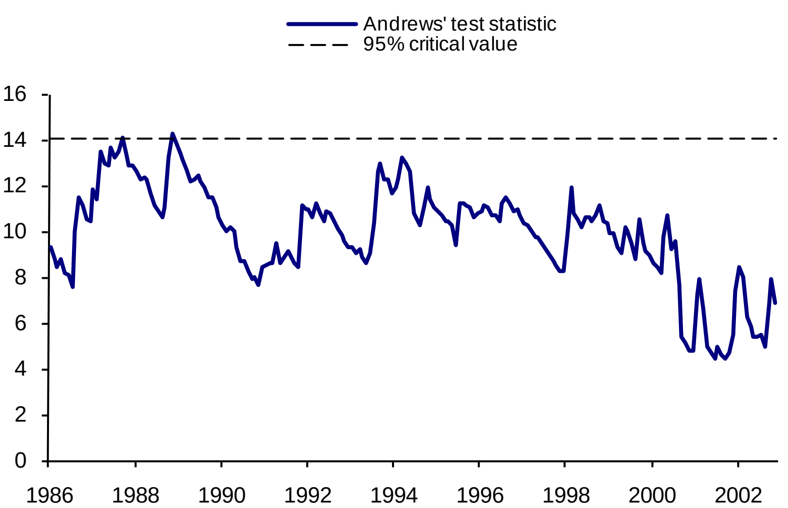


Figure 10, Panel A: Andrews Break Point Test of 10-year Treasury on the 3-month TB

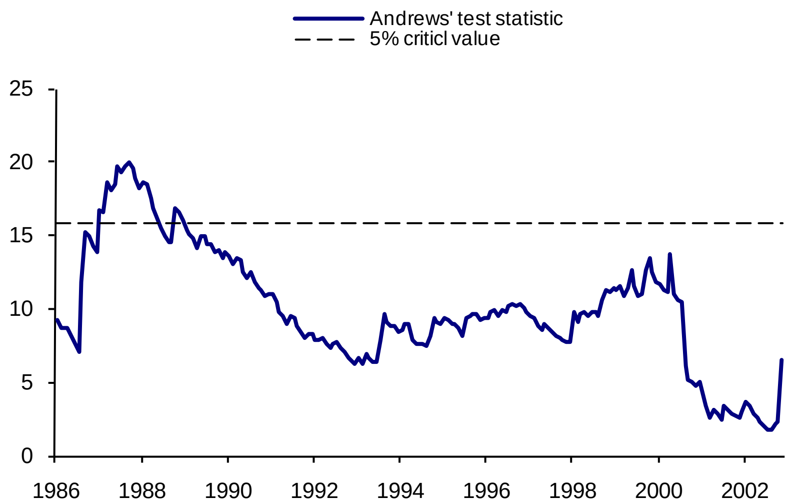


Figure 10, Panel B: Andrews Break Point Test of 10-year Treasury on the 6-month TB

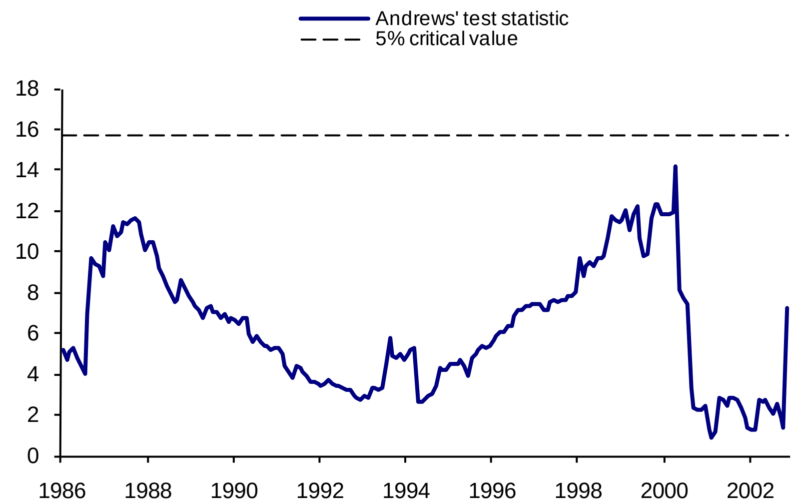


Figure 10, Panel C: Andrews Break Point Test of 10-year Treasury on the 1-year Treasury

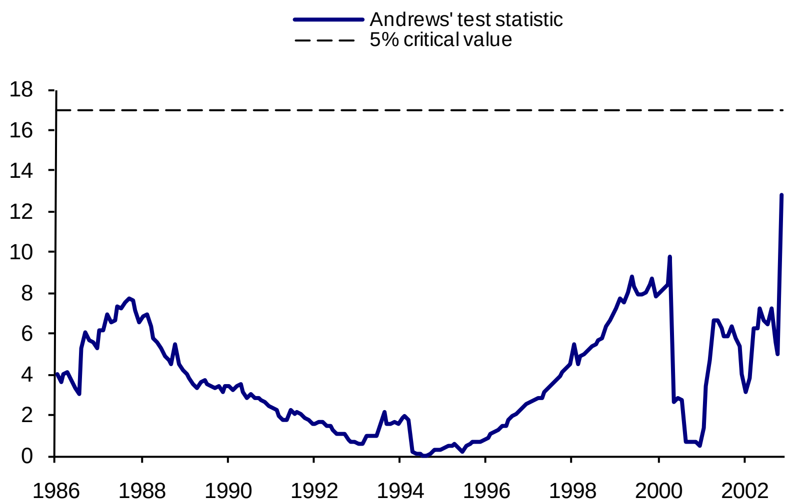
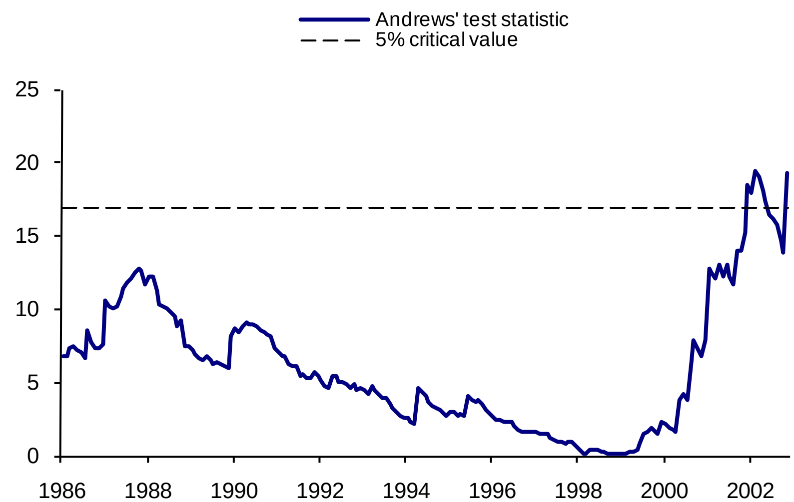


Figure 10, Panel D: Andrews Break Point Test of 10-year Treasury on the 5-year Treasury



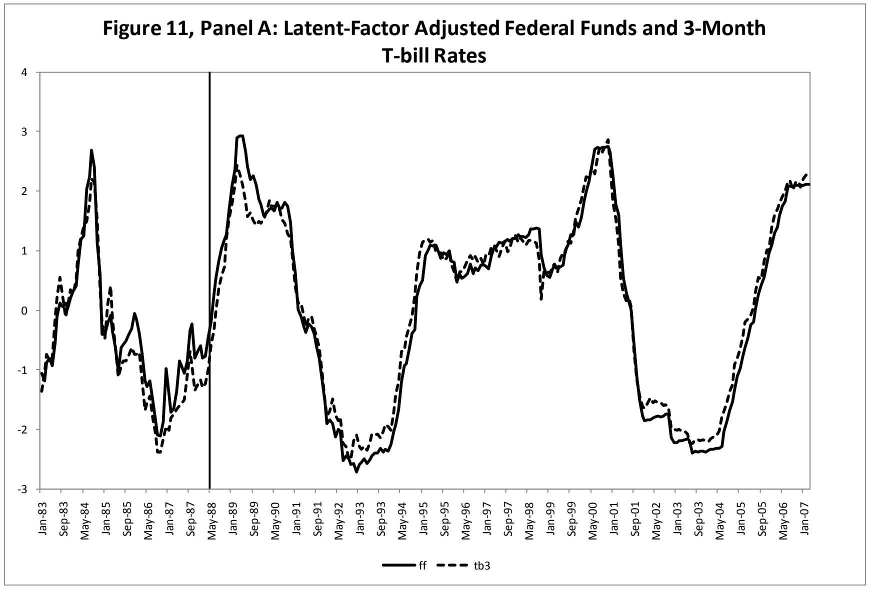


Figure 11, Panel A: Latent-Factor Adjusted Federal Funds and 3-Month T-bill Rates
ff
tb3

