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## **Predicting the Fed**

Kenneth B. Petersen

Laffer Associates and University of Connecticut

Vladimir Pozdnyakov

University of Connecticut

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341 Mansfield Road, Unit 1063

Storrs, CT 06269-1063

Phone: (860) 486-3022

Fax: (860) 486-4463

<http://www.econ.uconn.edu/>

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## **Abstract**

Predicting the federal funds rate and beating the federal funds futures market: mission impossible? Not so. We employ a Markov transition process and show that this model outperforms the federal funds futures market in predicting the target federal funds rate. Thus, by using purely historical data we are able to better explain future monetary policy than a forward looking measure like the federal funds futures rate. The fact that the federal funds futures market can be beaten by a statistical model, suggests that the federal funds futures market lacks efficiency. The market allocates too much weight to current Federal Reserve communication and other real-time macro events, and allocates too little weight to past monetary policy behavior.

**Journal of Economic Literature Classification:** E44, E47, E52, E58, G13

**Keywords:** Monetary policy, Federal funds futures market, Markov modeling

The views expressed here do not necessarily reflect the opinion and views of Laffer Associates.

# 1 Introduction

The Federal Open Market Committee (FOMC) changes the target *federal funds rate* in discrete steps. Since 1989 the FOMC has changed the target federal funds rate in multiples of 25 basis points, and these changes have almost exclusively been in the range (-50, 50). This makes the policy behavior of the FOMC an ideal candidate for a Markov process, which predicts future monetary policy by conditioning on past policy changes and nothing else. Surprisingly, we find that the Markov transition process, in the vast majority of the cases we consider, predicts the federal funds rate better than does the *federal funds futures* market.

Predicting the federal funds rate has preoccupied economists, banks, and financial market participants for decades. Several approaches have been employed: financial asset prices, such as term federal funds, federal funds futures, term Eurodollars, Eurodollar futures, T-Bills, and commercial paper; and time series models, such as Taylor-rules, random walks, AR(1) processes, VAR's, and BVAR's. Of these approaches, financial asset prices, especially federal funds futures prices, have been found to predict the federal funds rate the best. See, for instance, Krueger and Kuttner (1996), Evans (1998), Robertson and Tallman (2001), Soederstroem (2001), Soederlind et al. (2003), Lang et al. (2003), Piazzesi (2005), Piazzesi and Swanson (2006), Gurkaynak et al. (2007).

Prior to the late 1980s, the conventional wisdom was that central banking had to be mysterious and secretive. This had the effect that financial markets and the population at large considered monetary policy a black-box: un-systematic and hard to predict. Unfortunately, a monetary policy that is un-systematic and hard to predict, leads to large private sector expectational errors regarding the course of future monetary policy and causes the economy to be less stable.

This is not the case anymore. During the last two decades, Federal Reserve transparency, accountability, and credibility have improved markedly. Today the Federal Reserve communicates its objectives and reasoning in a sound and timely manner, and takes systematic steps (policy changes) to achieve its objectives of price stability and maximum employment.

Thanks to greater transparency and more systematic monetary policy, the Federal Reserve has earned greater credibility: people know that the Federal Reserve is committed to keeping inflation low and stable, so inflation and inflation

expectations stay anchored at a low level. In such an economic environment, the Federal Reserve is free, and able, to pursue its second objective of maximum employment as well.

The greater transparency has been very helpful for the financial market's ability to understand present and to predict future monetary policy, see, for example, Poole (2000, 2005), Poole and Rasche (2000), and Swanson (2006). Greater transparency has led to superior forecasting performance of financial assets, in particular the federal funds futures prices, relative to traditional time series models when it comes to predicting future monetary policy.

Yet, we are able to show that a simple Markov process has superior forecasting ability in comparison to the federal funds futures market during the period 2001-2007, a period during which FOMC transparency was at a historical high. This suggests that the federal funds futures market is not fully efficient.

The lack of efficiency in the federal funds futures market stems from three sources. First, market participants often fail to properly combine Federal Reserve communication and real-time macroeconomic events with past policy behavior. Second, Federal Reserve communication may not have reached optimality: speaking with one voice and clearly setting a conditional path for future monetary policy. Third, real-time macroeconomic data are inherently error prone- something the Federal Reserve is aware of - and this may cause the federal funds futures market to over-react in real-time.

The process towards greater transparency has been lengthy: in 1989 the FOMC began to target the federal funds rate explicitly, change the federal funds rate in multiples of 25 basis points, and make the target federal funds rate a multiple of 25 basis points; in 1994 the FOMC started to make policy changes at eight annual scheduled meetings<sup>1</sup> and release a statement whenever the federal funds rate was changed; in 1995 the statement began to include the target for the federal funds rate, and a verbatim transcript was released with a 5 year lag; and in 1999 the statement was augmented to include a description of the FOMC's policy bias and released, not only after FOMC meetings when the target federal funds rate was changed, but also after any FOMC meeting if the FOMC wanted to communicate a major shift in the policy bias going forward.

