The Fed and Interest Rates—A High-Frequency Identification

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This paper studies monetary-policy shocks, defined from federal funds target movements relative to daily interest-rate data. These shocks are nearly ideal measures of unexpected movements in monetary policy. Market expectations can summarize the vast amount of information used by the Fed in setting policy, and used by Fed-watchers in guessing the Fed's actions, thus surmounting the omitted-variables problem in estimated policy rules. Interest-rate-based forecasts can adapt to changes in the Fed's reactions to the rest of the economy—the time-varying parameter problem. If in one year the Fed worries about inflation, but in another year it places more weight on unemployment, market forecasts will adapt, but vector autoregressions (VARs) may not adapt and thus may incorrectly interpret anticipated actions to be shocks.

Finally, high-frequency data surmount painlessly the pervasive orthogonalization problem. Interest rates all move together. Does this movement reflect Fed reaction to interest rates, or interest-rate reactions to the Fed? Neither recursive identification is plausible for monthly data. Fed officials obviously look at interest rates just before the Federal Open Market Committee meeting, and just as obviously, interest rates react immediately to any change in the federal funds target. By contrast, the one-day correlation between a target change and interest-rate changes is obviously not a Fed reaction to intraday interest-rate news.

Orthogonalization matters a lot in monthly data. If one orthogonalizes the funds rate before other interest rates, one estimates that policy shocks have a strong, "level" effect on other interest rates. If one orthogonalizes with the funds rate after other interest rates, one recovers an idiosyncratic funds-rate movement that does not affect other rates. The effect of the funds shock on long-term interest rates is *entirely* determined by the orthogonalization.

Following this attractive intuition, Glenn Rudebusch (1998) and others have used fed funds futures data and the expectations hypothesis that the futures rate is equal to the expected future spot rate to define an expected fed funds target, and thus to define a shock. Alas, the institutional details of the funds rate and its futures market make this approach more complex than it seems. Also, the expectations hypothesis is currently most famous for the failure of the forward–spot spread to forecast interest-rate changes. Finally, this approach is limited to the sample since federal funds futures were introduced in 1988.

With these thoughts in mind, we follow Piazzesi (2001) in defining shocks from interest rates more generally, and without imposing the expectations hypothesis. We use two approaches. First, we run a regression of target-rate changes on interest rates just before the target change. Second, we define the shock as the change in the one-month Eurodollar rate from just before to just after the target change. Both measures use the fact that there has been a target-rate change; they omit from the shocks all dates on which the funds rate might have been expected to change but did not. Throwing out shocks need not bias responses, and we suspect that the response to unexpected target changes is different from the response to target changes,

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expected by some (usually overparameterized) regressions, that did not happen.

We are especially interested in the effect of target changes on interest rates. Target changes seem to be accompanied by large changes in long-term interest rates, and many estimates support this correlation. (Our own estimates include Cochrane [1989] and Piazzesi [2001 fig. 3]). This effect is puzzling. Why do 30-year bond yields not *decline* in response to funds rate shocks? Tight monetary policy should lead to lower inflation, which should lower long-term bond yields. Can the Fed really raise the real short rate 1 percent for five years or more, without leading to 1-percent lower inflation that would cancel any effect on longer yields?

Charles Evans and David Marshall (1998) look at interest-rate responses to the shocks identified by Lawrence Christiano, Martin Eichenbaum, and Charles Evans (1996) (henceforth, CEE). These shocks are residuals in a carefully orthogonalized monthly VAR. Evans and Marshall find that the CEE shocks only have "slope" effects on interest rates and do not move long-term rates much. Since "level" shocks dominate the variance of long-term rates, their view implies that the bulk of interest-rate movements is explained by the systematic component of policy. Evans and Marshall impose that interest rates do not forecast the federal funds rate either at lags or contemporaneously. Thus, their responses are the same as regressions of interest rates on unmodified CEE shocks. One of our prime questions is whether allowing interest rates to forecast the funds target changes their conclusions.