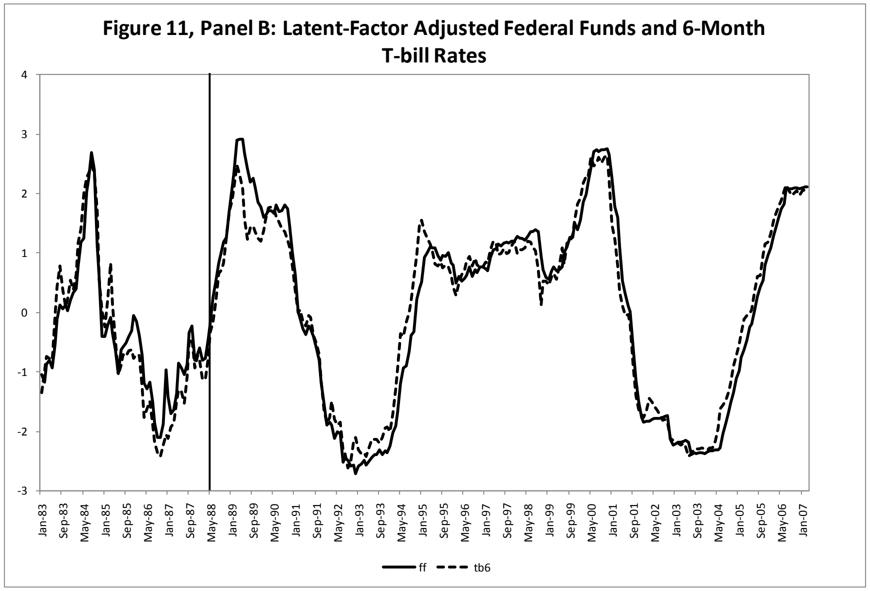


Figure 11, Panel B: Latent-Factor Adjusted Federal Funds and 6-Month T-bill Rates
ff
tb6

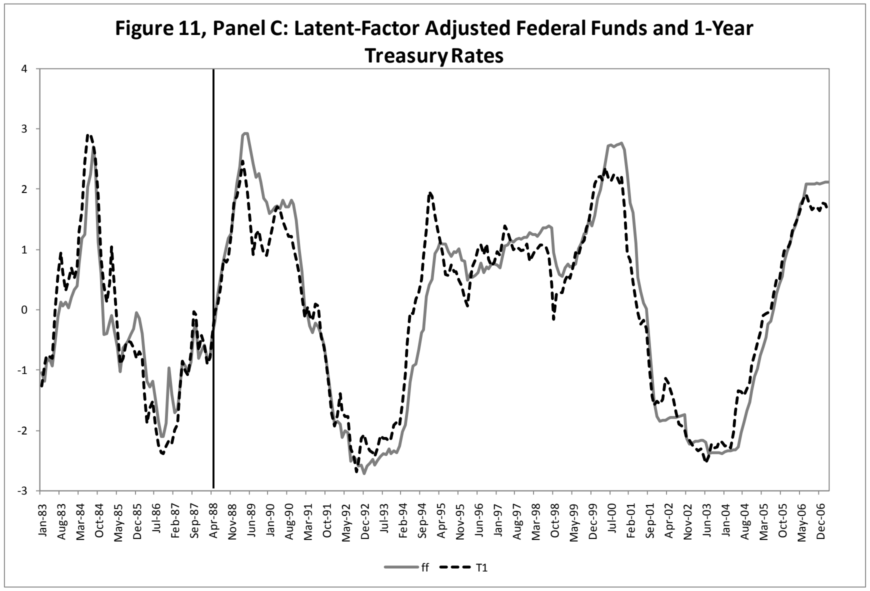


Figure 11, Panel C: Latent-Factor Adjusted Federal Funds and 1-Year Treasury Rates
ff
T1

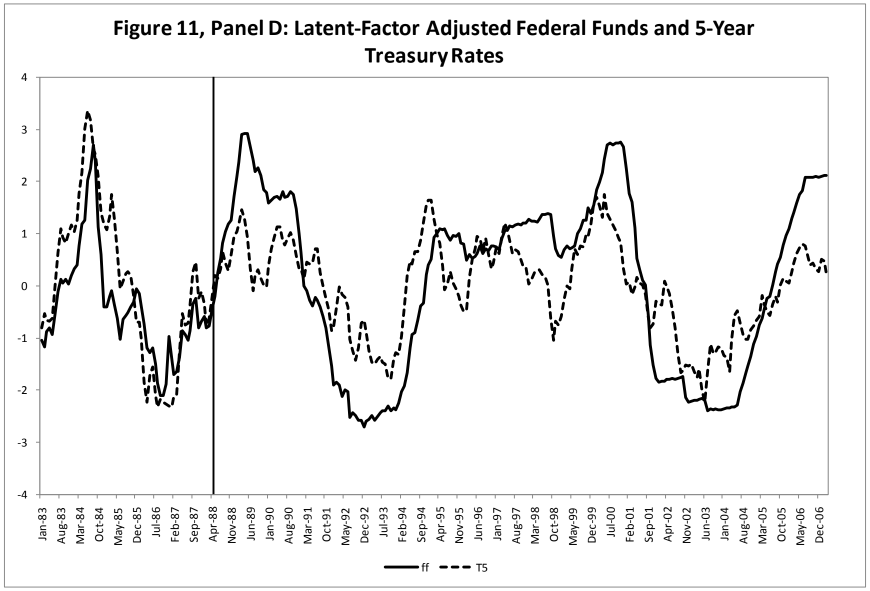


Figure 11, Panel D: Latent-Factor Adjusted Federal Funds and 5-Year Treasury Rates
ff
T5

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

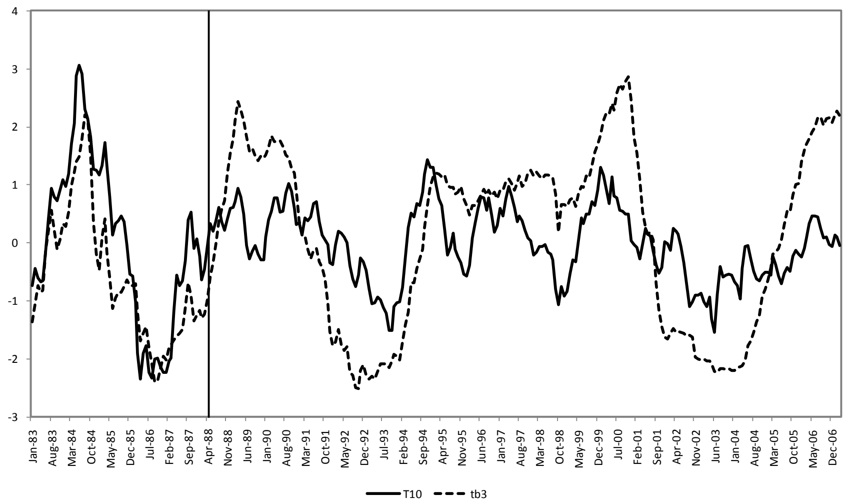


Figure 12, Panel B: Latent-Factor Adjusted 10-Year Treasury and 6-Month T-Bill Rates