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<sup>1</sup>The FOMC may change the target funds rate in-between FOMC meetings, if need be, but rarely does so. For instance, between November 2001 and July 2007, the FOMC changed the target funds rate only at its scheduled meetings.

Since 2000 the FOMC statement included a balance of risks assesment, instead of the policy bias, and the statement was released after each meeting even if the federal funds rate was left unchanged; since 2002 the statement included each FOMC member's vote; beginning in 2003 the statement included forward looking language; since 2005 the minutes were released with a 3 week lag.

The paper proceeds as follows. Section 2 introduces the federal funds market and how the FOMC conducts monetary policy. Section 3 presents the federal funds futures market and how it prices and predicts the federal funds rate. Section 4 shows how a Markov process can be used to predict future federal funds rates. Section 5 evaluates the forecasting ability of the federal funds futures market and the Markov process. Section 6 concludes.

## 2 The Federal Funds Market

The Federal Reserve Act of 1978 specifies that the FOMC must promote maximum employment, low and stable inflation, and moderate long-term interest rates. With these objectives in mind, the FOMC evaluates the current and expected future state of the economy and charts a path for monetary policy. Since 1982, the primary monetary policy instrument of the FOMC has been the *federal funds rate*, either directly or indirectly. To be precise, effective June 6 1989, the FOMC began to target the federal funds rate explicitly.

The federal funds market is the inter-bank market where banks borrow and lend reserves from and to each other. Banks participate in this market to make sure that they satisfy their reserve requirement and to hedge that they have enough funds to honor transactions over the Fed wire. The federal funds rate is the rate at which banks make over-the-counter unsecured loans to each other on an overnight basis.

The FOMC implements monetary policy by agreeing to a target rate for the federal funds rate at each of its eight annual meetings. The FOMC agrees upon a target rate in the form of a directive, and communicates this to the open market trading desk at the New York Federal Reserve Bank. As a result, the NY Fed performs open market operations (buys or sells Treasury securities) on a daily basis to make sure that the daily *effective* federal funds rate stays as

close as possible to the *target* federal funds rate dictated in the FOMC directive. The daily effective federal funds rate is the trade weighted average of all daily actual funds rates. Open market operations for the most part are repurchase agreements with very short maturities.

### 3 The Federal Funds Futures Market

The Chicago Board of Trade (CBOT) has been offering federal funds futures contracts since October 1988. These contracts are designed to help banks and financial market participants hedge against federal funds rate and short-term interest rate volatility. Unlike a T-bill futures contract, which specifies the T-bill rate on a specific future *day*, the federal funds futures contract is for the *simple average* of the daily *effective* federal funds rate during a specific future *month*. Each contract has a nominal value of \$5 million, a settlement price of 100 minus the (expected) average effective federal funds rate for the month of the contract, and can be written for the current month and for a month up to 24 months into the future.

The federal funds futures rate embodies the market's expectation of future monetary policy. Market participants make commitments that are contingent on what they believe the federal funds rate will be in the future, and they attempt to use all available relevant information in forming their expectations about future monetary policy.

Federal funds futures contracts are extremely liquid at expirations out to four months, and still very liquid out to six months. Therefore, federal funds futures prices represent an unbiased estimate of the market's expectations of monetary policy up to half a year into the future.

The counterparty credit risk in these instruments is relatively small due to the CBOT's daily mark-to-market and collateral requirements.

#### 3.1 The Futures Rate

Standard asset pricing theory suggests that the rate of return at time  $t$  on a financial instrument that is held from day  $t + j$  to day  $t + j + k$ , equals the

expected rate of return from an investment strategy of rolling-over overnight loans in the federal funds market from day  $t + j$  to day  $t + j + k$ , plus a possible non-zero risk premium,

$$r_{t,t+j,t+j+k} = E_t \left[ \prod_{i=t}^{t+k-1} (1 + ff_{i+j}) - 1 \right] + \rho_{t,t+j,t+j+k}, \quad (1)$$

where  $r_{t,t+j,t+j+k}$  is the rate of return,  $E_t$  denotes the expectation conditional on all available information up to period  $t$ ,  $ff_{i+j}$  is the overnight federal funds rate on day  $i + j$ , and  $\rho_{t,t+j,t+j+k}$  is the risk premium. See, for example, Campbell et al. (1997) for a general analysis of asset pricing.

