The Reaction of Term Structure of Interest Rates to the Monetary Policy Actions

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March 6, 2006

We would like to thank Daniel Grombacher of CBOT, Ray Sasaki of Sempra Energy and Doug Adams of Trans Market Group for providing data, insights and valuable information of Federal Funds Futures.

Abstract

This paper analyzes the response of the Term Structure of discount rates to the changes in the Federal Funds Target Rate. It also suggests a method of hedging fixed income portfolio's risk to the unexpected changes in monetary policy. We use two alternative widely used models of term structure of interest rates – the Extended Nelson-Siegel and the Extended Vasicek models. We show that only the slope of the term structure of zero-rates (also known as the spread between medium and short term rates) reacts significantly to the monetary policy. We also demonstrate that in our case, the Extended Vasicek model outperforms the Extended Nelson-Siegel model in capturing the impact of the monetary policy on the shape of the term structure. The results here can be used in practice to hedge the risk of the changes in the shape of the term structure of rates, due to monetary policy actions.

Key Words: Term Structure, Nelson-Siegel Model, Vasicek Model, Monetary Policy, Federal Funds Target Rate.

JEL classification: E52, G14

INTRODUCTION

How the markets react to the Federal Reserve actions has been a topic of interest for a long time. Many papers have addressed the impact of the Monetary policy on different asset classes. Recently, Bernanke and Kuttner [2005] measured and analyzed in some details the stock market's response to monetary policy actions. In an efficient markets framework, the actions of the monetary policy impact asset prices to the extent that they provide new information on the future of the economic growth or inflation or other variables that may explain the future earning. How financial asset prices respond to economic news is a topic of great interest for both academicians and practitioners. There is an extensive literature that studies the announcement effects of the monetary policy actions and its impact. Many researchers have studied the impact of macroeconomic news on equity markets and on fixed income markets. In particular, there are some papers that analyze the impact of the monetary policy on the bond prices.[1] Kuttner [2001] suggested using prices of Futures on Federal Funds Target Rates (FFTR from now on) as a measure of expected monetary policy. Thus, the prices of the latter securities can be used to measure the unexpected changes in the monetary policy, ex-post, and split the changes in the policy into expected and unexpected components. Under the light of the expectations hypothesis framework, the expected change in the fed policy (measured by the change in the federal funds target rate) should not have any impact on asset prices, but the unexpected change in the fed policy should impact the asset prices. Having this in mind, Kuttner [2001] measured the impact of monetary policy on interest rates of different maturities. He found that rates of all maturities have only small reaction to the expected changes in the FFTR, but have a strong and statistically significant positive reaction to the unexpected changes in the FFTR.

Thus, to measure the impact and hedge the risk of monetary policy surprises, we use the method of Kuttner [2001] to measure monetary policy surprises[2]. Instead of measuring the impact of the surprise changes in the FFTR on the bond prices or yields of different maturities, we will adopt the Nelson-Siegel model and the Vasicek model[3] of term structure of interest rates and measure the impact on the parameters of the model. Once the sensitivity of the parameters s determined, we will be able to suggest a strategy to hedge the risk of a fixed income portfolio. The approach used here for hedging the risk is similar to the one used by Fabozzi, Martellini and Priaulet [2005].

Data and the method

Measuring the impact of the fed policy

We follow Kuttner [2001] and use current-month federal funds futures prices to measure expected and unexpected changes in the rates and their impact. The Chicago Board of Trade (CBOT) began offering federal funds futures contracts in October 1988 (CBOT, 1992). The federal funds futures contract is for the simple average of the daily *effective federal funds rate* during the month of the contract[4]. The effective federal funds rate is a weighted average of all federal funds transactions for a group of federal funds brokers who report to the Federal Reserve Bank of New York each day. The CBOT offers contracts ranging from the current month to 24 months out. These contracts have a nominal value of $5 million, and their settlement price is equal to 100 minus the average of the effective federal funds rate for the month of the contract[5], and at maturity, the contract is cash-settled against the monthly average of daily effective federal funds rates, including weekends and holidays, as calculated and reported each business day by the Federal Reserve Bank of New York.[6]

Since their introduction in October 1988, prices of federal funds futures contracts have become very popular as a simple way of measuring market expectations about the future path of monetary policy and trying to predict future policy moves. Since these contracts are based on the monthly average of the federal funds rate, which is the main policy instrument of the Federal Reserve, efficient futures markets should set prices to reflect the expected path of Fed policy.

Since the federal funds rate on average follows the target set by the Federal Reserve, such measures could be interpreted as the expected average of the federal funds rate target for the remaining days of the month, and, in particular on the day before a meeting of the Federal Open Market Committee from 1994 onwards, as the level of the funds rate target expected to prevail after the meeting, since policy moves after 1994 have been made almost exclusively at FOMC meetings.

Kuttner [2001] uses the prices of 30 Day Federal Funds Futures on the FFTR to extract the shocks in the Fed Fund Target rates. We follow Kuttner [2001] to find the unanticipated fed funds target rate changes as follows: assume that the fed funds target rate is equal to the fed funds effective rate. Denote by r^- and r^+ the rate before and after the meeting (the event day). If the meeting is on the *d*-th day of the month that has *m* days, then

$$FFTR^- = \frac{d}{m} r^- + \frac{m-d}{m} E_-(r^-) + \varepsilon^-,$$

where $FFTR^{-}$ is the implied FFTR rate for the month and ε^{-} is the premium for the futures contract as of a day before the rate changes.

On the day of the rate changes (FOMC meetings), the rate for the rest of the month is known and the implied FFTR from the futures contract is

$$FFTR^{0} = \frac{d}{m} r^{-} + \frac{m-d}{m} (r^{-}) + \varepsilon^{0} .$$

Using the conventional way of measuring the surprise (unexpected) change in monetary policy as $\Delta^{sur} = r^{-} - E(r^{-})$ and using the two equations above, we get

$$\Delta^{sur} = \frac{m}{m-d}\left(FFTR^{0} - FFTR^{-}\right) - \frac{m}{m-d}\left(\varepsilon^{0} - \varepsilon^{-}\right).$$

Thus, assuming that premium ε is not significant[7] to have an impact on the policy, we get an expression for finding the unexpected portion of the monetary policy action[8]

$$\Delta^{sur} = \frac{m}{m-d}\left(FFTR^{0} - FFTR^{-}\right)$$

This breakdown of the change in the FFTR between expected and unexpected changes will be used to assess the impact of the monetary policy on asset prices and their subsequent continuation.

Exhibit 1 shows the descriptive statistics of the FFTR and the Exhibit 2 shows the distribution of the FFTR form 1989 to 2006. Some of the decisions on the FFTR were made on Federal Open Market Committee meeting days (FOMC) and some other on Non-FOMC days. Most event days after January 1994 are on FOMC meeting days. Out of 98 event days, the fed did not change the FFTR in 55 days. We study these days also as the market might have expected some changes and we would like to see the reaction in those cases too. The distribution of the actual rate changes is shown in Exhibit 2. We have both contracting and expanding environment in which the rates were raised or lowered. We have broken down the changes into two components (expected and unexpected) for the analysis, but do not report the details here.[9] We also study the problem for the entire period and the period after January 1994. The fed began announcing the changes in the FFTR immediately after the decision was made in February of 1994. That's why we would like to see the difference in the impact due to this practice. Now, we have data on the monetary policy, broken down into expected and unexpected components. Next, we will prepare the data to calibrate the parameters of the Nelson-Siegel and the Vasicek models of term structure of interest rates to study the impact.