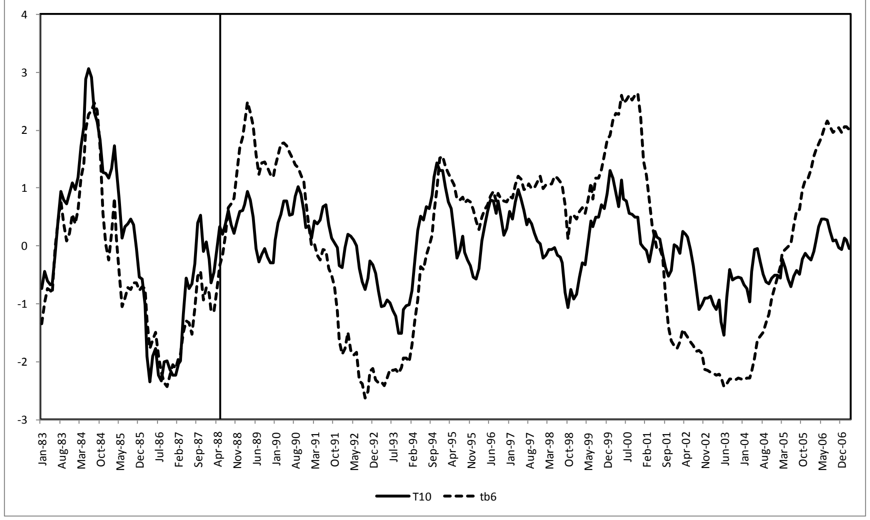


Figure 12, Panel C: Latent-Factor Adjusted 10-Year and 1-Year Treasury Rates

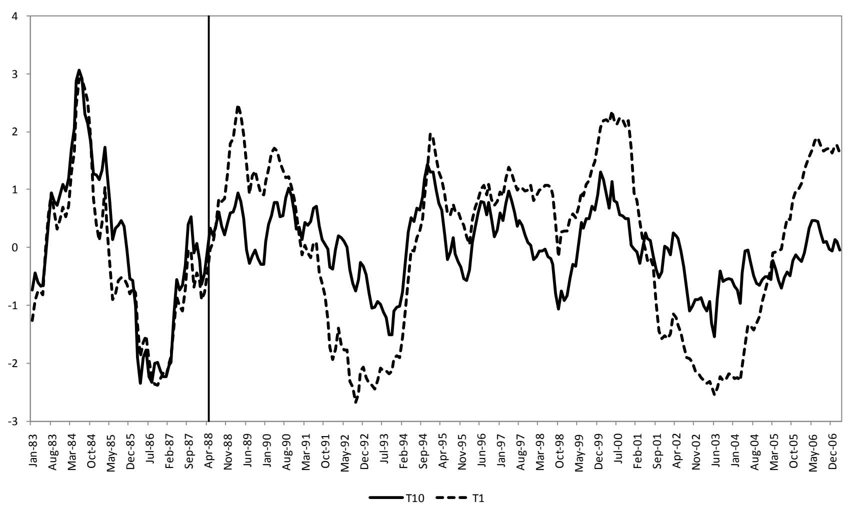


Figure 12, Panel D: Latent-Factor Adjusted 10-Year and 5-Year Treasury Rates

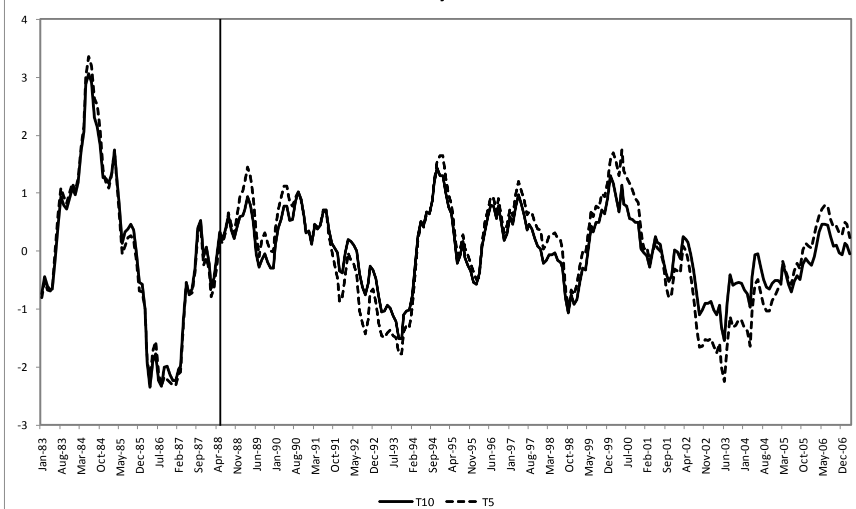


Figure 13: 24-Month Rolling Correlation of the Latent-Factor-Adjusted Treasury and Federal Funds Rates

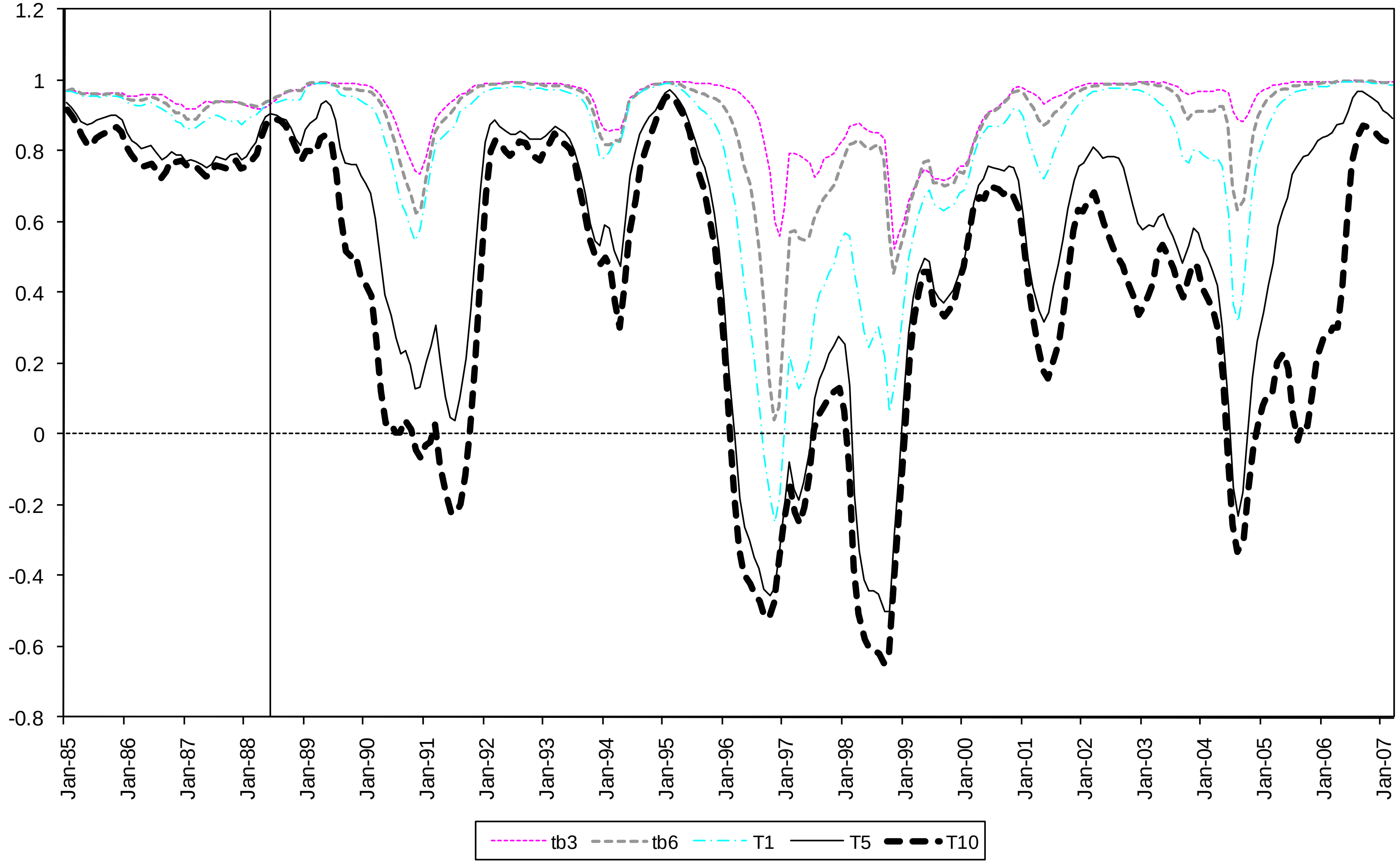
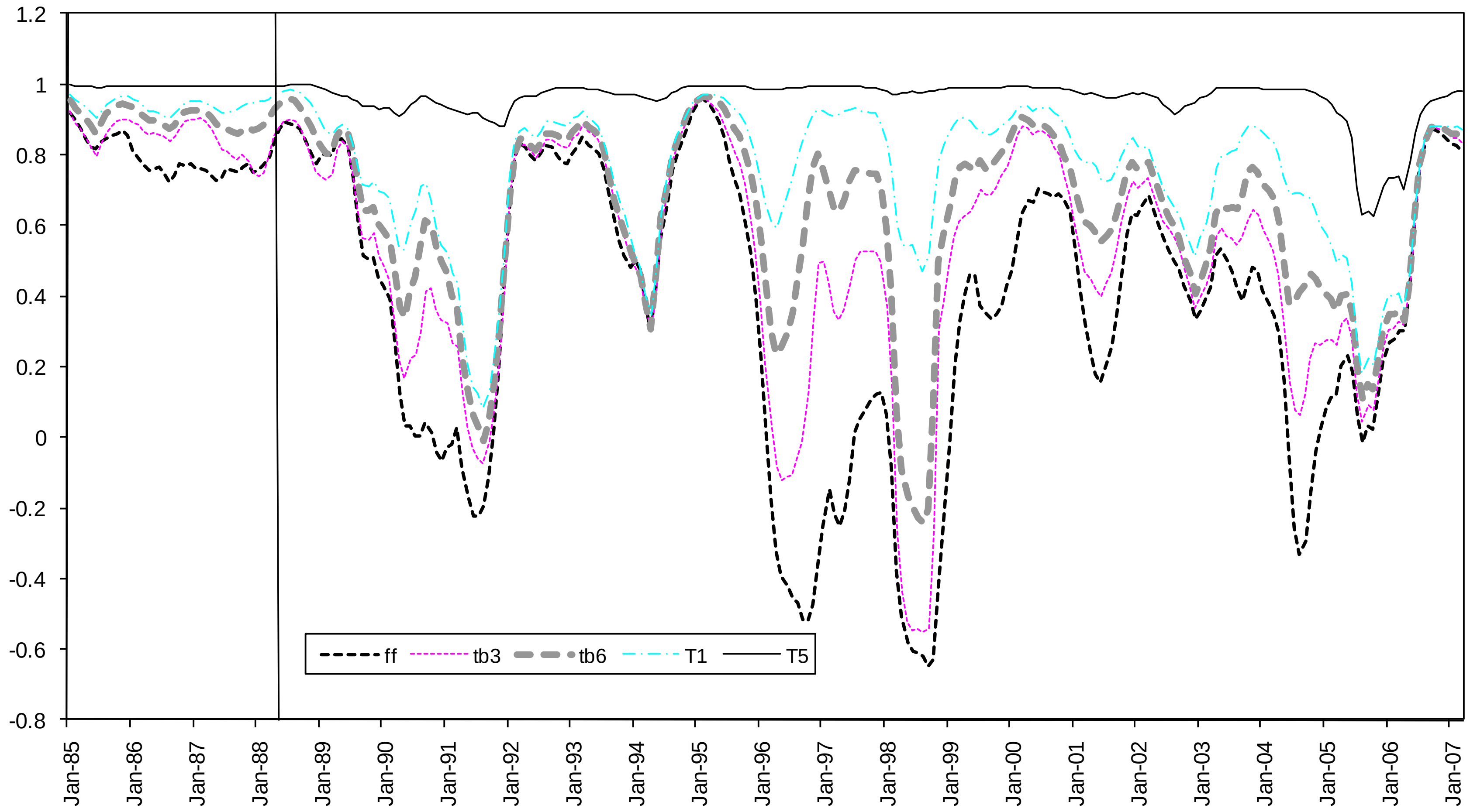


Figure 14: 24-Month Rolling Correlation of the Latent-Factor-Adjusted 10-Year Yield and Other Rates



Appendix A: Granger Causality Tests Results for All Possible Combinations of Lags from 2 through 6 (not intended for publication)

