The Unusual Behavior of the Federal Funds and 10-Year Treasury Rates: A Conundrum or Goodhart's Law?

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Abstract

In February 2005, former 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 show that the relationship between the 10-year Treasury yield and the federal funds rate changed dramatically in the late 1980s, well in advance of Greenspan's observation. I argue that the marked change in the relationship between the federal funds rate and the 10-year yield is a consequence of the Fed using the funds rate as a policy target rather than an operating instrument, as it did in the 1970s and early 1980s. The use of the funds rate as a policy target not only affected the relationship between the funds rate and the 10-year yield, but other rates in the term structure as well. Because of the close relationship between the funds rate and other shorter-term rates, it also affected the relationship between the 10-year yield and other shorter-term rates.

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It is widely recognized that the relationship between the federal funds rate and long-term rates, such as the 10-year Treasury yield, has changed since about 2004. Attention was brought to this fact when, in his February 17, 2005 testimony before the Committee on Banking, Housing, and Urban Affairs of the U.S. Senate, former Chairman 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 the aberrant behavior of the 10-year Treasury yield relative to the funds rate a "conundrum."

I argue that the change in the relationship between the federal funds rate and long-term yields occurred much earlier, in the late 1980s, and is a consequence of the fact that the FOMC switched from using the funds rate as an operating instrument to a policy target. The change in the relationship between the funds rate and long-term rates 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]

The simple intuition for why the relationship changed comes from noting that if all rates are free to respond to economic news, they tend to move together because they are responding to the same information. Once the FOMC began targeting the funds rate to implement monetary policy, the funds rate changed when the FOMC decided to change the target to achieve its policy objective. In contrast, the 10-year yield responded to information in much the same way as it always did. The result is a marked change in the relationship between the funds rate and 10-year Treasury yields. Because short-term debt instruments are close substitutes for federal funds, the change in the FOMC's use of

[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.

the funds rate target affected the relationship between shorter-term rates and the 10-year yield as well. It also affected the relationship between the funds rate and other short-term rates along the yield curve.

The remainder of the paper is divided into five sections. Section 2 defines the bond yield conundrum and discusses alterative hypotheses of its existence and recent attempts to resolve it. Section 3 presents a simple model of the federal funds rate and long-term bond yields and demonstrates how the FOMC's targeting of the funds rate for the purpose of implementing monetary policy can affect the relationship between these rates. Evidence of the change in the relationship between the federal funds rate and 10-year Treasury bond yield is presented in Section 4. Section 5 investigates the extent to which this change can be attributed to a change from using the funds rate as an operating instrument to a policy target. Section 6 concludes.

2.0 The Bond Yield Conundrum

The word conundrum was used to describe the behavior of bond yields when, in testimony before the U.S. Senate Committee on Banking, Housing, and Urban Affairs on February 17, 2005, former Federal Reserve Chairman Greenspan observed that

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

[2] Greenspan (2005).

Greenspan went on to argue that (a) only a portion of the decline in nominal forward rates could be attributed to a decline in long-run inflation expectations, (b) suggestions that forward real rate had declined were inconsistent with the rise in stock prices and the narrowing of credit spreads over this period, and (c) domestic explanations, such as weak credit demand and the eagerness of foreigners to lend in the U.S., were inconsistent with the facts that "bond yields and risk spreads have narrowed globally."[3] Finally, he noted that while a larger share of world savings is being lent across borders and that favorable inflation performance in a number of countries has likely reduced both 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 characterization of the decline in long-term yields as a global phenomenon has led some to view the conundrum as purely a long-term yield phenomenon. However, the 10-year yield in February 2005 was not unusually low historically. Indeed, it was higher than it was in the spring of 2003 and much higher than in the 1950s and 1960s. Moreover, the behavior of any particular rate can be considered unusual only relative to the rest of the rate structure. Indeed, Kuttner (2006) notes, "what is unusual about the 2004-05 episode is that bond yields remained relatively unchanged, despite the Fed's campaign to raise interest

[3] Greenspan (2005).
[4] Greenspan (2005), emphasis added.

rates."[5] The decline in U.S. long-term yields was due to a decline in real rates, as the 10-year inflation-indexed Treasury yield declined by about the same amount over that 9-month period. Indeed, long-term yields with various degrees of default risk declined over this period. What was unusual to policymakers and others was that real long-term rates declined despite the effort by the Fed to raise them. That yields in other countries also tended to decline about this time may not be all that unusual given the predominant role of the U.S. in the world economy and international integration of financial markets. The analysis here focuses solely on the relationship among rates in the U.S.

2.1 Attempts at Resolving the Bond Market Conundrum

Several analysts have attempted to explain the conundrum noted by Greenspan. While these studies provide useful insight into the behavior of long-term rates relative to short-term rates since mid-2004, none provides a convincing explanation for the change in the relationship between long-term and short-term rates.

Kim and Wright (2005) decompose the term structure of nominal interest rates into the expected future short-term rate and the term premium using the three-factor, arbitrage-free term structure model of Kim and Orphanides (2005). They find that most of the decline in long-term interest rates from June 29, 2004 to July 20, 2005, was due to a decline in the term premium. They conclude that the decline in long-term rates is due to "anything else that might affect the price of Treasury securities other than expected future monetary policy."[6]

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[5] Kuttner (2006), p. 123.
[6] Kim and Wright (2005), p. 7.

Rosenberg (2007) has attempted to decompose the decline in the term premium from updated estimates of Kim and Wright's (2005) model into the decline due to changes in risk, risk aversion, and foreign demand. He finds that only about half of the reduction in the term premium can be accounted for by these factors, with most of this accounted for by a marked—but unexplained—reduction in risk aversion.

Rudebusch, Swanson, and Wu (2006) investigate the conundrum by estimating two macro-finance models of the term structure—models that attempt to integrate standard macroeconomic analyses with finance (affine) term structure models. Specifically, they consider 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-December 2005. For the Rudebusch and Wu model, they compute the model's implications for yields of all maturities through December 2005 based on parameters of the model estimated over the period January 1988-December 2000. They find that the models' residuals are relatively large during 2005 and concluded that "from the perspective of both the BRS and RW models, the recent behavior of long-term Treasury yields does represent a conundrum."[7]

Rudebusch, Swanson, and Wu (2006) investigate possible factors that might underlie the conundrum by regressing the residuals from the two 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

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

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 left unexplained in the Bernanke, Reinhart, and Sack model and over 70 percent is left unexplained in 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.

3.0 Simple Model of the Federal Funds and 10-Year Treasury Rates

In a world with perfect markets and costless transactions, rates of return on all assets will be equivalent after accounting for differences in risk. Equivalence is a consequence of arbitrage. If the risk-adjusted rate of return were higher on one asset than another, economic agents would equilibrate the rates of return by buying the higher-return asset and simultaneously selling the lower-return asset until no further incentive for arbitrage exists. This is referred to as a no-arbitrage condition.

If the federal funds rate and 10-year Treasury yield are determined in highly efficient but imperfect markets, the these rates can be represented as

$$(1) \qquad \begin{aligned} ff &= r + \pi^e + rp^{ff} + \mu \\ T10 &= r + \pi^e + rp^{T10} + \mu' \end{aligned}$$

where ff and $T10$ denote the funds rate and the yield on 10-year Government securities, respectively, r denotes the level of the real natural rate of interest, and π^e denotes the steady-state expected rate of inflation. The possibility of a non-zero risk premium that is unique to the asset is represented by rp. Terms μ and μ' denote potential premiums or discounts that are due to the uniqueness of the particular market. For example, only banks and other financial institutions that hold deposits with the Federal Reserve are permitted to participate directly in the federal funds market. Likewise, 10-year Treasury securities are considered on-the-run, so that they typically trade a slight premium compared with off-the-run issues.

Changes in these rates are affected by changes in the economic fundamentals that determine them and can be represented by

$$(2) \qquad \begin{aligned} \Delta ff_t &= \beta \Delta F_t + \varepsilon_t^{ff} \\ \Delta T10_t &= \psi \Delta F_t + \varepsilon_t^{T10} \end{aligned}$$

where ΔF_t the change in economic fundamentals, e.g., fluctuations in the natural rate of interest, changes in inflation expectations, and the inflation risk premium. The terms, ε_t^{ff} and ε_t^{T10} are zero-mean, constant variance shocks that are unique to the particular rate and, hence, uncorrelated. The coefficients, β and ψ, may be different, reflecting the fact that the response of the rates to changes in economic fundamentals may be different.

The correlation between changes in the federal funds and 10-year rates is given by

$$(3) \qquad \rho = \frac{\beta\psi\sigma_{\Delta F}^2}{(\beta+\psi)\sigma_{\Delta F}^2 + \sigma_{\varepsilon^{ff}}^2 + \sigma_{\varepsilon^{T10}}^2} \neq 0,$$

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, regardless of how each responds. The correlation will be positive if both β and ψ have the same sign and negative if their signs are opposite.[8] Given the fact that interest rates are positively related to the real rate and inflation expectations, the correlation is expected to be positive.