Data, the Nelson-Siegel and Vasicek models

We calibrate to find the parameters of Nelson-Siegel and Vasicek models on a daily basis so that we can merge with previous dataset and study the relationship.

Originally, under assumption that the instantaneous forward rate follows the dynamics of the solution of a second-order differential equation, Nelson and Siegel [1987] derived a formula for the dynamics of instantaneous forward rates, which after integration leads to the following parametric model of zero-coupon rates

$$R(t) = \beta_0 + \beta_1 \left[\frac{1 - \exp\left(-\frac{t}{\tau_1} \right)}{\frac{t}{\tau_1}} \right] + \beta_2 \left[\frac{1 - \exp\left(-\frac{t}{\tau_1} \right)}{\frac{t}{\tau_1}} - \exp\left(-\frac{t}{\tau_1} \right) \right]$$

where

— $R(t)$ is the continuously compounded zero-coupon rate at time zero with maturity t;

— β_0 is the limit of $R(t)$ as $t \to \infty$, and in practice can be regarded as a long-term interest rate;

— β_1 is the limit of $R(t) - \beta_0$ as $t \to 0$, and we can treat it as the long-to-short-term spread;

— β_2 is a curvature parameter;

— τ_1 is a scale parameter that measures the rate at which short-term and the medium-term components decay to zero.

The advantage of this model is that the parameters $\beta_0, \beta_1, \beta_2$ can be interpreted as level, slope and curvature shifts in the yield curve, which allows us to obtain different shapes for the zero-coupon yield curve. However, it fails to fit U-shaped and hump-shaped curves. To correct this, Svensson [1994] proposed an extended and more flexible version of NS model for forward rates, which gives the so-called Nelson-Siegel Extended model for interest rates,

$$R(t) = \beta_0 + \beta_1 \left[\frac{1 - \exp\left(-\frac{t}{\tau_1} \right)}{\frac{t}{\tau_1}} \right] + \beta_2 \left[\frac{1 - \exp\left(-\frac{t}{\tau_1} \right)}{\frac{t}{\tau_1}} - \exp\left(-\frac{t}{\tau_1} \right) \right]$$
$$+ \beta_3 \left[\frac{1 - \exp\left(-\frac{t}{\tau_2} \right)}{\frac{t}{\tau_2}} - \exp\left(-\frac{t}{\tau_2} \right) \right]$$

where $R(t), \beta_0, \beta_1, \beta_2$ and τ_1 are the same as in NS model, τ_2 is a free parameter equal to the rate of decay of the corresponding factor to zero, and β_3 is the curvature parameter of the short-term end of the curve. Parameters τ_1 and τ_2 are typically picked up in the range [2; 10] and [.1; .4]. In this work we set a priori $\tau_1 = 3$ and $\tau_2 = .3$.

We will use the Extended NS and Extended Vasicek models for our analysis, however, we have also studied the Nelson-Siegel and Vasicek models for the robustness of the results and obtained similar results. To estimate the parameters $\beta_0, \beta_1, \beta_2$ and β_3 we use daily data on historical zero-rates of maturities up to 30 year[10].

Extended Vasicek model is derived from Vasicek [1977] model of short-term interest rates, in which the spot rate is modeled to follow an Ornstein-Uhlenbeck process $dr_t = \alpha(\gamma - r_t)dt + \sigma dW_t$, and as a consequence it is shown that the term structure of the interest rates has the form

$$R(t) = R_\infty - (R_\infty - r_0) \cdot \frac{1 - \exp(-\alpha t)}{\alpha t} + \frac{\sigma^2}{4\alpha^3 t} \cdot \left(1 - \exp(-\alpha t)\right)^2 .$$

From here, we get so-called Extended Vasicek model

$$R(t) = L_0 - S_0 \cdot \frac{1 - \exp(-at)}{at} + \gamma_0 \cdot \frac{\left(1 - \exp(-at)\right)^2}{4at} ,$$

where L_0 is the limit of $R(t)$ as $t \to \infty$, and in practice corresponds to a long-term interest rate, S_0 is the limit of $R(t) - L_0$ as $t \to 0$, and it can be seen as the long-to-short-term spread, γ_0 is a curvature parameter related to the volatility σ of the spot rate, and a is a scale parameter that measures the strength of the reversion of the short-term interest rate toward long-term mean. The parameter a usually is set to be in between .2 and .6. We take it equal to .3.

Similar to Nelson-Siegel model, we consider the following natural extension of the previous model for interest rates

$$R(t) = L_0 - S_0 \cdot \frac{1-\exp(-at)}{at} + \gamma_0 \cdot \frac{(1-\exp(-at))^2}{4at} - T_0 \cdot \frac{1-\exp(-bt)}{bt} + K_0 \cdot \frac{(1-\exp(-bt))^2}{4bt} .$$

This model can be found in the literature as Extended Vasicek 2 model (see, Martellini and Priaulet [2000]). Adding extra factors gives flexibility in fitting the short-term sector. We analyze all the different models for the robustness of the results and the findings are very similar, so we report only the Extended NS case.

For the calibration of the parameters, we use OLS approach and try minimizing the following by choosing the parameters of the Extended NS model.

$$\underset{\beta}{Min}\left\{\tilde{R}(t,\beta) - \beta_0 - \beta_1\left[\frac{1-\exp\left(-\frac{t}{\tau_1}\right)}{\frac{t}{\tau_1}}\right] - \beta_2\left[\frac{1-\exp\left(-\frac{t}{\tau_1}\right)}{\frac{t}{\tau_1}} - \exp\left(-\frac{t}{\tau_1}\right)\right] - \beta_3\left[\frac{1-\exp\left(-\frac{t}{\tau_2}\right)}{\frac{t}{\tau_2}} - \exp\left(-\frac{t}{\tau_2}\right)\right]\right\}^2 .$$

Here t is the day (this calibration is done on a daily basis), $\tilde{R}(t,\beta)$ is the market zero-coupon rate and $\beta = (\beta_0, \beta_1, \beta_2, \beta_3)$ is the vector of parameters of the model. [11] Similarly we calibrate the NS, Vasicek and Extended Vasicek models.

As widely accepted and used in practice, the parameters of the Extended NS model have intuitive explanation: they track the level, the slope and curvature of the term structure curve of interest rates. The Extended Vasicek parameters have similar explanations. We report the descriptive statistics of the extended NS and Vasicek models in Exhibit 3. The correlations between the parameters of the four models are reported along with their first and second moments. The coefficient of variation (CV) is the highest for the parameter that mimics the curvature in all the models. This can be seen clearly in the Panel B of Exhibit 3. Panel B of Exhibit 3 shows the time series behavior of all the parameters of all four models. The relative variation of the parameters can be seen in this panel.

In the next section we combine the data on the monetary policy and the term structure parameters on the days of the fed decisions to study the relationship. After we can estimate the impact of the monetary policy on the parameters, we know how to hedge the fixed income portfolio's risk.