F-Statistics with P-values in Parentheses

TABLE A1

January 1983 to May 1988: ff and tb3

tb3 does not Granger Cause ff

		Lags of ff				
	Lags of tb3	2	3	4	5	6
F	2	7.494	7.040	7.157	6.956	6.775
P-value		(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
F	3	6.840	7.579	7.914	7.675	7.483
P-value		(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
F	4	5.458	5.697	5.826	5.674	5.571
P-value		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
F	5	4.874	5.280	5.177	5.198	4.608
P-value		(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
F	6	3.758	4.067	3.976	4.062	3.762
P-value		(0.004)	(0.002)	(0.003)	(0.002)	(0.004)

ff does not Granger Cause tb3

		Lags of tb3				
	Lags of ff	2	3	4	5	6
F	2	0.755	2.600	2.620	2.395	2.659
P-value		(0.475)	(0.083)	(0.082)	(0.101)	(0.080)
F	3	0.866	2.716	2.476	2.361	2.415
P-value		(0.464)	(0.053)	(0.071)	(0.082)	(0.078)
F	4	0.709	2.089	2.159	1.993	2.019
P-value		(0.589)	(0.095)	(0.087)	(0.110)	(0.107)
F	5	0.584	1.650	1.857	1.734	1.818
P-value		(0.712)	(0.164)	(0.119)	(0.144)	(0.128)
F	6	0.823	1.427	1.708	1.674	1.497
P-value		(0.557)	(0.224)	(0.139)	(0.148)	(0.200)

January 1983 to May 1988: ff and tb6

tb6 does not Granger Cause ff

	Lags of tb6	Lags of ff 2	3	4	5	6
F	2	8.321	7.727	7.685	7.788	7.619
P-value		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
F	3	6.605	7.266	7.484	7.551	7.245
P-value		(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
F	4	5.271	5.452	5.508	5.559	5.340
P-value		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
F	5	4.875	5.203	5.083	5.054	4.447
P-value		(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
F	6	3.747	3.985	3.870	3.846	3.750
P-value		(0.004)	(0.003)	(0.003)	(0.003)	(0.004)

ff does not Granger Cause tb6

	Lags of ff	Lags of tb6 2	3	4	5	6
F	2	0.819	2.253	2.321	2.155	2.390
P-value		(0.446)	(0.115)	(0.108)	(0.126)	(0.102)
F	3	0.812	2.040	1.913	1.881	1.930
P-value		(0.492)	(0.119)	(0.139)	(0.145)	(0.137)
F	4	0.728	1.489	1.424	1.385	1.441
P-value		(0.577)	(0.219)	(0.239)	(0.253)	(0.235)
F	5	0.733	1.368	1.346	1.179	1.325
P-value		(0.602)	(0.252)	(0.260)	(0.333)	(0.270)
F	6	0.916	1.260	1.256	1.158	1.087
P-value		(0.492)	(0.293)	(0.295)	(0.345)	(0.384)

January 1983 to May 1988: ff and t1

t1 does not Granger Cause ff

	Lags of ff					
	Lags of t1	2	3	4	5	6
F	2	10.134	9.414	9.168	9.175	9.112
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	3	7.146	7.542	7.563	7.613	7.462
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	4	5.879	5.888	5.766	5.742	5.600
P-value		(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
F	5	5.032	5.094	5.026	4.981	4.549
P-value		(0.001)	(0.001)	(0.001)	(0.001)	(0.002)
F	6	3.944	3.979	3.924	3.868	3.944
P-value		(0.003)	(0.003)	(0.003)	(0.003)	(0.003)

ff does not Granger Cause t1

	Lags of t1					
	Lags of ff	2	3	4	5	6
F	2	0.350	1.178	1.260	1.235	1.398
P-value		(0.706)	(0.315)	(0.292)	(0.299)	(0.257)
F	3	0.466	1.065	0.909	0.911	0.982
P-value		(0.707)	(0.371)	(0.443)	(0.442)	(0.409)
F	4	0.425	0.787	0.743	0.820	0.985
P-value		(0.790)	(0.538)	(0.567)	(0.519)	(0.424)
F	5	0.570	0.919	0.767	0.719	0.902
P-value		(0.722)	(0.477)	(0.578)	(0.612)	(0.488)
F	6	0.701	0.868	0.820	0.810	0.736
P-value		(0.650)	(0.525)	(0.560)	(0.568)	(0.623)

January 1983 to May 1988: ff and t5

t5 does not Granger Cause ff

	Lags of ff					
	Lags of t5	2	3	4	5	6
F	2	7.254	6.776	6.629	6.771	7.643
P-value		(0.002)	(0.002)	(0.003)	(0.002)	(0.001)
F	3	4.676	4.816	4.821	4.975	5.486
P-value		(0.006)	(0.005)	(0.005)	(0.004)	(0.002)
F	4	3.967	3.929	3.849	3.914	4.348
P-value		(0.007)	(0.007)	(0.008)	(0.008)	(0.004)
F	5	3.447	3.414	3.346	3.282	3.452
P-value		(0.009)	(0.010)	(0.011)	(0.012)	(0.010)
F	6	2.736	2.701	2.648	2.600	3.108
P-value		(0.022)	(0.024)	(0.027)	(0.029)	(0.012)

ff does not Granger Cause t5

	Lags of t5					
	Lags of ff	2	3	4	5	6
F	2	0.113	0.551	0.415	0.420	0.494
P-value		(0.893)	(0.579)	(0.662)	(0.659)	(0.613)
F	3	0.495	0.363	0.366	0.364	0.456
P-value		(0.687)	(0.780)	(0.778)	(0.780)	(0.714)
F	4	0.404	0.249	0.473	0.558	0.828
P-value		(0.805)	(0.909)	(0.756)	(0.694)	(0.514)
F	5	0.560	0.446	0.490	0.486	0.706
P-value		(0.730)	(0.814)	(0.782)	(0.785)	(0.622)
F	6	0.649	0.500	0.639	0.624	0.590
P-value		(0.691)	(0.805)	(0.699)	(0.710)	(0.737)

January 1983 to May 1988: ff and t10

t10 does not Granger Cause ff

		Lags of ff				
	Lags of t10	2	3	4	5	6
F	2	7.280	6.829	6.668	6.745	7.578
P-value		(0.002)	(0.002)	(0.003)	(0.002)	(0.001)
F	3	4.630	4.724	4.674	4.764	5.234
P-value		(0.006)	(0.005)	(0.006)	(0.005)	(0.003)
F	4	3.955	3.895	3.813	3.847	4.287
P-value		(0.007)	(0.008)	(0.009)	(0.008)	(0.005)
F	5	3.423	3.367	3.311	3.251	3.435
P-value		(0.010)	(0.011)	(0.012)	(0.013)	(0.010)
F	6	2.753	2.702	2.658	2.625	3.074
P-value		(0.022)	(0.024)	(0.026)	(0.028)	(0.013)

ff does not Granger Cause t10

		Lags of t10				
	Lags of ff	2	3	4	5	6
F	2	0.056	0.351	0.249	0.247	0.260
P-value		(0.946)	(0.706)	(0.781)	(0.782)	(0.772)
F	3	0.402	0.277	0.386	0.389	0.461
P-value		(0.752)	(0.842)	(0.763)	(0.762)	(0.711)
F	4	0.340	0.205	0.462	0.608	0.797
P-value		(0.850)	(0.934)	(0.763)	(0.659)	(0.533)
F	5	0.549	0.443	0.536	0.546	0.711
P-value		(0.738)	(0.816)	(0.748)	(0.741)	(0.618)
F	6	0.560	0.444	0.599	0.593	0.580
P-value		(0.760)	(0.846)	(0.730)	(0.734)	(0.744)

January 1983 to May 1988: tb6 and tb3

tb6 does not Granger Cause tb3

		Lags of tb3				
	Lags of tb6	2	3	4	5	6
F	2	1.566	1.181	1.108	1.211	1.259
P-value		(0.218)	(0.315)	(0.338)	(0.306)	(0.293)
F	3	2.526	1.032	1.014	1.196	0.975
P-value		(0.067)	(0.386)	(0.394)	(0.321)	(0.412)
F	4	1.735	0.795	0.756	0.879	0.741
P-value		(0.156)	(0.534)	(0.559)	(0.483)	(0.569)
F	5	1.733	1.066	1.037	1.350	1.122
P-value		(0.144)	(0.390)	(0.406)	(0.259)	(0.362)
F	6	1.519	0.771	0.798	1.067	1.079
P-value		(0.191)	(0.597)	(0.576)	(0.395)	(0.389)

tb3 does not Granger Cause tb6

		Lags of tb6				
	Lags of tb3	2	3	4	5	6
F	2	2.041	2.075	2.075	2.080	1.800
P-value		(0.139)	(0.135)	(0.135)	(0.135)	(0.176)
F	3	3.600	2.405	2.486	2.634	2.005
P-value		(0.019)	(0.077)	(0.071)	(0.060)	(0.126)
F	4	2.816	1.976	1.978	2.051	1.514
P-value		(0.034)	(0.112)	(0.112)	(0.101)	(0.213)
F	5	2.225	1.614	1.641	2.005	1.557
P-value		(0.066)	(0.173)	(0.166)	(0.094)	(0.191)
F	6	1.868	1.183	1.177	1.436	1.761
P-value		(0.105)	(0.331)	(0.334)	(0.221)	(0.129)