Equation (1) can be rearranged to look more intuitive and relevant for the federal funds futures market,

$$r_{t,i} = E_t \overline{ff}_{t+i} + \rho_{t,i}, \quad (2)$$

where  $r_{t,i}$  is the futures rate at time  $t$  for the  $i$ -months ahead futures contract,  $\overline{ff}_{t+i}$  is the simple average of the daily effective federal funds rate during month  $t + i$ , and  $\rho_{t,i}$  is the risk premium. Thus, the futures rate is a measure of the market's prediction for the average effective federal funds rate during some future month, after allowing for a possible non-zero risk premium.

The risk premium may be non-zero if banks - which regularly finance a significant portion of their loan portfolios in the federal funds market - and financial market participants - who often obtain financing by issuing short-term financial instruments - also participate in the federal funds futures market. For instance, if these institutions use the futures market to hedge against increases in the federal funds rate and short-term interest rates, respectively, and if they represent the majority of trades, then the risk premium will be positive.

### 3.2 Predicting Monetary Policy

Two issues make it difficult to infer the market's expectation of FOMC behavior from the federal funds futures rate directly: 1.) identifying the market's expectation of the target rate and 2.) inferring the real-time risk premium.

### 3.2.1 Identification

The fact that the futures rate is not a forecast of the target federal funds rate leads to an identification problem. Specifically, equation (2) can be re-written as follows,

$$r_{t,i} = E_t \overline{fft}_{t+i} + E_t(\overline{ff}_{t+i} - \overline{fft}_{t+i}) + \rho_{t,i}, \quad (3)$$

where  $\overline{fft}_{t+i}$  is the average *target* federal funds rate for month  $t+i$ .

Equation (3) makes it clear that the risk premium adjusted futures rate may not necessarily represent the market's forecast of the average *target* federal funds rate. In particular, when the market expects the average *effective* federal funds rate to differ from the average *target* federal funds rate in a given future month, the risk premium adjusted futures rate no longer represents the market's prediction of the average target federal funds rate.

An obvious identifying assumption is to assume that the market does not expect the average effective and average target funds rates to deviate significantly from each other,  $E_t(\overline{ff}_{t+i} - \overline{fft}_{t+i}) = 0$ . Table 1 shows that this assumption is supported by the data, both prior to and during our prediction period, from November 2001 through March 2007.

Table 1: Effective vs. Target Federal Funds Rate

|                                              | 1994.1-2000.12 | 2001.11-2007.3 |
|----------------------------------------------|----------------|----------------|
| $\overline{ff}_{t+i} - \overline{fft}_{t+i}$ | 0.005          | 0.003          |
| p-values                                     | (0.38)         | (0.25)         |

NOTE: p-values use Newey-West heteroscedasticity and autocorrelation consistent standard errors.

The futures rate, adjusted for a possible risk premium, therefore can be interpreted as the market's expectation of the average target federal funds rate for a given future month,

$$r_{t,i} = E_t \overline{ff} t_{t+i} + \rho_{t,i}. \quad (4)$$

### 3.2.2 Risk Premium

Estimating the risk premium in real-time is not an easy task to perform. One approach is to use the average historical risk premium as a substitute for the real-time risk premium. This is the approach we take here.

To calculate the historical risk premiums, we rearrange equation (2) to arrive at the following standard interest rate forecasting regression equation,

$$\overline{ff} t_{t+i} = \alpha + \beta r_{t,i} + \varepsilon_t, \quad (5)$$

where the risk premium has been partitioned into a systematic (average) part,  $\alpha$ , and an irregular (stochastic) part,  $\varepsilon_t$ . To the extent that the risk premium is time-varying,  $\beta$  will differ from unity according to the degree of correlation between the futures rate and the stochastic risk premium. We therefore impose the restriction  $\beta = 1$  in equation (5) to ensure that the futures rate and the funds rate differ statistically only in terms of a possible constant risk premium. We use the negative of the estimated value of  $\alpha$  in this restricted regression to derive an estimate of the average risk premium  $\bar{\rho}$ .

We look at each month of the year in which the FOMC meets and record how that particular month's futures contract was trading 1.) one to six months earlier, and 2.) one to four meetings prior.<sup>2</sup> The monthly predictions are derived by recording the closing prices of the futures contracts on the same day as the FOMC meetings except one to six month earlier.<sup>3</sup> The meetings predictions are calculated by recording the closing prices of the futures contracts on the day after each of the last one to four FOMC meetings.<sup>4</sup>

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<sup>2</sup>If we use all twelve contracts of the year, the risk premiums will be much smaller, given that the FOMC primarily changes the funds rate during the eight scheduled annual meetings.