The results

To see the impact of the changes in the monetary policy on the term structure of rates, we run regressions, starting off by running regressions of the changes in the parameters on the actual changes in the FFTR. The results are reported in Exhibit 4. Panels A, B and C show the results of the regressions for different time periods. As can be seen, the period 1989-1993 does not have significant results. The reason for this is the way the monetary policy actions were transmitted to the market prior January 1994. The market would gradually learn about the changes in the FFTR and for that reason it probably took longer for the fixed income markets to adjust to the new information. That is, the lack of announcements resulted in longer adjustment times.[12] Thus, we will focus on the period of 1994-2005 in other cases, but also show the results for the entire period of study. Here we study the reaction of the changes in the parameters (measured in $\Delta\beta_i$, which is the difference of the betas on the event day and the day before) and the reaction of the unexpected changes in the parameters (measured in $\beta_i^{unexp} = \beta_i^{actual} - E(\beta_i)$, where the actual beta is the beta on the event day and $E(\beta_i)$ is the expected value of the beta, measured by its average). The results show that the level and the slope react significantly to the actual changes in the interest rates, whereas the convexity parameter β_2 does not respond. A reason for this could be that the long-end of the term structure is not responsive to the actions of the monetary policy, which impacts directly the short end of the term structure of the rates. From the Exhibit 4 we see that the R^2 is the highest for the "slope" parameter - β_1. The unexpected change in this parameter (the slope) is positively related to the actual changes in the FFTR, with the ratio of about 0.6. That is, when the fed cuts the rates, the slope of the term structure is reduced, or the spread is narrowed and if the fed raises the rates, so does the spread. The reason for this is the significant impact of the fed policy on the short end of the term structure, documented by many researchers and not-so-significant impact on the long-end of the term structure.[13] In Exhibit 5 we study the impact of the expected and unexpected FFTR changes on the parameters of the Extended NS model. We would like to see the impact of especially the unexpected component of FFTR changes on the changes in betas. Again, we see significant impact on the parameters that proxy the level and the slope of the term structure. The impact on the slope is more significant than the one on the level. Here too, the unexpected change in the slope of the term structure, due to the changes in monetary policy, is stronger and more significant, than the change from a day earlier.

The R^2 of the regressions in the case of unexpected change in the slope is 34% (for the period 1994-2005) which is higher than the 30% in Exhibit 4. That is, the breakdown of the FFTR changes into components helps to increase the explanatory power of the results. Next, we try to analyze the results and see if the results change if we consider the cases, in which there was a positive surprise change in the FFTR, or when there was no change or the change was positive. We add more independent variables in the regressions. The results are reported in Exhibit 6. Panel A is for the entire period and Panel B is for the period after January 1994. The results in Panel B of Exhibit 6 show that the reaction of the slope is the strongest and the reaction of the convexity parameters is somewhat strong. Also, by comparing the two panels we see that the results are stronger for the period after 1994, consistent with the results in Exhibits 4 and 5. The slope parameter reacts significantly to the expected and unexpected changes in the FFTR, though the reaction to the unexpected changes is stronger. This reaction is significant and is independent of whether the surprise change was of any particular sign, or if the rate change was in monetary policy tightening environment (rate increases) or not. Thus, the term structure curve response to the changes in the monetary policy is reflected in the change in the spread between medium and short term rates (or the slope of the term structure). The results of Exhibits 6 and 5 are very similar. By adding more variables to the regressions does not improve the explanatory power of the relationships between the changes in the FFTR and the changes in the parameters of the model. Thus, we can just use the results of the Exhibit 5 and assess the impact of the monetary policy on the term structure of interest rates.

We also analyze but do not report the response of the parameters of the NS model and the Vasicek model to the monetary policy changes.[14] Next, we study the impact on the parameters of the Extended Vasicek model. As in the case of the Nelson-Siegel model, we see significant impact on the slope parameter (proxied by S_0) and to some extent the parameter that is a proxy for the level of the rates term structure (measured in L_0). Exhibit 7 reports the results of the regression of the changes in the parameters of the Extended Vasicek model on the actual changes in the FFTR. We see that the R^2 of the regressions in the case of actual change in S_0 is about 40% for the period after 1994. This is higher than the 30% in case of Extended NS model (in Panel C of Exhibit 4). Here too, we report the results for three different time-periods and for the case of the change in the parameters and the unexpected change in the parameters of the model. Exhibit 8 reports the results of the case in which the change in the FFTR is broken down to expected and surprise components and we study their impact on the parameters. In this Exhibit we report the results for two time periods – the entire period and the period after January 1994. In both cases, the response of the slope parameter to the expected and unexpected changes is significant and the explanatory power is higher than in the case of actual changes in the FFTR in Exhibit 7. That is, the breakdown helps to see better the real impact of the monetary policy on the term structure of interest rates. The R^2 of the regression for S_0 in the period 1994-2005 is about 61%. As said before, the expected change in the FFTR is already reflected in prices/yields and theoretically should not have any impact on the prices/yields. It is the unexpected component that impacts the prices/yields. However, we see a significant reaction of the slope of the term structure to the expected change in the FFTR also. This could be viewed as a "resolution of uncertainty" effect. Even though it was expected that the FFTR would change by a certain amount, the realization of this reduces the uncertainty and thus has impact on the term structure. This impact is measured and reported in Exhibit 8. Using the after 1994 data we see that the impact of the unexpected change in the FFTR on the changes in the slope of the term structure is stronger than the one of the expected portion of the change in FFTR. For robustness of the results and completeness of the results, we analyze the impact in different situations. Exhibit 9 reports the results of the regression in which we add some other independent variables to see whether the impact on the parameters changes if we only consider the days in which the FFTR was unchanged (the market could've expected certain changes in those days) or when the rates were increased or the market was surprised by realizing a positive unexpected change in the FFTR. We add dummy variables $d^{sur}, d^{chg=0}, d^{chg>0}$ to capture the above mentioned effects. The results are almost the same as the ones reported in Exhibit 8. In the case of 1994-2005, we see that again the slope reaction to the expected and unexpected changes in FFTR is significant and is very close to the ones reported in Exhibit 8. That is, by adding more variables in the regression, we do not improve the explanatory power of the relationships: the R^2 in both cases in Exhibit 9 are very close to the ones of Exhibit 8.

Thus we will use the results of Exhibit 8 to assess the impact of the monetary policy on the term structure of interest rates.

Comparing the results of Exhibits 5-9, we see that we would be better off by using the results of Exhibit 8 – it has the highest explanatory power and is not complicated for implementation. Thus, the Vasicek model works better than the Nelson-Siegel model to capture the impact of the monetary policy on the term structure of interest rates.

Next we address the issue of hedging the risk of exposure of a fixed income portfolio to the monetary policy (or changes in the FFTR).

We have the sensitivity of the parameters of the model (both Vasicek and Nelson-Siegel) to the changes (expected and unexpected) in the fed funds target rate. Assigning a distribution to the expected change (which can be extracted not only from the futures on the 30-Day fed funds, but also from the options on them) would result in the expected (and subjective) measure of "expected" and "surprise" changes in the FFTR. Having the sensitivities of the parameters to the latter is enough to hedge the risk of the portfolio.[15]

We can use butterfly strategies here to trade on expectations on the changes in the shape of the term structure of interest rates.[16] Since we know the sensitivities of the parameters of the model under consideration to the events (changes in the FFTR), we can construct a strategy that hedges the risk of the changes in the term structure (unparallel and not necessarily small). Thus, in our case, having the distribution of the components of the changes in FFTR gives us the expected changes in the parameters of the model, for simplicity say the level and the slope.