Now assume that the FOMC targets the funds rate and that the funds rate remains close to the target level. The funds rate target is determined by the Fed's policy objectives and, consequently, does not necessarily respond to changes in economic fundamentals in the same way the market does. For example, many economists believe that the FOMC's policy is well approximated by a Taylor rule of the general form

(4) $$ff_t^T = \tilde{r}_t + \alpha(\pi_t - \pi^*) + \lambda(y_t - \tilde{y}^p)$$

where ff_t^T is the Fed's federal funds rate target implied by the Taylor rule and is set equal to the policymakers' estimate of the natural rate, $\tilde{r}_t$, at time t plus magnitudes determined by the extent to which inflation deviates from the policymakers' inflation objective, π^*, and the amount by which output, y, deviates from policymakers' estimate of potential, $\tilde{y}^p$. If the funds rate is determined by (4), changes in the funds rate would be given by

(5) $$\Delta ff_t = \Delta\tilde{r}_t + \alpha\Delta\pi_t - \alpha\Delta\pi^* + \lambda\Delta y_t - \lambda\Delta\tilde{y}^p,$$

i.e., changes in the FOMC's inflation objective, changes in the FOMC's perception of potential output or the natural rate, and changes in actual inflation or

[8] Of course, it would be negative if both coefficients are negative and if $|(\beta+\psi)\sigma^2_{\Delta F}| > |\sigma^2_{\varepsilon^{ff}} + \sigma^2_{\varepsilon^{T10}}|$.

output. Note that $\Delta\tilde{r}_t$, $\Delta\tilde{y}^p$, $\Delta\pi_t$, and Δy_t are news about economic fundamentals, while $\Delta\pi*$ denotes a change in policymakers' inflation objective.

There are a number of reasons to believe that the behavior of the funds rate represented by (5) will differ from that given by (2). First, news about economic fundamentals, reflected in (5), might be a subset of the news about fundamentals that drive market yields, i.e., $(\Delta r_t, \Delta y_t, \Delta\pi_t, \Delta y_t^p) \subset \Delta F_t$.

Second, if the funds rate target is changed because the FOMC changes its inflation objective, the market may not be aware of this unless the FOMC communicates its intentions explicitly.

Third, even if the FOMC responds to a wider array of economic fundamentals than those suggested by the Taylor rule, it might not respond to ΔF_t in the same way as market rates. For example, the FOMC might react more aggressively to news that inflation or inflation expectations have risen.[9]

Finally, given the persistence in the FOMC's funds rate target, it is unlikely that it will respond at the same time as the market. Indeed, it is now commonplace in monetary policy models to assume that policymakers' behavior is inertial, e.g.,

(6) $$ff_t^* = \lambda\, ff_t^T + (1-\lambda)\, ff_t^*,$$

where ff_t^* denotes the funds rate target and $0 < \lambda \le 1$. Policymakers' behavior is non-inertial only if $\lambda = 1$—the funds rate target is adjusted to the level determined by (5), so that the target and the funds rate implied by the Taylor rule coincide. The closer λ is to zero, the slower the adjustment of the target to the desired

[9] This is the so-called Taylor principle, e.g., Davig and Leeper (2007)

level. While the FOMC's funds rate target may not be adequately reflected by a Taylor rule, there is little doubt about the inertial behavior of the funds rate target. Unlike market rates that change with changing economic fundamentals, the funds rate target may be unchanged for months at a time.

4.0 The Empirical Relationship between the Funds and 10-Year Rates

This section investigates the empirical relationship between the federal funds rate and 10-year Treasury yield. The analysis begins with the simple regression,

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

The data are monthly and cover the period January 1983 through March 2007.

The possibility of a change in the relationship between $\Delta T10$ and Δff is investigated by estimating a 33-month rolling regression of (7). The window size is equal to the number of months from July 2004 to March 2007—the period of the conundrum. The estimates, which are plotted on the first month in the 33-month sample, are presented in Figure 1. The estimate of β is in the range of 0.40 until the early 1990s and then declines, becoming negative for a period during the latter part of the sample. More importantly, the estimate of $\bar{R}^2$ is essentially zero from the mid-1990s on. The correlation between monthly changes in the 10-year Treasury yield and the funds rate, that characterized the 1980s and early 1990s, not only changes in the mid-1990s but appears to vanish.

4.1 The Relationship at the Quarterly Frequency

The rolling regression estimates indicate a marked change in the relationship between the 10-year yield and the funds rate at the monthly frequency. It could be, however, that the FOMC was simply slow to respond to the economic fundamentals that affect the 10-year rate so that the correlation at lower frequencies is unaffected by the FOMC's targeting of the funds rate. To investigate this possibility, (7) is estimated using quarterly data. The sample period, 1983.Q1 to 2007.Q1, consists of 97 quarterly observations. When (7) is estimated using the 46 observations from 1983.Q1 to 1994.Q2, the estimate of β is 0.569 with a t-statistic of 5.19 and $\bar{R}^2 = 0.366$, indicating a strong positive relationship between changes in the funds rate and changes in the 10-year yield at the quarterly frequency. However, when (7) is estimated over the period 1994.Q3 to 2007.Q1, the estimate of β declines to 0.129 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 is observed at the quarterly frequency as well.

4.2 When Did the Change Occur?

To estimate when the change occurred, Andrews (1993) 'supremum' method of identifying a single endogenous break point is used to determine the most likely date of a change in the parameters of (7) using monthly data. There are too few observations to use quarterly data. Specifically, (7) is estimated over the first 45 months of the entire sample and the remaining 246 months and a 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 it from the latter period until there are 246 months in the first period and 45 months in the second. The break point is given by the largest value, i.e., the supremum, of the likelihood ratio statistic obtained from this procedure. Following the suggestion of Diebold and Chen (1996), a bootstrap approximation to the finite sample distribution of the test statistic is used.

The likelihood ratio test statistics for all possible break points are presented in Figure 2 along with the critical value for the 1.0 percent significance level obtained from 10,000 replications of the sample data under the null hypothesis of no change 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 the 1.0 percent critical value of 18.58. The results indicate that the break in the relationship between the federal funds rate and the 10-year yield using monthly data likely occurred earlier than estimates presented in Figure 1 suggest. Interestingly, there is a sharp rise in the likelihood ratio statistic in late 1989 and again in mid-1994. The latter coincides with the sharp drop in $\bar{R}^2$ using either monthly or quarterly data.

5.0 Switch from an Operating Instrument to a Policy Target

The analysis in Section 4 establishes that there was a marked change in the relationship between the federal funds rate and the 10-year Treasury yield in the late 1980s, long before Greenspan noted the relationship had changed. This section investigates the hypothesis that the marked change in the relationship between the federal funds rate and the 10-year Treasury yield is a consequence the FOMC’s switch from using the funds rate as an operating instrument to a policy target. The analysis begins by considering the FOMC's use of the funds rate during the late 1970s and the early 1980s.

5.1 Funds Rate "Targeting" in the 1970s

In distinguishing between a funds rate operating procedure and a funds rate target in the 1970's it is important to note that there was no wide-spread acceptance of the view that monetary policy could control long-run inflation as there is today. Nelson (2005), Romer and Romer (2002) provide documentary evidence suggesting that the great inflation of the 1970s was a consequence of policymakers having a nonmonetary theory of the inflation process. This conclusion is supported by verbatim transcripts of the 1978 and 1979 FOMC meetings. There are many comments by Chairmen Burns and Miller, and other Committee members, indicating the belief that inflation was largely of the cost-push variety and not amenable to control by monetary policy. For example, at the January 1978 in a discussion of the shrinking value of the dollar, Chairman Burns suggested four corrective actions, the second of which was "we need an anti-inflation policy on the part of the Administration, something we don't have at the present time."[10] This nonmonetary view of inflation was held by the Board staff as well. Two examples serve to illustrate this. The first is an FOMC briefing prepared by James Kichline and dated March 21, 1978. Kichline notes that in the absence of an effective Administration anti-inflation program, the risks appear weighted toward higher rather than lower rates of inflation. The second, an FOMC Report prepared by Joseph S. Zeisel for the October 1978 FOMC meeting

[10] FOMC transcript, January 17, 1978, p. 5.

addressed what he termed, “a major force driving inflation—the increase in wages and labor costs.” Zeisel went on to note that

> hourly compensation costs have continued rising rapidly over the past several years, reflecting large negotiated wage settlements, as well as legislated increases in the minimum wage and social security taxes. Recent rapid price rises are expected to continue the upward pressure on wage settlements in the heavy round of contract negotiations scheduled for next year. Moreover, with further hikes in the minimum wage and in social security taxes scheduled for the beginning of 1979, no relief is in sight; we are projecting a rise of over 9-1/2 per cent in compensation costs in 1979.[11]

The Committee believed that its ability to control inflation was limited because the inflationary pressures were from the cost side. Nevertheless, they attempted to manipulate aggregate demand to affect the behavior of the real economy. They attempted to do this by affecting the growth rate of monetary aggregate, not by setting the funds rate. Meulendyke (1998) describes the Fed’s funds rate operating procedure during the period 1970 – 1979 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.[12]

The funds rate was a guide to conducting daily open market operations, not a target that the FOMC set to achieve a specific policy objective. If the funds rate began trading “high” relative to the Desk would initially resist the rise by

[11] FOMC Transcript, October 17, 1978, “FOMC Briefing,” pp. 5-6.
[12] Muelendyke (1998), pp. 44-45.

injecting reserves. If the rise persisted, the funds rate "target" would be adjusted. Adjustments to the funds rate target were frequent. Rudebusch (1995a,b) reports that there were 99 adjustments to the funds rate objective during the period September 13, 1974 and September 19, 1979—an average of an adjustment every 2.5 weeks. The daily funds rate and Rudebusch's funds rate objective are presented in Figure 3. Many of the changes in the funds rate target that Rudebusch reports were made by the Desk. The FOMC's official funds rate objective, as it is more appropriately called, was stated as a range, typically about 50 to 75 basis points.[13] Despite frequent adjustments of the funds rate objective, differences of the funds rate from the funds rate objective were relatively large. The average absolute difference of the funds rate from the funds rate target was 13 basis points, with a standard deviation of 28 basis points.

Because the funds rate "target" was adjusted quickly with economic and financial market conditions and the funds rate deviated considerably from the target, the funds rate responded to news about economic fundamentals in much the same way as market rates. Hence, there is no reason to expect to see a marked change in the relationship between the funds rate and 10-year Treasury yields at this time.

