Futures Prices as Risk-Adjusted Forecasts of Monetary Policy*

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Abstract

Many researchers have used federal funds futures rates as measures of financial markets' expectations of future monetary policy. However, to the extent that federal funds futures reflect risk premia, these measures require some adjustment for risk premia. In this paper, we document that excess returns on federal funds futures have been positive on average. We also document that expected excess returns are strongly countercyclical. In particular, excess returns are surprisingly predictable by employment growth and other business-cycle indicators such as Treasury yields and corporate bond spreads. Excess returns on eurodollar futures display similar patterns. We document that simply ignoring these risk premia has important consequences for the future expected path of monetary policy. We also investigate whether risk premia matter for conventional measures of monetary policy surprises.

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1 Introduction

There is by now a very large and well accepted body of evidence against the expectations hypothesis of the term structure of interest rates for Treasury yields (Fama and Bliss 1987, Campbell and Shiller 1991, and Cochrane and Piazzesi 2003 provide evidence and references). Excess returns on long Treasury securities over a very wide range of sample periods have been positive on average and predictable over time. This paper documents similar patterns for fed funds and eurodollar futures. We show that excess returns on federal funds futures contracts at even the shortest horizons have been positive on average and predictable. The R^2s depend on the holding period and range from 8% for the 1-month horizon to 43% for the 6-month horizon. We document that expected excess returns are clearly countercyclical. We find that *employment numbers* capture this predictability well. Surprisingly, we find that nonfarm payroll numbers do better than financial business-cycle indicators, such as Treasury yield spreads and corporate bond spreads. We find that this behavior is robust both pre- and post-1994, is evident in rolling regressions, and is also displayed by eurodollar futures.

Having documented significant predictability of excess returns in the federal funds futures market, we investigate to what extent accounting for risk premia would affect forecasts of the future course of monetary policy. Here, we find that simply ignoring risk premia can produce very misleading results. Specifically, forecasts based on the expectations hypothesis tend to *adapt too slowly to changes in the direction of monetary policy.* For example, right before recessions, when the Fed has already started easing, fed funds futures keep forecasting high funds rates. Moreover, these forecast errors are highly autocorrelated. As a consequence, we find that defining policy shocks as the difference between actual target and lagged fed funds futures is not accurate. If risk premia only change at business-cycle frequencies, it may be preferable to measure monetary policy shocks as changes in near-dated federal funds futures.

Our findings on fed funds futures differ from those for Treasuries in several dimensions. First, we find that the most important predictive variable is a macroeconomic variable: nonfarm payroll employment. Previous studies found significant results only for financial variables (such as term spreads). Second, fed funds future returns are actually traded securities, while the zero-coupon yield data used in the paper cited above is constructed by interpolation schemes. Thus, our results shed light on whether these predictability patterns truly exist in fixed income and futures markets. Third, fixed income and federal funds futures markets are potentially very different markets,[1] and the fact that we find similar patterns of predictable excess returns across the two markets is interesting in itself. For example, federal funds futures contracts have maturities of just a few months and may therefore be much less risky than long Treasuries, which have maturities of

[1] For example, the largest participants in the federal funds futures market (and eurodollar futures and swaps markets) are typically financial institutions looking to "lock in" funding at prespecified rates (to hedge their own commercial and industrial loan portfolio, for example). The portfolios and hedging demands of these institutions are potentially very different from the largest participants in the Treasury bond markets—foreign governments, state and local governments, insurance companies, and the like. See Stigum (1990) for additional technical details on the Treasury and money markets.

several years; also, the holding periods relevant for measuring excess returns on fed funds futures contracts are much less than one year—contracts with more than six months to maturity are rarely traded, and the vast majority of open interest is in contracts with just one or two months to settlement—while the results for Treasuries typically assume that the investor holds the securities for an entire year. Given the short maturities and required holding periods to realize excess returns in the fed funds futures market, one might think that risk premia in this market would be very small or nonexistent. We find that this is not the case.

The remainder of the paper proceeds as follows. Section 2 measures excess returns in federal funds futures, and shows that these excess returns have varied over time and can be predicted using a simple function of Treasury yields or other leading indicators of the business cycle, such as corporate bond spreads. Section 3 shows that these excess returns were predictable in real time as well as ex post. Section 4 shows that failing to adjust for risk can lead to substantial errors in measuring monetary policy expectations, so that the predictability of excess returns is economically as well as statistically significant.

2 Excess Returns on Federal Funds Futures

Since Krueger and Kuttner (1996), Rudebusch (1998), and Brunner (2000), it has become increasingly popular to measure near-term monetary policy expectations using federal funds futures rates. Federal funds futures contracts have traded on the Chicago Board of Trade exchange since October 1988 and settle based on the average federal funds rate that prevails over a given calendar month.[2] Let $f_t^{(n)}$ denote the federal funds futures contract rate for month $t+n$ as quoted at the end of month t. We will refer to $n=1$ as the one-month-ahead futures contract, $n=2$ as the two-month-ahead contract, and so on. Let r_{t+n} denote the ex post realized value of the federal funds rate for month $t+n$, calculated as the average of the daily federal funds rates in month $t+n$ for comparability to the federal funds futures contracts.

The buyer of a fed funds futures contract locks in the contracted rate $f_t^{(n)}$ for the contract month $t+n$ on a \$5 million deposit. The contracts are cash-settled a few days after expiration (with expiration occurring at the end of the contract month). At that time, the buyer receives \$5 million times the difference between $f_t^{(n)}$ and the realized funds rate r_{t+n} converted to a monthly rate.[3] As is standard for many futures contracts, there is no up-front cost to either party of entering into the contract; both parties simply commit to the contract rate and each posts a relatively small amount of securities as margin collateral. Note that there is essentially no "alternative use of funds" or "opportunity

[2] The average federal funds rate is calculated as the simple mean of the daily averages published by the Federal Reserve Bank of New York, and the federal funds rate on a non-business day is defined to be the rate that prevailed on the preceding business day.

[3] This means that $f_t^n - r_{t+n}$ gets multiplied by (number of days in month/360), since the quoting convention in the spot fed funds and fed funds futures markets use a 360-day year. See the CBOT web site for additional details.

cost" for the collateral, since margin requirements are typically posted with interest-bearing U.S. Treasury securities.

We can therefore define the ex post realized excess return to the buyer of the futures contract as

$$rx_{t+n}^{(n)} = f_t^{(n)} - r_{t+n}. \tag{1}$$

Since we will consider futures contracts with maturities n ranging from 1 to 6 months, the excess returns in (1) will correspond to different holding periods for different values of n. To make excess returns on these different contracts directly comparable, we annualize the returns by multiplying them by $12/n$. Also, we measure returns in basis points. These conventions will apply throughout the paper.