Fabozzi, Martellini and Priaulet [2005] use similar method to study the trading strategies in an environment when the term structure changes are predictable. We do not repeat the method of constructing a portfolio of bonds to hedge the risk of the changes in the shape of the term structure and refer interested readers to Fabozzi et al. [2005] and chapter 8 of Martellini et al. [2003].

Conclusion

In this paper we measure the expected and unexpected components of the change in the federal funds target rate and the sensitivity of the term structure of zero-rates to those changes. We use two alternative models of term structure – the Nelson-Siegel and the Vasicek models. We calibrate both models and along with the data on any changes in the fed funds target rate, study the impact of the monetary policy on the shape of the term structure of rates, by studying the impact on the parameters of the models. We show that only the slope of the term structure of zero-rates (also known as the spread between medium and short term rates) reacts significantly to the monetary policy actions. We also demonstrate that in our case, the Extended Vasicek model tends to perform better than the Extended Nelson-Siegel model in capturing the impact of the monetary policy on the shape of the term structure. The results here can be used in practice to either take speculative positions around the days of FOMC meetings or hedge the risk of the changes in the shape of the term structure of rates, due to monetary policy actions.

References

Pierluigi, B., G. Bertola, and S. Foresi. “A Model of Target Changes and the Term Structure of Interest Rates.” *Journal of Monetary Economics*, 39 (July, 1997), pp. 223-249.

Pierluigi, B., G. Bertola, and S. Foresi, and L. Klapper, “Interest Rate Targeting and the Dynamics of Short-term Rates.” *Journal of Money, Credit, and Banking*, 30 (February, 1998), pp. 26-50.

Bernanke, B.S., and K.N. Kuttner. “What Explains the Stock Market’s Reaction to Federal Reserve Policy.” *Journal of Finance*, Vol 60, LX 3 (June 2005), pp.1221-1257.

Cook, T. and T. Hahn. “The effect of changes in the federal funds rate target on market interest rates in the 1970s.” *Journal of Monetary Economics*, 24(1989), pp. 331-351.

Fabozzi, F., Martellini, L., and P. Priaulet. “Exploiting predictability in the time-varying shape of the term structure of interest rates.” *Journal of Fixed-Income*, 15(2005), pp. 40-53.

Goukasian, L. “The (mis)reaction of the Stock Market to the changes in Monetary Policy.” Working Paper, Pepperdine University (2005).

Goukasian, L., and M. Majbouri, The Impact of the Monetary Policy on Real Estate. Working Paper, Pepperdine University, (2006).

Goukasian, L. and L.K. Whitney, Does the stock market underreact to the monetary policy actions? Working Paper, Pepperdine University, (2006).

Krueger, J., and K. Kuttner, “The fed funds rate as a predictor of federal reserve policy.” *Journal of Futures Markets* 16 (1996), pp. 865–879.

Kuttner, K.N., “Monetary Policy surprises and interest rates: Evidence from the Fed funds futures market.” *Journal of Monetary Economics*, Vol. 47 (2001), pp. 523-544.

Martellini, L., and P. Priaulet. “Fixed-Income Securities: Dynamic Methods for Interest Rate Risk Pricing and Hedging.” John Wiley & Sons, Chichester, 2000.

Martellini, L., P. Priaulet, and S. Priaulet, “Fixed-Income Securities: Valuation, Risk Management and Portfolio Strategies.” John Wiley & Sons, 2003.

Nelson, C.R. and A.F. Siegel. “Parsimonious Modeling of Yield Curves.*”, Journal of Business*, 60(4) (1987), pp. 473-489.

Reichenstein, William. "The Impact of Money on Short-term Interest Rates." *Economic Inquiry XXV* (January 1987), pp. 67-82.

Rigobon, R. and B. Sack. “The Impact of Monetary Policy on Asset Prices,” National Bureau of Economic Research Working Paper No. 8794, 2002.

Robertson, J.C. and D.L. Thornton, “Using federal funds futures rates to predict Federal Reserve actions." *Federal Reserve Bank of St. Louis Review*, 79 (6), (November/December 1997), pp. 45-53.

Rudebusch, G. D. “Federal Reserve Interest Rate Targeting, Rational Expectations and the Term structure.” *Journal of Monetary Economics*, 35(1995), pp. 245-74.

Sack, B. “Extracting the Expected Path of Monetary Policy From Futures Rates.” *Journal of Futures Markets*, 24(8) (2004),733-754.

Svensson, L. “Estimating and Interpreting Forward Interest Rates: Sweden 1992-1994”, *NBER Working Paper Series*, Working Paper No. 4871(1994).

Vasicek, O.A. “An Equilibrium Characterization of the Term Structure.” *Journal of Financial Economics*, 5(1977), pp. 177-188.

Exhibit 1

Descriptive Statistics of Fed funds rates

The full sample consists of 155 observations. We exclude September 17, 2001 from the sample. There were 135 FOMC days and 20 rate changes that occurred not on FOMC days. In 86, out of 155, days, there were no changes in the FFTR and in the other 69 days there were changes made in the FFTR. There were 55 days before February, 1994 and 100 days after (and including) it.

	Number of FOMC days	**Number of NON-FOMC Days**	**Number of FFTR changes**	**Number of no changes in FFTR**	**St. Dev. Of unexpected changes**	**Average of FFTR**
05/1989-01/1994	37	18	24	31	10.23	576
02/1994-12/2005	98	2	45	55	9.34	408
05/1989-12/2005	135	20	69	86	9.88	468

Comments:
1. All the numbers are in basis points.
2. September 17, 2001 is included in the sample, but not in the subsequent analysis.

Exhibit 2

The distribution of changes in the Fed Funds target rates (in bps)

FFTR change	**05/1989- 02/2006**	**05/1989-02/1994**	**02/1994-02/2006**
-50	12	3	9
-25	31	21	10
0	86	31	55
25	21	0	21
50	4	0	4
75	1	0	1

Exhibit 3

Panel A

Descriptive statistics of the Nelson-Siegel and Vasicek Models

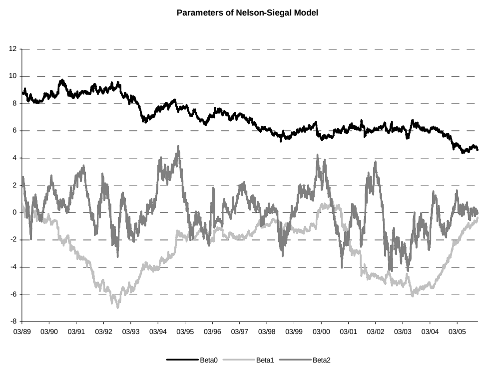
Mean is the sample mean of the time-series of the parameter, **Std** is its sample standard deviation, and **CV** is the coefficient of variation: Std/Mean.