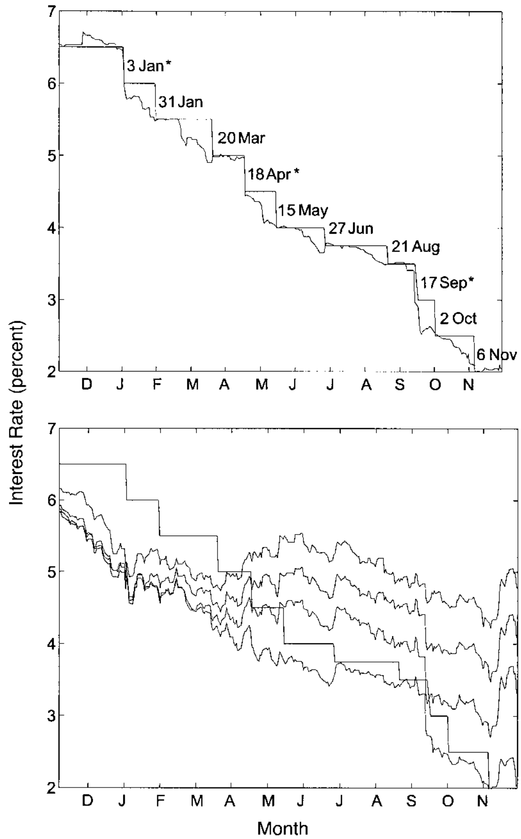

FIGURE 1. INTEREST RATES AND FEDERAL FUNDS TARGET IN 2001: (TOP) TARGET AND ONE-MONTH EURODOLLAR RATE; (BOTTOM) TARGET AND ONE-, THREE-, FIVE-, AND TEN-YEAR TREASURY YIELDS

Note: Changes outside regular Federal Open Market Committee meetings are marked with an asterisk (*).

I. A Revealing Episode

Figure 1 presents fed funds target changes, the one-month Eurodollar rate, and long-term treasury yields through 2001. (Our data are all taken from the New York Fed web site, release H.15, and target data augmented by Rudebusch. Eurodollar rates are recorded at 9:30 A.M. Eastern time, while the other data are recorded at the end of the day, so we assign the Eurodollar rates to the previous day.) The top panel of Figure 1 instantly suggests which target changes were anticipated and which were unanticipated. The changes on 3 January, 18 April, and 17 September all took the one-month Eurodollar rate by surprise. In fact, on 3 January the one-month rate fell *more* than the target. The market may have inferred that another cut was coming soon. On the other hand, the changes on 31 January, 15 May, and 21 August were completely and exactly anticipated by the one-month rate. On 20 March and 27 June, the one-month rate actually *rose* slightly relative to the target cut. Apparently, markets expected a larger cut, so the "shock" was positive rather than negative. On 2 October and 6 November, the market had anticipated a good part but not all of the change. We could read these events as some chance of a change, which then happened. In Figure 1, as in the larger sample, most target changes seem completely expected by bond markets, suggesting that many conventionally measured shocks (i.e., from monthly VARs) are anticipated.

The bottom panel of Figure 1 strongly suggests that unexpected target moves affect long-term rates. For example, around the 50-bp (basis points) target-rate change on 3 January, the one- and three-year rates fell 70 bp, and the five-year rate fell about 50 bp. The natural interpretation is that the cut signaled a change of direction; in the place of further tightening, there would be further rate cuts. If the *average* shock has a smaller impact on long-term rates (as found by Evans and Marshall [1998], for example), the average shock must be more transitory, or anticipated but misclassified as a shock in a monthly regression.

The response of yields to shocks is quite consistent over maturities. When the one-month rate in the top half of the figure is "surprised," so are the long-term rates in the bottom half, and conversely when the one-month rate is not surprised, neither are the long-term rates.

The target change on 17 September is particularly interesting. The terrorist attack was on Tuesday, 11 September. Bond markets reopened Thursday, 13 September. The one- and three-year rates dropped 50 bp. The natural interpretation is that the markets correctly anticipated that, on Monday 17 September, the Fed would lower the target 50 bp. That is exactly what the Fed did, and yields did not move on that news. Now, is this a shock, or an expected movement? A monthly VAR would count it as a shock. But the target move was clearly taken in response to events, and to a threat that output would otherwise decline. It should not count as a shock, and our measures do not count it as a shock.