January 1983 to May 1988: t1 and tb3

t1 does not Granger Cause tb3

		Lags of tb3				
	Lags of t1	2	3	4	5	6
F	2	1.489	1.164	1.034	1.057	1.473
P-value		(0.234)	(0.320)	(0.363)	(0.355)	(0.239)
F	3	1.970	1.131	1.055	1.186	1.161
P-value		(0.129)	(0.345)	(0.376)	(0.324)	(0.334)
F	4	1.352	0.899	0.971	0.974	1.201
P-value		(0.263)	(0.471)	(0.431)	(0.430)	(0.323)
F	5	1.340	1.205	1.272	1.636	1.611
P-value		(0.262)	(0.320)	(0.291)	(0.168)	(0.176)
F	6	1.289	0.954	1.156	1.469	1.521
P-value		(0.280)	(0.466)	(0.345)	(0.209)	(0.193)

tb3 does not Granger Cause t1

		Lags of t1				
	Lags of tb3	2	3	4	5	6
F	2	0.604	0.664	0.575	0.560	0.437
P-value		(0.550)	(0.519)	(0.566)	(0.575)	(0.649)
F	3	2.401	1.022	1.030	1.078	0.671
P-value		(0.077)	(0.390)	(0.387)	(0.367)	(0.574)
F	4	2.127	1.119	0.790	0.818	0.498
P-value		(0.090)	(0.357)	(0.537)	(0.520)	(0.737)
F	5	1.637	0.868	0.606	0.981	0.744
P-value		(0.167)	(0.509)	(0.695)	(0.439)	(0.595)
F	6	1.533	0.869	0.795	0.964	1.318
P-value		(0.187)	(0.525)	(0.578)	(0.460)	(0.268)

January 1983 to May 1988: t5 and tb3

t5 does not Granger Cause tb3

		Lags of tb3				
	Lags of t5	2	3	4	5	6
F	2	2.390	1.379	1.338	1.497	2.272
P-value		(0.101)	(0.260)	(0.271)	(0.233)	(0.114)
F	3	2.219	0.925	0.901	1.023	1.484
P-value		(0.096)	(0.435)	(0.447)	(0.390)	(0.230)
F	4	1.797	1.082	1.112	1.094	1.884
P-value		(0.143)	(0.375)	(0.361)	(0.370)	(0.128)
F	5	1.692	1.218	1.286	1.190	1.656
P-value		(0.153)	(0.314)	(0.285)	(0.328)	(0.164)
F	6	1.619	1.094	1.416	1.334	1.478
P-value		(0.162)	(0.379)	(0.228)	(0.261)	(0.207)

tb3 does not Granger Cause t5

		Lags of t5				
	Lags of tb3	2	3	4	5	6
F	2	0.161	0.211	0.138	0.126	0.071
P-value		(0.852)	(0.810)	(0.872)	(0.882)	(0.932)
F	3	1.092	0.220	0.238	0.217	0.113
P-value		(0.360)	(0.882)	(0.870)	(0.884)	(0.952)
F	4	0.898	0.278	0.235	0.232	0.330
P-value		(0.472)	(0.891)	(0.918)	(0.919)	(0.856)
F	5	0.707	0.216	0.180	0.276	0.356
P-value		(0.621)	(0.954)	(0.969)	(0.924)	(0.876)
F	6	0.637	0.343	0.461	0.488	0.471
P-value		(0.700)	(0.910)	(0.834)	(0.814)	(0.826)

January 1983 to May 1988: t10 and tb3

t10 does not Granger Cause tb3

	Lags of t10	Lags fo tb3 2	3	4	5	6
F	2	2.279	1.282	1.280	1.442	2.198
P-value		(0.112)	(0.285)	(0.286)	(0.246)	(0.122)
F	3	1.928	0.892	0.915	1.034	1.456
P-value		(0.136)	(0.451)	(0.440)	(0.385)	(0.238)
F	4	1.563	1.085	1.078	1.105	1.775
P-value		(0.197)	(0.373)	(0.377)	(0.365)	(0.149)
F	5	1.603	1.334	1.372	1.261	1.654
P-value		(0.176)	(0.265)	(0.251)	(0.296)	(0.165)
F	6	1.472	1.165	1.435	1.341	1.420
P-value		(0.207)	(0.340)	(0.221)	(0.258)	(0.228)

tb3 does not Granger Cause t10

	Lags of tb3	Lags of t10 2	3	4	5	6
F	2	0.117	0.068	0.069	0.074	0.039
P-value		(0.890)	(0.935)	(0.934)	(0.929)	(0.961)
F	3	0.529	0.074	0.118	0.114	0.064
P-value		(0.664)	(0.974)	(0.949)	(0.951)	(0.979)
F	4	0.415	0.082	0.200	0.239	0.363
P-value		(0.797)	(0.988)	(0.937)	(0.915)	(0.833)
F	5	0.324	0.063	0.153	0.243	0.332
P-value		(0.896)	(0.997)	(0.978)	(0.941)	(0.891)
F	6	0.292	0.140	0.300	0.353	0.351
P-value		(0.938)	(0.990)	(0.934)	(0.905)	(0.905)

January 1983 to May 1988: t1 and tb6

t1 does not Granger Cause tb6

	Lags of t1	Lags of tb6 2	3	4	5	6
F	2	1.111	1.193	1.122	0.939	1.451
P-value		(0.336)	(0.311)	(0.333)	(0.398)	(0.244)
F	3	2.045	0.785	0.734	0.620	0.954
P-value		(0.118)	(0.508)	(0.536)	(0.605)	(0.422)
F	4	1.621	0.746	1.439	1.250	1.972
P-value		(0.182)	(0.565)	(0.234)	(0.302)	(0.114)
F	5	1.298	0.634	1.188	1.114	1.682
P-value		(0.279)	(0.675)	(0.328)	(0.365)	(0.157)
F	6	1.289	0.635	1.380	1.409	1.452
P-value		(0.280)	(0.702)	(0.242)	(0.231)	(0.216)

tb6 does not Granger Cause t1

	Lags of tb6	Lags of t1 2	3	4	5	6
F	2	0.173	0.211	0.168	0.135	0.334
P-value		(0.842)	(0.810)	(0.846)	(0.874)	(0.717)
F	3	1.659	0.353	0.329	0.309	0.347
P-value		(0.186)	(0.787)	(0.804)	(0.819)	(0.792)
F	4	1.344	0.403	0.545	0.528	0.755
P-value		(0.266)	(0.805)	(0.704)	(0.716)	(0.560)
F	5	1.073	0.356	0.431	0.482	0.706
P-value		(0.386)	(0.876)	(0.825)	(0.788)	(0.622)
F	6	1.036	0.369	0.674	0.722	0.781
P-value		(0.413)	(0.895)	(0.671)	(0.634)	(0.589)

January 1983 to May 1988: t5 and tb6

t5 does not Granger Cause tb6

	Lags of t5	Lags of tb6 2	3	4	5	6
F	2	1.779	1.174	1.217	1.396	1.881
P-value		(0.178)	(0.317)	(0.304)	(0.257)	(0.163)
F	3	2.023	0.796	0.828	0.943	1.303
P-value		(0.121)	(0.502)	(0.484)	(0.427)	(0.284)
F	4	1.923	1.101	1.316	1.330	2.300
P-value		(0.120)	(0.366)	(0.276)	(0.272)	(0.072)
F	5	1.630	0.987	1.195	1.052	1.802
P-value		(0.169)	(0.435)	(0.325)	(0.398)	(0.131)
F	6	1.615	0.995	1.553	1.462	1.484
P-value		(0.163)	(0.439)	(0.182)	(0.212)	(0.205)

tb6 does not Granger Cause t5

	Lags of tb6	Lags of t5 2	3	4	5	6
F	2	0.060	0.013	0.038	0.038	0.077
P-value		(0.942)	(0.987)	(0.963)	(0.962)	(0.926)
F	3	1.121	0.059	0.122	0.110	0.115
P-value		(0.349)	(0.981)	(0.947)	(0.954)	(0.951)
F	4	0.897	0.126	0.527	0.531	0.885
P-value		(0.472)	(0.972)	(0.716)	(0.713)	(0.480)
F	5	0.760	0.158	0.435	0.417	0.694
P-value		(0.582)	(0.977)	(0.822)	(0.835)	(0.631)
F	6	0.624	0.142	0.630	0.616	0.576
P-value		(0.710)	(0.990)	(0.706)	(0.716)	(0.747)

January 1983 to May 1988: t10 and tb6

t10 does not Granger Cause tb6

		Lags of tb6				
	Lags of t10	2	3	4	5	6
F	2	1.721	1.070	1.102	1.295	1.782
P-value		(0.188)	(0.350)	(0.340)	(0.283)	(0.179)
F	3	1.801	0.708	0.725	0.855	1.179
P-value		(0.158)	(0.551)	(0.542)	(0.470)	(0.327)
F	4	1.730	1.074	1.257	1.387	2.242
P-value		(0.157)	(0.379)	(0.299)	(0.252)	(0.078)
F	5	1.527	1.002	1.218	1.102	1.756
P-value		(0.197)	(0.426)	(0.315)	(0.371)	(0.140)
F	6	1.471	1.002	1.514	1.457	1.436
P-value		(0.207)	(0.435)	(0.194)	(0.214)	(0.221)

tb6 does not Granger Cause t10

		Lags of t10				
	Lags of tb6	2	3	4	5	6
F	2	0.188	0.059	0.077	0.093	0.090
P-value		(0.830)	(0.943)	(0.926)	(0.912)	(0.914)
F	3	0.710	0.083	0.153	0.147	0.147
P-value		(0.550)	(0.969)	(0.927)	(0.931)	(0.931)
F	4	0.527	0.074	0.597	0.670	0.906
P-value		(0.716)	(0.990)	(0.666)	(0.616)	(0.468)
F	5	0.489	0.143	0.570	0.528	0.713
P-value		(0.783)	(0.981)	(0.723)	(0.754)	(0.617)
F	6	0.379	0.105	0.621	0.596	0.582
P-value		(0.889)	(0.995)	(0.713)	(0.732)	(0.743)