<sup>3</sup>For example, if the FOMC meets on 9/16/2003, we record the closing price of the September 2003 futures contract on 8/16/2003, 7/16/2003, etc.

<sup>4</sup>For example, if the FOMC meets on 9/16/2003, we record the closing price of the September 2003 futures contract on 8/13/2003, 6/26/2003, etc.

Table 2 makes it clear that the average risk premiums are positive, but not statistically significant. Also,  $\beta$  never significantly differs from 1. Hence, there is neither reason to believe that the risk premium on average is different from zero, nor that it is time-varying during the period November 2001 through March 2007.

Table 2:  $\overline{f}f_{t+i} = \alpha + \beta r_{t,i} + \varepsilon_t$

|               | $\alpha$    | $\beta$     | $\beta = 1$ | $\bar{\rho}$ |
|---------------|-------------|-------------|-------------|--------------|
| Futures       |             |             |             |              |
| One-month     | -0.00(0.88) | 0.998(0.00) | (0.77)      | 0.68(0.51)   |
| Two-month     | -0.02(0.69) | 0.995(0.00) | (0.73)      | 2.88(0.45)   |
| Three-month   | -0.04(0.54) | 0.990(0.00) | (0.66)      | 6.15(0.33)   |
| Four-month    | -0.08(0.36) | 0.996(0.00) | (0.90)      | 8.57(0.30)   |
| Five-month    | -0.15(0.25) | 1.008(0.00) | (0.88)      | 12.95(0.29)  |
| Six-month     | -0.16(0.32) | 1.003(0.00) | (0.97)      | 15.56(0.29)  |
| One-meeting   | -0.01(0.70) | 0.999(0.00) | (0.98)      | 0.77(0.53)   |
| Two-meeting   | -0.04(0.40) | 1.002(0.00) | (0.88)      | 3.25(0.44)   |
| Three-meeting | -0.09(0.33) | 1.003(0.00) | (0.92)      | 8.07(0.35)   |
| Four-meeting  | -0.15(0.33) | 1.005(0.00) | (0.95)      | 13.75(0.32)  |

NOTE: p-values are reported in parentheses and use Newey-West heteroscedasticity and autocorrelation consistent standard errors. Sample period: 2001.11-2007.3 with 8 annual observations (FOMC meetings), sampled one to six month prior, and one to four meetings prior. The average risk premium,  $\bar{\rho}$ , is expressed in basis points (bp), whereas  $\alpha$  and  $\beta$  are expressed in decimals.

The monthly predictions almost have constant forecast horizons: the one-month prediction varies from 28 to 31 days; the two-months prediction varies from 59 to 61 days; the three-months prediction varies from 89 to 92 days; the four-months prediction varies from 120 to 123 days; the five-months prediction varies from 150 to 153 days; and the six-months prediction varies from 181 to 184 days prior to the FOMC meeting date. However, the meetings ahead forecast horizons vary considerably: the one-meeting ahead prediction varies from 34 to 58 days; the two-meetings prediction varies from 70 to 106 days; the three-meetings prediction varies from 112 to 154 days; and the four-meetings prediction varies

from 162 to 204 days.

In Section 5 we assume that the average risk premiums we calculate here, were the ones that financial market participants had in mind when operating in real-time.

## 4 The Markov Transition Process

The FOMC changes the federal funds rate in discrete steps. Specifically, since 1989 the FOMC has changed the target federal funds rate in multiples of 25 basis points; for the most part these changes have been in the range (-50, 50). This kind of discreteness makes the policy behavior of the FOMC an ideal candidate for a first order Markov process. With the policy changes following a first order Markov process, our prediction of the target federal funds rate follows a second order Markov process,

$$E(i_{t+n} | \Delta i_t = x_k) = i_t + \sum_{j=1}^n P_k^j x, \quad (6)$$

where  $x$  is a vector of possible policy changes,  $x_k$  is the realized policy change at time  $t$ ,  $P$  is the  $m \times m$  transition probability matrix,  $P_k^j$  is row  $k$  of the  $j$ 'th multiple of matrix  $P$ , and  $i_{t+n}$  is the target federal funds rate  $n$  meetings from time  $t$ . To be precise, we assume that  $x = (-50, -25, 0, 25, 50)$  and, therefore, that  $P$  is a  $5 \times 5$  matrix.<sup>5</sup>

To facilitate a direct comparison with the federal funds futures rate, which is a prediction for the *average* federal funds rate during a given future month, we calculate and use the following weighted  $n$  meetings ahead prediction,

$$E(\bar{i}_{t+n} | \Delta i_t = x_k) = \omega_{t+n-1} E(i_{t+n-1}) + \omega_{t+n} E(i_{t+n}), \quad (7)$$