2.1 Average Excess Returns

To check whether the average excess returns are zero, we run the regression

$$rx_{t+n}^{(n)} = \alpha^{(n)} + \varepsilon_{t+n}^{(n)} \tag{2}$$

for different contract horizons n.

Table 1 presents results from regression (1) for the forecast horizons $n = 1, \ldots, 6$ months over the entire sample period for which we have federal funds futures data: October 1988 through December 2003. This period will be the baseline for all of our regressions below. We run the regression at monthly frequency, sampling the futures data on the last day of each month t. We compute standard errors using the heteroskedasticity- and autocorrelation-consistent procedure described in Hodrick (1992). Specifically, we use standard errors (1A) from Hodrick (1992), which generalizes the Hansen-Hodrick (1988) procedure to heteroskedastic disturbances.

Table 1. Average Excess Returns

n	1	2	3	4	5	6
$\alpha^{(n)}$	41.2	44.6	49.9	57.5	66.3	73.4
t-stat	3.7	3.5	3.2	3.1	3.1	2.9

NOTE: The sample is 1988:10-2003:12. The observations are from the last day of each month. The regression equation is (2) . $\alpha^{(n)}$ is measured in basis points. "t-stat" represents the t-statistic based on Hodrick 1A standard errors.

According to the expectations hypothesis, expected excess returns on fed funds futures should be zero. Table 1 shows, however, that excess returns on fed funds futures are on average positive and significant. As noted above, to make average excess returns on different contracts comparable, we have annualized them. For example, buying the fed fund futures contract today and holding it until it matures 6 months from now generates an excess return of 73.4 basis points on average per year.[4] The average excess returns in Table 1 increase with the maturity of the futures contract and range between 41 and 73 basis points per year. The averages for the post-1994 period are just a bit lower at 32.4, 35.9, 38.9, 44.7, 51.1, and 58.3 basis points per year.

2.2 Excess Returns over the Business Cycle

Previous work using federal funds futures has generally stopped at this point, and proceeded under the assumption that expected excess returns on federal funds futures are constant. However, in studies of long- and short-term Treasury markets, it has been well-documented (Fama and Bliss 1987, Cochrane and Piazzesi 2003) that excess returns on Treasury securities are predictable. In particular, expected excess returns on Treasuries are related to the business cycle: they are high in economic recessions and low in expansions.

Figure 1 graphs the realized excess return $rx_{t+4}^{(4)}$ on the 4-month-ahead federal funds futures contract from October 1988 through December 2003. Certainly, the time-variation in these realized excess returns has been large, ranging from -462 to 474 bp. (These values are again annualized). The graph also suggests that there have been several periods during which fed funds futures have generated particularly large excess returns. These periods are periods during which the Federal Reserve lowered interest rates. These were the years 1991 & 1992, early in 1995, fall of 1998 and the years 2001 & 2002. Two of these periods 1991/2 and 2001/2, coincided with the only two recessions in our sample, when the Federal Reserve lowered interest rates. The other two periods were not recessions, but also periods with slower economic growth.

As a first step to understanding the predictability of excess returns of fed fund futures, we therefore regress their excess returns on a constant and a recession dummy D_t:

$$rx_{t+n}^{(n)} = \beta_0^{(n)} + \beta_1^{(n)} D_t + \varepsilon_{t+n}^{(n)} \tag{3}$$

Figure 1 shows the fitted values from this regression (as a step function) together with the realized excess returns. Table 2 shows that the recession dummy is significant for all contracts with maturity longer than just 1 month. The estimated coefficient on the recession dummy suggests that excess returns are roughly 3 times higher in recessions compared to what they are on average during other periods.

[4]This is not a percentage excess return, because the cost of purchasing the contract is zero, as discussed previously. In other words, the unannualized excess return on the six-month-ahead contract is, on average, \$5 million times .367% times (number of days in contract month/360). The annualized excess return is just double this amount (multiplying by 12/6).

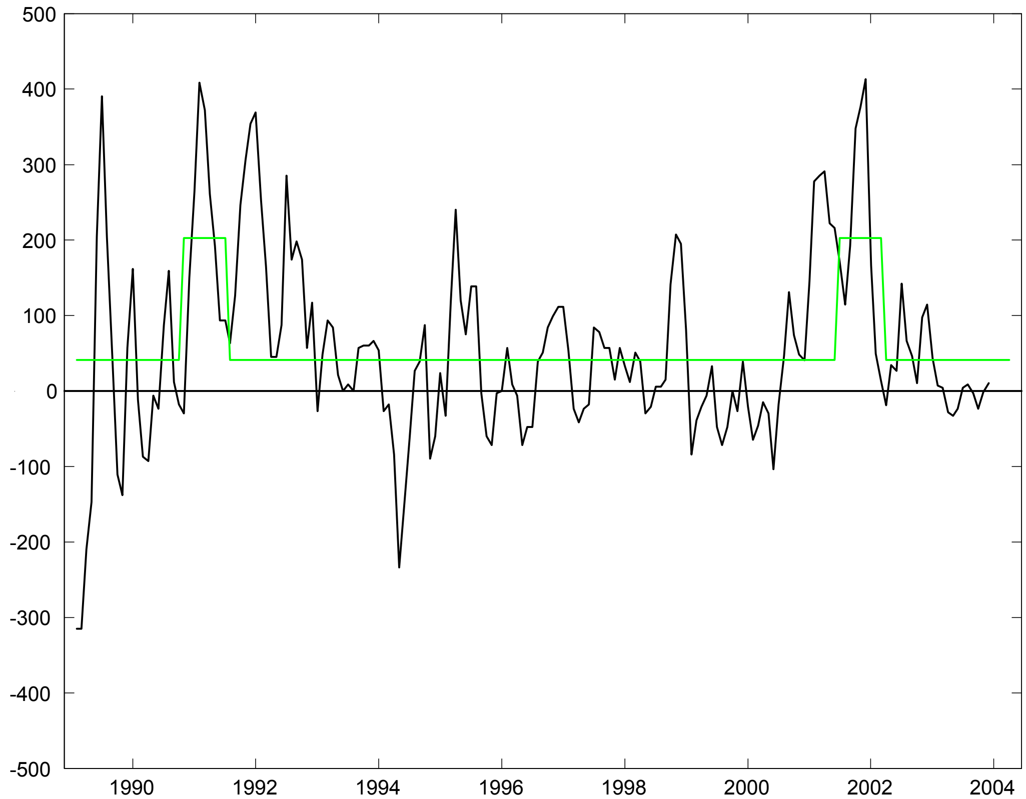

Figure 1: Annualized excess returns on the federal funds futures contract 4 months ahead. The step function represents the fitted values from a regression of $rx_{t+4}^{(4)}$ on a constant and a recession dummy.