January 1983 to May 1988: t5 and t1

t5 does not Granger Cause t1

		Lags of t1				
	Lags of t5	2	3	4	5	6
F	2	0.941	0.466	0.736	0.883	1.145
P-value		(0.396)	(0.630)	(0.484)	(0.420)	(0.326)
F	3	1.546	0.317	0.490	0.594	0.771
P-value		(0.213)	(0.813)	(0.691)	(0.622)	(0.516)
F	4	1.721	0.870	0.549	0.630	1.111
P-value		(0.159)	(0.488)	(0.701)	(0.643)	(0.362)
F	5	1.471	0.791	0.543	0.501	0.872
P-value		(0.215)	(0.561)	(0.743)	(0.774)	(0.507)
F	6	1.440	0.800	0.758	0.736	0.721
P-value		(0.218)	(0.575)	(0.606)	(0.623)	(0.635)

t1 does not Granger Cause t5

		Lags of t5				
	Lags of t1	2	3	4	5	6
F	2	0.089	0.005	0.054	0.066	0.097
P-value		(0.915)	(0.995)	(0.947)	(0.936)	(0.908)
F	3	1.230	0.051	0.135	0.126	0.143
P-value		(0.307)	(0.985)	(0.939)	(0.945)	(0.933)
F	4	1.164	0.275	0.418	0.430	0.760
P-value		(0.337)	(0.893)	(0.795)	(0.786)	(0.557)
F	5	0.946	0.259	0.367	0.340	0.596
P-value		(0.459)	(0.933)	(0.869)	(0.886)	(0.703)
F	6	0.773	0.198	0.528	0.515	0.487
P-value		(0.595)	(0.976)	(0.784)	(0.794)	(0.815)

January 1983 to May 1988: t10 and t1

t10 does not Granger Cause t1

		Lags of t1				
	Lags of t10	2	3	4	5	6
F	2	0.959	0.445	0.663	0.800	1.091
P-value		(0.389)	(0.643)	(0.520)	(0.455)	(0.344)
F	3	1.410	0.293	0.438	0.523	0.718
P-value		(0.249)	(0.831)	(0.727)	(0.668)	(0.546)
F	4	1.559	0.880	0.554	0.672	1.105
P-value		(0.198)	(0.482)	(0.697)	(0.615)	(0.365)
F	5	1.375	0.807	0.564	0.532	0.866
P-value		(0.249)	(0.550)	(0.727)	(0.751)	(0.511)
F	6	1.310	0.831	0.758	0.746	0.709
P-value		(0.270)	(0.551)	(0.606)	(0.615)	(0.644)

t1 does not Granger Cause t10

		Lags of t10				
	Lags of t1	2	3	4	5	6
F	2	0.240	0.073	0.091	0.105	0.094
P-value		(0.788)	(0.930)	(0.913)	(0.900)	(0.910)
F	3	0.851	0.124	0.228	0.204	0.227
P-value		(0.472)	(0.946)	(0.877)	(0.893)	(0.877)
F	4	0.726	0.187	0.538	0.609	0.825
P-value		(0.578)	(0.944)	(0.709)	(0.658)	(0.515)
F	5	0.645	0.229	0.574	0.498	0.676
P-value		(0.667)	(0.948)	(0.719)	(0.776)	(0.644)
F	6	0.491	0.154	0.608	0.570	0.576
P-value		(0.812)	(0.987)	(0.723)	(0.752)	(0.748)

January 1983 to May 1988: t10 and t5

t10 does not Granger Cause t5

		Lags of t5				
	Lags of t10	2	3	4	5	6
F	2	0.274	0.091	0.017	0.018	0.036
P-value		(0.762)	(0.913)	(0.983)	(0.983)	(0.964)
F	3	1.241	0.064	0.082	0.059	0.160
P-value		(0.304)	(0.979)	(0.970)	(0.981)	(0.922)
F	4	1.496	0.739	0.234	0.261	0.306
P-value		(0.216)	(0.569)	(0.918)	(0.901)	(0.873)
F	5	1.226	0.602	0.239	0.219	0.242
P-value		(0.310)	(0.698)	(0.943)	(0.953)	(0.942)
F	6	1.034	0.589	0.229	0.223	0.224
P-value		(0.415)	(0.737)	(0.965)	(0.967)	(0.967)

t5 does not Granger Cause t10

		Lags of t10				
	Lags of t5	2	3	4	5	6
F	2	0.230	0.115	0.036	0.034	0.033
P-value		(0.795)	(0.891)	(0.965)	(0.966)	(0.967)
F	3	0.887	0.158	0.289	0.210	0.319
P-value		(0.453)	(0.924)	(0.833)	(0.889)	(0.812)
F	4	1.021	0.535	0.299	0.298	0.354
P-value		(0.405)	(0.710)	(0.877)	(0.878)	(0.840)
F	5	0.843	0.443	0.300	0.235	0.278
P-value		(0.526)	(0.816)	(0.910)	(0.945)	(0.923)
F	6	0.702	0.416	0.264	0.234	0.231
P-value		(0.650)	(0.865)	(0.951)	(0.963)	(0.964)

TABLE A2

June 1988 to March 2007: tb3 and ff

tb3 does not Granger Cause ff

		Lags of ff				
	Lags of tb3	2	3	4	5	6
F	2	36.661	36.185	36.998	36.767	37.021
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	3	29.739	24.687	25.414	25.150	25.234
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	4	29.478	22.781	21.169	20.887	21.079
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	5	23.686	18.296	16.826	16.731	16.934
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	6	19.611	15.145	13.883	13.839	14.065
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

ff does not Granger Cause tb3

		Lags of tb3				
	Lags of ff	2	3	4	5	6
F	2	4.654	2.325	0.986	1.114	0.690
P-value		(0.010)	(0.100)	(0.375)	(0.330)	(0.503)
F	3	5.316	3.695	0.740	0.882	0.651
P-value		(0.001)	(0.013)	(0.529)	(0.451)	(0.583)
F	4	4.635	3.383	0.553	0.683	0.516
P-value		(0.001)	(0.010)	(0.697)	(0.605)	(0.724)
F	5	3.784	2.809	0.526	0.552	0.430
P-value		(0.003)	(0.018)	(0.756)	(0.736)	(0.827)
F	6	3.223	2.536	0.733	0.752	0.734
P-value		(0.005)	(0.022)	(0.624)	(0.608)	(0.623)

June 1988 to March 2007: ff and tb6

tb6 does not Granger Cause ff

		Lags of ff				
	Lags of tb6	2	3	4	5	6
F	2	44.627	40.533	42.411	42.167	42.386
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	3	32.143	27.053	28.604	28.337	28.498
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	4	29.602	23.223	22.666	22.438	22.974
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	5	23.846	18.600	17.991	17.893	18.293
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	6	20.553	16.015	15.114	15.000	15.221
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

ff does not Granger Cause tb6

		Lags of tb6				
	Lags of ff	2	3	4	5	6
F	2	2.951	1.960	0.445	0.563	0.433
P-value		(0.054)	(0.143)	(0.641)	(0.570)	(0.649)
F	3	2.432	1.810	0.297	0.406	0.288
P-value		(0.066)	(0.146)	(0.828)	(0.749)	(0.834)
F	4	2.331	1.786	0.286	0.517	0.324
P-value		(0.057)	(0.133)	(0.887)	(0.723)	(0.862)
F	5	1.877	1.496	0.253	0.412	0.290
P-value		(0.100)	(0.192)	(0.938)	(0.840)	(0.918)
F	6	1.856	1.529	0.781	0.866	0.597
P-value		(0.090)	(0.170)	(0.586)	(0.521)	(0.733)

June 1988 to March 2007: ff and t1

t1 does not Granger Cause ff

		Lags of ff				
	Lags of t1	2	3	4	5	6
F	2	38.749	36.231	39.010	38.649	39.351
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	3	26.164	24.223	25.886	25.645	26.110
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	4	24.306	20.437	20.551	20.438	21.415
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	5	19.513	16.285	16.520	16.556	17.156
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	6	17.151	13.798	13.693	13.685	14.234
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

ff does not Granger Cause t1

		Lags of t1				
	Lags of ff	2	3	4	5	6
F	2	0.502	1.002	0.226	0.246	0.135
P-value		(0.606)	(0.369)	(0.798)	(0.782)	(0.874)
F	3	0.655	1.404	0.297	0.512	0.255
P-value		(0.581)	(0.242)	(0.827)	(0.674)	(0.858)
F	4	1.034	1.383	0.258	0.541	0.286
P-value		(0.391)	(0.241)	(0.904)	(0.706)	(0.887)
F	5	0.879	1.270	0.243	0.434	0.251
P-value		(0.496)	(0.278)	(0.943)	(0.825)	(0.939)
F	6	1.176	1.470	1.034	1.012	0.828
P-value		(0.320)	(0.190)	(0.404)	(0.418)	(0.549)