More formally, the Andrews (1993) test was applied to a regression of the change in the 10-year Treasury yield on the change in the funds rate using monthly data from January 1974 through March 2007. Consistent with the above

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

analysis, the test indicates a statistically significant break on May 1988. There is no indication of a break in the relationship during the 1970s.

5.2 The Return to 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's (2006) analysis of FOMC transcripts reveals that the FOMC effectively returned to a federal funds rate operating procedure at this time. While the FOMC now understood that its actions had a significant effect on the long-term inflation rate, initially, the FOMC "targeted" the funds rate in much the same way as it did during the pre-1979 period. For policy purposes, the FOMC continued to focus on monetary aggregates (M2 and, to a lesser extent, M3). As Meulendyke (1998) notes, the Committee adjusted its operating objective up or down, "whenever money seemed to be deviating significantly from the desired growth path."[14]

The lack of a predictable stable relationship between the monetary aggregates and output or inflation, coupled with a desired to reduce the long-term inflation rate, caused the FOMC to shift from using the funds rate as an operating instrument to a policy target. The first indication that the FOMC was using the funds rate as a policy target occurred in early May of 1988. On May 9, 1988, the funds rate objective was increased from 6.75 percent to 7.0 following a conference call. There is no transcript of this conference call; however, the discussion at the regularly scheduled FOMC meeting on May 17, 1988 makes it

[14] Meulendyke (1998), p. 53.

clear that the increase was due to concerns about the course of inflation.

Greenspan noted 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.[15]

Greenspan summed up the discussion noting that

> there seems to be a consensus for alternative B and asymmetrical language, with a fairly strong willingness—desire, if I can put it that way—to give instructions to the Chairman and the Desk to move before the next period. I would interpret that to mean that, unless we see events which clearly are contrary to the general consensus of the outlook as one hears it today, it's almost an automatic increase. There is a strong, and I think convincing, case that is being made that we should not, under any conditions, allow ourselves to get behind the power curve on this question.[16]

Just as he indicated, Greenspan increased the funds rate objective from 7.0 to 7.25 percent on May 25. Fears of accelerating inflation prompted the Fed to increase the funds rate objective in a series of moves to 9.75 percent by February 24, 1989.

Short-term market rates, such as the 3-month T-bill rate, peaked in late March and began to fall. Nevertheless, the FOMC made a small increase in the funds rate objective, 6.25 basis points, on May 17, 1989. Moreover, the FOMC did not reduce its target for the funds rate despite a sharp drop in other short-term rate. Between March 27, 1989 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 had declined 96 basis points.

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[15] FOMC Transcript, May 17, 1988, p. 1. There is no available transcript for the first part of this meeting.
[16] FOMC Transcript, May 17, 1988, p. 10.

At the conference call on June 5 Greenspan announced that he was requesting the Desk to adjust the borrowing objective to bring the funds rate down 25 basis points. In response to one Committee member's concern about the "urgency" of the move given uncertainty about inflation and the strength of the economy, Greenspan responded that his "major concerns are (1) the money supply data and (2) evidence that is emerging that the commodity price inflation is beginning to subdue."[17] Consistent with Greenspan's concern, Thornton (2004) noted 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.[18]

The behavior of reserves and M1 is consistent with the idea that by May 1988 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 this decline 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 was sufficiently large. There is little doubt that the FOMC was now using the funds rate as a policy target.[19]

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[17] Transcript of June 5, 1989 conference call, p. 3.
[18] Thornton (2004), p. 494.
[19] Poole, Rasche, and Thornton (2002) 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

The change in the Committee's behavior with respect to the funds rate is reflected in the monthly average difference in the daily funds rate from the funds rate objective present in Figure 4. 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, as was the case in the 1970's 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, and the funds rate target was changed less frequently—30 times, an average of once every 2.25 months. After the FOMC began the practice of announcing policy actions in February 1994, the absolute difference became even smaller and target changes became less frequent—the absolute average difference from February 1994 to March 2007 was 2.6 basis points and there were 49 target changes, an average of once every 3.25 months.

5.3 The Relationship between the 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 FOMC's use of the funds rate as a policy instrument, the relationship between the 10-year yield and other non-targeted rates should be affected less than the relationship with the funds rate. Indeed, one

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that the Fed was targeting the funds rate or that the funds rate target had changed. They 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.

might expect that the relationship between the 10-year yield and non-targeted rates should be affected in proportion to the relationship of other rates with the funds rate. Because shorter-term rates are more closely aligned with the funds rate than longer-term rates, we should expect to see the relationship between 10-year yield and shorter-term non-targeted rates most affected.

The relationship between changes in the funds rate and the 10-year yield and other rates is investigated by estimating 33-month rolling regressions of changes in the 10-year yield on changes in each of the other rates. The rates considered are the 3- and 6-month T-bill rates, $tb3$ and $tb6$, and the 1- and 5-year Treasury yields, $T1$ and $T5$. Because the estimate of $\bar{R}^2$ adequately reflects changes in the relationships, and to conserve space, only the rolling estimates of $\bar{R}^2$ are presented. All estimates are plotted on the first month in the sample.

The estimated $\bar{R}^2$s are presented in Figure 5. Like the federal funds rate, the estimate of $\bar{R}^2$ for all of the rates, except for T5, declines around May 1988. Unlike the estimate for the federal funds rate, which goes to zero in the mid-1990s, estimates for other rates cycle around a non-zero average level until around 1999, when they decline sharply, and then rise. The estimate goes to zero for $tb3$ and $tb6$ 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 estimate for $T5$ is relatively constant over the sample period.

The Andrews (1993) single break point test is applied to regressions of $\Delta T10$ on the changes in each of these rates. As before, the sample period is

January 1983 to March 2007, and the truncation is set at 45 observations. Consistent, with the estimates of the rolling regressions, none of the tests is significant at the 1 percent significance level. However, the test is significant at the 5 percent level for the 3-month T-bill rate. The likelihood ratio test statistics for all possible break points for the 3-month T-bill rate is presented in Figure 6. As with the federal funds rate, the test statistic has a global maximum at May 1988. All other rates have a local maximum at or near May 1988; however, none is statistically significant at even the 10 percent significance level.

The hypothesis that the change in the behavior is due to using the funds rate as a policy target rather than an operational target can be further investigated by noting that if the marked change in the relationship between $T10$ and ff is a consequence of the FOMC's use of its funds rate target as a policy target, the distortion should be larger during months when the FOMC adjusted its funds rate target than in months when it is not. In the latter months, market rates would be free to respond to economic fundamentals without the 'noise' associated with the FOMC's actions.

To investigate this implication the equation

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

is estimated, where $j = ff, tb3, tb6, T1, T5$, and $D^{\Delta ff^*}$ is a dummy variable that is equal to 1 during months when the funds rate target was changed and zero elsewhere. $D^{no\Delta ff^*} = 1 - D^{\Delta ff}$. The funds rate target series is from Thornton (2006). After November 1989 there are no differences between this series and other publicly available funds rate target series. Because the data are monthly,

$D^{\Delta ff^*}$ is one for the month following a target change if the change occurred on the last three business days of the month. Otherwise, it is one during the month when the target was changed.

Equation 8 is estimated over two sample periods, January 1983-May 1988, and June 1988-March 2007. The results are presented in Table 1. The results for the first period are presented in Panel A. For the funds rate and the 3-month T-bill rates, the estimate of $\beta^{\Delta ff^*}$ is somewhat larger than the estimate of $\beta^{no\Delta ff^*}$. In the case of the funds rate, the estimate is considerably larger. In both cases, however, the difference is not statistically significant. The reverse is true for the other three rates, where the estimate of $\beta^{\Delta ff^*}$ is smaller than the estimate of $\beta^{no\Delta ff^*}$. Again, however, none of the differences is statistically significant.

The estimates over the post-May 1988 period, presented in Panel B, are consistent with the hypothesis. For all rates except the federal funds rate, the estimate of $\beta^{\Delta ff^*}$ is smaller than that of $\beta^{no\Delta ff^*}$. Moreover, in every instance, the difference is statistically significant at the 5 percent significance level or lower. In addition, the estimate of $\bar{R}^2$ declines substantially relative to the January 1983-May 1988 period. Consistent with the hypothesis that the change in the relationship with the 10-year yield is a consequence of funds rate targeting, the decline in the estimate of $\bar{R}^2$ is proportionally larger the shorter the term to maturity. In the case of $T5$, the decline in the estimate of $\bar{R}^2$ is modest.

In the case of the federal funds rate, the estimate of $\beta^{\Delta ff^*}$ is larger than the estimate of $\beta^{no\Delta ff^*}$. Indeed, as was the case for the January 1983-May 1988 period, the estimate of $\beta^{no\Delta ff^*}$ is not statistically significant, suggesting no relationship between the funds rate and the 10-year yield except during months when the target was unchanged. Even then, the relationship is weak, i.e., $\overline{R}^2 = 0.0276$. One possible explanation for the relationship between the funds rate and the 10-year only during months when the target is changed is that FOMC used long-term rates as an indicator of changing inflation pressures. Indeed, Goodfriend (1993) argues that during much of the period between 1979 and 1992, "the Fed's policy actions were directed at resisting inflation scares signaled by large sustained increases in the long rate."[20]

5.4 The Relationship between the Levels of Rates

Interest rates trended down over the period January 1983-March 2007. The downward trend is likely due to downward drift of inflation expectations and reductions in the inflation risk premium as a consequence of the FOMC's implicit inflation target. It might also reflect a less volatile real rate associated with the well-documented "great moderation," e.g., McConnell and Perez Quiros, (2000). In any event, the trend in rates tends to obscure the effect of the change in the relationship on the level of nominal interest rates. The effect of these latent factors on interest rates is removed by estimating,

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

where $i = ff, tb3, tb6, T1, T5$ or $T10$. The six equations are estimated over the entire sample period with the cross-equation restrictions $\delta_1^i = \delta_1^j$ and $\delta_2^i = \delta_2^j$, for all i and j, imposed. These restrictions are innocuous. The Chi-square statistics

[20] Goodfriend (1993), p. 2.

