Market-Based Measures of Monetary Policy Expectations[*]

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Abstract

A number of recent papers have used short-maturity financial instruments to measure expectations of the future course of monetary policy, and have used high-frequency changes in these instruments around FOMC dates to measure monetary policy shocks. This paper evaluates the empirical success of a variety of market instruments in predicting the future path of monetary policy. We find that federal funds futures dominate other market-based measures of monetary policy expectations at horizons out several months. For longer horizons, the predictive power of many of the instruments considered is very similar. In addition, we present evidence that monetary policy shocks computed using the current-month federal funds futures contract are influenced by changes in the timing of policy actions that do not influence the expected course of policy beyond a horizon of about six weeks. We propose alternative shock measures that capture changes in market expectations of policy over slightly longer horizons.

1. Introduction

Measures of monetary policy expectations are an important element of many empirical papers in the macroeconomics and finance literatures. Lately, a strand of literature has focused on measuring policy expectations from asset prices. In this context, market interest rates have often been used to parse out the unexpected component of policy decisions—often referred to as monetary policy shocks. An important issue in this approach is the choice of the proper asset to be used in measuring expectations. The abundance of short-term interest rates that potentially measure federal funds rate expectations has led to a proliferation of asset-price-based monetary policy expectation measures. For example, 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.

This paper evaluates the ability of these and other market interest rates to capture expectations of the future course of monetary policy and, correspondingly, to measure monetary policy shocks. We first review some of the market interest rates that could be used in this context, describing the markets for each of those instruments and highlighting the potential benefits and shortcomings of each as a measure of policy expectations. We then perform empirical tests to evaluate the extent to which different market rates forecast changes in the federal funds rate over different horizons, under the interpretation

that those instruments that have the highest predictive power will best incorporate policy expectations.

The results indicate that since 1994, federal funds futures rates dominate all other market interest rates for predicting changes in the federal funds rate over horizons out several months. For longer horizons, the predictive power of many of the instruments considered is very similar, with eurodollar futures rates edging out many of the other market rates at horizons out to one year.

These findings have important implications for measuring monetary policy shocks. In many of the papers using market-based measures of policy expectations, policy shocks correspond to revisions to the expected path of the federal funds rate at the time of policy decisions. Based on our findings, it appears that the best measure of shocks to the immediate policy setting would be based on federal funds futures rates, such as the approach described by Kuttner (2001). However, as he discusses, shocks to the immediate policy setting can be influenced by shifts in the timing of policy actions that would presumably have limited effects on asset prices or the economy. We therefore compute two alternative measures of policy shocks based on the rates on federal funds and eurodollar futures with slightly longer horizons rates. Those shocks capture changes to the expected near-term policy path rather than the immediate policy setting, and hence are less influenced by the timing of policy actions.

2. Rates that Potentially Measure Monetary Policy Expectations

Expectations about the near-term course of monetary policy are an important determinant of most short-term market interest rates. This relationship is very explicit in

some cases. For example, federal funds futures are contracts where the payout on the instrument is directly linked to the realized level of the federal funds rate. In other cases the relationship arises because investors can potentially substitute between different strategies for obtaining short-term returns. In this section we review a number of market interest rates that could be used to measure monetary policy expectations. The discussion touches on characteristics of the underlying instruments that might influence their information content, including the liquidity of the instruments and the potential size of the risk premia that also influence these rates.

Term Federal Funds Rates. The federal funds rate—the policy instrument of the Federal Reserve—is the rate at which banks make unsecured loans to one another on an overnight basis. But banks can also borrow and lend to one another for longer periods in the federal funds market. The rates on these longer-term loans, or term federal funds rates, should provide information about expected future levels of the overnight federal funds rate, given the ability of banks to substitute between locking in a longer-term rate for borrowing (lending) and rolling over overnight borrowing (lending) over the same horizon. By far the most active segment of the federal funds market is in overnight lending, which is appealing to banks given the uncertainties in daily fluctuations of reserve needs and the ability to lock in longer-term financing in other markets. There is some activity in the market for loans out to maturities of six months, but virtually no activity beyond that horizon.

Federal Funds Futures Rates. In 1988, the Chicago Board of Trade (CBOT) introduced federal funds futures contracts. These contracts have a payout at maturity based on the average effective federal funds rate during the month of expiration. Thus,

the value of these securities is importantly affected by the expected month-average federal funds rate.[1] The CBOT offers contracts with monthly expirations out to two years, but most trading activity is concentrated in contracts with shorter horizons. Currently, federal funds futures contracts are extremely liquid at expirations out to three months and are still fairly liquid out a few more months, but liquidity drops off sharply at horizons beyond that. Open interest in federal funds futures contracts has risen considerably over the past several years.

Term Eurodollar Deposit Rates. Term eurodollars are dollar-denominated time deposits held at financial institutions outside the United States. Eurodollar deposit maturities range from overnight to several years, although volumes fall off considerably after one year—indeed, the British Bankers' Association does not provide quotes for eurodollar deposit rates (or Libor rates) for maturities longer than one year. The set of participants on the eurodollar market may differ in credit quality from those in the term federal funds market, which could potentially drive a wedge between Libor rates and the corresponding term federal funds rate. Nevertheless, many large banks do actively substitute between domestic deposits and eurodollar deposits, suggesting that the linkage is fairly tight.

Eurodollar Futures Rates. Eurodollar futures have traded on the Chicago Mercantile Exchange (CME) since 1982 and are the most actively traded futures instruments in the world. These contracts are cash settled based on the quoted three-month Libor rate on the settlement date. Contracts expiring in March, June, September

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[1] More specifically, the value of the contract at expiration is equal to *100-r*, where *r* is the average effective federal funds rate for the expiration month. In the following analysis, we will use the implied rates from these contracts, or the rate *r* corresponding to the settlement prices on the contracts. Eurodollar futures are priced using the same convention.

and December are available out to horizons of ten years, although liquidity tends to decline at longer horizons.[2] Volume and open interest are exceptionally high, however, for contracts expiring over the first several years. Of course, the value of these contracts is directly tied to Libor rather than to the federal funds rate, and hence the success of these contracts for predicting U.S. monetary policy depends, as with term eurodollars, on the extent to which Libor tracks the federal funds rate in the markets.

Treasury Bill Rates. The U.S. Treasury bill market trades the short-term debt instruments of the U.S government, and is known for its extraordinary liquidity, high volume, and narrow bid-ask spreads. At various times, the U.S. Treasury has issued bills with maturities ranging from one month to one year, but has only consistently offered three-month and six-month securities over our sample period. Treasury bills have some tax advantages, and are viewed as being free of credit risk, while the federal funds rate is a private short-term interest rate that has no tax advantages and contains credit risk, which introduces a potential shortcoming of bill rates as a predictor of future federal funds rates. Nevertheless, the linkage between these short-term rates is thought to be fairly tight.

Commercial Paper Rates. Commercial paper (CP) is unsecured debt with maturity shorter than 270 days issued by investment-grade corporations. The U.S. CP market is larger even than the Treasury bill market, but almost all of the activity lies in direct placements, with very thin secondary market trading. CP issuance is concentrated at maturities of less than 90 days, with an average maturity of around 30 days. The

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[2] The CME offers futures contracts for the other months once they are within [six] months of expiration. However, liquidity in those contracts is well below those of the quarter-end months. In addition, the CME offers futures on one-month Libor rates with monthly expirations. However, these contracts also are less liquid. We do not consider these contracts in this paper.

linkage between CP and federal funds arises because investors can substitute between

holding CP and making federal funds loans (or holding other short-term assets whose

rates are influenced by the federal funds rate).

3. Deriving the Forecasting Equations

This section describes the empirical framework that will be used to compare the

predictive power of the various market instruments considered. The ability of investors

to substitute between different investment strategies suggests that the rate of return $r_{t,t+k}$

on a market instrument from day t to day $t+k$ is determined by the expected rate of return

from an investment strategy of rolling over overnight loans in the federal funds market

from day t to day $t+k$, up to a risk premium ρ:

$$r_{t,t+k} = E_t \left[\prod_{j=t}^{t+k-1} (1 + ff_j) - 1 \right] + \rho , \qquad (1)$$

where ff_j is the overnight federal funds rate on day j. A common approach in the

literature is to assume that the risk premium is time-invariant.[3]

One way to motivate equation (1) is through the following theoretical analysis.