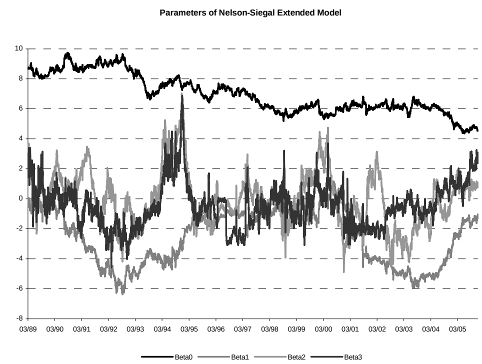
	Nelson-Siegel Model			Nelson-Siegel Extended Model			
	β_0	β_1	β_2	β_0	β_1	β_2	β_3
Mean	6.96	-2.65	0.19	6.97	-2.52	0.04	-0.46
Std	1.28	1.95	1.67	1.28	1.84	1.86	1.46
CV	0.18	-0.74	8.64	0.18	-0.73	50.44	-3.17
Correlation Matrix							
β_0	1	-0.23	0.23	1	-0.21	0.15	-0.18
β_1		1	0.25		1	0.23	0.17
β_2			1			1	0.50
β_3							1

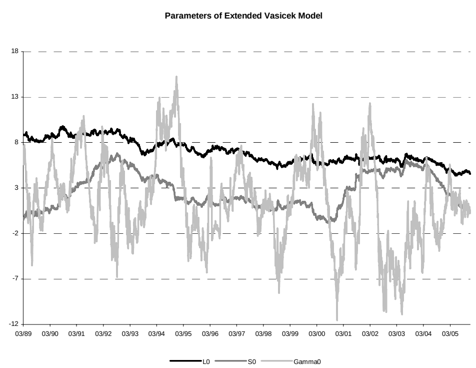
	Extended Vasicek			Extended Vasicek 2				
	L_0	S_o	γ_0	L_0	S_o	γ_0	T_o	K_o
Mean	6.97	2.69	1.51	7.02	2.10	-1.46	0.42	-3.16
Std	1.30	1.95	4.72	1.28	2.50	5.45	1.02	4.77
CV	0.19	0.72	3.13	0.18	1.19	-3.73	2.45	-1.51
Correlation Matrix								
L_0	1	0.24	0.30	1	0.19	0.38	-0.15	-0.02
S_o		1	-0.09		1	0.50	-0.73	0.40
γ_0			1			1	-0.47	0.47
T_o							1	-0.25
K_o								1

Panel B

Time Series of the parameters of the NS, Extended NS, Vasicek and Extended Vasicek models of term structure of interest rates







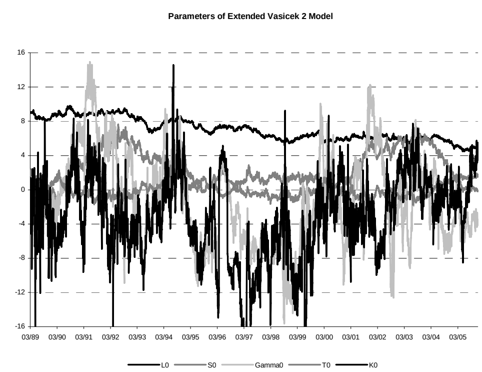


Exhibit 4

The impact of the changes in the FFTR on the changes in
the parameters of the Extended Nelson-Siegel Model

Here we are using the actual changes only. The regressions run here are of the following type: $\Delta\beta_i = \alpha + \gamma^{Actual}(Actual\,chg\,in\,FFTR) + \varepsilon_i$, where ε are random noise. The $\Delta\beta_i$ are the daily changes in the coefficients in the Extended NS model and $\beta_i^{un\exp} = \beta_i^{actual} - E(\beta_i)$ is the unexpected change in the coefficients, due to the changes in the monetary policy.

Panel A
Time Period 1989-2005
Number of observations is 155

Panel B
Time Period 1989-1993
Number of observations 55

Panel C
Time Period 1994-2005
Number of observations 100

$\Delta\beta$ s	Panel A α	Panel A γ^{Actual}	Panel A R^2	Panel B α	Panel B γ^{Actual}	Panel B R^2	Panel C α	Panel C γ^{Actual}	Panel C R^2
$\beta_0^{un\exp}$	-2.403	-0.089	0.016	-1.374	-0.007	0.000	-2.386	-0.107	0.030
	(-1.94)	(-1.59)		(-0.47)	(-0.05)		(-1.64)	(-1.73)	
$\beta_1^{un\exp}$	2.549	0.603	0.233	-0.110	0.365	0.045	2.308	0.660	0.309
	(1.30)	(6.82)		(-0.02)	(1.59)		(0.98)	(6.62)	
$\beta_2^{un\exp}$	-8.143	0.162	0.004	-8.588	1.091	0.087	-0.976	-0.210	0.009
	(-1.82)	(0.80)		(-0.91)	(2.25)		(-0.18)	(-0.93)	
$\beta_3^{un\exp}$	-8.708	0.246	0.007	-6.454	0.957	0.061	-4.715	-0.003	0.000
	(-1.70)	(1.07)		(-0.64)	(1.85)		(-0.72)	(-0.01)	
$\Delta\beta_0$	-0.453	-0.044	0.025	1.395	0.054	0.019	-0.788	-0.057	0.048
	(-0.92)	(-2.00)		(1.36)	(1.01)		(-1.30)	(-2.21)	
$\Delta\beta_1$	0.500	0.252	0.149	-0.042	0.176	0.043	0.244	0.275	0.185
	(0.46)	(5.18)		(-0.02)	(1.54)		(0.18)	(4.71)	
$\Delta\beta_2$	-3.523	-0.029	0.000	-7.480	0.196	0.012	0.429	-0.174	0.012
	(-1.27)	(-0.24)		(-1.57)	(0.80)		(0.12)	(-1.10)	
$\Delta\beta_3$	-6.540	0.053	0.001	-4.068	0.532	0.048	-4.395	-0.101	0.004
	(-2.05)	(0.37)		(-0.64)	(1.63)		(-1.08)	(-0.59)	

Exhibit 5

The impact of the changes in the FFTR on the changes in the parameters of the Extended Nelson-Siegel Model

Here we are using the expected and the unexpected changes in FFTR. The regressions are of the following type: $\Delta\beta_i = \alpha + \gamma^{\exp}(Exp.\, chg\ in\ FFTR) + \gamma^{sur}(Sur\ chg\ in\ FFTR) + \varepsilon_i$ where ε are random noise. The $\Delta\beta_i$ are the daily changes in the coefficients in the Extended NS model and $\beta_i^{un\exp} = \beta_i^{actual} - E(\beta_i)$ is the unexpected change in the coefficients, due to the changes in the monetary policy. Here we omit the period 1989-1993 as the results are all similar.