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. There is no important or statistically significant difference in effect of latent factors on interest rates over this sample period.

The mean-adjusted, de-trended estimates of each rate compared with the $T10$ are presented in Figure 7.[21] The vertical line indicates May 1988. Consistent with the statistical analysis presented above, the figures suggest a marked change in the relationship between the 10-year yield and each of the rates that appears to occur around May 1988. Prior to May 1988 all of the rates cycle with the 10-year yield. After May 1988, however, they move more independently of the 10-year yield, moving in the same direction during some periods and opposite directions during others. Again, consistent with the previous analysis, the degree to which other rates diverge from the 10-year yield appears to increase monotonically as the maturity of the asset become shorter. The 5-year Treasury yield is the least affected, but even here the effect is noticeable.

The marked change in the relationship between these rates is further illustrated in Figure 8, which plots the 24-month rolling correlation between the de-trended rates. The data are again plotted on the first month in the sample and the vertical line denotes May 1988. The figure shows a strong, steady relationship between these rates until late 1980s when the correlations begin to cycle. Most often the correlation is positive, but there are several periods of two years or longer when the correlation is negative for ff, $tb3$, and $tb6$.

[21] Differences in the level of the trends between rates represent the estimate of the average relative risk premium.

Because the rolling correlations suggest that the relationship between the levels of the de-trended rates may have changed before May 1988, the Andrews test is applied to regressions of the change in the de-trended 10-year yield on the change in de-trended level of each of the rates. The test statistics rise dramatically in early 1987 and decline equally dramatically beginning in mid-1988 and are relatively flat between April 1987 and June 1988. The test statistic for all of the rates reaches it surpremum during this interval. The date is June 1987 for the federal funds rate, April 1987 for the T-bill rates and June and October 1988 for $T1$ and $T5$, respectively. All in all, these results suggest that there was a significant break in the relationship between the 10-year bond yield and shorter-term rates that occurred around mid-1987 to mid-1988.

Consistent with the hypothesis that the FOMC switched its use of the funds rate in the late 1980s, there is a marked change in the relationship between the federal funds rate and all rates considered here. This is shown in Figure 9, which shows the 24-month rolling correlation of the detrended funds rate and the other detrended rates. Not surprisingly, the relationship is most affected for longer-term rates. But even the 3- and 6-month T-bill rates are affected.

5.6 Greenspan's Conundrum

There is compelling evidence of a marked change in the behavior of the funds rate and 10-year Treasury yield in around May 1988. Moreover, the behavior of other rates and the documentary evidence in the previous section is consistent with the hypothesis that the FOMC switched from using the funds rate as an operational objective to a policy target. Was there yet another change in the behavior of these rates in 2004? Figures 8 and 9 show mark decline in the correlation between both the funds rate and the 10-year yield and other rates that occurs in early to mid-2004. To test for a possible break in after May 1988, the Andrews test was applied to a regression of the change in the 10-year yield on the change in the funds rate over the period June, 1988 – March, 2007 using both de-trended and not de-trended data. The truncation was set at 35 observations. There was no statistically significant break in the relationships over this period at even the 10 percent significance level. Moreover, the likelihood ratio test statistics were relatively small for breaks occurring in 2004. Hence, there is no evidence of a break in the relationship that is consistent with Greenspan's observation of a marked change in the relationship between the 10-year yield and the funds rate at this time.

6.0 Conclusions

This paper shows that there was a marked change in the relationship between the funds rate and the 10-year Treasury yield that former Federal Reserve Chairman Greenspan first noticed in February 2005 occurred in the late 1980s, with the most likely date of the change being May, 1988. Moreover, it argues that the change in behavior is a consequence of the FOMC switching from using the funds rate as an operating target to a policy target—an example of Goodhart's Law. Once the Fed began using the funds rate as a policy target, the behavior of the funds rate necessarily differed from what it would have been had it not been constrained by the Fed's policy targeting procedure. This hypothesis is supported by an array of documentary and statistical evidence. Consistent with the hypothesis advanced here, the relationship between the funds rate and shorter-term rates changed as well. The relationship between the 10-year yield and shorter-term rates also changed as a consequence of arbitrage between the funds rate and other rates at the shorter end of the term structure. Hence, the FOMC's decision to use the funds rate as policy target affected the relationship among rates along the entire term structure.

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Table 1: Results of the regression						
Panel A: January 1983--May 1988						
	α	$\beta^{\Delta ff^*}$	$\beta^{no\Delta ff^*}$	$\overline{R}^2$	s.e.	Chi-Square Test
Δff	0.0001 (0.9976)	0.5758 (0.0001)	0.2477 (0.2724)	0.2176	0.3332	1.5616 (0.2114)
$\Delta tb3$	-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						
Δff	-0.0164 (0.2682)	0.2387 (0.0045)	-0.0739 (0.6760)	0.0276	0.2203	2.5548 (0.1100)
$\Delta tb3$	-0.0203 (0.1360)	0.3788 (0.0000)	0.6772 (0.0000)	0.1785	0.2025	3.8497 (0.0498)
$\Delta tb6$	-0.0206 (0.0865)	0.4508 (0.0000)	0.9618 (0.0000)	0.3625	0.1784	16.6507 (0.0000)
$\Delta T1$	-0.0173 (0.0906)	0.5210 (0.0000)	0.9472 (0.0000)	0.5353	0.1523	21.7755 (0.0000)
$\Delta T5$	-0.0048 (0.2247)	0.7956 (0.0000)	0.8914 (0.0000)	0.9286	0.0597	8.9015 (0.0028)

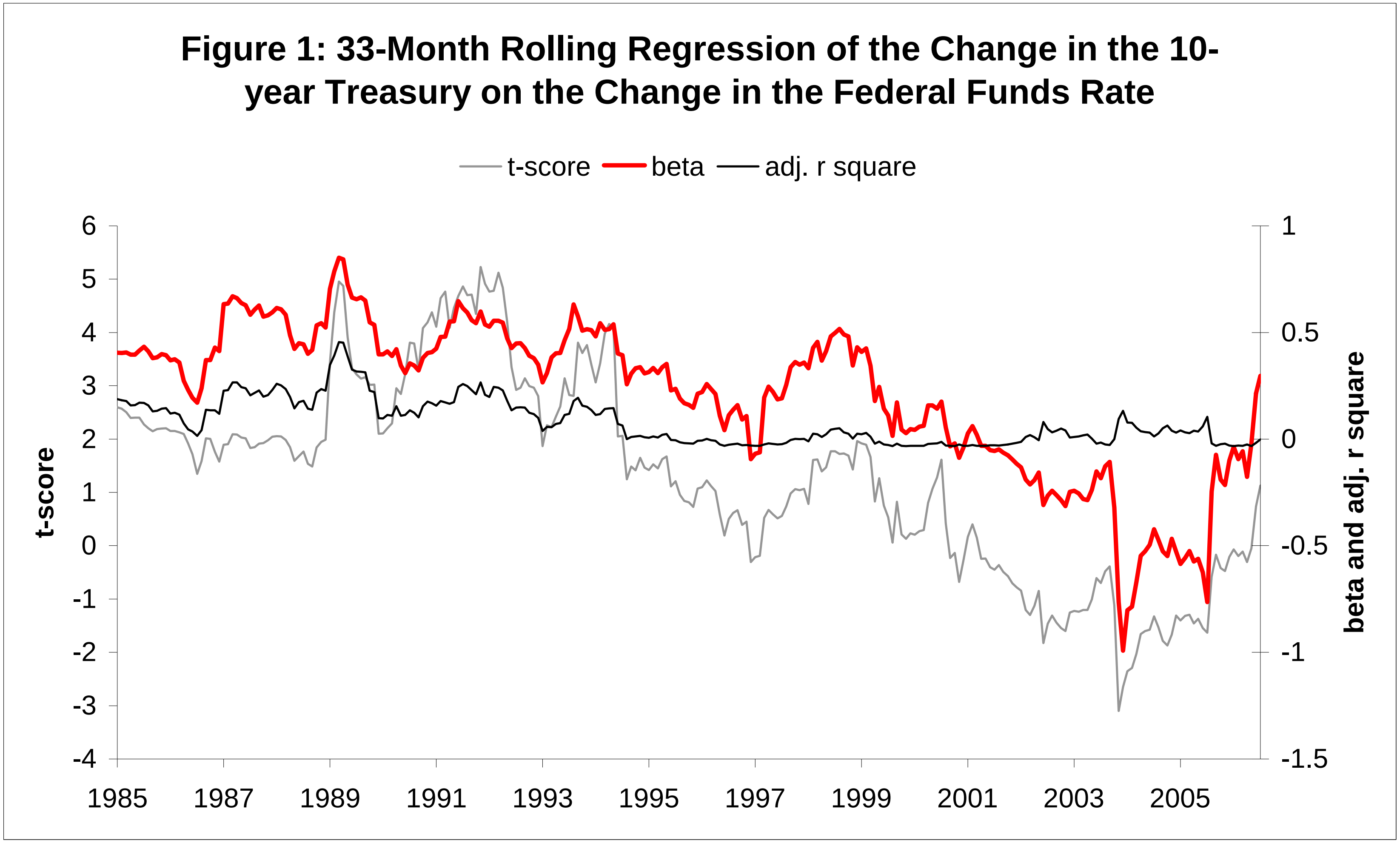


Figure 1: 33-Month Rolling Regression of the Change in the 10-year Treasury on the Change in the Federal Funds Rate
t-score
beta
adj. r square
6
5
4
3
2
1
0
-1
-2
-3
-4
1
0.5
0
-0.5
-1
-1.5
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
t-score
beta and adj. r square