Standard asset pricing theory implies that, in the absence of arbitrage opportunities, any

asset i with net rate of return $r_{t,t+k}$ from day t to day $t+k$ must in equilibrium satisfy:

$$E_t[(1 + r_{t,t+k}) M_{t,t+k}] = 1 , \qquad (2)$$

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[3]This assumption is often referred to as the "expectations hypothesis" in the literature. It should be noted
that the expectations hypothesis is not rejected for the relatively short-term instruments considered in our
paper, over our sample period (1994-2001). However, we will still discuss to what extent and in what
respects systematic time-variation in risk premia are a potential issue for our results below.

where $M_{t,t+k}$ is the stochastic pricing kernel (see, for example, Campbell, Lo, and MacKinlay, 1997, for an introduction to stochastic pricing kernels). From (2), the following equation must hold:

$$E_t\left[(1+r_{t,t+k})\right] = \frac{\left(1 - Cov\left((1+r_{t,t+k}), M_{t,t+k}\right)\right)}{E_t\left[M_{t,t+k}\right]} \qquad . \tag{3}$$

Equation (3) states that investors will demand a higher expected return to hold assets for which the returns covary more negatively with the pricing kernel.

A similar equation holds for the net rate of return from the investment strategy of rolling over overnight loans in the federal funds market from day t to day $t+k$. In that case, however, the gross return on the "asset" is $\prod_{j=t}^{t+k-1}(1+ff_j)$. Writing out equation (3) for both assets and differencing yields:

$$E_t\left[(1+r_{t,t+k})\right] = E_t\left[\prod_{j=t}^{t+k-1}(1+ff_j)\right] + \frac{\left(Cov\left(\prod_{j=t}^{t+k-1}(1+ff_j), M_{t,t+k}\right) - Cov\left((1+r_{t,t+k}, M_{t,t+k})\right)\right)}{E_t\left[M_{t,t+k}\right]} . \tag{4}$$

In other words, the expected gross return on asset i equals the expected return to lending in the overnight federal funds market, plus an additional term that reflects the difference in covariances of the two assets with the pricing kernel.

Of course, we do not directly observe the expected return on asset i. For a market interest rate $r_{t,t+k}$ at day t with maturity date $t+k$, the expected return is the quoted yield adjusted for the probability of default. The risk premium ρ between asset i and the federal funds rate is then defined as the sum of the last term in equation (4) and the

expected loss from the possibility of default.[4] Under that definition, equation (1) follows

immediately from equation (4).

To implement equation (1), we rearrange terms to arrive at the following

regression equation:

$$\bar{f\!f}_{t,t+k} = \alpha + \beta \cdot r_{t,t+k} + \varepsilon_t , \tag{5}$$

where, to simplify notation, we let $\bar{f\!f}_{t,t+k} = \left[\prod_{j=t}^{t+k-1} (1 + f\!f_j) - 1 \right]$ equal the (compounded)

return to the strategy of rolling over federal funds loans. Equation (5) is a standard

interest rate forecasting regression that has been widely used in the literature. Under the

assumptions of no arbitrage opportunities and constant risk premia, we should find β

equal to 1, α equal to $-\rho$ (the negative of the risk premium on the asset), and the residual

ε_t equal to the forecast error $\bar{f\!f}_{t,t+k} - E_t \bar{f\!f}_{t,t+k}$, which is uncorrelated with all information

at time t. We will also be interested in the R^2 statistic from this regression, as it provides

a basis for comparing the ability of different market interest rates $r_{t,t+k}$ to forecast future

values of the federal funds rate.

An econometric issue arises in estimating equation (5) directly, however. If the

nominal rates of return in the equation are integrated variables (or nearly so), the

estimated coefficients will be dominated by their long-run relationship (the cointegrating

vector), regardless of their short-run relationships. Since we are primarily interested in

their short-run relationships—that is, in the ability of market rates to predict the funds

rate over the next several months or quarters—we follow common practice and

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[4] Note that this risk premium could possibly be negative for some assets, a possibility which we confirm
empirically for Treasury Bills below. This can happen when an asset's covariance with the stochastic
pricing kernel is smaller in magnitude than the federal funds rate's covariance with the kernel.

"stochastically detrend" (5) by subtracting off the current level of the federal funds rate from both sides of the equation:

$$\bar{ff}_{t,t+k} - ff_t = \alpha + \beta \cdot \left(r_{t,t+k} - ff_t \right) + \varepsilon_t \tag{6}$$

The coefficients α and β have the same interpretations as before, but the R^2 statistic now measures the fraction of *changes* in the federal funds rate explained by the yield *spread*.

Equation (6) forms the basis of our empirical investigation for all our term interest rates below (term federal funds loans, eurodollar deposits, Treasury bills, and commercial paper). Of course, we are also interested in federal funds and eurodollar *futures*. While term interest rates predict the federal funds rate over some interval beginning at time t, futures rates predict the federal funds rate over some interval beginning at some point in the future. Let $f_{t,t+k,n}$ denote the futures market quote on day t for a guaranteed n-day return of $r_{t+k,t+k+n}$ on a loan from day $t+k$ to day $t+k+n$. A derivation analogous to the above yields the regression equation:

$$\bar{ff}_{t+k,t+k+n} - ff_t = \alpha + \beta \cdot \left(f_{t,t+k,n} - ff_t \right) + \varepsilon_t, \tag{7}$$

where β should again equal 1, α should equal $-\rho$ (the negative of the sum of the risk premia on the underlying asset and the futures contract), and ε_t represents the forecast error $\bar{ff}_{t+k,t+k+n} - E_t \bar{ff}_{t+k,t+k+n}$. The R^2 statistic from this regression now reflects the ability of the futures rate to predict changes in the federal funds rate from its current level to its average level over some interval in the future.

We use equation (7) for eurodollar futures and for forward rates derived from market interest rates (discussed in more detail in the next section). For federal funds futures, however, we must replace the left-most term in (8) (the compounded federal

funds rate) with the straight average of the federal funds rate over the expiration month (without compounding), because this is the basis for the cash settlement specified in the federal funds futures contracts.

4. The Predictive Power of Market Instruments

We now turn to the results obtained from running the above regression specifications on our various market instruments. An immediate difficulty is that some of the instruments are term interest rates while others are futures rates, which forecast the federal funds rate over different periods. Indeed, the previous section derived two equations for testing the predictive power of market interest rates—equation (6) for term rates and equation (7) for futures and forward rates. To be able to make direct comparisons across the various instruments in our sample, we first derive forward rates from all of our term interest rates and rely exclusively on equation (7).[5]

We will use the R^2 statistic from regression (7)—which measures the ability of the forward or futures rates to predict the change in the federal funds rate from today to its average level in some subsequent month—as the basis for our comparison of the different instruments.[6] We take as our sample the period from January 1994 through May 2001. The starting date of the sample is convenient because the FOMC began to announce its policy decisions in 1994. The horizons covered by our instruments reach as far ahead as

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[5] The forward interest rate is the rate that an investor would demand today for making an investment at some point in the future, which can be derived from term interest rates bracketing the period of the forward rate. Forward rates and futures rates are not identical instruments, however. Because the value of a term investment is a non-linear function of the interest rate, forward rates are influenced by "convexity." In contrast, the value of a futures contract at expiration is linear in the interest rate levels, and thus futures rates are not influenced by convexity. This may benefit the relative predictive power of futures rates when there is time-varying interest rate volatility.
[6] Results using the root-mean square error (RMSE) are very similar in all cases, since the two measures essentially summarize the same information.

twelve months, as described in Table 1. Each regression also includes two dummy variables to capture systematic spikes in risk premia: a Y2K dummy variable that is nonzero for the observation spanning the century date change, and a year-end dummy variable that is nonzero for observations spanning the end of any year.[7]

For our first set of regressions, we compute one-month forward rates at horizons one to six months ahead. Unfortunately, eurodollar futures have quarterly expiration dates, and our Treasury bill quotes include quarterly maturities only. Thus, we cannot compute one-month forward rates for these instruments, and so they must be excluded from this first set of results. The readings of the market rates are monthly, with observations taken near the end of the month.[8]

The performance of the various forward and futures rates in forecasting the federal funds rate is summarized in Figure 1. The figure shows the R^2 statistics from the forecasting regressions (8) as a function of the horizon considered, with each line corresponding to a different type of market instrument.[9] Overall, the ability of the market-based instruments to predict the federal funds rate is remarkable—the R^2 statistics often fall in the 50 to 80 percent range for the horizons considered.[10] Moreover, the coefficient on the yield spread, β, is almost always equal to 1, consistent with the theory presented above. The exceptional performance of this equation since 1994 is consistent with the notion that markets have become more successful at anticipating monetary policy actions in the 1990s, as discussed in Lange, Sack, and Whitesell (2002).