Table 2. Excess returns and Recessions

n	1	2	3	4	5	6
const.	34.1	32.1	35.4	41.3	49.1	60.8
t-stat	3.8	3.1	2.6	2.6	2.6	2.7
Dummy	71.9	125.7	144.6	161.3	167.5	157.2
t-stat	1.0	2.1	4.3	12.3	10.0	5.5
R^2	0.02	0.10	0.13	0.15	0.16	0.13

NOTE: The regression equation is (3), where D_t is a recession dummy. Excess returns are annualized and measured in basis points.

Of course, recession dummies are only rough indicators of economic growth and, moreover, are not useful as predictive variables. The reason is that recessions are not known in real time, since the NBER's business cycle dating committee declares recession peaks and troughs as long as 2 years after they have actually occurred. In other words, recession dummies do not represent information that investors can condition on when deciding about their portfolios. Figure 1 suggests, however, that any business cycle indicator may be a good candidate for forecasting excess returns. In what follows, we consider several business cycle indicators, including employment, Treasury yield spreads and the corporate bond spread.

2.3 Employment

To see which variables forecast excess returns on fed funds futures, we run the predictive regression

$$rx_{t+n}^{(n)} = \beta_0^{(n)} + \beta_1^{(n)} X_t + \varepsilon_{t+n}^{(n)}, \tag{4}$$

where X_t is a vector of variables known to financial markets in month t. Since GDP data are only available at a quarterly frequency, it does not provide a very useful variable for forecasting monthly excess returns. We therefore turn to a closely related measure of real activity: employment. More precisely, we use monthly observations on the growth rate in nonfarm payroll numbers from last year to this year.

Table 3 reports the forecasting results based on employment growth. The regression also includes the futures rate itself on the right-hand side. The results show that employment growth is a significant forecasting variable for contracts of any maturity. As we would expect from our results using the recession dummy, expected excess returns and employment growth are inversely related. The estimated slope coefficients in Table 3 increase with maturity and are between -0.13 and -0.62. Employment growth is measured in basis points, which means that a 100 basis point drop in employment growth increases expected excess returns by about 13 to 62 basis points. Over our sample, the mean and standard deviation of employment growth were 141 and 144 basis points, which means that a one-standard deviation shock to employment makes us expect around 90 basis points more in excess returns on the 6-month futures contract. The futures rate $f_t^{(n)}$ is significant for contracts with maturities of 3 months and higher.

Table 3. Excess Returns and Employment

n	1	2	3	4	5	6
const.	16.6	22.9	19.5	14.8	2.9	-17.1
t-stat	0.6	0.7	0.6	0.4	0.1	-0.5
$f_t^{(n)}$	0.09	0.12	0.17	0.22	0.29	0.37
t-stat	1.1	1.5	2.1	3.2	4.5	5.7
NFP	-0.13	-0.28	-0.39	-0.48	-0.56	-0.62
t-stat	-1.2	-2.5	-3.5	-5.1	-8.0	-10.8
R^2	0.02	0.07	0.15	0.21	0.28	0.38

NOTE: The regression equation is (4), where X_t contains $f_t^{(n)}$ and nonfarm payroll employment (NFP) growth from $t - 12$ to t. The data on nonfarm payroll numbers is from the Federal Reserve Economic Database in Saint Louis. Excess returns and NFP growth are annualized and measured in basis points.

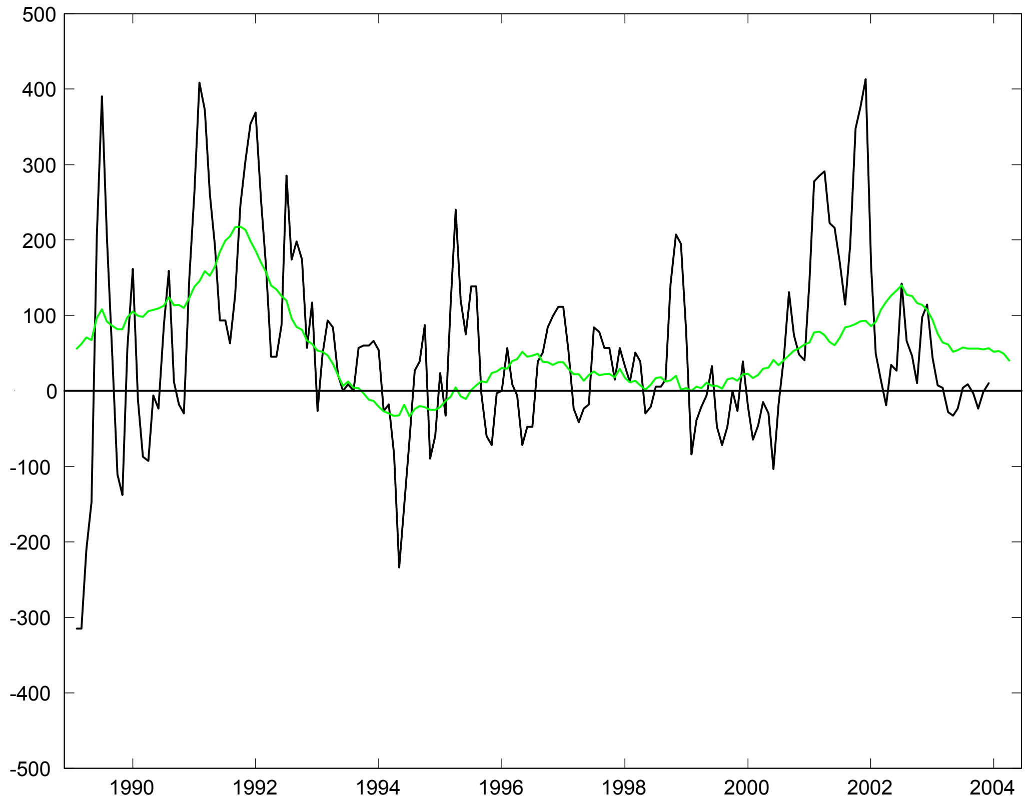

Figure 2: Annualized excess returns on the federal funds futures contract 4 months ahead. The gray (green in color) function represents the fitted values from a regression of $rx_{t+4}^{(4)}$ on a constant, employment growth and $f_t^{(4)}$ itself.

The R^2 in Table 3 suggest that we capture up to 38% of the variation in future excess returns with employment growth and the futures rate. This result is remarkable, since these R^2 are comparable in size to those in Cochrane and Piazzesi (2003) who study excess returns on Treasuries over much longer holding periods. To be more precise, we study holding periods for fed funds futures that match their maturities, which range from as short as 1 month up to 6 months, while Cochrane and Piazzesi (2003) study annual holding periods for Treasuries. (We may be confusing the reader by annualizing the excess returns of holding fed funds futures until they mature, which occurs in a few months. This normalization just involves multiplying excess returns with $12 \times n$. This multiplication does not affect the t-statistics or R^2 in our regressions).