II. Shocks from Daily Data

Figure 1 naturally suggests that we use the change in the one-month Eurodollar rate surrounding the target change to measure its unexpected component. Detailed inspection of some of the target changes shows interest-rate movements the day before target-rate changes, which may reflect dating errors. For this reason, we define the interest-rate move corresponding to the shock as the move from two days before to one day after the change, and our regression forecast of target changes uses data two days before the change.

TABLE 1—REGRESSION RESULTS

	Euro		Treasury			
Statistic	1 mo	3 mo	3 mo	1 yr	3 yr	10 yr
A. *Yield Change on Target Change:*						
b	0.52	0.46	0.37	0.37	0.29	0.19
t	9.1	8.0	7.6	6.7	5.0	3.5
R^2	0.39	0.32	0.28	0.24	0.15	0.08
B. *Yield Change on One-Month Euro Change:*						
b		0.91	0.62	0.72	0.67	0.52
t		22.1	6.8	10.8	8.8	5.2
R^2		0.87	0.54	0.63	0.55	0.39

Notes: The dependent variable is the change in yield from two days before a target-rate change to one day after the change. The independent variable is (A) the target-rate change itself or (B) the change in the one-month eurodollar rate.

Table 1 presents regressions of interest rates on these target shocks. The relation between interest rates and unexpected target changes is clearly much stronger and more consistent than the relation between interest rates and raw target changes. The size of the coefficients is particularly startling. A 1-percent unexpected target change affects Treasury yields by 60–70 bp all the way out to five years, and 52 bp at a 10-year maturity!

We also measure policy shocks from a more conventional target-forecasting regression. We started with a regression of target changes on all yields, but with many similar coefficients and small t statistics, we iteratively eliminated the variables with the smallest t statistics to end up with the simpler and more interpretable form given in Table 2. (The R^2 value declined from 0.66 to 0.64 as we excluded yields.)

Table 2 gives a strong and appealing message. First, there is some slow mean reversion, shown in the coefficient on the target. Second, and interestingly given the visual appeal of Figure 1, the long-term rates are far more important than the short-term rates in forecasting Fed moves. (In the regression with all yields, the one-month Eurodollar rate had a coefficient of -0.06 and a t statistic of -0.8.) This finding contradicts expectations hypothesis logic, which suggests that the shortest possible inter-

TABLE 2—FORECAST REGRESSION OF TARGET-RATE CHANGES

			Interest Rates			
Statistic	Constant	Target	3 mo	2 yr	5 yr	10 yr
b	0.29	−0.037	0.12	0.87	−0.87	0.24
t	3.1	−3.7	2.0	6.7	−3.5	1.57

Notes: The dependent variable is the change in the federal funds rate target. The independent variables are the target and interest-rate spreads over the target two days before the change. The regression is only run on dates corresponding to target changes, 1984–2001. The R^2 is 0.64.

est rate should be the best forecaster of target changes. It suggests instead that interest rates forecast target moves because the Fed *responds* to expected inflation information embodied in long-term rates, not just from expectations-hypothesis logic. This pattern is suggested by Taylor rules, especially as specified by Richard Clarida et al. (2000), though the coefficient is well below 1. Third, the spread between the two- and five-year rate is the most important target-forecasting variable of all. This spread is a potent forecaster of real activity, which naturally suggests the output component of a Taylor rule. However, as in Piazzesi (2001), these interest-rate regressions far outperform conventional Taylor rules in forecasting the target.