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[7] Downing and Oliner (2002) discuss the importance of accounting for the year-end premium in testing the expectations hypothesis on commercial paper.

[8] See appendix A for more details on quoting conventions and the construction of forward rates.

[9] All the instruments have a higher R^2 statistic at a two-month horizon than at a one-month horizon. This is due to the fact that there is little systematic variation in the dependent variable to explain at a horizon of only one month—indeed, the next policy meeting is three weeks away on average. RMSEs are in fact strictly increasing with the length of the forecast horizon for all of our instruments, as one would expect.

[10] Tables reporting all of the regression results underlying Figures 1 and 2 are given in appendix B.

Regarding the relative predictive power of the various instruments, the most striking finding is that federal funds futures dominate all other instruments for predicting near-term changes in the federal funds rate. The difference in the relative performances is substantial over the first several months, where the liquidity of the federal funds futures contracts is at its highest. These findings suggest that federal funds futures provide the most accurate measure of the expected near-term path of monetary policy.[11]

Other instruments do a fairly effective job at forecasting the funds rate as well. Term federal funds loans and eurodollar deposits are very comparable in performance, with R^2 statistics approaching that of the federal funds futures for horizons of three months or longer. Commercial paper performs better than term federal funds or eurodollar deposit rates over the first two months, although its performance drops off at the three-month horizon, perhaps because the market is less active at longer maturities.

The performance of the various market-based measures can be directly compared by including them in a single prediction regression. The results of this exercise are shown in Table 2. For horizons out to four months, only the coefficient on the federal funds futures rate is significant, indicating that it dominates all the other market rates over that region. We can test the hypothesis that the federal funds futures rate is "encompassing"—or summarizes all of the information in the other instruments—by testing (jointly) that its coefficient equals 1 and that the coefficients on the other measures equal 0. As evident from the bottom of the table, we cannot reject the hypothesis that the federal funds futures rate is encompassing for horizons out to four

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[11] This finding seems to contradict Söderström (2001), who finds that federal funds futures rates have weak predictive power. The difference from our approach is that Söderström uses futures rates to forecast the funds rate for the remainder of the spot month, rather than for future months. The predictive power of federal funds futures rates has also been investigated by Krueger and Kuttner (1996), Carlson, McIntire, and Thomson (1995), and Robertson and Thornton (1997).

months, except for a marginal rejection at three months. Moreover, we can reject that

any of the other market rates are encompassing, with the exception of eurodollar deposit

rates at horizons of four months.[12] At a horizon of five and six months, eurodollar

deposits are the preferred measure.

The second set of results that we present is based on predicting quarterly averages

of the federal funds rate over horizons out to one year. For Treasury bills and eurodollar

futures, a quarter is the shortest horizon of expectations that could be computed. We also

include term federal funds and eurodollar deposit rates by computing one-quarter forward

rates. The readings of the market interest rates are quarterly, with observations taken just

before the expiration dates of the eurodollar futures contracts. Of course, moving from

monthly to quarterly frequency decreases the number of observations significantly, which

could limit our ability to distinguish between the predictive power of the various

measures.

The results are shown in Figure 2, which is presented in the same manner as

Figure 1. The performances of the rates on eurodollar futures, eurodollar deposits, and

term federal funds loans are very similar, with eurodollar futures rates edging out the

other two at horizons of one, two, and four quarters. The Treasury bill rate performs very

well at the two-quarter horizon (in fact, it has the highest R^2 by a slight margin) but does

poorly over one quarter. One reason for this may be that the Treasury bill market is more

segmented at shorter maturities, which allows its rate to be more idiosyncratic.

Similar conclusions emerge from Table 3, which provides a direct comparison of

the measures analogous to Table 2. Overall, the multicollinearity of the regressors tends

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[12] We also experimented with the methods for combining forecasts described in Clemen and Winkler
(1986). We could not reject the hypothesis that federal funds futures performed as well as those measures.

to wipe out the significance of the individual regressors and to allow more than one measure to be encompassing at most horizons. The eurodollar futures rate is encompassing at all horizons except two quarters. At the two-quarter horizon, the regression prefers the Treasury bill rate, consistent with the higher R^2 statistic shown in Figure 2. The results indicate that other market rates are also encompassing at different horizons, including the term federal funds rate at horizons of one, three, and four quarters and Libor rates at horizons of two and four quarters.

One possible explanation for the similarity of the performance of different market rates is that these instruments are to a large extent priced off one another. The eurodollar futures contract is the most liquid instrument at horizons beyond a couple of quarters, and hence it is likely to be widely used to derive the quoted rates on eurodollar deposits and term federal funds loans.

5. The Risk Premia Embedded in Market Rates

While the previous section focused on the ability of the market interest rates considered to forecast future changes in the federal funds rate, the results also provide some evidence on the magnitude of the risk premium embedded in those rates. In particular, if the slope coefficient from the above regressions is restricted to 1, the negative of the constant will measure the average excess return (relative to rolling over overnight federal funds loans) that was earned over the sample by holding that instrument, which, in a long enough sample, will primarily reflect the risk premium on that instrument (as defined in section 3). In the following, we calculate the risk premia for the forward rate regressions (8) used in Figures 1 and 2, only imposing that the slope

16

coefficient equals 1 in each regression. Since we found that most slope coefficients were not statistically different from 1, this is not a strong assumption. The results are shown in Figures 3 and 4, which are presented in the same way as the earlier figures.[13]

As is evident from Figure 3, the risk premia embedded in federal funds futures rates are quite small, beginning at just a few basis points for one-month contracts and increasing only a few basis points per month thereafter. The risk premia embedded in other instruments are more sizable, because they embed the credit risk associated with lending to an institution for a longer period than overnight (the basis for the pricing of the federal funds futures). Eurodollar deposits have risk premia that begin around 15 basis points and increase steadily to over 35 basis points for forward rates six months ahead. Risk premia on term federal funds loans are about the same in magnitude, which is not surprising given the similarities of the two markets. Commercial paper, on the other hand, has a smaller risk premium, possibly because the market is composed of very high quality borrowers who are typically required to have backup lines of credit.[14]

Similar patterns are seen across the four instruments for the quarterly horizons, as shown in Figure 4. Note that the risk premium on eurodollar futures is smaller than that on eurodollar deposits or term federal funds loans, again because of the term structure of credit risk. The two-quarter-ahead forward rate on a eurodollar deposit, for example, is the rate that an investor would demand in order to commit to lending to a specific institution after two quarters. The two-quarter-ahead futures rate instead is, in essence, the rate at which an investor would commit to lend to a firm that is guaranteed to be in

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[13] Unfortunately, the risk premia estimates are fairly sensitive to the sample chosen, most likely because the constant term is also influenced by the average expectation error, which can be non-zero in the short samples considered.

[14] In this paper we use the rates on high quality A1/P1 securities. Using the rates on lower quality A2/P2 paper makes CP perform much worse, as expected.

the British Bankers' Association Libor panel after two quarters, which is a less risky proposition. The risk premium on Treasury securities is instead extremely small, and even negative for the three-month bill, as these instruments have essentially no credit risk and tax advantages that may lower their yields.

To the extent that these risk premia are constant, one can simply adjust a given market quote by our estimated constant term to obtain a more precise reading of policy expectations. However, to the extent that these risk premia also change over time, they could contaminate our instruments as measures of monetary policy expectations. [15] We discuss this possibility in greater detail below.

6. Measuring Monetary Policy Shocks

The results from section 4 indicated that market interest rates provide useful measures of monetary policy expectations. However, in many applications one might want to focus on *changes* in policy expectations. Indeed, changes to those expectations that occur at the times of Federal Reserve policy meetings or policy actions have been cited by a number of authors as measures of monetary policy shocks. Such measures can be obtained from changes in the market rates discussed above, where different market rates can be used to capture shifts in expectations over different horizons.