Figure 2 shows that employment is not only doing well in the two recessions. Indeed, employment also forecasts high returns in 1995 and shows little up-wiggles in 1998. Employment also does a good job at capturing periods with low returns, such as 1994 and 1999.

Nonfarm payroll numbers are released by the Bureau of Labor Statistics on the first Friday of each month. In other words, January payroll numbers are only released on the first Friday of February. To perform the regressions in Table 3 in real time, however, we need to know the January payroll number at the end of January, since we are forecasting returns from buying fed funds futures at the end of January and holding them until expiration. To see whether the regression would give very different results, we also forecast excess returns from January to expiration using employment numbers only up through December. The results (not reported) are virtually identical. The relevant R^2 are 2, 7, 15, 21, 30 and 37%. The point estimates and t-statistics are almost identical to those in Table 3.

An additional real-time data issue is that we have used the final vintage of nonfarm payroll employment data from the Federal Reserve Bank of St. Louis's FRED database. In actuality, however, the nonfarm payrolls numbers are revised twice after their initial release and undergo an annual benchmark revision every June, so the final vintage numbers are not available for forecasting in real time. Ignoring this issue may thus bias our results somewhat in favor of predictability. This error should be small though, given that we are using 12-month (rather than 1-month) changes in employment and that our results are robust to lagging employment an entire month, which confirms that the predictability of excess returns is exploiting the low-frequency movements in payroll growth from Figure 2, rather than month-to-month variation. In addition, we demonstrate next that we are able to generate very much the same pattern of predictability (albeit with slightly lower R^2) using financial market variables such as yield spreads and corporate risk spreads, which are data that were clearly available to market participants in real time.

2.4 Yield Spreads and Corporate Spreads

In studies of long- and short-term Treasury markets, it has been well-documented (Fama and Bliss 1987, Cochrane and Piazzesi 2003) that expected excess returns on Treasury securities can be forecasted with the Treasury yield curve. For example, Cochrane and Piazzesi show that a simple tent-shaped function of 1 through 5-year forward rates explains excess returns on holding long Treasuries securities for 1 year with an R^2 of 35–40%. Of course, these findings are related to the fact that yields have been used as business cycle indicators. For example, the Stock and Watson (1989) leading index is mainly based on term spreads. A natural question is therefore whether yields also forecast excess returns on fed funds futures.

Table 4 reports results from predictions based on a set of yield spreads. We select four different term spreads based on differences of the 6 month T-bill rate and the 1, 2, 5, and 10 year zero-coupon Treasury yields.[5] As can be seen in Table 4, there is significant evidence that excess returns on federal funds futures contracts have been significantly predictable with yield spreads for contracts with 3 months to maturity or more: R^2 values range from 8–21% for the longer horizon contracts and some t-statistics are well above

[5] We also considered other Treasury bills, but none of them entered significantly. Moreover, we included the own fed funds futures rate $f_t^{(n)}$ as another regressor, but it was not significant.

2. Although generally not statistically significant at the 5% level for shorter horizons, we consistently estimate the same pattern of coefficients for the shorter-horizon contracts as for the longer-horizon contracts, with the magnitudes of the coefficients increasing monotonically with the horizon of the contract n (except for the $n = 1$ loadings on the 2-1 and 10-5 year spreads).

Table 4. Excess Returns and Treasury Spreads

n	const.	1 - 1/2 yr	2 - 1 yr	5-2 yr	10-5 yr	R^2
1	56.4	0.37	−1.21	1.46	−1.32	0.01
	(2.0)	(0.3)	(−1.1)	(1.7)	(−1.7)	
2	62.6	−0.27	−0.96	1.50	−1.29	0.02
	(2.2)	(−0.2)	(−0.7)	(1.6)	(−1.7)	
3	79.5	−0.67	−1.29	2.27	−2.00	0.04
	(2.5)	(−0.5)	(−1.2)	(−2.0)	(−4.5)	
4	98.7	−0.79	−1.80	3.19	−2.87	0.08
	(2.6)	(−0.7)	(−1.6)	(3.3)	(−3.6)	
5	131.2	−1.43	−1.90	4.03	−3.90	0.14
	(2.8)	(−1.2)	(−1.2)	(2.6)	(−3.1)	
6	164.9	−2.32	−1.51	4.26	−4.43	0.21
	(3.4)	(−1.8)	(−1.0)	(3.2)	(−4.0)	

NOTE: The regression equation is (3), where X_t consists of yield spreads on zero-coupon Treasuries (measured in basis points). The maturities of the Treasuries are 1-1/2 year, 2-1 year, 5-2 year and 10-2 year. t-statistics are reported in parentheses. The Treasury yield data are from the Federal Reserve Board.

Figure 3 plots realized excess returns on the four-month-ahead fed funds futures contract together with the fitted values from Table 4 (where realized returns are shifted up by 500 bp to more clearly present both in the same graph). The yield spreads seem to be most successful at capturing the rise in excess returns in 2001 and the runups in 1990 through 1992, suggesting that the estimated linear combination of yields may indeed capture the relationship between excess returns and the business cycle.

We also investigate whether another leading indicator of the business cycle, the BBB-Treasury risk spread on 10-year corporate bonds, can also help to predict excess returns on fed funds futures. Results are reported in Table 5, and corroborate the hypothesis that measures of business cycle risk in general may be useful predictors of excess returns in the fed funds futures market. The estimated coefficients on the corporate bond spread in these regressions are significant for federal funds futures contracts at all maturities, with R^2 of 11–16% for the longer-horizon contracts. The fitted values from this regression for the four-month-ahead contract are also plotted in Figure 3.