Panel A
Time Period 1989-2005
Number of observations 155

Panel B
Time Period 1994-2005
Number of observations 100

$\Delta\beta$ s	α	$\gamma^{\exp}$	γ^{sur}	R^2	$\Delta\beta$ s	α	$\gamma^{\exp}$	γ^{sur}	R^2
$\beta_0^{un\exp}$	-2.526	-0.075	-0.133	0.017	$\beta_0^{un\exp}$	-2.629	-0.078	-0.243	0.037
	(-1.96)	(-1.10)	(-1.02)			(-1.77)	(-1.12)	(-1.45)	
$\beta_1^{un\exp}$	3.590	0.482	0.973	0.253	$\beta_1^{un\exp}$	3.256	0.549	1.189	0.340
	(1.79)	(4.54)	(4.77)			(1.39)	(4.95)	(4.48)	
$\beta_2^{un\exp}$	-8.424	0.195	0.062	0.005	$\beta_2^{un\exp}$	-1.920	-0.099	-0.737	0.017
	(-1.82)	(0.79)	(0.13)			(-0.35)	(-0.39)	(-1.20)	
$\beta_3^{un\exp}$	-9.570	0.346	-0.060	0.010	$\beta_3^{un\exp}$	-5.836	0.129	-0.628	0.008
	(-1.80)	(1.24)	(-0.11)			(-0.87)	(0.41)	(-0.83)	
$\Delta\beta_0$	-0.538	-0.034	-0.074	0.028	$\Delta\beta_0$	-0.891	-0.045	-0.115	0.055
	(-1.06)	(-1.28)	(-1.44)			(-1.44)	(-1.54)	(-1.64)	
$\Delta\beta_1$	0.941	0.201	0.409	0.162	$\Delta\beta_1$	0.705	0.221	0.533	0.210
	(0.84)	(3.42)	(3.62)			(0.51)	(3.38)	(3.40)	
$\Delta\beta_2$	-2.682	-0.127	0.270	0.009	$\Delta\beta_2$	0.346	-0.164	-0.220	0.012
	(-0.93)	(-0.84)	(0.93)			(0.09)	(-0.92)	(-0.51)	
$\Delta\beta_3$	-4.662	-0.165	0.721	0.033	$\Delta\beta_3$	-3.235	-0.237	0.547	0.026
	(-1.43)	(-0.96)	(2.19)			(-0.79)	(-1.22)	(1.18)	

Exhibit 6

The impact of the changes in the FFTR on the changes in the parameters of the Extended Nelson-Siegel Model

Here we are using the expected and the unexpected changes in FFTR. The $\Delta\beta_i$ are the daily changes in the coefficients in the Extended NS model and $\beta_i^{un\exp} = \beta_i^{actual} - E(\beta_i)$ is the unexpected changes in the coefficients, due to the changes in the monetary policy. The regressions run are of the form:

$$\Delta\beta_i = \alpha + \gamma^{\exp}(Exp.\,chg\ in\ FFTR) + \gamma^{sur}(Sur\ chg\ in\ FFTR) + d^{sur>0}(Sur\ in\ FFTR > 0)$$
$$+ d^{chg=0}(Chg\ in\ FFTR = 0) + d^{Chg>0}(Chg\ in\ FFTR > 0) + \varepsilon_i .$$

Panel A - Time Period 1989-2005, Number of observations 155.

$\Delta\beta$ s	α	$\gamma^{\exp}$	γ^{sur}	$d^{sur>0}$	$d^{chg=0}$	$d^{chg>0}$	R^2
$\beta_0^{un\exp}$	-2.539	-0.078	-0.167	-0.103	0.255	0.313	0.021
	(-1.60)	(-1.02)	(-1.05)	(-0.16)	(0.59)	(0.43)	
$\beta_1^{un\exp}$	2.844	0.485	0.840	0.239	0.491	0.451	0.259
	(1.15)	(4.03)	(3.38)	(0.25)	(0.72)	(0.39)	
$\beta_2^{un\exp}$	-9.723	0.103	0.447	1.113	-4.216	-1.565	0.053
	(-1.73)	(0.38)	(0.79)	(0.50)	(-2.75)	(-0.60)	
$\beta_3^{un\exp}$	-6.737	0.322	0.655	-0.536	-3.558	-2.870	0.053
	(-1.05)	(1.03)	(1.02)	(-0.21)	(-2.03)	(-0.97)	
$\Delta\beta_0$	-0.609	-0.027	-0.077	0.101	-0.021	-0.170	0.030
	(-0.97)	(-0.89)	(-1.22)	(0.41)	(-0.12)	(-0.59)	
$\Delta\beta_1$	-1.190	0.220	0.171	1.123	0.289	0.022	0.217
	(-0.89)	(3.40)	(1.28)	(2.14)	(0.79)	(0.04)	
$\Delta\beta_2$	-0.462	-0.198	0.536	-1.544	-0.528	0.937	0.022
	(-0.13)	(-1.16)	(1.51)	(-1.11)	(-0.55)	(0.57)	
$\Delta\beta_3$	2.643	-0.245	1.495	-4.084	-0.677	0.574	0.110
	(0.68)	(-1.31)	(3.86)	(-2.68)	(-0.64)	(0.32)	

Panel B - Time Period 1994-2005, Number of observations 100.

$\Delta\beta$ s	α	$\gamma^{\exp}$	γ^{sur}	$d^{sur>0}$	$d^{chg=0}$	$d^{chg>0}$	R^2
$\beta_0^{un\exp}$	-2.586	-0.098	-0.324	-0.200	0.265	0.608	0.048
	(-1.36)	(-1.22)	(-1.41)	(-0.30)	(0.59)	(0.83)	
$\beta_1^{un\exp}$	2.032	0.602	0.844	0.765	0.933	-0.251	0.358
	(0.68)	(4.75)	(2.35)	(0.74)	(1.32)	(-0.22)	
$\beta_2^{un\exp}$	-3.663	-0.249	-0.099	0.221	-3.882	0.191	0.076
	(-0.54)	(-0.86)	(-0.12)	(0.09)	(-2.40)	(0.07)	
$\beta_3^{un\exp}$	0.276	-0.059	1.243	-3.191	-4.947	-0.629	0.100
	(0.03)	(-0.17)	(1.26)	(-1.13)	(-2.54)	(-0.20)	
$\Delta\beta_0$	-0.872	-0.051	-0.094	-0.037	-0.091	0.046	0.058
	(-1.10)	(-1.50)	(-0.99)	(-0.13)	(-0.48)	(0.15)	
$\Delta\beta_1$	-1.600	0.241	0.184	1.072	0.295	0.035	0.264
	(-0.93)	(3.30)	(0.89)	(1.80)	(0.72)	(0.05)	
$\Delta\beta_2$	2.140	-0.217	-0.100	-1.170	0.228	1.092	0.018
	(0.44)	(-1.05)	(-0.17)	(-0.70)	(0.20)	(0.58)	
$\Delta\beta_3$	5.568	-0.332	1.786	-4.257	-0.826	0.440	0.123
	(1.11)	(-1.56)	(2.96)	(-2.46)	(-0.69)	(0.23)	

Exhibit 7

The impact of the changes in the FFTR on the changes in
the parameters of the Extended Vasicek Model

Here we are using the actual changes only. The regressions run here are of the following type: $\Delta C = \alpha + \gamma^{Actual}(Actual.chg\ in\ FFTR) + \varepsilon_i$, where ε are random noise. ΔC are the daily changes in the coefficients in the Extended Vasicek model and $C_i^{un\exp} = C_i^{actual} - E(C_i)$ is the unexpected change in the coefficients, due to the changes in the monetary policy.