Measures of Policy Shocks. The above results indicate that federal funds futures provide the best measures of near-term policy expectations and, one would presume,

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[15] In addition, the risk premia may exhibit predictable patterns over the calendar year. For example, private lending rates (CP, term federal funds, and eurodollars) often tick higher when they span the quarter-end or year-end, as firms are reluctant to have such loans on their books for their quarterly reporting requirements. In the federal funds futures market, market participants frequently take into account the tendency of the funds rate to be soft or firm relative to its target not just on quarter-ends, but on Treasury settlement dates, holidays, and the ends of maintenance periods. Thus, one might be able to improve the predictive performance of the various market rates by assuming some structure to the risk premium. We have taken the first step in that direction by allowing for a year-end and a "Y2K" premium on our various instruments.

changes to those expectations. A small complication arises with federal funds futures because their rates are based on the average federal funds rate realized over the expiration month. This feature necessitates an adjustment for the timing of policy meetings within the month. As described by Kuttner (2001), one can use the current month federal funds futures contract to compute a shock that captures the revision to the federal funds rate expected from the time of an FOMC meeting (or intermeeting action) through the end of the current month, as follows:

$$mp1_t = \frac{D1}{D1 - d1} \Delta ff1_t,$$ (8)

where $\Delta ff1_t$ is the change in the current month federal funds futures rate on the day of the FOMC meeting, $d1$ is the day of the month of the meeting, and $D1$ is the total number of days in the month. Equation (8) can be obtained by observing that the day before the FOMC meeting, the current month futures rate is

$$ff1_{t-1} = \frac{d1}{D1} \bar{ff} + \frac{D1 - d1}{D1} E_{t-1}\bar{ff}_t + \rho,$$ (9)

where $\bar{ff}$ is the average effective funds rate observed over the first $d1$ days of the month (leading up to the FOMC meeting) and $E_{t-1}\bar{ff}_t$ is the expected average effective funds rate from the FOMC date until the end of the month. At time t, $\bar{ff}_t$ is observed, so that leading equation (9) by one period and differencing gives $mp1_t = \bar{ff}_t - E_{t-1}\bar{ff}_t$.

A measure can also be constructed to capture the change in the federal funds rate expected to prevail after the *next* FOMC meeting.[16] Given the unexpected change in the

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[16] Demiralp and Gürkaynak (2002) discuss ways of measuring changes in expected policy moves and interest rates at various future dates.

federal funds rate following the current meeting, $mp1_t$, the change in the rate expected after the subsequent meeting, $mp2_t$, can be calculated as follows:

$$mp2_t = \frac{D2}{D2 - d2}(\Delta ff2_t - \frac{d2}{D2} mp1_t) ,$$ (10)

where $\Delta ff2_t$ is the change in the federal funds futures contract for the month of the next FOMC meeting.

To derive the unexpected change to the policy path at longer horizons, one might want to use eurodollar futures, given their impressive liquidity and the fact that they perform slightly better than many of the other instruments in predicting the federal funds rate over horizons out to a year (see section 4). Eurodollar futures have the complication that they expire only quarterly, which creates some variation in the horizons of the contracts available on FOMC meeting dates. However, one can use a combination of the first two eurodollar futures contracts to compute the revision to the federal funds rate expected to prevail for a fixed horizon of three to six months ahead, which will approximately capture the average funds rate expected not at the current or the next FOMC meetings, but at the two meetings after that. In particular, this procedure involves taking a simple average of the rates on the first two eurodollar contracts, where the weights depend on their time to expiration, as follows:

$$mp3_t = \frac{d3}{91} \cdot \Delta ed1_t + \frac{91 - d3}{91} \cdot \Delta ed2_t,$$ (11)

where *d3* is the number of days to the expiration of the first eurodollar futures contract.

Figure 5 compares the three shock measures using scatter plots. The shocks are highly correlated with one another, as the observations generally fall along the 45-degree line. However, the shocks differ considerably on some dates—particularly the *mp1* and

20

mp2 measures. We argue that these differences largely reflect revisions to the expected timing of policy actions, as addressed next.

  The Influence of Timing Shocks. The appropriate horizon to be considered by the shock measure will depend on the specific application, as policy shocks measured over different horizons simply capture different information. However, an important consideration is the extent to which these shocks are influenced by changes in the expected timing of policy actions, as opposed to shifts in the near-term path of policy expectations.

  As discussed above, although the policy shocks *mp1* likely provide the best measure of unexpected changes to the immediate policy setting, they might be affected by shifts in the timing of policy actions.[17] To get at this issue, we perform a simple exercise that decomposes the policy shocks into two components: one that influences the path of policy expectations (the "path" factor), and one that represents shifts in the timing of policy actions at the two meetings (the "time" factor). Formally, the decomposition is as follows:

$$\begin{bmatrix} mp1_t \\ mp2_t \end{bmatrix} = \begin{bmatrix} 1 & 1 \\ \alpha & 0 \end{bmatrix} \cdot \begin{bmatrix} path \\ time \end{bmatrix} \quad .$$

Note that increases in either factor, *path* or *time*, push up the current FOMC policy shock $mp1_t$. An increase in *path* reflects a shift to the expected near-term path of the interest rate, with the rate after the subsequent FOMC meeting going up by α. By contrast, an increase in *time* has no effect on the level of the funds rate expected after the subsequent FOMC meeting, but only on the timing of policy actions across the two meetings.

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[17] Rigobon and Sack (2002) point to this issue in motivating their use of the three-month eurodollar futures rate to measure policy shocks.

We solve this decomposition based on the variance-covariance matrix from the observed policy shocks, under the assumption that the two factors are orthogonal. The estimated value of α is 1.11, suggesting that the *path* factor is a nearly parallel shift in the policy outlook. Both types of shocks are sizable: The standard deviation of path shocks is 7.4 basis points, compared to 6.6 basis points for timing shocks. Figure 6 shows the realized values of the two factors since 1994.

One observation that stands out is that timing shocks were more sizable early in the sample, particularly in 1994 and 1995. This finding might reflect the shift in the behavior of the FOMC beginning in 1994, when it began to make policy moves predominantly at FOMC meetings. The results suggest that it might have taken market participants some time to fully recognize this shift in behavior.[18] In recent years, some of the largest timing surprises have taken place at intermeeting policy moves. Indeed, two of the three sizable timing shocks in 2001 took place on January 3 and September 17.

The measure *mp1* is strongly influenced by these timing shocks, which account for 44 percent of its variance over the sample (30 percent since 1995). The measure *mp2*, by construction, is not influenced at all by the timing shocks. Moreover, if we regress the measure *mp3* on the two identified factors, it responds significantly to the path shocks with a coefficient around 1, and it does not respond significantly to the timing shocks. Thus, one way to avoid the influence of changes in the timing of policy actions is to focus on these shocks measured over slightly longer horizons.

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[18] Because of its simple structure, the decomposition does not always capture the correct interpretation of market developments. For example, the FOMC easing in July 1995 was apparently viewed as suggesting that additional policy actions would be forthcoming. However, because α is estimated to be close to 1, the decomposition interprets the market response as a large negative shift in the path factor and a large positive shift in the timing factor.

Variation in Risk Premia. Of course, changes in market rates can also arise from changes in the risk premia that they embed, which could contaminate the shock measures computed above. This consideration argues in favor of using futures rates rather than term rates to measure policy shocks. As shown above in Figures 3 and 4, futures rates tend to have smaller risk premia than comparable term rates, for the reasons discussed earlier. Because they tend to be smaller, the risk premia on futures rates would presumably have less scope for variation.[19] This is clearly the case for federal funds futures, which have average premia of only a few basis points. Eurodollar futures rates have larger risk premia on average that, judging from evidence presented by Sack (2002), appear to vary over time. However, the results from that paper suggest that the daily variation in risk premia is fairly limited relative to the revisions in policy expectations that often take place around FOMC dates, at least for the contract horizons considered above.

Some additional evidence that the variation in the risk premium is relatively small comes directly from the prediction regressions estimated in section 4. Considerable time variation in the risk premium (if orthogonal to policy expectations) would tend to push the estimated coefficients β from equation (7) below 1. However, the coefficients from the regressions underlying Figures 1 and 2 instead are almost always close to 1 (see the tables in the appendix). In fact, the hypothesis that the coefficient equals 1 cannot be rejected for any of the instruments with horizons beyond one month. These findings suggest that most of the movements in the market instruments considered instead reflects the influence of policy expectations.