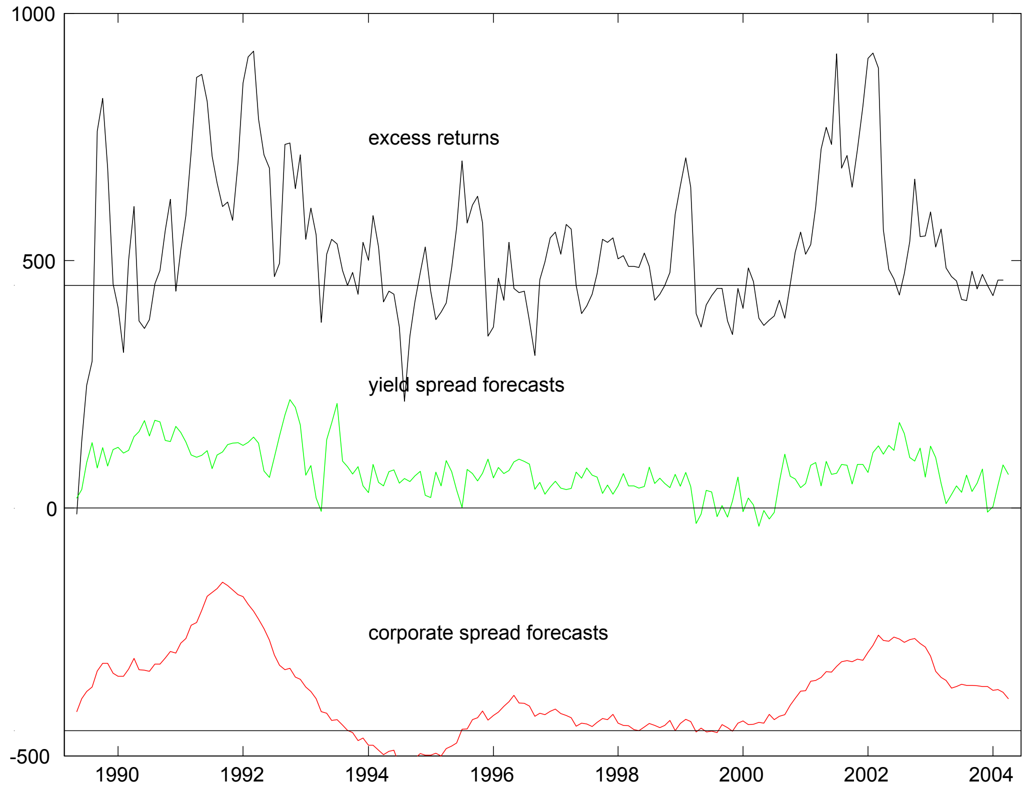

Figure 3: The top line are annualized excess returns $rx_{t+4}^{(4)}$ on the 4-month ahead futures contract (shifted up by 500 bp), the middle line are fitted values from the regression on Treasury yield spreads (Table 4) and the bottom line are fitted values from the regression on the corporate bond spread (Table 5, shifted down by 500 bp).

Table 5. Excess Returns and Corporate Bond Spreads

n	1	2	3	4	5	6
const.	−28.0	−56.5	−79.2	−94.2	−115.6	−128.7
t-stat	−0.6	−1.2	−1.6	−1.7	−1.9	−1.9
$f_t^{(n)}$	0.04	0.05	0.07	0.10	0.14	0.17
t-stat	0.7	0.8	1.3	1.6	2.0	2.2
BBB	0.29	0.48	0.59	0.65	0.72	0.76
t-stat	1.5	2.2	2.5	2.5	2.7	2.4
R^2	0.02	0.06	0.09	0.11	0.15	0.16

NOTE: The regression equation is (3), where X_t consists of the own futures contract rate $f_t^{(n)}$ and the BBB-Treasury corporate bond spread. The note to Table 1 applies. Data on BBB corporate bond yields with 10 years to maturity are from Merrill Lynch; data on 10-year Treasury par yields (the comparable Treasury yield) are from the Federal Reserve Board.

To sum up, we find substantial evidence for time variation in expected excess returns on fed funds futures. Surprisingly, the strongest evidence comes from conditioning on employment growth—a macroeconomic variable—instead of lagged financial data. However, our sample is short, just 15 years, and we therefore do have to treat this result with the appropriate caution.

2.5 One-Month Holding Period Returns

Our sample period only spans 15 years, which results in as few as 30 independent windows for our longest-horizon (6-month-ahead) fed funds futures contracts. A way to reduce this problem and check on the robustness of our results is to consider the excess returns an investor would realize from holding an n-month-ahead federal funds futures contract for just one month—by purchasing the contract and then selling it back as an $(n-1)$-month-ahead contract in one month's time—rather than holding the contract all the way through to maturity. By considering one-month holding period returns on fed funds futures, we reduce potential problems of serial correlation and sample size for the longer-horizon contracts, and give ourselves 180 completely independent windows of data for all contracts.

We thus consider regressions of the form:

$$f_t^{(n)} - f_{t+1}^{(n-1)} = \beta_0^{(n)} + \beta_1^{(n)} X_t + \varepsilon_{t+1}^{(n)} \tag{5}$$

where $f_t^{(n)}$ denotes the n-month-ahead contract rate on the last day of month t, $f_{t+1}^{(n-1)}$ denotes the $(n-1)$-month-ahead contract rate on the last day of month $t+1$, and the difference between these two rates is the ex post realized one-month holding period return on the n-month-ahead contract.[6] Using specification (5), the residuals are serially uncorrelated under the null hypothesis of no predictability of excess returns, because all variables in equation (5) are in financial markets' information set by the end of month $t+1$.

Tables 6 presents the results of our previous analyses applied to this alternative specification, where the regressors are the own contract rate and employment growth. Although the R^2 values are uniformly lower, as is to be expected from quasi-first-differencing the left-hand side variable, our previous results are robust to this alternative specification.

[6] The investor's realized monetary return on this transaction is \$5 million times the difference in rates $f_t^{(n)} - f_{t+1}^{(n-1)}$ times (number of days in contract month/360). Since these contracts are "marked to market" essentially every day, the investor realizes the full monetary return to this transaction in month $t+1$; in particular, the investor does not need to wait until the contracts mature at the end of month $t+n$ to realize the return. As before, the opportunity cost of engaging in this transaction is negligible, so the realized return is also the realized excess return.

Table 6. One-Month Excess Returns and Employment

n	2	3	4	5	6
const.	29.8	26.8	39.7	40.7	-19.5
t-stat	0.7	0.5	0.6	0.5	-0.2
$f_t^{(n)}$	0.16	0.24	0.29	0.33	0.59
t-stat	1.5	1.7	1.7	1.6	2.2
Nonfarm	-0.43	-0.63	-0.76	-0.83	-1.03
t-stat	-3.2	-3.8	-4.2	-4.2	-4.1
R^2	0.07	0.10	0.11	0.10	0.14

NOTE: The regression equation is (5), where X_t contains $f_t^{(n)}$ and nonfarm payroll employment growth from $t-12$ to t. One-month excess returns are annualized by multiplying them with 12 and measured in basis points.

2.6 Eurodollar Futures

We also check whether our predictability results hold for eurodollar futures. Some advantages of considering eurodollar futures in addition to federal funds futures are that eurodollar futures contracts are more liquid (they are currently the most actively traded futures contracts in the world), eurodollar futures are available over a slightly longer sample period (our data begin in March 1985), and eurodollar futures have maturities that extend out to several years, providing an intermediate horizon between fed funds futures and longer-dated Treasury securities.