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

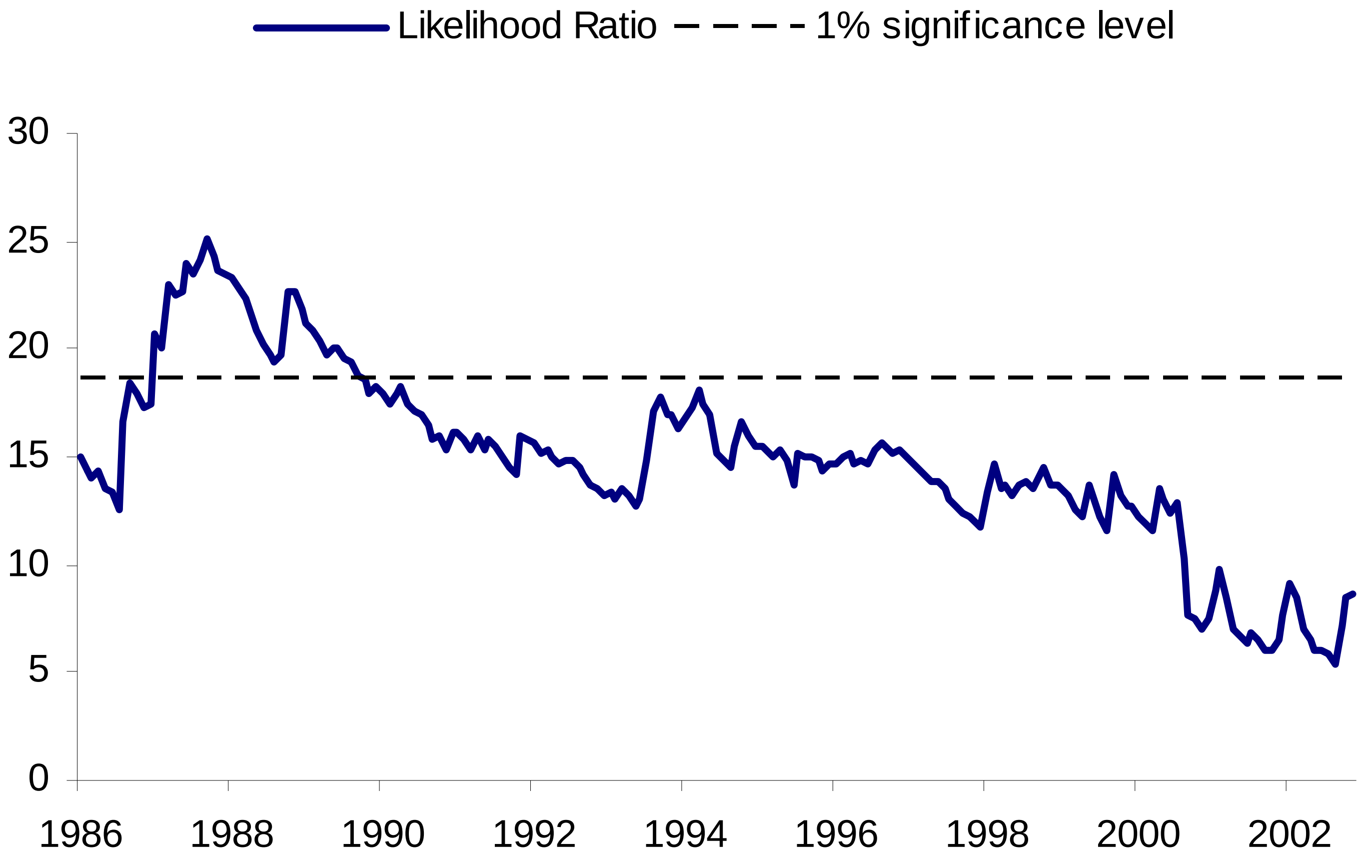


Figure 3: Effective Federal Funds Rate and the Fed's Funds Rate Objective

September 12, 1994 - October 5, 1997

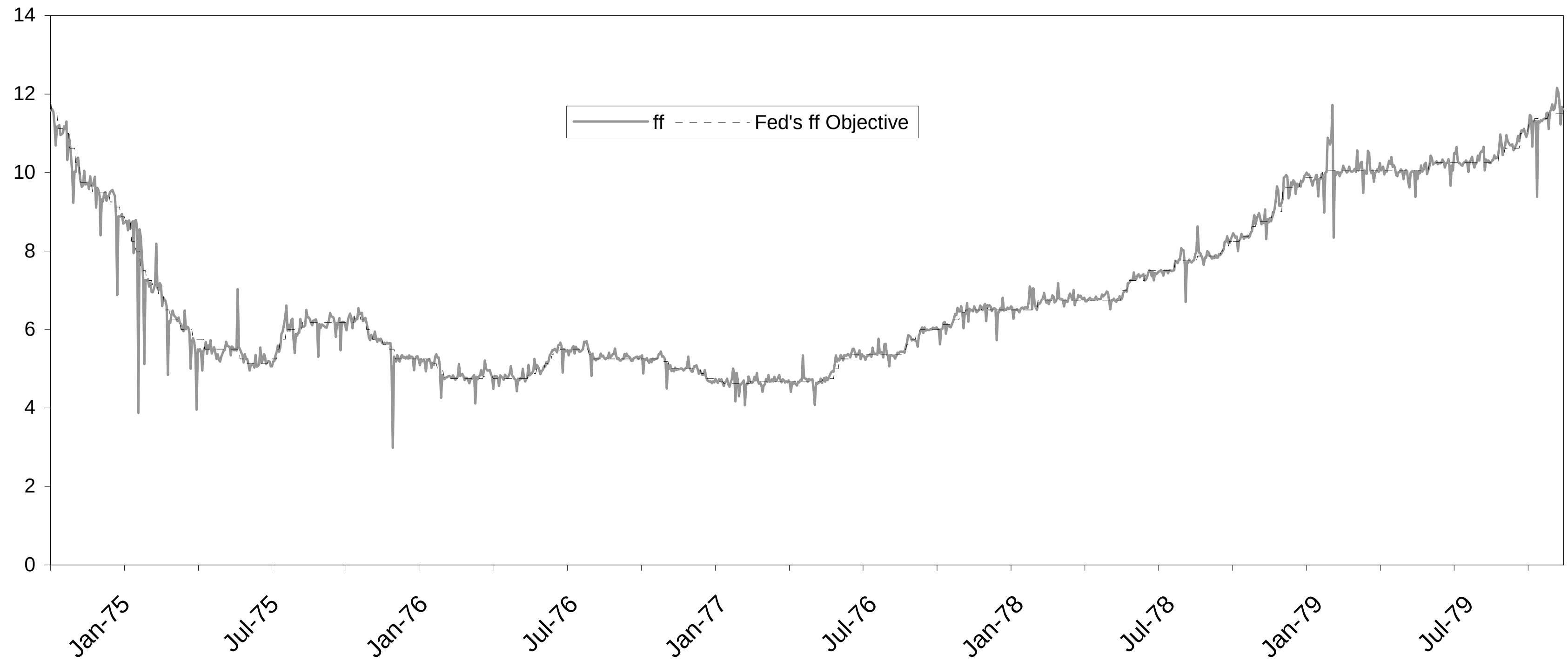


Figure 4: Average Difference Between the Federal funds Rate and the FOMC's Funds Rate Target

(January 1983 - March 2007)

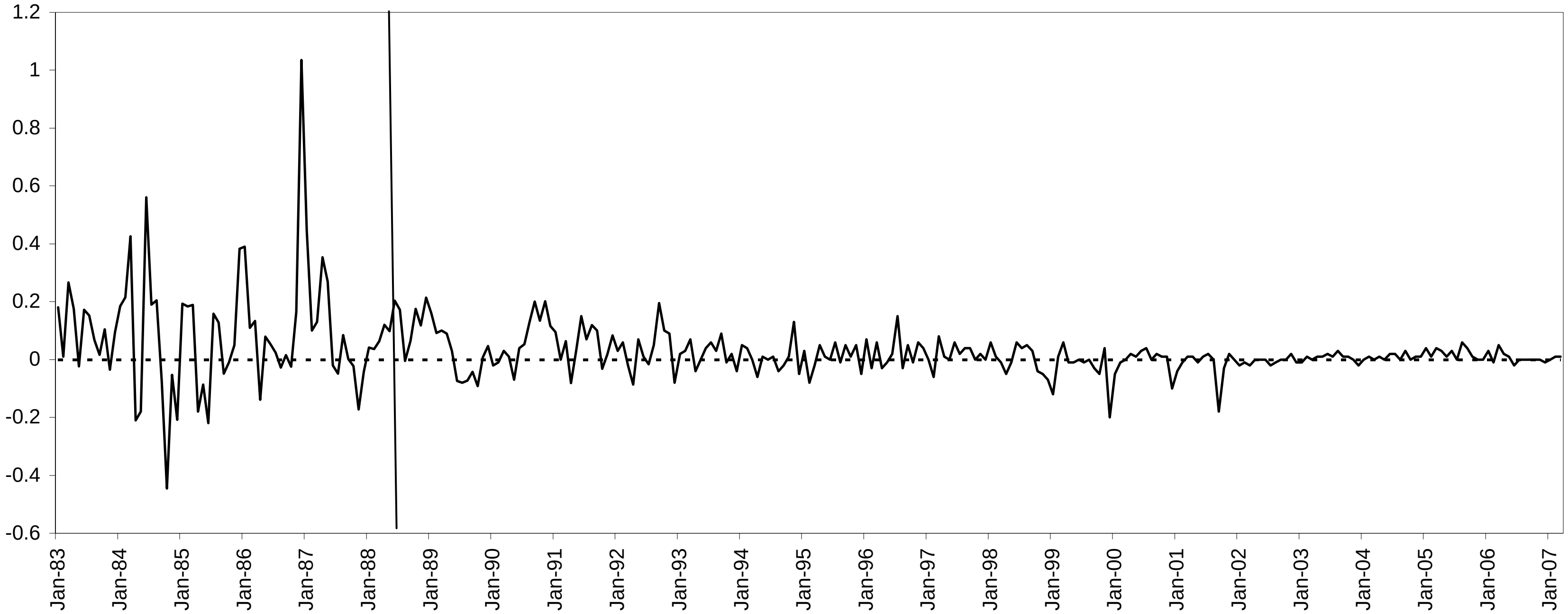


Figure 5: 33-Month Rolling Adj-Rsquares of Regressions of the Change in the 10-Year Yield on Changes in Various Rates