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[19] This would also be an argument for using the six-month Treasury bill rate, which has the smallest risk premium.

7. Conclusions

Two notable results emerge from this paper. First, federal funds futures clearly dominate other market-based measures of monetary policy expectations at horizons out to about five months. Their predictive power for the future federal funds rate is higher, their risk premium is lower, and we cannot reject the hypothesis that they encompass the information contained in all of our other market-based forecast measures combined.

Second, for horizons longer than a few months, eurodollar futures seem to provide the best measure of monetary policy expectations, but a number of other instruments are of comparable quality. This latter finding may reflect the degree to which these markets are integrated with one another.

These findings have important implications for the computation of monetary policy shocks. For changes in the very near-term stance of policy, our results support measures based on federal funds futures. However, we presented some statistical evidence that shocks computed from the current-month federal funds futures contract may be influenced by changes in the *timing* of policy actions that do not influence the expected course of the federal funds rate beyond a horizon of about six weeks. We thus computed alternative shock measures that capture changes in market expectations of the course of monetary policy over slightly longer horizons, which may be more appropriate for some purposes.

It is our hope that this paper will serve as a reference for, and encourage the use of, market-based measures of monetary policy expectations, including the use of these instruments for computing monetary policy surprises surrounding FOMC announcements and other high-frequency events.

References

Bomfim, Antulio (2002), "Pre-Announcement Effects, News Effects, and Volatility: Monetary Policy and the Stock Market," forthcoming, *Journal of Banking and Finance*.

Carlson, John B., Jean M. McIntire, and James B. Thomson, "Federal Funds Futures as an Indicator of Future Monetary Policy: A Primer," Federal Reserve Bank of Cleveland *Economic Review* 31, 20-30.

Clemen, Robert T. and Robert L. Winkler (1986), "Combining Economic Forecasts," *Journal of Business and Economic Statistics* 4, 39-46.

Cochrane, John H. and Monika Piazzessi (2002), "The Fed and Interest Rates: A High Frequency Identification," *American Economic Review Papers and Procedings* 92, 90-101.

Demiralp, Selva and Refet Gürkaynak (2002), "Monetary Policy Shocks from an Interest Rate Path Perspective," Mimeo, Board of Governors of the Federal Reserve System.

Downing, Chris and Steve Oliner, "The Term Structure of Commercial Paper Rates: Evidence of Time-Varying Risk Premia," Mimeo, Board of Governors of the Federal Reserve System.

Ellingson, Tore and Ulf Soderstrom (1999), "Monetary Policy and Market Interest Rates," Working Paper in Economics and Finance No. 242, Stockholm School of Economics.

Faust, Jon, Eric Swanson, and Jonathan H. Wright (2001), "Identifying VARs Based on High Frequency Futures Data," International Finance Discussion Papers No. 720, Board of Governors of the Federal Reserve System.

Krueger, Joel T. and Kenneth N. Kuttner (1996), "The Fed Funds Futures Rate as a Predictor of Federal Reserve Policy," *Journal of Futures Markets* 16, 865-879.

Kuttner, Kenneth (2001), "Monetary Policy Surprises and Interest Rates: Evidence from the Fed Funds Futures, *Journal of Monetary Economics*, 523-544.

Lange, Joe, Brian Sack, and William Whitesell (2002), "Anticipations of Monetary Policy in Financial Markets," forthcoming, *Journal of Money, Credit, and Banking*.

Poole, William and Robert H. Rasche (2000), "Perfecting the Market's Knowledge of Monetary Policy," *Journal of Financial Services Research*, 255-298.

Rigobon, Roberto and Brian Sack (2002), "The Impact of Monetary Policy on Asset Prices," National Bureau of Economic Research Working Paper No. 8794.

Robertson, John C. and Daniel L. Thornton, "Using Federal Funds Futures to Predict Federal Reserve Actions," Federal Reserve Bank of St. Louis *Review* 78, 19-31.

Sack, Brian (2002), "Extracting the Expected Path of Monetary Policy from Futures Rates," Mimeo, Board of Governors of the Federal Reserve System.

Soderstrom, Ulf (2001), "Predicting Monetary Policy with Federal Funds Futures Prices," *Journal of Futures Markets* 21, 377-391.

Table 1: Data Description

Instrument	Horizon Covered
Term Federal Funds Loans	1 to 12 Months
Federal Funds Futures	1 to 5 Months
Eurodollar Deposits	1 to 12 Months
Eurodollar Futures	1 to 4 Quarters
Treasury Bills	3 and 6 Months
Commercial Paper	1 to 3 Months

Notes: Data for federal funds futures and eurodollar futures are from CBOT and CME, respectively. Data for term federal funds loans are from Bloomberg, and that for eurodollar deposits are from the British Bankers Association. Treasury and commercial paper data come from the Federal Reserve's H.15 data release. Before 1997, the commercial paper data is based on a survey of dealers.

Table 2: Direct Comparison of Measures – Horizons of 1 to 6 Months

	--- Horizon (months) ---					
	1	2	3	4	5	6
Coefficients:						
Fed funds futures	1.03 (4.85)	1.26 (5.37)	0.98 (3.07)	0.75 (2.02)	0.46 (1.09)	--
Commercial paper	0.15 (0.78)	0.00 (0.01)	-0.26 (-1.64)	--	--	--
Term fed funds	-0.16 (-0.53)	0.03 (0.11)	0.27 (0.85)	0.42 (0.76)	0.57 (1.47)	0.13 (0.77)
Eurodollar deposits	-0.03 (-0.10)	-0.20 (-0.64)	0.11 (0.41)	-0.03 (-0.04)	0.11 (0.18)	0.95 (3.70)
Encompassing Tests (Significance):						
Fed funds futures	0.45	0.74	0.05	0.71	0.03	--
Commercial paper	0.00	0.00	0.00	--	--	--
Term fed funds	0.00	0.00	0.04	0.07	0.07	0.00
Eurodollar deposits	0.00	0.00	0.00	0.23	0.49	0.74

All regressions include a constant, a year-end dummy variable, and a Y2K dummy variable.
T-statistics shown in parentheses are robust to serially correlated errors.

Table 3: Direct Comparison of Measures -- Horizons of 1 to 4 Quarters

| | --- *Horizon (quarters)* --- | | | |
	1	2	3	4
Coefficients:				
Eurodollar futures	1.23 (1.02)	3.69 (2.67)	-0.05 (-0.05)	3.23 (1.13)
Treasury bills	0.14 (1.30)	0.46 (0.91)	--	--
Term fed funds	0.21 (0.31)	0.09 (0.06)	1.17 (0.94)	-2.73 (-1.71)
Eurodollar deposits	-0.36 (-0.32)	-3.25 (-2.29)	0.09 (0.07)	0.76 (0.30)
Encompassing Tests (Significance):				
Eurodollar futures	0.13	0.02	0.17	0.39
Treasury bills	0.00	0.09	--	--
Term fed funds	0.13	0.00	0.87	0.12
Eurodollar deposits	0.03	0.00	0.48	0.36

All regressions include a constant, a year-end dummy variable, and a Y2K dummy variable.
T-statistics shown in parentheses are robust to serially correlated errors.

Appendix A: Details on Quoting Conventions and Forward Rate Calculations

The market rates used in the analysis differ in terms of their quoting conventions and settlement periods, as described in the following table:

Description of Market Quotes

Instrument	Day Count	Settlement
Term Federal Funds Loans	360	t+2
Federal Funds Futures	*	*
Eurodollar Deposits	360	t+2
Eurodollar Futures	**	**
Treasury Bills	365	t+1
Commercial Paper	365	t
Overnight Federal Funds	360	t

* Based on the average value of the overnight federal funds rate over a month.
** Based on the value of the eurodollar deposit rate at expiration.

Given that these instruments are not coupon-bearing, the returns on each is simply the quoted rate multiplied by the number of days covered by the instrument and divided by the day count. To make the quoted rates comparable to one another, the first step we take is to convert all of the quotes to a 365 day count, which simply involves multiplying the quoted rates by 365/360. In addition, our commercial paper rates are quoted on a discount basis, and thus must first be converted to a coupon-equivalent basis before the above conversion. (Our Treasury bill quotes are on a coupon-equivalent basis, but this is not the case for many other data sources.) We also take account of the 360-day count of overnight federal funds in computing the dependent variable in our regressions.