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<sup>5</sup>Only once during the period 1990-2007 did the FOMC change the federal funds rate by a number beyond our assumed rate changes: the target federal funds rate was increased by 75 bp in November 1994. We record this as a 50 bp change.

where  $\bar{i}_{t+n}$  is the average target federal funds rate,  $\omega_{t+n-1}$  represents the fraction of time prior to the FOMC meeting during the month of the FOMC meeting  $n$  meetings ahead, and  $\omega_{t+n}$  is the fraction of time left in that same month  $n$  meetings ahead. Hence, the  $n$  meetings ahead average target federal funds rate prediction is a linear combination of the  $n - 1$  meetings ahead prediction and the  $n$  meetings ahead prediction for the target funds rate.

We use the period August 1990 through October 2001 to estimate the transition matrix, and then use a rolling window during the period November 2001 through March 2007 to predict the average target federal funds rate. The estimation and prediction periods were selected because 1.) the FOMC begins to target the federal funds rate and change the target rate in multiples of 25bp in June 1989, and setting the target federal funds rate in multiples of 25bp in October 1989 (we decide to give the FOMC until August 1990 to get familiar with this new practice), 2.) the period is of sufficient length to give us enough observations (100 observations) from which to make accurate predictions, 3.) all changes in the target federal funds rate between November 2001 and March 2007 take place at scheduled FOMC meetings only, and we therefore have a consistent model forecast horizon during this period, and 4.) the prediction period is of sufficient length (44 observations) to draw statistical conclusions.

## 5 Forecasting Monetary Policy

To evaluate how accurately the federal funds futures market and the Markov model predict the policy behavior of the FOMC, we evaluate the forecast performance of each by calculating the root mean square error (RMSE) and the mean absolute deviation (MAD). The data for the federal funds rate and the federal funds futures rate are from Fred II and Barchart, respectively.

Table 3 reveals that the Markov model performs remarkably well.

Table 3: Forecast Performance

| Futures | 1-month   | 2     | 3     | 4     | 5     | 6     |
|---------|-----------|-------|-------|-------|-------|-------|
| RMSE    | 6.01      | 20.69 | 22.78 | 18.43 | 28.76 | 37.96 |
| MAD     | 3.36      | 9.76  | 12.07 | 13.15 | 21.90 | 27.29 |
| Futures | 1-meeting | 2     | 3     | 4     |       |       |
| RMSE    | 7.15      | 12.12 | 22.08 | 35.19 |       |       |
| MAD     | 4.19      | 8.64  | 16.12 | 25.84 |       |       |
| Markov  | 1-meeting | 2     | 3     | 4     |       |       |
| RMSE    | 7.91      | 11.36 | 21.47 | 32.72 |       |       |
| MAD     | 3.14      | 7.47  | 16.36 | 26.51 |       |       |

NOTE: Forecast period: 2001.11-2007.3. Results are stated in basis points (bp).

The Markov model clearly outperforms the futures market in the meetings ahead comparison in terms of RMSE, except for the one-meeting ahead prediction. In terms of MAD, the Markov model predicts the federal funds rate best at the one and two-meetings ahead forecast horizon.

To gauge the importance of the variability in the forecast horizon at the meetings ahead predictions from the federal funds futures market (see section 4), we look at monthly prediction errors as well. The relevant comparisons here are: one-meeting model forecast (45 days) vs. one-month futures forecast (30 days) or two-month futures forecast (60 days); two-meetings (91 days) vs. three-months (91 days); three-meetings (136 days) vs. four-months (121 days) or five-months (151 days); and four-meetings (181 days) vs. six-months (182).<sup>6</sup>

<sup>6</sup>The days reported are the average forecast horizons. As mentioned in section 4, the monthly forecast horizons vary very little around their average.

The RMSE performance measure has the Markov model outperforming the futures market in all cases, if the one-meeting model forecast is compared to the two-month futures prediction and the three-meetings model forecast is compared to the five-months futures prediction. The MAD measure, shows that the Markov model outperforms the futures market in all comparisons, if the three-meetings model forecast is compared to the five-months futures prediction.

Since the federal funds futures market is not able to surpass a purely backward looking model in forecast accuracy, the market is not efficient. This lack of efficiency in the federal funds futures market stems from market participants failing to properly combine Federal Reserve communication and real-time macroeconomic events with past policy behavior. Also, it is possible that the Federal Reserve communication strategy needs to improve further: all FOMC members must speak with one voice and clearly state a conditional path for future monetary policy. Besides, real-time macroeconomic data are inherently error prone - something the Federal Reserve takes into account in its decision making - and that may cause the federal funds futures market to over-react in real-time.

Figures 1-8 show the prediction errors graphically, see appendix A.