Panel A Time Period 1989-2005, Number of observations is 155

Panel B Time Period 1989-1993, Number of observations 55

Panel C Time Period 1994-2005, Number of observations 100

	Panel A α	Panel A γ^{Actual}	Panel A R^2	Panel B α	Panel B γ^{Actual}	Panel B R^2	Panel C α	Panel C γ^{Actual}	Panel C R^2
ΔL_0	-0.620	-0.047	0.031	1.058	0.059	0.027	-0.796	-0.065	0.064
	(-1.31)	(-2.21)		(1.12)	(1.20)		(-1.33)	(-2.59)	
ΔS_0	1.308	-0.274	0.395	0.790	-0.332	0.305	1.173	-0.258	0.405
	(2.15)	(-9.99)		(0.59)	(-4.82)		(1.57)	(-8.16)	
$\Delta \gamma_0$	-3.764	-0.207	0.003	-17.368	0.033	0.000	5.833	-0.491	0.017
	(-0.56)	(-0.69)		(-1.56)	(0.06)		(0.65)	(-1.28)	
ΔT_0	-3.245	0.096	0.014	-1.632	0.521	0.114	-1.013	-0.048	0.007
	(-2.21)	(1.46)		(-0.42)	(2.61)		(-0.72)	(-0.81)	
ΔK_0	-5.888	-0.331	0.003	-7.509	-0.486	0.003	-6.115	-0.292	0.003
	(-0.53)	(-0.66)		(-0.30)	(-0.37)		(-0.45)	(-0.51)	
$L_0^{un\exp}$	-2.764	-0.086	0.015	-1.710	0.037	0.001	-2.451	-0.120	0.037
	(-2.24)	(-1.55)		(-0.60)	(0.26)		(-1.67)	(-1.93)	
$S_0^{un\exp}$	-0.408	-0.675	0.415	1.533	-0.592	0.176	-0.909	-0.680	0.483
	(-0.28)	(-10.42)		(0.45)	(-3.36)		(-0.54)	(-9.57)	
$\gamma_0^{un\exp}$	-15.846	0.057	0.000	-18.965	2.112	0.059	1.233	-0.797	0.020
	(-1.44)	(0.12)		(-0.84)	(1.82)		(0.09)	(-1.40)	
$T_0^{un\exp}$	-5.741	0.192	0.014	-7.891	0.610	0.062	-1.391	-0.003	0.000
	(-2.02)	(1.49)		(-1.25)	(1.87)		(-0.42)	(-0.02)	
$K_0^{un\exp}$	-2.972	0.252	0.001	18.070	1.132	0.008	-8.510	0.198	0.001
	(-0.18)	(0.34)		(0.52)	(0.63)		(-0.42)	(0.23)	

Exhibit 8

The impact of the changes in the FFTR on the changes in the parameters of the Extended Vasicek Model

Here we are using the actual changes only. The regressions run here are of the following type: $\Delta C = \alpha + \gamma^{\exp}(Exp.\,chg\ in\ FFTR) + \gamma^{sur}(Sur\ chg\ in\ FFTR) + \varepsilon_i$, where ε are random noise. The ΔC are the daily changes in the coefficients in the Extended Vasicek model and $C_i^{un\exp} = C_i^{actual} - E(C_i)$ is the unexpected change in the coefficients in the Extended Vasicek model due to the changes in the monetary policy.

Panel A
Time Period 1989-2005
Number of observations 155

Panel B
Time Period 1994-2005
Number of observations 100

	Panel A α	Panel A $\gamma^{\exp}$	Panel A γ^{sur}	Panel A R^2	Panel B α	Panel B $\gamma^{\exp}$	Panel B γ^{sur}	Panel B R^2
ΔL_0	-0.667	-0.042	-0.064	0.032	-0.897	-0.054	-0.122	0.071
	(-1.36)	(-1.61)	(-1.28)		(-1.47)	(-1.87)	(-1.77)	
ΔS_0	0.330	-0.160	-0.622	0.539	0.335	-0.160	-0.726	0.614
	(0.60)	(-5.51)	(-11.11)		(0.55)	(-5.52)	(-10.44)	
$\Delta \gamma_0$	-3.358	-0.254	-0.063	0.003	4.198	-0.300	-1.404	0.025
	(-0.48)	(-0.69)	(-0.09)		(0.46)	(-0.69)	(-1.35)	
ΔT_0	-2.243	-0.020	0.453	0.056	-0.754	-0.079	0.096	0.016
	(-1.51)	(-0.25)	(3.00)		(-0.52)	(-1.16)	(0.59)	
ΔK_0	-3.575	-0.599	0.492	0.007	-3.412	-0.609	1.217	0.014
	(-0.31)	(-0.98)	(0.42)		(-0.25)	(-0.94)	(0.78)	
$L_0^{un\exp}$	-2.929	-0.067	-0.145	0.017	-2.758	-0.084	-0.292	0.048
	(-2.29)	(-0.99)	(-1.11)		(-1.85)	(-1.19)	(-1.73)	
$S_0^{un\exp}$	-1.208	-0.582	-0.959	0.432	-1.582	-0.601	-1.056	0.506
	(-0.82)	(-7.50)	(-6.43)		(-0.94)	(-7.61)	(-5.57)	
$\gamma_0^{un\exp}$	-15.796	0.051	0.075	0.000	-0.425	-0.602	-1.722	0.024
	(-1.39)	(0.09)	(0.06)		(-0.03)	(-0.93)	(-1.11)	
$T_0^{un\exp}$	-5.000	0.106	0.455	0.021	-1.029	-0.046	0.199	0.003
	(-1.70)	(0.68)	(1.52)		(-0.30)	(-0.28)	(0.51)	
$K_0^{un\exp}$	-8.300	0.870	-1.644	0.011	-14.153	0.860	-2.953	0.022
	(-0.50)	(0.98)	(-0.97)		(-0.69)	(0.89)	(-1.27)	

Exhibit 9

The impact of the changes in the FFTR on the changes in
the parameters of the Extended Vasicek Model

Here we are using the actual changes only. The regressions run here are of the following type:

$$\Delta C = \alpha + \gamma^{\exp}(Exp.chg\ in\ FFTR) + \gamma^{sur}(Sur\ chg\ in\ FFTR) + d^{sur>0}(Sur\ in\ FFTR > 0) + d^{chg=0}(Chg\ in\ FFTR = 0) + d^{Chg>0}(Chg\ in\ FFTR > 0) + \varepsilon_i,$$

where ε are random noise. The ΔC are the daily changes in the coefficients in the Extended Vasicek model and $C_i^{un\exp} = C_i^{actual} - E(C_i)$ is the unexpected change in the coefficients in the Extended Vasicek model due to the changes in the monetary policy.

Panel A- Time Period 1989-2005, Number of observations 155.

	α	$\gamma^{\exp}$	γ^{sur}	$d^{sur>0}$	$d^{chg=0}$	$d^{chg>0}$	R^2
ΔL_0	-0.603	-0.039	-0.052	0.004	-0.042	-0.104	0.033
	(-0.99)	(-1.32)	(-0.85)	(0.02)	(-0.25)	(-0.37)	
ΔS_0	0.335	-0.159	-0.606	0.044	-0.117	-0.135	0.540
	(0.49)	(-4.82)	(-8.86)	(0.16)	(-0.63)	(-0.43)	
$\Delta \gamma_0$	-3.802	-0.370	-0.002	-0.468	-1.015	1.740	0.006
	(-0.44)	(-0.89)	(-0.00)	(-0.14)	(-0.43)	(0.44)	
ΔT_0	-0.056	-0.010	0.751	-0.791	-0.674	-1.014	0.123
	(-0.03)	(-0.11)	(4.21)	(-1.13)	(-1.39)	(-1.23)	
ΔK_0	16.961	-0.863	2.381	-12.472	0.320	4.446	0.049
	(1.21)	(-1.27)	(1.69)	(-2.26)	(0.08)	(0.68)	
$L_0^{un\exp}$	-2.963	-0.076	-0.158	-0.081	0.063	0.267	0.018
	(-1.87)	(-0.99)	(-0.99)	(-0.13)	(0.15)	(0.36)	
$S_0^{un\exp}$	-1.443	-0.583	-1.023	0.007	0.323	0.339	0.434
	(-0.79)	(-6.63)	(-5.61)	(0.01)	(0.65)	(0.40)	
$\gamma_0^{un\exp}$	-22.512	-0.170	0.478	4.038	-8.750	-2.233	0.035
	(-1.62)	(-0.25)	(0.34)	(0.74)	(-2.31)	(-0.35)	
$T_0^{un\exp}$	-5.704	0.145	0.648	1.287	-2.017	-2.619	0.059
	(-1.60)	(0.84)	(1.81)	(0.91)	(-2.06)	(-1.58)	
$K_0^{un\exp}$	6.459	0.718	0.363	-7.101	-4.882	-2.228	0.031
	(0.31)	(0.72)	(0.18)	(-0.88)	(-0.87)	(-0.23)	

Panel B - Time Period 1994-2005, Number of observations 100.