Another complication arises from small differences in their maturity structures. For example, one-month term federal funds loans and eurodollar deposits mature on the same calendar day in the subsequent month, and thus the exact horizon covered can vary from 28 to 31 days. In contrast, "one-month" commercial paper always has a maturity of 30 days. To account for this, in computing the dependent variable of the regressions, we

construct the compounded overnight federal funds rate return ($\bar{ff}_{t,t+k} = \left[\prod_{j=t}^{t+k-1}(1+ff_j)-1 \right]$)

separately for each market instrument, in each case exactly matching the horizon spanned by that instrument.

The horizon covered by the dependent variable also varies due to the different settlement procedures on the instruments. As shown in the table, those procedures range from same-day settlement to two-day settlement. While we can adjust the dependent variable accordingly, these differences leave a small discrepancy in the comparison of the instruments. For example, term federal funds predict the overnight federal funds rate beginning two business days forward, while commercial paper predicts the overnight federal funds rate beginning the same day. This gives a slight advantage to commercial paper. Treasury bills also have an advantage given that they have next-day settlement; eurodollar deposits instead have two-day settlement. By design, federal funds futures predict the overnight funds rate over a fixed calendar month. To make their horizon comparable to two-day settlement, we take our monthly quotes on the second to last business day of the month.

Lastly, we review the construction of forward rates from the rates on term deposits. Consider calculating the one-month forward rate beginning two months ahead, denoted *fwd*. The forward rate is defined by the following equation:

$$\left(1+r3\cdot\frac{d3}{365}\right)=\left(1+r2\cdot\frac{d2}{365}\right)\cdot\left(1+fwd\cdot\frac{d3-d2}{365}\right),$$

where *r2* and *r3* are the two- and three-month interest rates, respectively, and *d2* and *d3* are the number of days covered by those rates. Thus, the forward rate can be calculated as follows:

$$fwd = \left[\frac{\left(1+r3\cdot\dfrac{d3}{365}\right)}{\left(1+r2\cdot\dfrac{d2}{365}\right)} - 1 \right]\cdot\frac{365}{d3-d2}.$$

Note, however, that the day counts *d2* and *d3* will vary across instruments and across time, given the maturity differences mentioned above.

Appendix B: Regression Results

This appendix reports the results from the regressions underlying Figures 1 and 2.

Monthly Regressions
Estimates of Equation (7)

|	α	β	R^2	Sig: $\beta=1$
Federal Funds Futures:				
One-month	-0.02 (-1.82)	0.96 (10.11)	0.62	.65
Two-month	-0.07 (-2.87)	1.08 (10.11)	0.74	.43
Three-month	-0.10 (-2.08)	1.12 (7.11)	0.73	.44
Four-month	-0.14 (-1.68)	1.15 (5.37)	0.68	.49
Five-month	-0.19 (-1.53)	1.15 (4.59)	0.63	.55
Term Federal Funds Loans:				
One-month	-0.01 (-0.35)	0.55 (4.04)	0.33	.00
Two-month	-0.15 (-3.45)	0.92 (7.97)	0.62	.50
Three-month	-0.24 (-3.13)	1.00 (6.55)	0.71	.99
Four-month	-0.28 (-2.42)	1.10 (5.17)	0.67	.63
Five-month	-0.37 (-2.34)	1.12 (5.09)	0.63	.59
Six-month	-0.35 (-1.47)	0.99 (3.40)	0.49	.97
Eurodollar Deposits				
One-month	-0.04 (-0.94)	0.61 (3.81)	0.33	.02
Two-month	-0.19 (-3.67)	0.94 (7.76)	0.63	.64
Three-month	-0.30 (-3.46)	1.08 (6.37)	0.71	.66
Four-month	-0.32 (-2.42)	1.11 (5.00)	0.66	.62
Five-month	-0.38 (-2.23)	1.13 (4.77)	0.63	.58
Six-month	-0.42 (-1.79)	1.08 (3.62)	0.55	.80
Commercial Paper:				
One-month	-0.01 (-0.33)	0.67 (7.94)	0.52	.00
Two-month	-0.07 (-2.12)	0.89 (8.19)	0.64	.34
Three-month	-0.12 (-1.40)	0.92 (4.49)	0.58	.68

All regressions include a constant, a year-end dummy variable, and a Y2K dummy variable.
T-statistics shown in parentheses are robust to serially correlated errors.

Quarterly Regressions
Estimates of Equation (7)

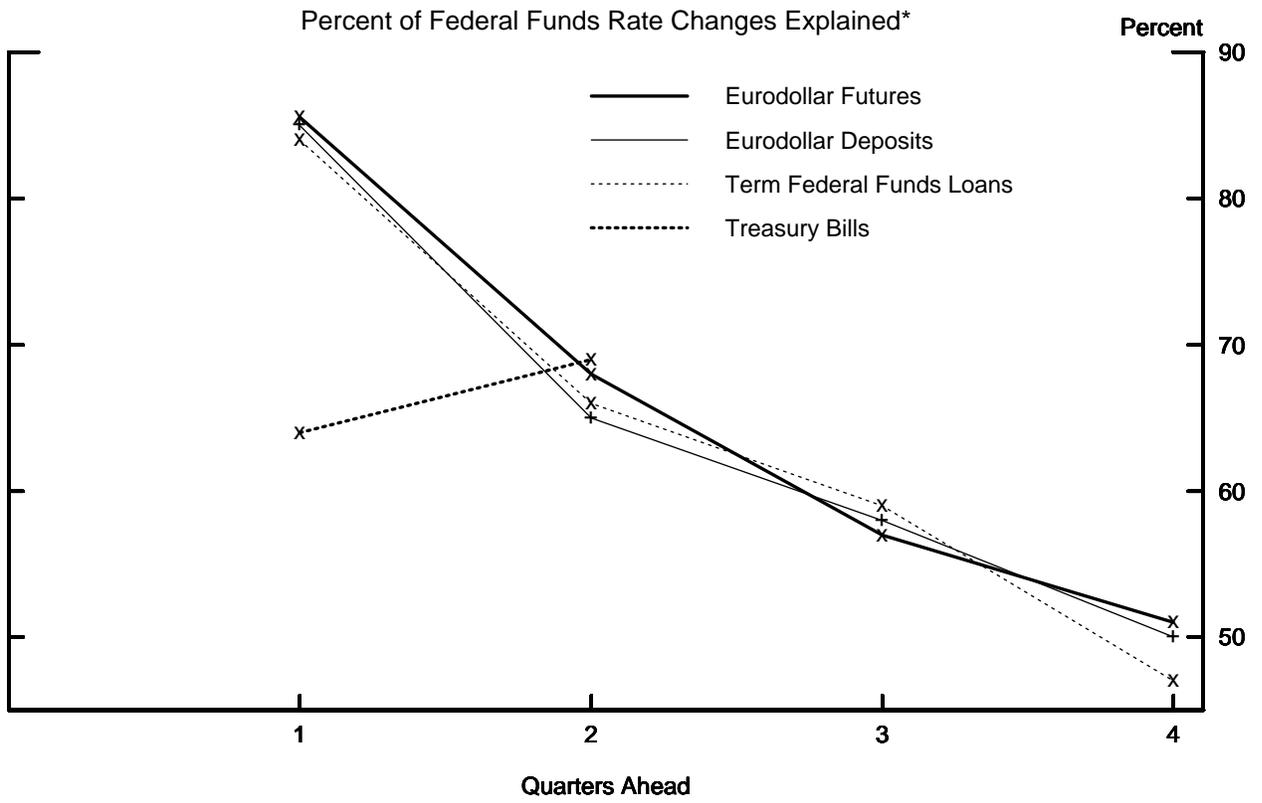|	α	β	R^2	Sig: $\beta=1$
Eurodollar Futures:				
One-quarter	-0.13 (-3.73)	1.22 (11.67)	0.86	.03
Two-quarter	-0.26 (-1.69)	1.11 (4.30)	0.68	.68
Three-quarter	-0.50 (-1.37)	1.17 (2.92)	0.57	.67
Four-quarter	-0.77 (-1.41)	1.25 (3.01)	0.51	.54
Term Federal Funds Loans:				
One-quarter	-0.18 (-4.97)	1.14 (13.70)	0.84	.08
Two-quarter	-0.34 (-2.13)	1.13 (4.20)	0.66	.64
Three-quarter	-0.60 (-1.55)	1.20 (3.17)	0.59	.60
Four-quarter	-0.85 (-1.45)	1.20 (3.02)	0.47	.61
Eurodollar Deposits				
One-quarter	-0.23 (-5.72)	1.22 (11.96)	0.85	.03
Two-quarter	-0.35 (-2.02)	1.09 (4.20)	0.65	.72
Three-quarter	-0.62 (-1.58)	1.23 (3.12)	0.58	.57
Four-quarter	-0.91 (-1.52)	1.27 (3.08)	0.50	.52
Treasury Bills:				
One-quarter	0.35 (10.42)	0.85 (4.60)	0.64	.43
Two-quarter	-0.02 (-0.17)	1.01 (4.11)	0.69	.98