Eurodollar futures have traded on the Chicago Mercantile Exchange since 1981 and settle based on the spot three-month LIBOR eurodollar time deposit rate prevailing on the date of expiration.[7] In contrast to federal funds futures, eurodollar futures have maturities that are denominated in quarters rather than months, so we let $ef_t^{(n)}$ denote the eurodollar futures contract rate in quarter t for a contract expiring at the end of quarter $t+n$. The corresponding realized rate er_{t+n} is the spot three-month eurodollar rate that prevails on the day of expiration of the futures contract $ef_t^{(n)}$. The ex post excess return realized from holding the n-quarter-ahead contract to maturity is $ef_t^{(n)} - er_{t+n}$, and the ex post realized excess return to holding the n-quarter-ahead contract for one quarter is $ef_t^{(n)} - ef_{t+1}^{(n-1)}$. Regression equations for analyzing these excess returns are otherwise identical to equation (3) for federal funds futures.

Table 7 presents the results of our previous analyses applied to eurodollar futures

[7] The spot three-month London Interbank Offered Rate for three-month time deposits of U.S. dollars in London is collected and published daily by the British Bankers' Association. The spot eurodollar market is a very active one, thus these rates match three-month time deposit rates in the U.S. very closely. The March, June, September, and December eurodollar futures contracts are by far the most actively traded, with expiration on these contracts near the middle of those months. Contracts are cash-settled a few days after expiration with the purchaser receiving \$1 million times the difference $ef_t^n - er_{t+n}$ times (91/360). See the CME web site for additional details.

contracts with maturities of $n = 1, \ldots, 8$ quarters ahead. Panel A shows that average excess returns on eurodollar futures are between 60 and 105 basis points per year. Excess returns also exhibits the same type of predictability pattern as fed funds futures. Panel B shows that nonfarm payroll employment growth is statistically significant at all horizons, with R^2 values ranging from 21 to over 43%. The results for Treasury yield spreads and corporate bond spreads are also significant and similar to those for fed funds futures (not reported). These results show that if anything, risk premia are even more important for eurodollar futures than what we have estimated for federal funds futures.

Table 7. Results for Eurodollar Futures

Panel A: Average excess returns (annualized)

n	1	2	3	4	5	6	7	8
const.	59.9	81.1	70.7	102.5	104.4	102.8	99.1	105.8
t-stat	2.5	2.7	2.8	2.8	2.7	2.7	2.7	3.0

Panel B: Predictive regressions using employment growth and futures rate

const.	13.36	−8.9	−14.0	−22.5	−29.1	−26.4	−29.6	−52.4
t-stat	0.2	−0.2	−0.4	−0.6	−0.6	−0.5	−0.6	−1.0
$ef_t^{(n)}$	0.32	0.41	0.42	0.42	0.39	0.36	0.33	0.34
t-stat	2.5	4.7	6.4	6.3	5.5	5.0	5.2	5.1
NFP	−0.84	−0.90	−0.87	−81.8	−0.73	−0.65	−0.55	−0.44
t-stat	5.3	−8.3	−11.2	−11.2	−11.6	−10.9	−10.2	−7.6
R^2	0.21	0.31	0.38	0.42	0.44	0.42	0.39	0.43

3 Predictability of Excess Returns in Real Time

We have documented that excess returns on federal funds futures were predictable by business-cycle indicators such as employment growth, Treasury yield spreads or the corporate bond spread. To what extent could an investor have predicted these returns in real time? To answer this question, we first perform a set of rolling "out-of-sample" regressions. To see whether market participants may have based their investment strategies on similar forecasts, we provide some intriguing historical evidence on actual trades in the fed funds and eurodollar futures market.

3.1 Rolling Regressions

Figure 4 shows real-time forecasts together with full-sample forecasts from Table 2 based on employment growth and the own futures rate. The real-time forecasts for month $t+1$ are constructed by estimating the slope coefficients with data up to the current month t.

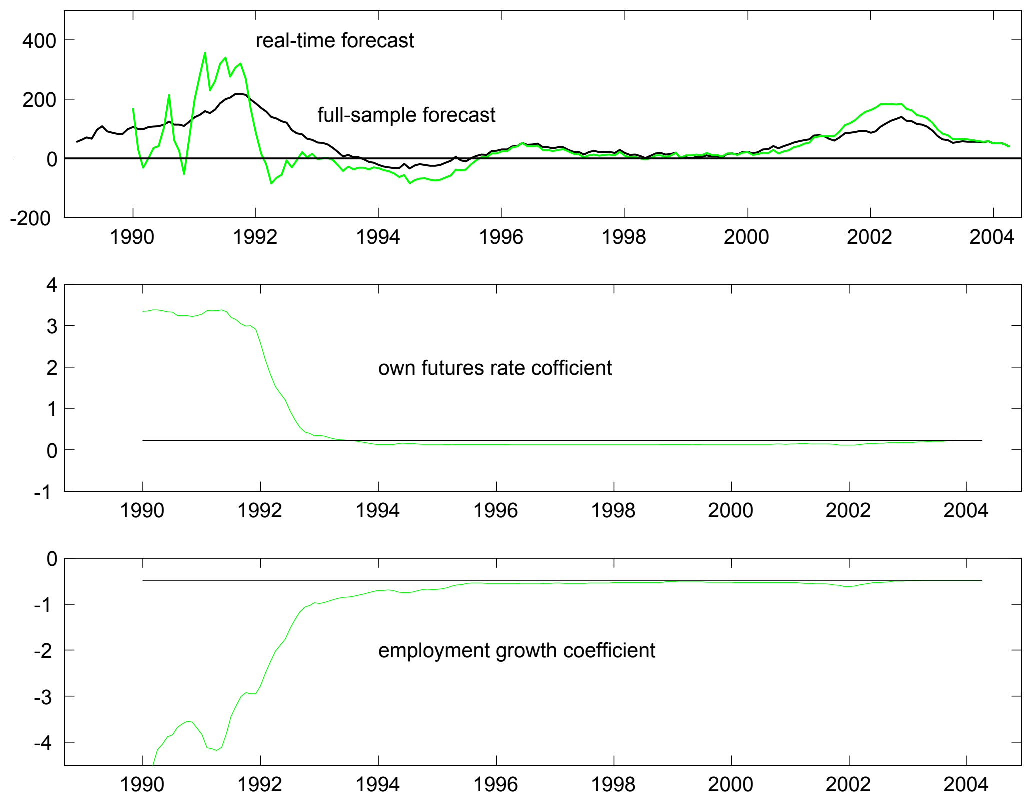

Figure 4: The top panel shows real-time and full-sample forecasts of $rx_{t+4}^{(4)}$. The middle panel shows the rolling estimates of the coefficient on the own futures rate $f_t^{(4)}$. The flat line is the full-sample coefficient from Table 2. The lower panel shows the rolling estimates of the coefficient on employment growth. Again, the flat line is the full-sample coefficient from Table 2.