## 6 Conclusion

Federal funds futures prices have up until now been considered the best forecaster of future monetary policy. To be precise, federal funds futures prices outperform other asset prices, such as the term federal funds rate, term Eurodollar rate, Eurodollar futures, T-Bills, and commercial paper, but also outperforms standard statistical models, such as the random walk, AR(1) processes, VAR's, and BVAR's, as well as Taylor-rules.

We show that a simple Markov transition process can outperform the federal funds futures market in forecasting future FOMC policy. Thus, we are able to show that a model that only takes into account *past* monetary policy, and doesn't incorporate FOMC member speeches, statements, minutes, Beige Book, or other timely and forward looking information from the Federal Reserve, is better at predicting the federal funds rate than the forward looking federal

funds futures market. This implies that the federal funds futures market lacks efficiency.

The market does not use the information in its information set efficiently: too much emphasis is given to current Federal Reserve communication and other macro events, and too little weight is put on past policy behavior. Besides, Federal Reserve communication may not be optimal, and inherently error prone real-time macroeconomic data may cause the federal funds futures market to over-react in real-time.

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## A Appendix

This appendix presents the Markov model and the federal funds futures market prediction errors graphically.

Figure 1: The One Meeting Ahead Markov Model Prediction Errors vs. the One Month Ahead Federal Funds Futures Prediction Errors

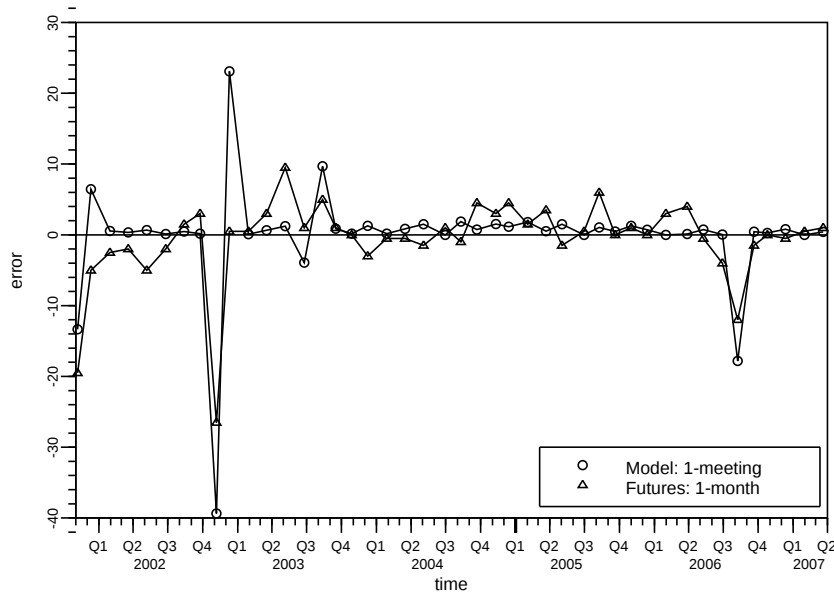


Figure 2: The Two Meetings Ahead Markov Model Prediction Errors vs. the Three Month Ahead Federal Funds Futures Prediction Errors

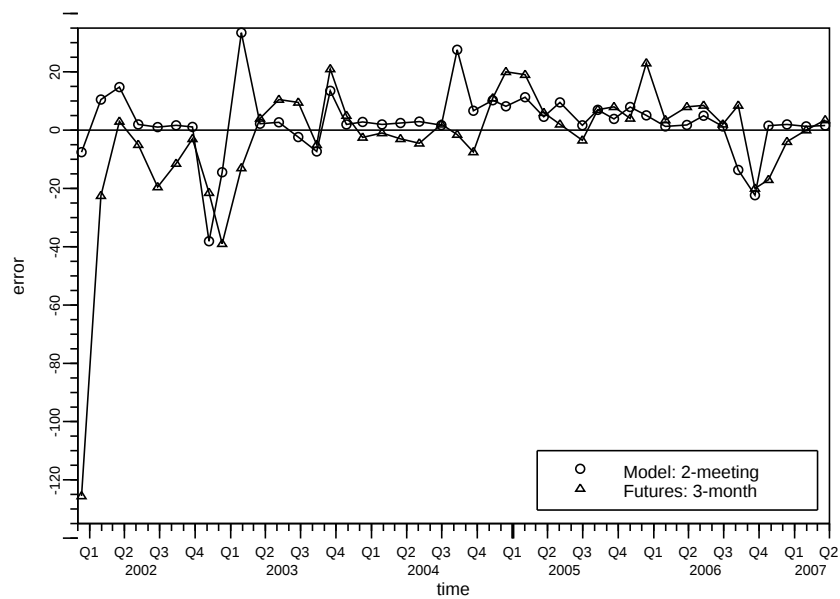


Figure 3: The Three Meetings Ahead Markov Model Prediction Errors vs. the Four Month Ahead Federal Funds Futures Prediction Errors