All regressions include a constant, a year-end dummy variable, and a Y2K dummy variable.
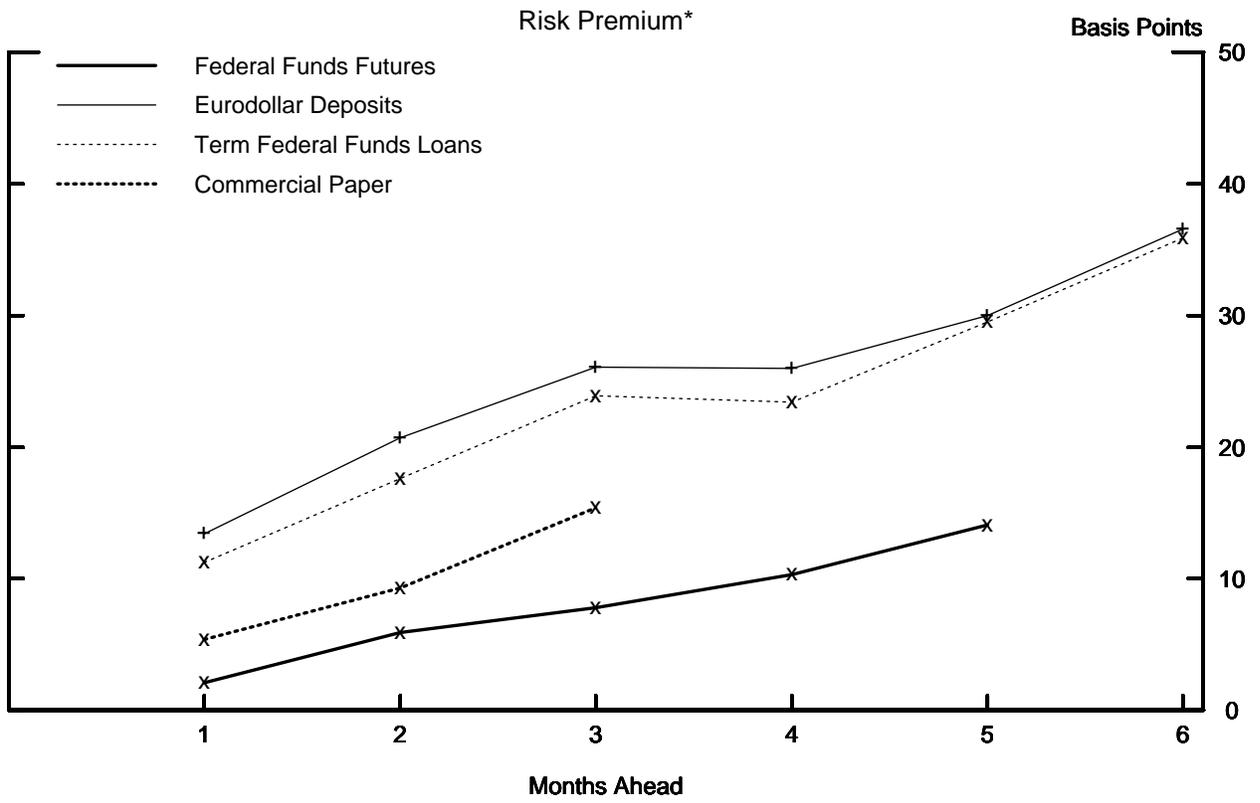T-statistics shown in parentheses are robust to serially correlated errors.

Figure 1

Percent of Federal Funds Rate Changes Explained*
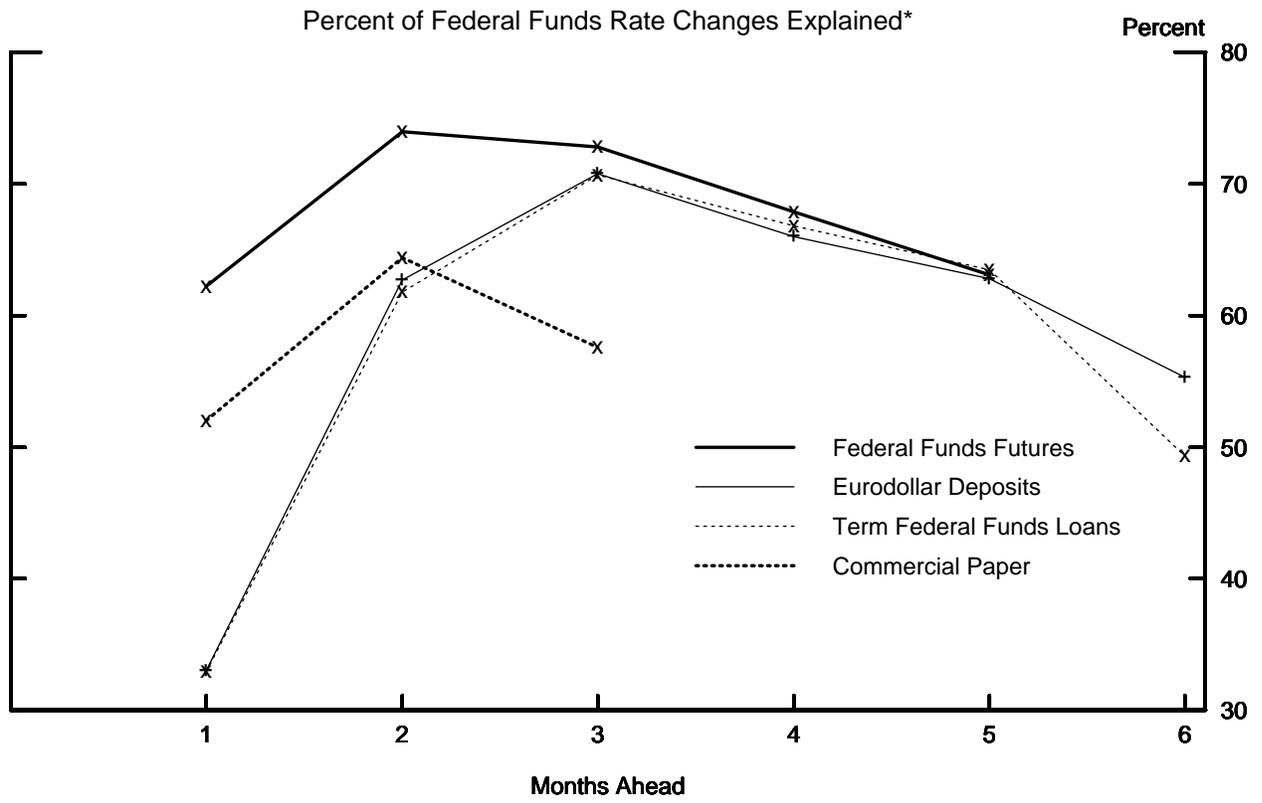
Months Ahead

*Change to the average levels over the one-month periods ending 1 to 6 months ahead

Figure 2

Percent of Federal Funds Rate Changes Explained*

Quarters Ahead

*Change to the average levels over the three-month periods ending 1 to 4 quarters ahead

Figure 3

Risk Premium*

Basis Points

Legend:
- Federal Funds Futures
- Eurodollar Deposits
- Term Federal Funds Loans
- Commercial Paper