June 1988 to March 2007: ff and t5

t5 does not Granger Cause ff

		Lags of ff				
	Lags of t5	2	3	4	5	6
F	2	13.557	18.664	21.825	21.609	22.283
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	3	9.139	12.480	15.311	15.245	15.798
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	4	7.950	9.708	11.782	11.908	12.561
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	5	6.406	7.716	9.489	9.660	10.038
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	6	5.525	6.367	7.856	8.041	8.424
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

ff does not Granger Cause t5

		Lags of t5				
	Lags of ff	2	3	4	5	6
F	2	2.650	1.672	2.982	2.438	1.928
P-value		(0.073)	(0.190)	(0.053)	(0.090)	(0.148)
F	3	2.100	1.490	2.159	1.844	1.571
P-value		(0.101)	(0.218)	(0.094)	(0.140)	(0.197)
F	4	1.623	1.257	1.728	1.464	1.240
P-value		(0.170)	(0.288)	(0.145)	(0.214)	(0.295)
F	5	1.436	1.217	1.411	1.204	1.019
P-value		(0.213)	(0.302)	(0.221)	(0.309)	(0.407)
F	6	1.318	1.126	1.384	1.170	1.047
P-value		(0.251)	(0.348)	(0.223)	(0.324)	(0.396)

June 1988 to March 2007: ff and t10

t5 does not Granger Cause ff

		Lags of ff				
	Lags of t10	2	3	4	5	6
F	2	8.913	13.197	14.752	14.556	14.754
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	3	6.352	9.403	11.554	11.466	11.782
P-value		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
F	4	4.987	7.045	8.707	8.708	9.002
P-value		(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
F	5	4.097	5.586	6.955	6.995	7.171
P-value		(0.001)	(0.000)	(0.000)	(0.000)	(0.000)
F	6	3.413	4.636	5.913	5.989	6.174
P-value		(0.003)	(0.000)	(0.000)	(0.000)	(0.000)

ff does not Granger Cause t5

		Lags of t10				
	Lags of ff	2	3	4	5	6
F	2	1.742	1.118	2.013	2.173	1.748
P-value		(0.178)	(0.329)	(0.136)	(0.116)	(0.177)
F	3	1.521	1.073	1.537	1.595	1.355
P-value		(0.210)	(0.361)	(0.206)	(0.192)	(0.258)
F	4	1.518	1.466	1.745	1.834	1.584
P-value		(0.198)	(0.214)	(0.141)	(0.123)	(0.180)
F	5	1.240	1.228	1.384	1.461	1.263
P-value		(0.291)	(0.297)	(0.232)	(0.204)	(0.281)
F	6	1.062	1.042	1.182	1.283	1.104
P-value		(0.386)	(0.399)	(0.317)	(0.266)	(0.361)

June 1988 to March 2007: tb6 and tb3

tb6 does not Granger Cause tb3

		Lags of tb3				
	Lags of tb6	2	3	4	5	6
F	2	16.075	12.782	7.615	7.726	7.696
P-value		(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
F	3	10.348	8.531	5.128	5.160	5.296
P-value		(0.000)	(0.000)	(0.002)	(0.002)	(0.002)
F	4	9.841	8.582	3.843	3.863	3.966
P-value		(0.000)	(0.000)	(0.005)	(0.005)	(0.004)
F	5	8.085	7.004	3.319	3.507	3.547
P-value		(0.000)	(0.000)	(0.007)	(0.005)	(0.004)
F	6	6.489	5.858	2.953	3.037	2.967
P-value		(0.000)	(0.000)	(0.009)	(0.007)	(0.008)

tb3 does not Granger Cause tb6

		Lags of tb6				
	Lags of tb3	2	3	4	5	6
F	2	5.185	3.779	1.146	1.600	1.301
P-value		(0.006)	(0.024)	(0.320)	(0.204)	(0.274)
F	3	3.226	2.512	0.771	1.071	0.939
P-value		(0.023)	(0.060)	(0.511)	(0.362)	(0.422)
F	4	3.829	3.249	0.852	1.195	0.947
P-value		(0.005)	(0.013)	(0.494)	(0.314)	(0.438)
F	5	3.083	2.665	0.771	1.152	0.891
P-value		(0.010)	(0.023)	(0.572)	(0.334)	(0.488)
F	6	2.378	2.027	0.727	1.001	0.740
P-value		(0.030)	(0.063)	(0.628)	(0.426)	(0.618)

June 1988 to March 2007: t1 and tb3

t1 does not Granger Cause tb3

		Lags of tb3				
	Lags of t1	2	3	4	5	6
F	2	10.848	8.017	5.819	5.697	5.893
P-value		(0.000)	(0.000)	(0.003)	(0.004)	(0.003)
F	3	6.962	5.391	3.909	3.833	3.912
P-value		(0.000)	(0.001)	(0.010)	(0.011)	(0.010)
F	4	8.682	7.358	3.156	3.099	3.189
P-value		(0.000)	(0.000)	(0.015)	(0.017)	(0.014)
F	5	7.187	6.285	2.981	3.514	3.440
P-value		(0.000)	(0.000)	(0.013)	(0.005)	(0.005)
F	6	5.947	5.114	2.490	2.840	2.865
P-value		(0.000)	(0.000)	(0.024)	(0.011)	(0.011)

tb3 does not Granger Cause t1

		Lags of t1				
	Lags of tb3	2	3	4	5	6
F	2	0.988	1.193	0.047	0.217	0.123
P-value		(0.374)	(0.305)	(0.954)	(0.805)	(0.884)
F	3	0.542	1.193	0.363	0.841	0.397
P-value		(0.654)	(0.313)	(0.780)	(0.473)	(0.755)
F	4	1.480	2.004	0.271	0.631	0.298
P-value		(0.209)	(0.095)	(0.896)	(0.641)	(0.879)
F	5	1.145	1.573	0.220	0.967	0.629
P-value		(0.337)	(0.169)	(0.953)	(0.439)	(0.678)
F	6	0.854	1.062	0.183	0.710	0.531
P-value		(0.530)	(0.386)	(0.981)	(0.642)	(0.785)

June 1988 to March 2007: t5 and tb3

t5 does not Granger Cause tb3

	Lags of t5	Lags of tb3: 2	3	4	5	6
F	2	1.022	1.487	3.301	3.265	3.667
P-value		(0.362)	(0.228)	(0.039)	(0.040)	(0.027)
F	3	1.005	1.009	2.325	2.322	2.816
P-value		(0.391)	(0.390)	(0.076)	(0.076)	(0.040)
F	4	3.186	3.044	1.903	1.952	2.341
P-value		(0.014)	(0.018)	(0.111)	(0.103)	(0.056)
F	5	2.590	2.573	1.685	1.976	2.122
P-value		(0.027)	(0.028)	(0.139)	(0.084)	(0.064)
F	6	2.135	2.059	1.607	1.805	2.138
P-value		(0.051)	(0.059)	(0.147)	(0.099)	(0.050)

tb3 does not Granger Cause t5

	Lags of tb3	Lags of t5: 2	3	4	5	6
F	2	2.956	2.146	3.502	2.919	2.571
P-value		(0.054)	(0.119)	(0.032)	(0.056)	(0.079)
F	3	2.274	2.134	3.006	2.681	2.552
P-value		(0.081)	(0.097)	(0.031)	(0.048)	(0.057)
F	4	1.693	1.588	2.562	2.312	2.166
P-value		(0.153)	(0.179)	(0.040)	(0.059)	(0.074)
F	5	1.338	1.267	2.061	1.953	1.822
P-value		(0.249)	(0.279)	(0.072)	(0.087)	(0.110)
F	6	1.118	1.046	1.711	1.596	1.543
P-value		(0.353)	(0.397)	(0.120)	(0.150)	(0.166)

June 1988 to March 2007: t10 and tb3

t10 does not Granger Cause tb3

		Lags of tb3				
	Lags of t10	2	3	4	5	6
F	2	1.023	1.891	3.435	3.366	3.700
P-value		(0.361)	(0.153)	(0.034)	(0.036)	(0.026)
F	3	0.858	1.270	2.496	2.462	2.923
P-value		(0.464)	(0.285)	(0.061)	(0.064)	(0.035)
F	4	2.530	2.597	2.105	2.136	2.494
P-value		(0.042)	(0.037)	(0.081)	(0.077)	(0.044)
F	5	2.028	2.098	1.735	1.847	2.047
P-value		(0.076)	(0.067)	(0.128)	(0.105)	(0.073)
F	6	1.851	2.080	2.233	2.337	2.824
P-value		(0.091)	(0.057)	(0.041)	(0.033)	(0.012)

tb3 does not Granger Cause t10

		Lags of t10				
	Lags of tb3	2	3	4	5	6
F	2	2.068	1.536	2.380	2.573	2.270
P-value		(0.129)	(0.218)	(0.095)	(0.079)	(0.106)
F	3	1.739	1.716	2.163	2.225	2.152
P-value		(0.160)	(0.165)	(0.093)	(0.086)	(0.095)
F	4	1.245	1.346	2.194	2.264	2.158
P-value		(0.293)	(0.254)	(0.071)	(0.063)	(0.075)
F	5	0.992	1.097	1.754	1.803	1.719
P-value		(0.424)	(0.363)	(0.124)	(0.114)	(0.132)
F	6	0.848	0.952	1.479	1.523	1.446
P-value		(0.534)	(0.459)	(0.187)	(0.172)	(0.199)