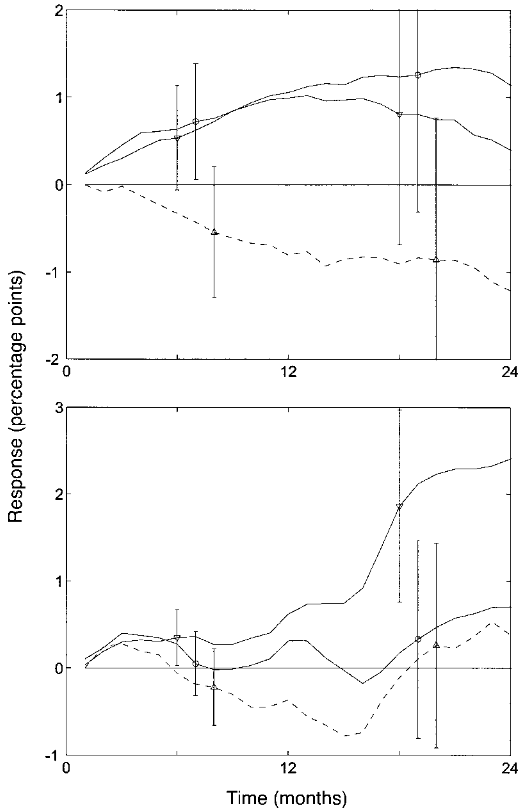

FIGURE 2. RESPONSE OF EMPLOYMENT (TOP) AND THE CONSUMER PRICE INDEX (BOTTOM) TO FEDERAL FUNDS SHOCKS

Notes: The solid lines give the response to our shocks, calculated from daily interest rates. The larger response in the bottom panel is to the regression shock. The dashed line represents the response to the CEE VAR shock.

III. Monthly Shocks and Responses

To construct monthly impulse-response functions, we sum up the daily shock series. For comparison purposes, we construct monthly CEE shocks. The VAR consists of nonfarm employment, the consumer price index, the commodity price index, and the federal funds rate. We orthogonalize shocks recursively in that order and estimate the VAR with six monthly lags.

Our shock series is zero in a month with no target changes, and many target changes are almost completely anticipated. As a result, and especially in the latter half of the sample, we see few shocks. Inference from VAR shocks after about 1990 is dominated by expected movements that do not happen, rather than by unexpected movements that do. The two high-frequency measures also see the early 1990's rate declines and the recovery after 1994 as largely positive shocks, while the CEE measure shows positive and negative shocks.

To calculate the impulse response for horizon j, we run single regressions of the changes in variables on the policy shocks, $y_{t+j} - y_t$, on ε_{t+1}. We follow this procedure since we cannot include all the state variables (interest rates on the day before a target change) in the autoregressive representation of the VAR. It also has a very nice intuition. The impulse-response function is, after all, a summary of the experience of the target variable following a shock. This procedure is consistent and gives results quite similar to the autoregressive simulation when applied to the CEE VAR.

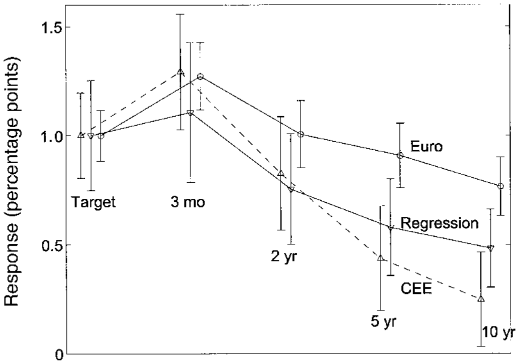

FIGURE 3. IMPACT (ONE MONTH) RESPONSE OF YIELDS TO A 1-PERCENT FEDERAL FUNDS TARGET SHOCK

Figure 2 contrasts responses of employment and the consumer price index to our shocks and to CEE VAR shocks. Our shocks show employment *rising* following a target shock, while employment declines slowly following a CEE shock. The difference results from a different interpretation of interest-rate movements as expected versus unexpected, and thus a different view of output episodes. CEE shocks count months around the 1987 stock-market crash as much larger negative shocks than the daily measures, and the daily measures see larger negative shocks in early 1991. Alas, neither set of responses is statistically significant, as found by CEE in this sample. This is unfortunate. All of our information about the output effects of monetary policy comes from interpretation of the 1979–1982 experience.

The two high-frequency shocks give quite different answers about inflation. The results for the one-month Eurodollar shocks agree with those based on the the CEE shocks that monetary policy has nearly no effect on inflation. The regression shock shows a large, though dubiously significant, *increase* in inflation following a shock. However, the standard errors are large enough that we basically conclude that there is no inflation response. This is also troubling. Federal funds shocks should lower inflation, but as in larger samples, there is no evidence that they do so.