These forecasts are performed starting in January 1990, when we only have 12 months of data to estimate three parameters. The graph suggests that the real-time fitted values are quite close to the full-sample fitted values over most of the sample - indeed, the two series are essentially identical from the beginning of 1994 onward. The middle and lower panels in Figure 4 show the rolling estimates of the slope coefficients together with their full sample counterparts. The graphs suggest that the rolling point estimates settle down after 1994.

3.2 Data on Market Participants' Long and Short Positions

The previous section shows that excess returns on fed funds and eurodollar futures were *potentially* predictable to investors in real time using rolling regressions. In this section, we present some evidence indicating that informed investors at the time actually *did* correctly forecast the excess returns that were subsequently realized.

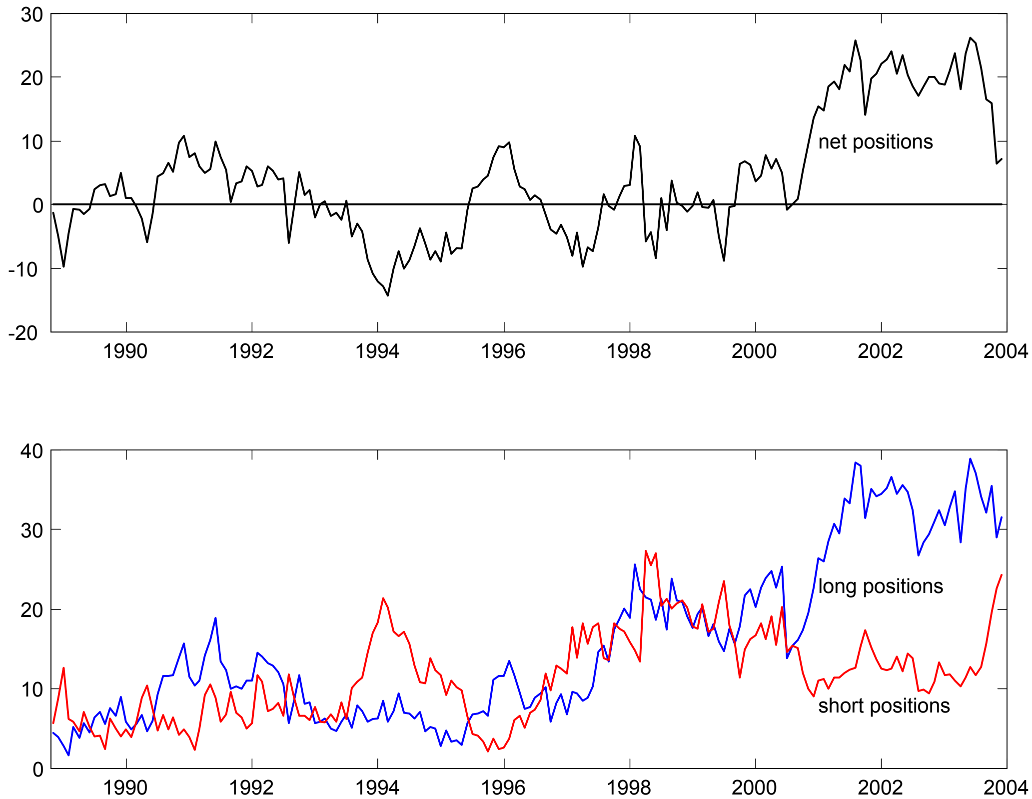

Figure 5: The upper panel shows net positions in eurodollar futures. The lower panel shows long and short positions separately.

The U.S. Commodity Futures Trading Commission (CFTC) requires all individuals or institutions holding 10,000 futures contracts or more in a given commodity to report their positions to the CFTC, and the extent to which these positions are hedged.[8] In the eurodollar (fed funds) futures markets, about 90% (95%) of open interest is held by individuals or institutions that must report to the CFTC as a result of this requirement. The CFTC reports the aggregates of these data with a three-day lag, broken down into hedging and non-hedging categories and into short and long positions, in the weekly Commitments of Traders report, available on the CFTC's web site.

The lower panel in Figure 5 plots the percentage of long and short open interest in eurodollar futures held by noncommercial market participants—those market participants that are classified by the CFTC as *not* hedging offsetting positions that arise out of their normal (non-futures related) business operations.[9] The number of all open long positions in these contracts held by noncommercial market participants, expressed as a

[8]The exact reporting threshold varies by commodity. The 10,000 number applies to eurodollar futures, as reported on the CME's web site.

[9]The primary example of a *commercial* participant in the eurodollar futures market would be a financial institution engaged in lending to commercial and industrial enterprises for periods of 1 to 5 years.

percentage of total reportable open interest, is plotted in blue, and the number of all open short positions (as a percentage of reportable open interest) held by these participants is plotted in red. Analogous data are available for fed funds futures, but we focus on eurodollar futures positions here as this market is thicker, data are available back to 1986, and contracts run off less frequently (only once per quarter rather than every month), which reduces some high-frequency variation in the percentage long and short series.[10] The patterns in federal funds futures noncommercial holdings look very similar, albeit noisier for the reasons cited above.

The patterns that emerge in Figure 5 are striking when compared to the realized excess return series plotted earlier. Noncommercial market participants began taking on a huge net long position in late 2000, only a few months before excess returns in these contracts (both eurodollars and fed funds futures) began to soar. Noncommercial market participants also took on substantial net long positions from mid-1990 through mid-1991 and in late 1995, again correctly forecasting excess returns over these periods, and noncommercial participants took on a very substantial net *short* position in late 1993 through mid-1994, correctly anticipating the strongly negative excess returns that were realized when the Fed began tightening in 1994.

The upper panel of Figure 5 plots the difference between the noncommercial percentage long and short series as the "net long position" of noncommercial market participants. Just from eyeballing the figure, we can see that net positions forecast subsequent excess returns in both the fed funds futures and eurodollar futures markets. Regression analysis confirms that this variable is highly significant as a predictor of excess returns in the fed funds futures market at horizons of 3 month or more (and eurodollar futures markets at horizons of 1 quarter or more), with R^2 values ranging from 7–19%.