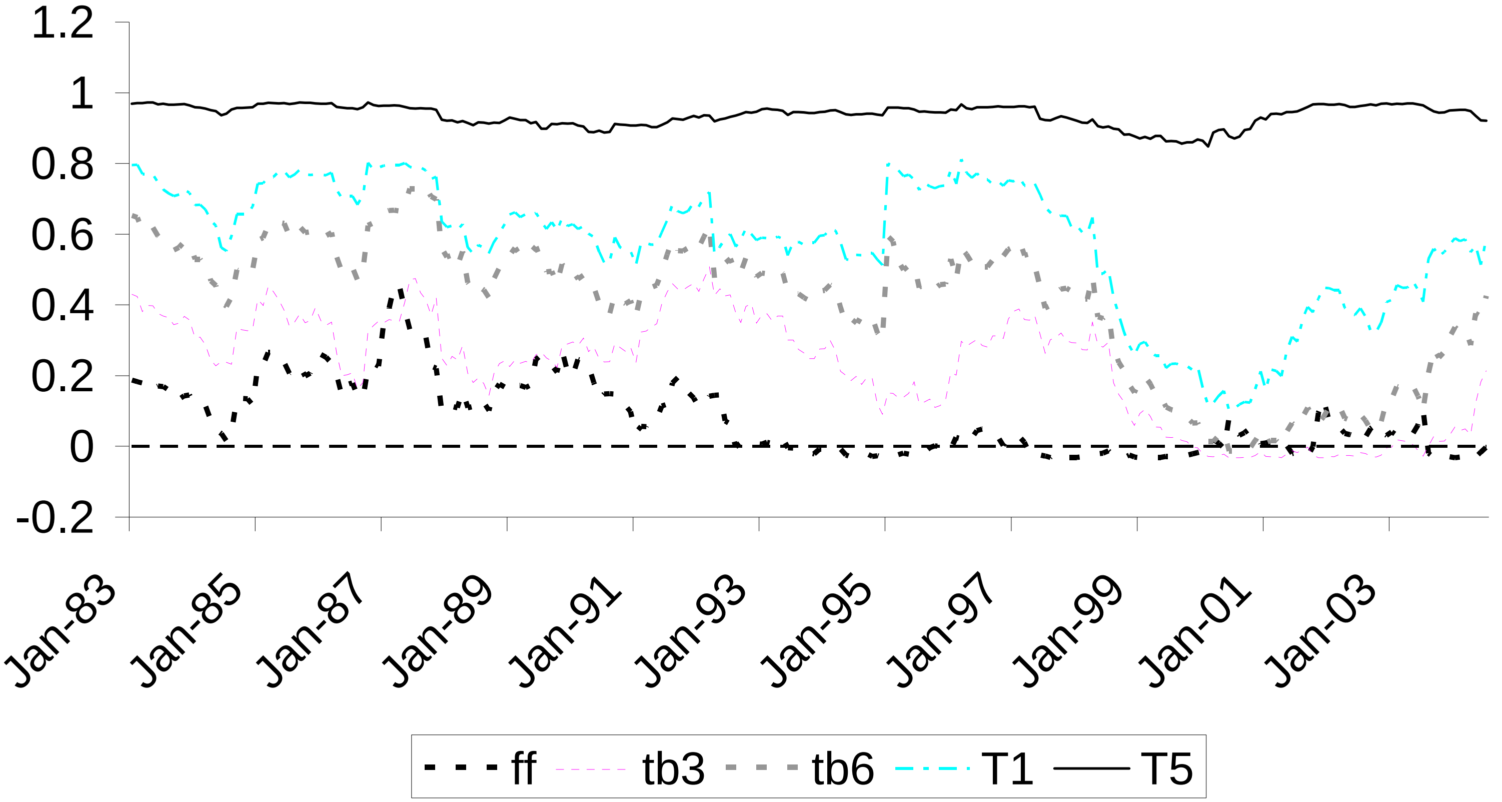


Figure 6: Andrews Break Point Test, The Change in the 10-Year Treasury Yield on the Change in the 3-month T-bill Rate

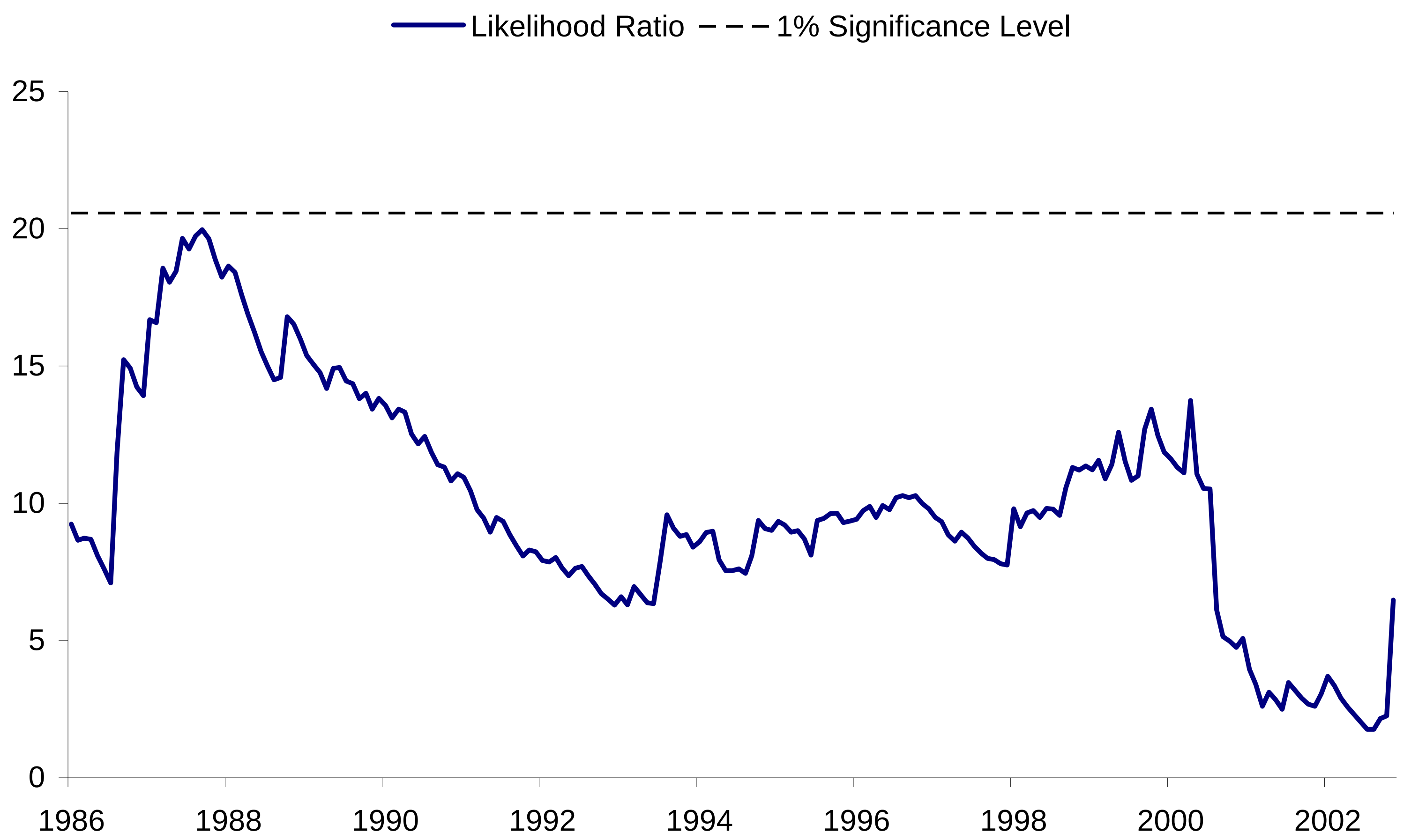
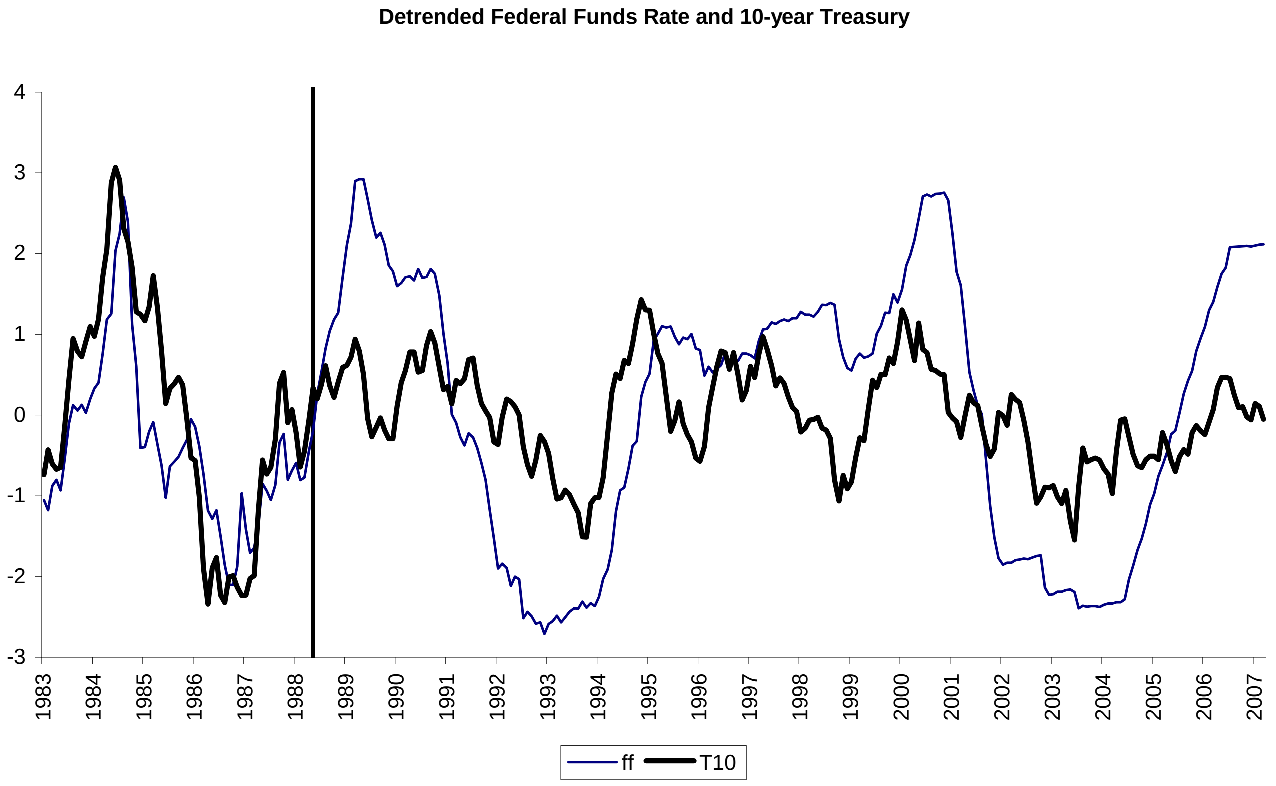