Months Ahead

*Implied by the rate on the one-month instrument ending 1 to 6 months ahead

Figure 4

Risk Premium*
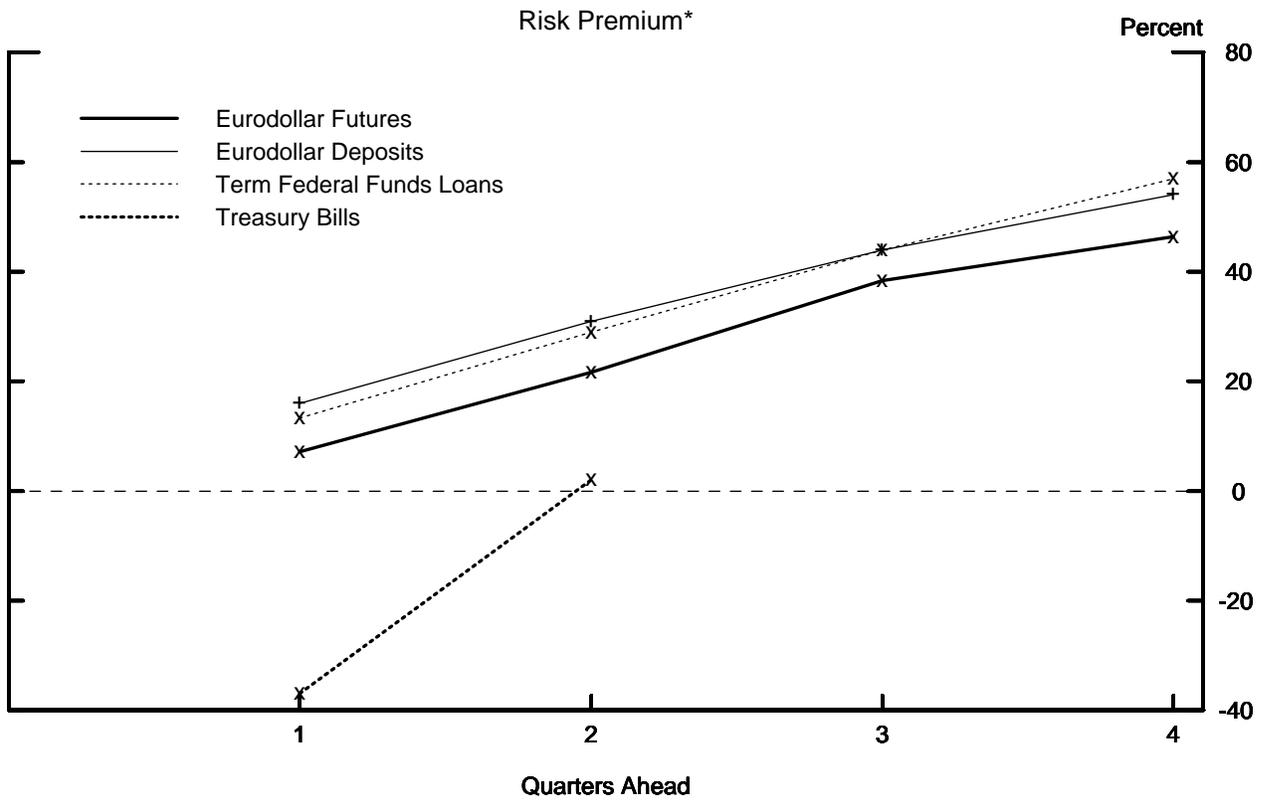
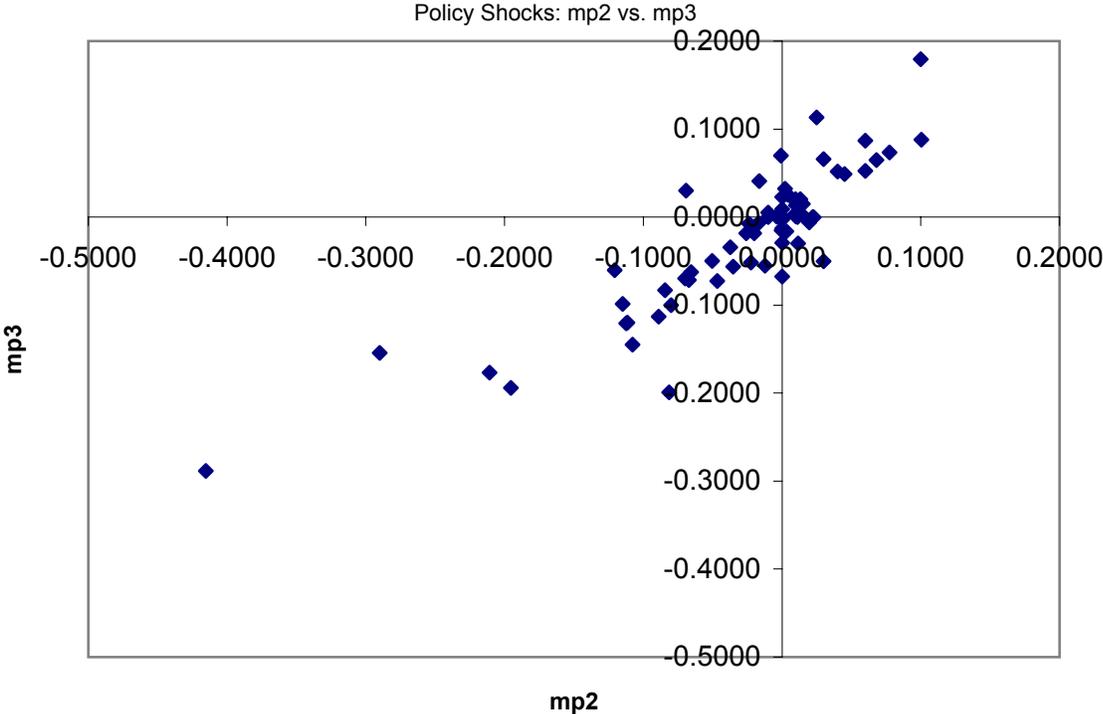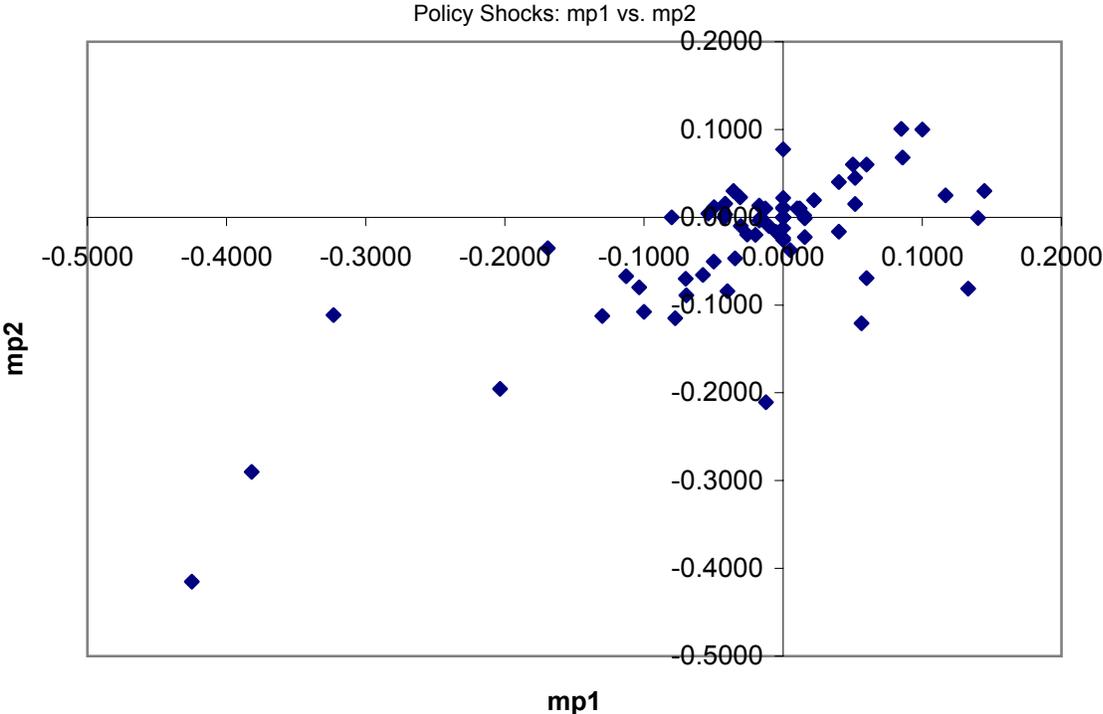*Implied by the rate on the three-month instrument ending 1 to 4 quarters ahead

Figure 5
Comparison of Policy Shocks

Figure 6
Decomposition of Policy Shocks

Feb 1994 to March 1998

April 1998 to January 2002