	α	$\gamma^{\exp}$	γ^{sur}	$d^{sur>0}$	$d^{chg=0}$	$d^{chg>0}$	R^2
ΔL_0	-0.750	-0.063	-0.090	-0.118	-0.086	0.112	0.076
	(-0.96)	(-1.90)	(-0.95)	(-0.44)	(-0.46)	(0.37)	
ΔS_0	0.013	-0.155	-0.756	0.177	-0.022	-0.095	0.615
	(0.02)	(-4.60)	(-7.96)	(0.65)	(-0.12)	(-0.31)	
$\Delta\gamma_0$	0.963	-0.348	-2.220	0.798	1.410	2.412	0.036
	(0.08)	(-0.70)	(-1.57)	(0.20)	(0.50)	(0.53)	
ΔT_0	1.428	-0.066	0.462	-0.779	-0.302	-0.708	0.098
	(0.81)	(-0.88)	(2.17)	(-1.27)	(-0.72)	(-1.04)	
ΔK_0	24.358	-0.946	4.835	-13.842	-1.599	2.923	0.093
	(1.44)	(-1.31)	(2.37)	(-2.36)	(-0.40)	(0.45)	
$L_0^{un\exp}$	-2.777	-0.111	-0.342	-0.203	0.091	0.633	0.057
	(-1.46)	(-1.37)	(-1.49)	(-0.31)	(0.20)	(0.86)	
$S_0^{un\exp}$	-2.403	-0.607	-1.252	0.252	0.340	0.466	0.514
	(-1.13)	(-6.67)	(-4.86)	(0.34)	(0.67)	(0.57)	
$\gamma_0^{un\exp}$	-11.104	-0.856	-1.596	3.627	-6.664	1.012	0.060
	(-0.64)	(-1.16)	(-0.77)	(0.61)	(-1.62)	(0.15)	
$T_0^{un\exp}$	1.124	-0.124	1.110	-1.059	-2.766	-0.780	0.099
	(0.27)	(-0.69)	(2.21)	(-0.73)	(-2.78)	(-0.48)	
$K_0^{un\exp}$	3.850	0.457	1.215	-9.169	-8.798	-0.391	0.064
	(0.15)	(0.42)	(0.39)	(-1.03)	(-1.43)	(-0.04)	

[1] Cook and Hahn [1989] study the bond prices' reaction to the monetary policy actions from 1974 to 1989. Kuttner [2001] measured the impact of monetary policy (through the changes in the FFTR) on interest rates of different maturities, Rigobon and Sack [2002] use heteroskedasticity-based estimators to estimate the response of asset prices and interest rates to the changes in the monetary policy. Bernanke and Kuttner [2005] measure and analyze in some details the stock market's response to monetary policy actions. Kuttner [2001] and Faust, Swanson, and Wright [2001] use the current month federal funds futures contract, Bomfim [2002] and Poole and Rasche [2000] use the month-ahead federal funds futures contract, Cochrane and Piazzessi [2002] use the one-month eurodollar deposit rate, Ellingsen and Soderstrom [1999] use the three-month Treasury bill, and Rigobon and Sack [2002] use the three-month eurodollar futures rate. Thornton [1998] studies the reaction of interest rates of 3 month, 12 months, 10 yr and 30 yr maturities to the changes in FFTR. Thornton argues that the rate changes or no responses are related to the market's future inflation expectations. The paper does not break down the changes in the FFTR to study the impact of the expected and unexpected changes in the FFTR on interest rates.

[2] Goukasian, Whitney [2006], Goukasian[2005] and Goukasian and Majbouri [2006] use the same method and extract the surprise changes in the FFTR for up to December 2005. More details on the method can be found in those papers.

[3] We also studied the problem, using Extended Nelson-Siegel model, Vasicek model and the Extended Vasicek model of Term Structure of Interest rates.

[4] The effective federal funds rate is a weighted average of the rates on those overnight federal funds transactions arranged through New York brokers.

[5] For example, market price of 94.75 for a one-month contract on June 12 means that the current futures rate for July is 5.25% (100 – 94.75).

[6] A buyer of a federal funds futures contract will pay (or receive from) the seller an amount corresponding to the interest on $5 million held for the contract month. The interest rate is determined by the difference between the average funds rate for the month and the prevailing futures rate at time of the trade. The contract is marked-to-market daily, so payments are made each day as the futures price changes, using a constant tick size of $41.67 (which is one basis point of $5 million over a month). If during a trading day the futures price falls by two basis points (or the implied funds rate increases by 2 bps), the buyer pays the seller 2 * $41:67 = $83.34 per contract. In total, a buyer of a futures contract at a price of 94.75 will, if the futures price settles at 94.50, have paid the seller 25*$41:67 = $1,041.75 at maturity, equal to the difference between a 5.25% and a 5.50% interest on $5 million held for 30 days.

[7] Since we are using daily data on the fed funds futures and sometimes intraday data, the premium for such a small time interval will be negligible.

[8]When the event day is on the first days of month, we take the open and close prices of futures on the days to find the surprise change in rates. If the event day is on the last day of the month, we take the 1-month out futures prices on the last day of the previous month and the current-month prices on the first day of the month to find the surprise change in the fed funds target rate.

[9] See Goukasian, Whitney [2006] for the details of the calculations of surprise changes in the FFTR.

[10] We use data on the discount rates of the following maturities: 0.25, 0.5,1,2,3,4,5,7,10,15,20,30 yrs. For the robustness of the results we also calibrate the model using different combination of maturities. In all cases the results are the same as with the case with all twelve maturities.

[11] See Martellini et al. 2003 for more details on the calibration and related issues. Also, Fabozzi et al. [2006] use similar method to assess the predictability of shape of the term structure of interest rates.

[12] Goukasian and Whitney [2005] show that the stock markets underreact to the monetary policy actions and that this is even more severe for the period 1989-1994. The reason for this could be the slower reaction by the market to the fed decisions, if no announcements are made.

[13] See Kuttner [2001] for the results and references for related work.

[14] The results can be obtained by contacting the authors.

[15] This method does not rely on the assumption of parallel shift in the term structure or small changes in the rates. Although these assumptions are good enough to hedge the risk on a daily basis, they would not be admissible in the case of the days, in which a decision is made on the fed fund rates.

[16] We refer interested readers to chapter 8 of the book by Martellini et al. [2003] for strategies on fixed income portfolio management. Butterfly strategy is a combination of bullet and barbell strategies that target specific maturities.