Figure 7: Detrended Federal Funds and Other Rates



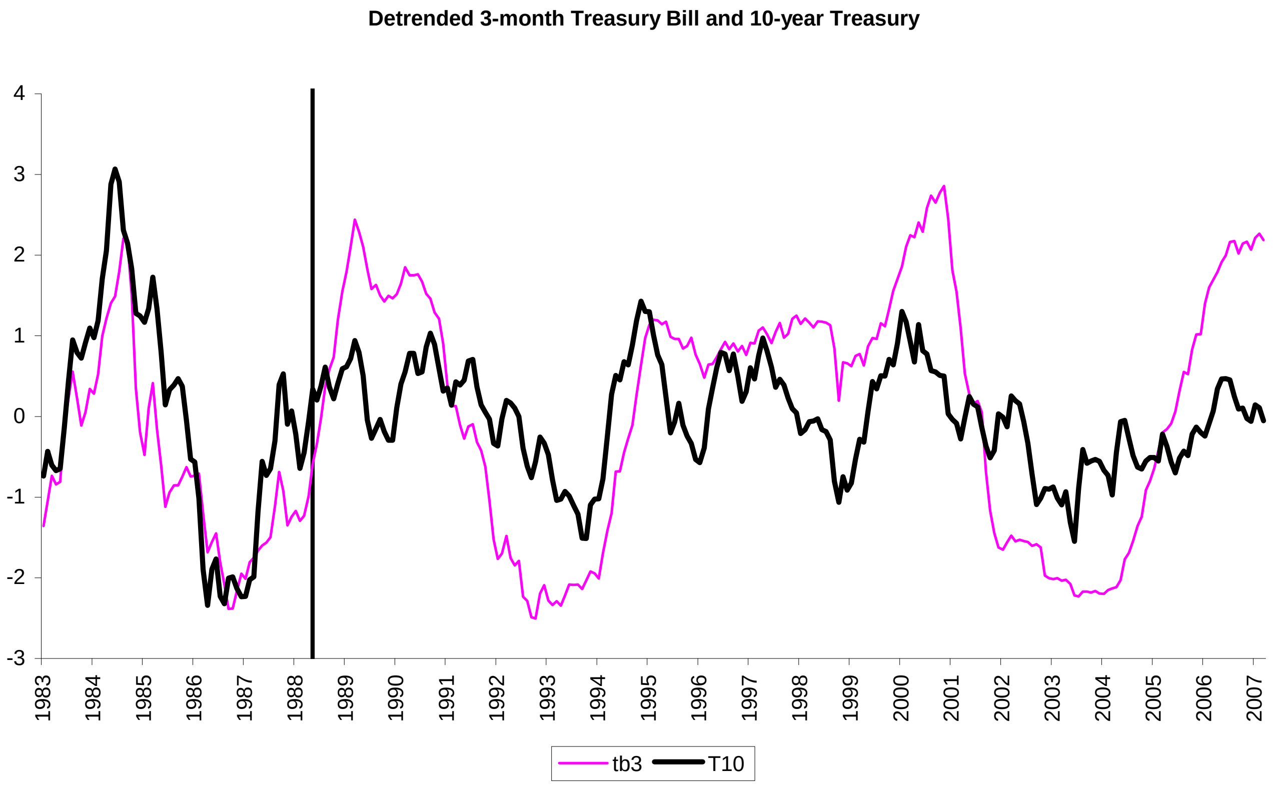
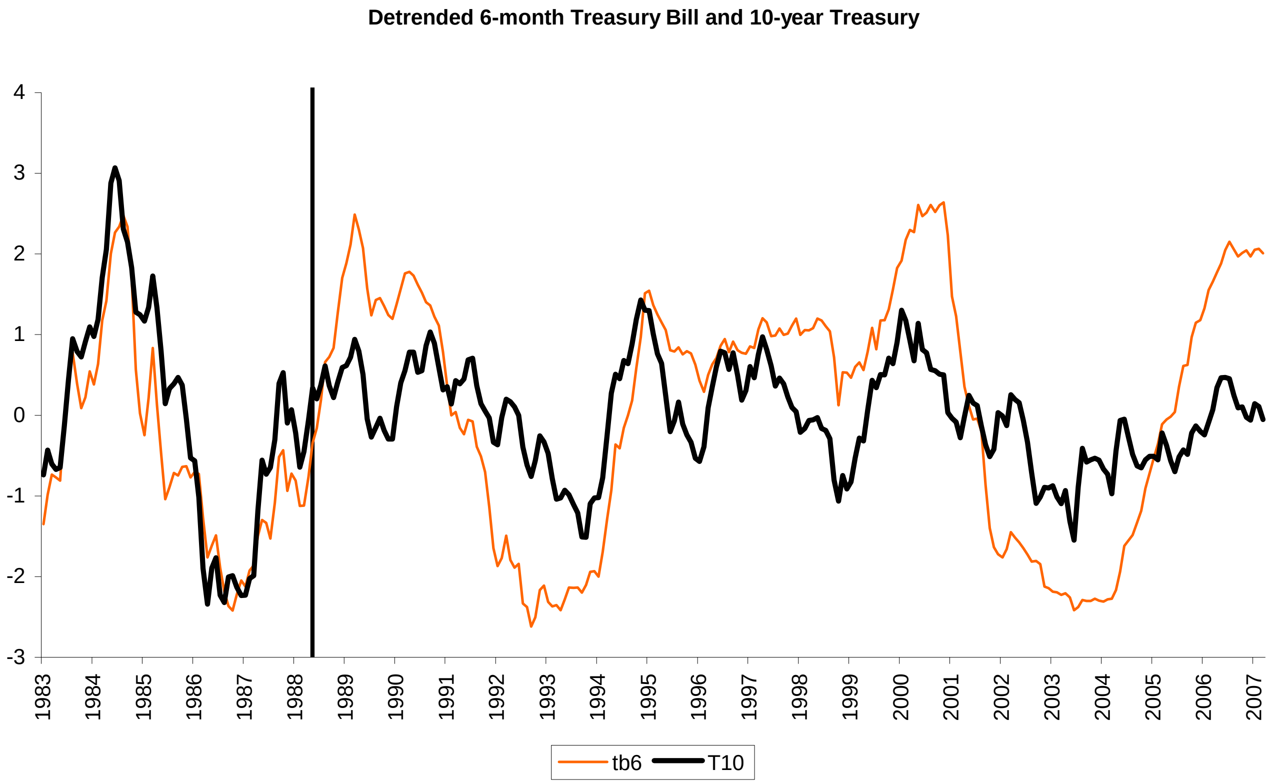