The obvious interpretation of this result is that noncommercial market participants at the time were well aware of the upcoming excess returns on these contracts and positioned themselves accordingly, at the expense of those engaged in hedging other financial activities. The hedgers – commercial firms – essentially paid an insurance premium to noncommercial market participants for providing hedging services. These rents are not "competed away" by other noncommercial market participants. There are several possible answers to this question. The futures market may not be perfectly competitive, with barriers to entry and noncommercial market participants facing limits on the size of the positions that they may take; commercial participants with hedging demand thus do not face a perfectly elastic supply curve for either the long or short side of these futures contracts. Moreover, noncommercial market participants may themselves be risk averse. For example, futures traders in these markets may be most averse to taking on risky positions precisely when their own jobs are in jeopardy, around the times of depressed aggregate economic activity. The hypothesis that excess returns in these markets would be competed away requires both an assumption of perfectly competitive futures markets and of risk-neutral market participants – both of these assumptions may not apply.

[10] Open interest is almost always highest in the front-month or front-quarter contract, so the running off of these contracts can create jumps.

4 Risk-Adjusted Monetary Policy Expectations

How misleading would it be to ignore risk premia on fed funds and eurodollar futures—or to allow for constant risk premia but to ignore the time-variation in these premia—and treat the unadjusted (or constant risk-adjusted) prices of these securities as measures of monetary policy expectations? For fed funds futures, these forecast errors are just the excess returns on the fed funds futures contract. For example, the excess return on the 4-month ahead contract $rx_{t+4}^{(4)} = f_t^{(4)} - r_{t+4}$ is simply minus the error in forecasting r_{t+4}. Therefore, we can therefore use our previous results to adjust these forecasts for risk premia.

Table 8 reports summary statistics on forecasting errors made by forecasting the funds rate with the appropriate future rate over different horizons. Panel A shows that average forecast errors are negative, which suggests that futures rates tend to underestimate the actual funds rate by 3 to 37 basis points on average. However, errors in different directions cancel each other, when we take the average. We therefore also compute the absolute value of these errors. Their mean absolute values range from 8 to 51 basis points. The autocorrelation of these errors is substantial, especially for longer horizon forecasts. The autocorrelation coefficient of these errors is 0.84 for 6-month ahead forecasts. These coefficients suggest that using fed fund futures as unadjusted forecasts leads to systematic errors.

Table 8. Forecast Errors using Fed Funds Futures

Panel A: Expectations Hypothesis

n	1	2	3	4	5	6
avg. error	−3.4	−7.4	−12.5	−19.2	−27.6	−36.7
MAE	7.9	14.6	22.6	32.4	42.8	51.3
autocorr.	0.06	0.47	0.70	0.76	0.81	0.84

Panel B: Risk-adjusted Forecasts

MAE	8.1	13.8	20.6	28.1	33.7	36.1
auto	0.05	0.44	0.66	0.71	0.75	0.79

NOTE: "n" is the forecasting horizon, "avg. error" is the average forecast error, "MAE" is the mean absolute error, "autocorr." is the first-order autocorrelation coefficient.

To visualize the situations in which these errors are made, Figure 6 plots the realized funds rate r_{t+4} in the upper panel and forecast errors $r_{t+4} - f_t^{(4)}$ for that realization in the lower panel. In other words, these forecasts are based on information available 4 months ago. The forecast errors are already demeaned. Interestingly, Figure 6 suggests that forecasts based on the expectations hypothesis tend to adjust to slowly to changes in direction. For example, forecast errors tend to be negative in periods when the funds rate falls. They tend to be positive in periods when the funds rate goes up. In other words, futures rates are useful as an indication of where the funds rate will be in the future. However, the indication provided by unadjusted futures rates "lags behind:" long after the Fed has started easing, the futures rate still forecasts high future funds rates.

We can now use our results from Table 3 to adjust futures-based forecasts for risk premia. Panel B in Table 8 reports the summary statistics of these forecasts. Since the forecasts are mean zero by construction, we do not report the corresponding rows. For short horizons, the absolute errors are comparable to those under the expectations hypothesis. For long-horizon forecasts, however, risk-adjusted forecasts are more successful than unadjusted forecasts. The difference between the two types of forecasts is 15 basis points. Also, while risk-adjusted forecasts still produce autocorrelated mistakes, the autocorrelation coefficients tend to be smaller than for unadjusted forecasts.

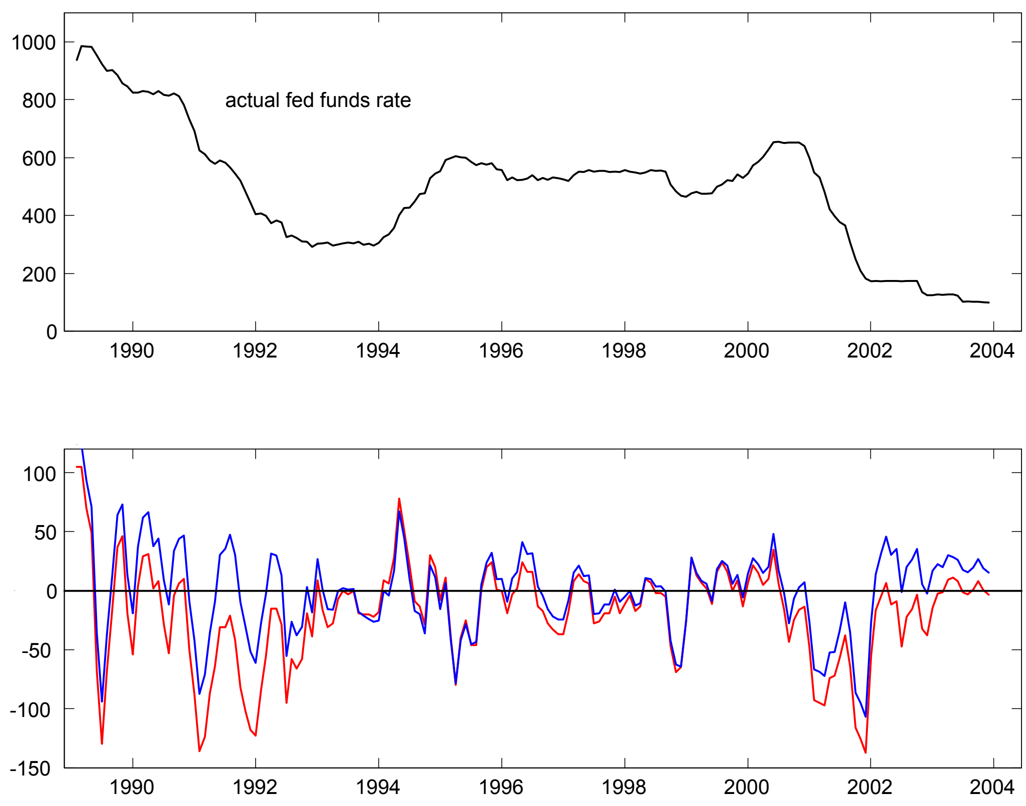

Figure 6: The upper panel shows the actual funds rate. The lower panel shows forecast errors with unadjusted (red) and adjusted forecasts (blue).

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