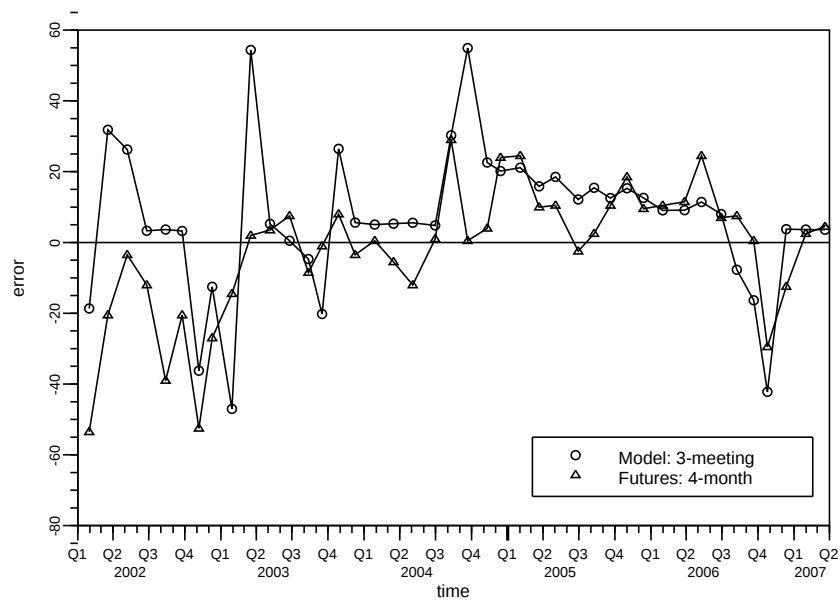


Figure 4: The Four Meetings Ahead Markov Model Prediction Errors vs. the Six Month Ahead Federal Funds Futures Prediction Errors

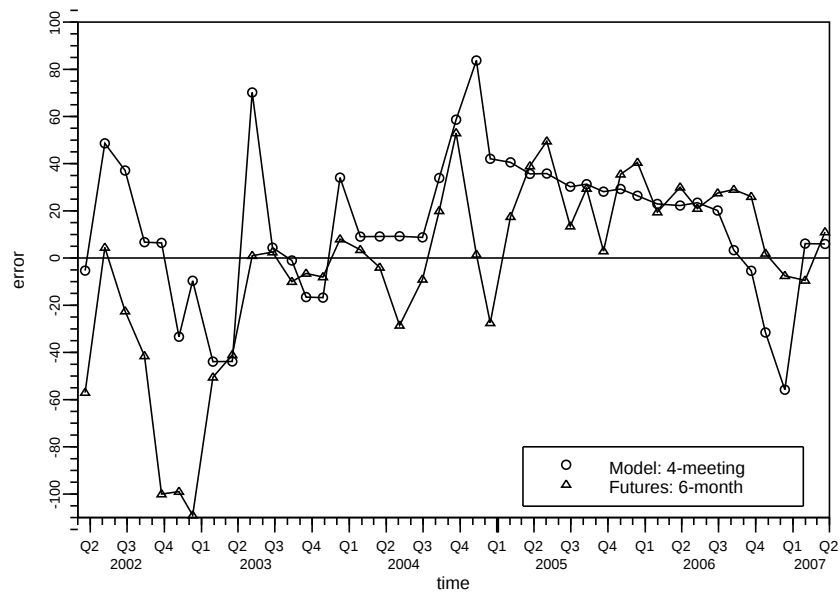


Figure 5: The One Meeting Ahead Markov Model Prediction Errors vs. the One Meeting Ahead Federal Funds Futures Prediction Errors