Figure 7: Continued



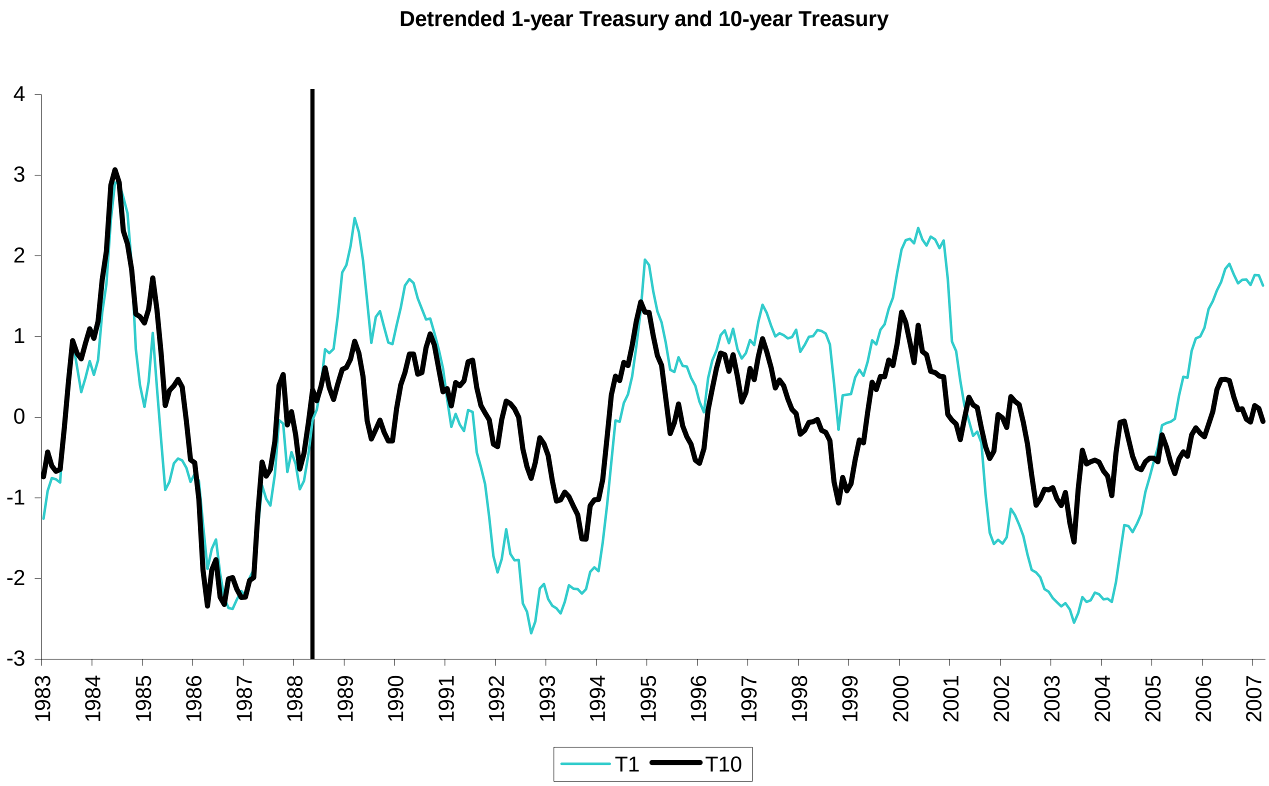


Figure 7: Continued

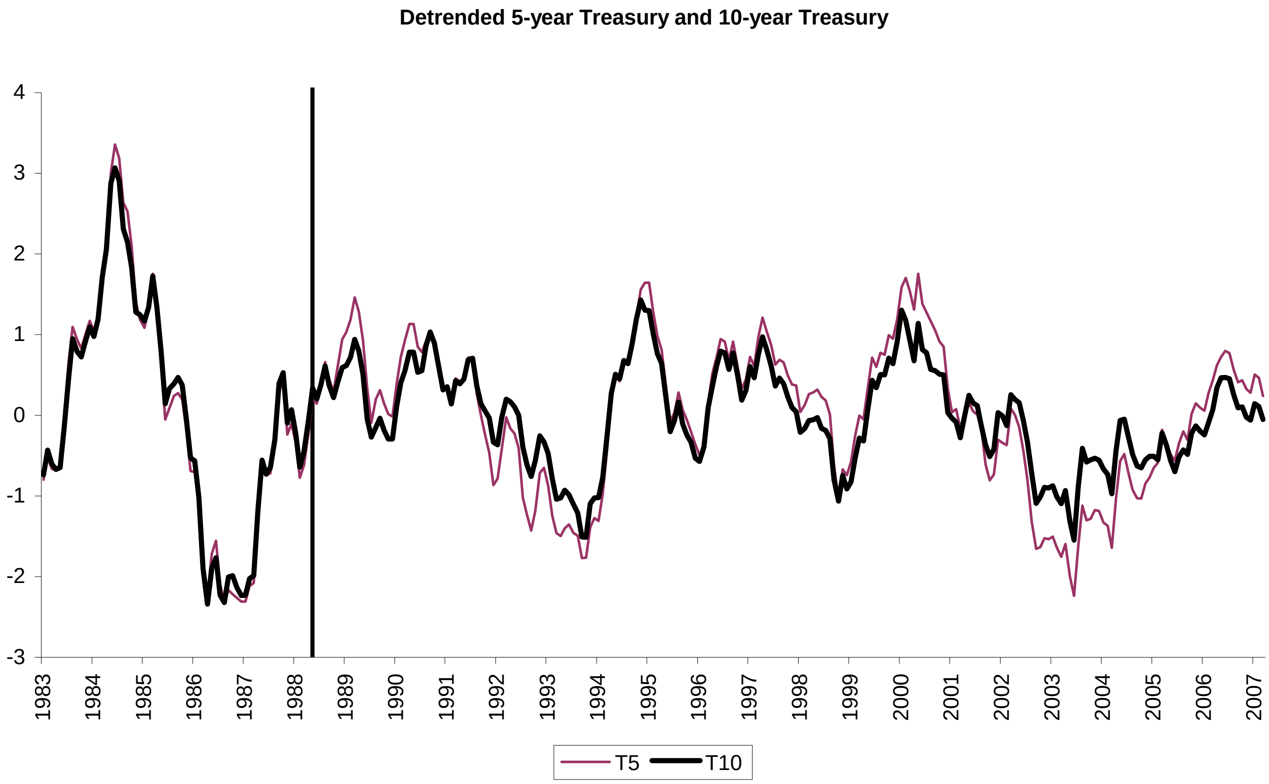


Figure 8: 24-Month Rolling Correlation of De-Trended Rates with the De-Trended 10-Year Yield

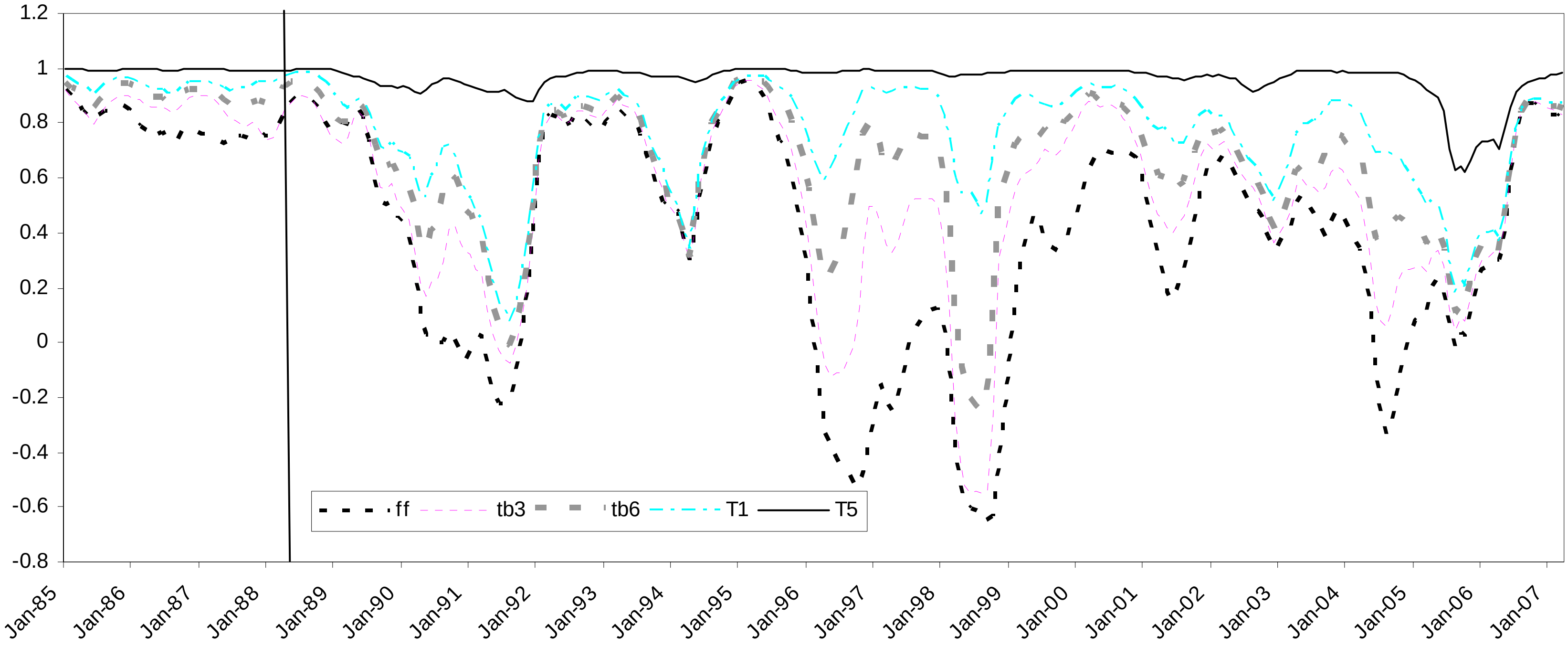


Figure 9: 24-Month Rolling Correlation of De-Trended Rates with the De-Trended Funds Rate