Figure 3 shows the instantaneous (one month) responses of yields to the target shock. Both high-frequency shocks produce flatter yield-curve responses, and notably

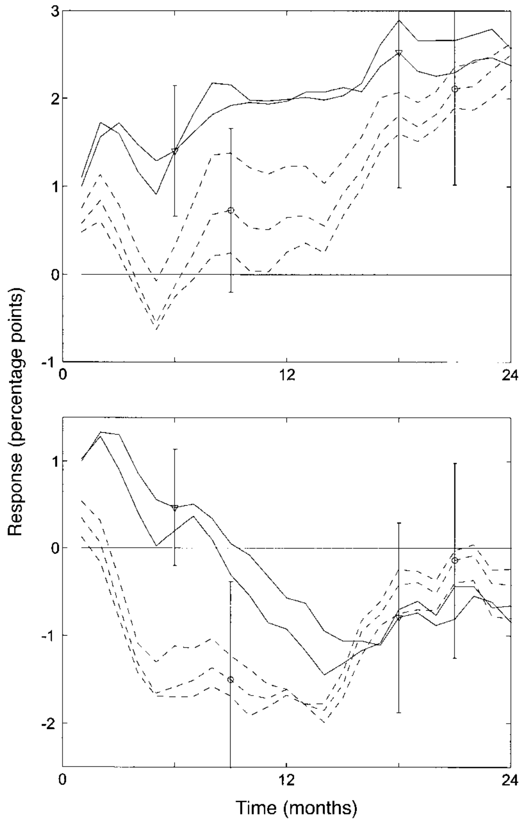

FIGURE 4. DYNAMIC RESPONSE OF YIELDS TO A 1-PERCENT FEDERAL FUNDS SHOCK: (TOP) RESPONSE TO DAILY REGRESSION SHOCK; (BOTTOM) RESPONSE TO CEE VAR SHOCK

Notes: The solid lines are the target and three-month Eurodollar yield. The dashed lines are the two-, five-, and ten-year Treasury yields.

larger changes at the long end of the yield curve. As we found in the daily data, the measure based on the one-month Eurodollar rates produces a very large response. The 10-year rate rises by 0.8 percentage points when the funds target rises 1 percent, in contrast to 0.2 percentage points for the CEE shock. The fact that funds shocks do not lower inflation, and in fact seem to raise inflation, is consistent with the finding that funds shocks raise long-term rates.

Figure 4 presents the dynamic responses of yields to the regression shock and the CEE shock. (The Eurodollar shock produces results quite similar to the regression shock.) Here too, the high-frequency shocks produce quite different response functions. After a blip at six months, all interest rates keep rising following a shock. By contrast, the CEE VAR shock produces a quite short-lived response.

IV. Concluding Remarks

We construct measures of monetary-policy shocks from target-rate changes that surprise bond markets in daily data. The "rule" we estimate is sensible: the Fed responds to long-term interest rates, perhaps embodying inflation expectations, and to the slope of the term structure, which forecasts real activity. Short-term interest rates do not help to forecast target changes. This fact suggests that interest-rate forecasts of target changes occur because the Fed *reacts* to interest rates, not just because interest rates forecast target changes.

As often happens, the purer the shock, the more unusual the response. Interest rates move in the same direction as policy shocks, and by surprisingly large amounts. It is natural to presume that policy shocks should lower long-term rates. Tore Ellingsen and Ulf Söderström (2002) do find such a negative response in a narrative classification, but at the cost that their shocks must become predictable. Output and price responses are poorly measured, but there is no evidence that inflation declines following a surprise increase in the target.

It is tempting to interpret these responses by the "price puzzle" logic. Output might rise following a tightening, if the Fed is tightening to offset a foreseen output rise. However, the Fed cannot systematically fool the markets, so this is a difficult interpretation. One must believe that the Fed has a consistent information advantage over the private sector, which is a difficult case to make. This puzzle and the 17 September 2001 episode challenge our notions of a shock. The Fed always explains its actions as a response to economic events. It never says "we added another half percent just for the heck of it." Perhaps there are no true shocks.

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