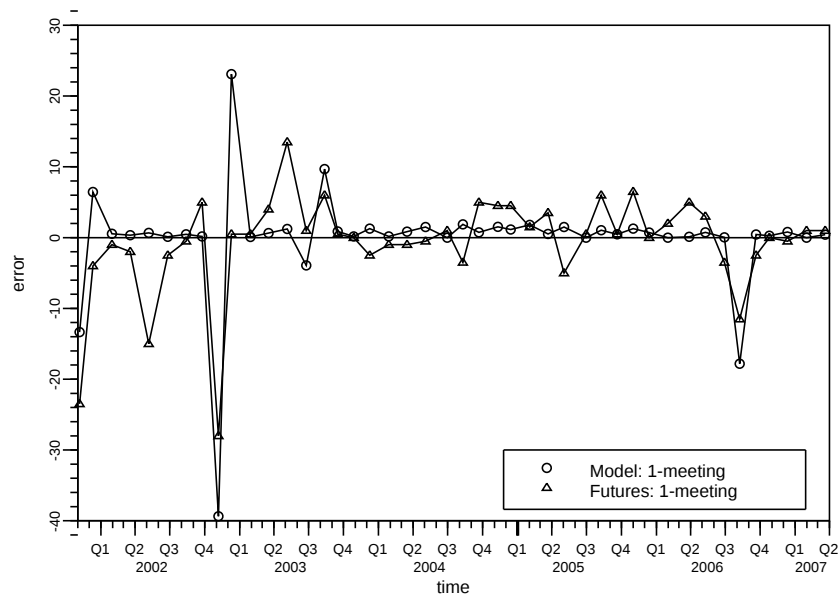


Figure 6: The Two Meetings Ahead Markov Model Prediction Errors vs. the Two Meetings Ahead Federal Funds Futures Prediction Errors

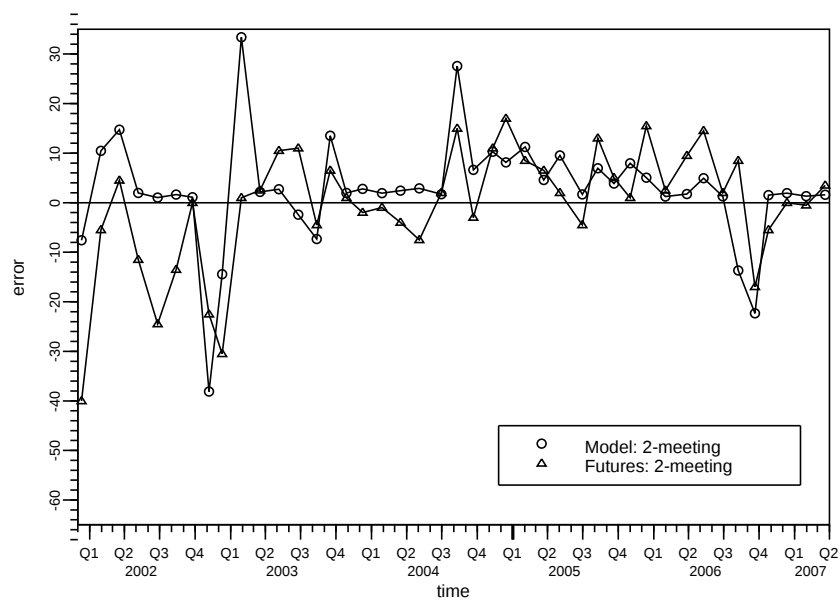


Figure 7: The Three Meetings Ahead Markov Model Prediction Errors vs. the Three Meetings Ahead Federal Funds Futures Prediction Errors

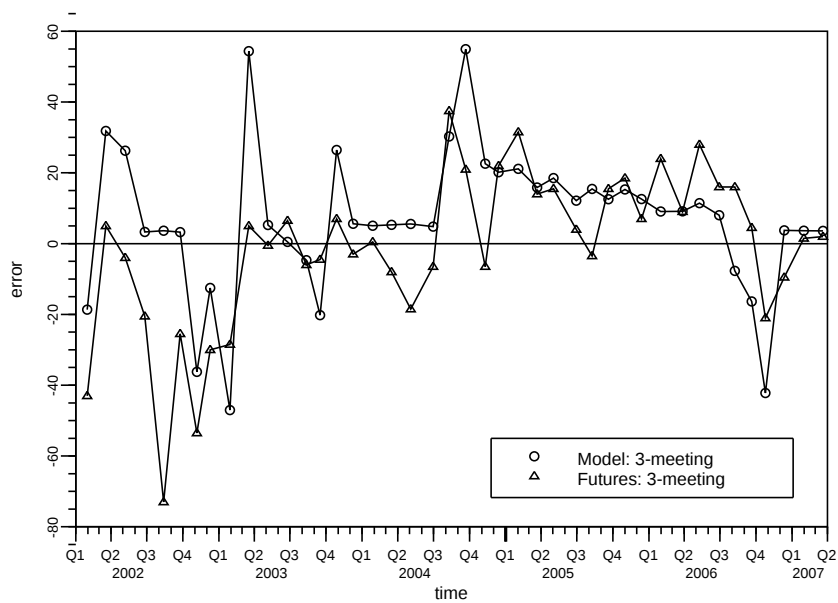


Figure 8: The Four Meetings Ahead Markov Model Prediction Errors vs. the Four Meetings Ahead Federal Funds Futures Prediction Errors