June 1988 to March 2007: t1 and tb6

t1 does not Granger Cause tb6

		Lags of tb6				
	Lags of t1	2	3	4	5	6
F	2	2.956	2.139	3.127	3.048	3.239
P-value		(0.054)	(0.120)	(0.046)	(0.050)	(0.041)
F	3	1.888	2.602	3.166	3.212	2.824
P-value		(0.133)	(0.053)	(0.025)	(0.024)	(0.040)
F	4	4.618	4.770	2.444	2.480	2.368
P-value		(0.001)	(0.001)	(0.048)	(0.045)	(0.054)
F	5	3.739	4.088	2.277	2.712	2.512
P-value		(0.003)	(0.001)	(0.048)	(0.021)	(0.031)
F	6	3.339	3.317	1.991	2.237	2.180
P-value		(0.004)	(0.004)	(0.068)	(0.041)	(0.046)

tb6 does not Granger Cause t1

		Lags of t1				
	Lags of tb6	2	3	4	5	6
F	2	0.336	0.368	0.116	0.046	0.094
P-value		(0.715)	(0.693)	(0.891)	(0.955)	(0.910)
F	3	0.158	0.990	0.552	0.832	0.537
P-value		(0.925)	(0.398)	(0.647)	(0.478)	(0.658)
F	4	1.655	2.274	0.475	0.657	0.537
P-value		(0.162)	(0.062)	(0.754)	(0.623)	(0.709)
F	5	1.299	1.856	0.446	1.116	0.894
P-value		(0.265)	(0.103)	(0.816)	(0.353)	(0.486)
F	6	1.002	1.304	0.555	1.016	0.887
P-value		(0.425)	(0.257)	(0.766)	(0.416)	(0.505)

June 1988 to March 2007: t5 and tb6

t5 does not Granger Cause tb6

		Lags of tb6				
	Lags of t5	2	3	4	5	6
F	2	1.005	2.022	4.246	4.178	4.654
P-value		(0.368)	(0.135)	(0.016)	(0.017)	(0.011)
F	3	0.757	2.040	3.007	2.941	3.113
P-value		(0.520)	(0.109)	(0.031)	(0.034)	(0.027)
F	4	2.981	3.605	2.372	2.343	2.605
P-value		(0.020)	(0.007)	(0.053)	(0.056)	(0.037)
F	5	2.422	2.964	2.039	2.256	2.284
P-value		(0.037)	(0.013)	(0.074)	(0.050)	(0.048)
F	6	1.982	2.354	1.757	1.909	2.417
P-value		(0.070)	(0.032)	(0.109)	(0.081)	(0.028)

tb6 does not Granger Cause t5

		Lags of t5				
	Lags of tb6	2	3	4	5	6
F	2	3.529	2.660	3.986	3.399	3.035
P-value		(0.031)	(0.072)	(0.020)	(0.035)	(0.050)
F	3	2.521	2.372	3.075	2.733	2.622
P-value		(0.059)	(0.071)	(0.029)	(0.045)	(0.052)
F	4	1.975	1.806	2.751	2.458	2.388
P-value		(0.099)	(0.129)	(0.029)	(0.047)	(0.052)
F	5	1.564	1.465	2.184	2.025	1.971
P-value		(0.171)	(0.203)	(0.057)	(0.076)	(0.084)
F	6	1.294	1.216	1.917	1.750	1.835
P-value		(0.261)	(0.299)	(0.079)	(0.111)	(0.094)

June 1988 to March 2007: t10 and tb6

t10 does not Granger Cause tb6

		Lags of tb6				
	Lags of t10	2	3	4	5	6
F	2	1.661	2.830	4.773	4.696	5.066
P-value		(0.192)	(0.061)	(0.009)	(0.010)	(0.007)
F	3	1.176	2.423	3.253	3.193	3.362
P-value		(0.320)	(0.067)	(0.023)	(0.025)	(0.020)
F	4	2.772	3.291	2.576	2.554	2.798
P-value		(0.028)	(0.012)	(0.039)	(0.040)	(0.027)
F	5	2.249	2.646	2.123	2.170	2.265
P-value		(0.051)	(0.024)	(0.064)	(0.059)	(0.049)
F	6	1.902	2.317	2.103	2.171	2.960
P-value		(0.082)	(0.035)	(0.054)	(0.047)	(0.009)

tb6 does not Granger Cause t10

		Lags of t10				
	Lags of tb6	2	3	4	5	6
F	2	2.106	1.563	2.257	2.383	2.097
P-value		(0.124)	(0.212)	(0.107)	(0.095)	(0.125)
F	3	1.501	1.386	1.671	1.729	1.628
P-value		(0.215)	(0.248)	(0.174)	(0.162)	(0.184)
F	4	1.048	1.041	1.989	2.100	2.037
P-value		(0.383)	(0.387)	(0.097)	(0.082)	(0.090)
F	5	0.829	0.849	1.593	1.674	1.622
P-value		(0.530)	(0.516)	(0.163)	(0.142)	(0.156)
F	6	0.706	0.747	1.400	1.491	1.480
P-value		(0.645)	(0.612)	(0.216)	(0.182)	(0.186)

June 1988 to March 2007: t5 and t1

t5 does not Granger Cause t1

	Lags of t5	Lags of t1: 2	3	4	5	6
F	2	3.384	3.394	5.573	5.051	5.429
P-value		(0.036)	(0.035)	(0.004)	(0.007)	(0.005)
F	3	2.484	2.800	3.791	3.463	3.618
P-value		(0.062)	(0.041)	(0.011)	(0.017)	(0.014)
F	4	4.550	4.506	2.878	2.621	2.789
P-value		(0.002)	(0.002)	(0.024)	(0.036)	(0.027)
F	5	3.702	3.646	2.461	2.287	2.321
P-value		(0.003)	(0.003)	(0.034)	(0.047)	(0.044)
F	6	2.954	2.919	2.097	1.950	2.543
P-value		(0.009)	(0.009)	(0.055)	(0.074)	(0.021)

t1 does not Granger Cause t5

	Lags of t1	Lags of t5: 2	3	4	5	6
F	2	4.110	3.184	4.268	3.761	3.389
P-value		(0.018)	(0.043)	(0.015)	(0.025)	(0.036)
F	3	2.870	2.264	2.846	2.519	2.320
P-value		(0.037)	(0.082)	(0.039)	(0.059)	(0.076)
F	4	2.527	1.966	2.411	2.107	1.988
P-value		(0.042)	(0.101)	(0.050)	(0.081)	(0.098)
F	5	2.071	1.674	1.929	1.678	1.588
P-value		(0.070)	(0.142)	(0.091)	(0.141)	(0.165)
F	6	1.621	1.330	1.648	1.430	1.563
P-value		(0.143)	(0.245)	(0.136)	(0.204)	(0.159)

June 1988 to March 2007: t10 and t1

t10 does not Granger Cause t1

		Lags of t1				
	Lags of t10	2	3	4	5	6
F	2	4.204	4.239	6.256	5.795	6.156
P-value		(0.016)	(0.016)	(0.002)	(0.004)	(0.003)
F	3	3.228	3.509	4.316	4.039	4.140
P-value		(0.023)	(0.016)	(0.006)	(0.008)	(0.007)
F	4	4.644	4.576	3.363	3.130	3.283
P-value		(0.001)	(0.001)	(0.011)	(0.016)	(0.012)
F	5	3.763	3.681	2.798	2.553	2.628
P-value		(0.003)	(0.003)	(0.018)	(0.029)	(0.025)
F	6	3.176	3.140	2.580	2.391	3.169
P-value		(0.005)	(0.006)	(0.020)	(0.030)	(0.005)

t1 does not Granger Cause t10

		Lags of t10				
	Lags of t1	2	3	4	5	6
F	2	2.260	1.838	2.340	2.379	2.110
P-value		(0.107)	(0.162)	(0.099)	(0.095)	(0.124)
F	3	1.636	1.291	1.555	1.582	1.403
P-value		(0.182)	(0.278)	(0.201)	(0.195)	(0.243)
F	4	1.275	0.998	1.657	1.786	1.686
P-value		(0.281)	(0.410)	(0.161)	(0.133)	(0.154)
F	5	1.024	0.843	1.313	1.500	1.374
P-value		(0.404)	(0.521)	(0.260)	(0.191)	(0.235)
F	6	0.801	0.689	1.131	1.311	1.303
P-value		(0.570)	(0.659)	(0.345)	(0.254)	(0.257)

June 1988 to March 2007: t10 and t5

t10 does not Granger Cause t5

		Lags of t5				
	Lags of t10	2	3	4	5	6
F	2	3.931	3.375	3.773	3.467	3.299
P-value		(0.021)	(0.036)	(0.025)	(0.033)	(0.039)
F	3	3.705	2.944	2.858	2.697	2.587
P-value		(0.012)	(0.034)	(0.038)	(0.047)	(0.054)
F	4	3.992	3.203	2.611	2.376	2.294
P-value		(0.004)	(0.014)	(0.036)	(0.053)	(0.061)
F	5	3.171	2.551	2.070	2.698	2.528
P-value		(0.009)	(0.029)	(0.070)	(0.022)	(0.030)
F	6	2.815	2.360	2.062	2.384	2.331
P-value		(0.012)	(0.032)	(0.059)	(0.030)	(0.034)

t5 does not Granger Cause t10

		Lags of t10				
	Lags of t5	2	3	4	5	6
F	2	2.726	2.758	3.055	3.047	2.742
P-value		(0.068)	(0.066)	(0.049)	(0.050)	(0.067)
F	3	2.471	2.097	2.060	2.053	1.868
P-value		(0.063)	(0.102)	(0.107)	(0.108)	(0.136)
F	4	2.639	2.151	1.751	1.795	1.678
P-value		(0.035)	(0.076)	(0.140)	(0.131)	(0.156)
F	5	2.115	1.745	1.392	2.288	2.038
P-value		(0.065)	(0.126)	(0.229)	(0.047)	(0.075)
F	6	1.701	1.441	1.209	1.920	1.905
P-value		(0.122)	(0.200)	(0.303)	(0.079)	(0.081)