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Ben S. Bernanke
Kenneth N. Kuttner

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Abstract

This paper analyzes the impact of unanticipated changes in the federal funds rate target on equity prices, with the aim of both estimating the size of the typical reaction and understanding the reasons for the market's response. We find that over the June 1989-December 2002 sample period, a typical unanticipated rate cut of 25 basis points is associated with an increase of roughly 1 percent in the level of stock prices, as measured by the CRSP value-weighted index. There is some evidence of a stronger stock price response to changes in rates that are expected to be more permanent or that represent a reversal in the direction of rate changes. The estimated response of stock prices to fund rate surprises varies widely across industries, but in a manner consistent with the predictions of the standard capital asset pricing model. Applying the methods of Campbell (1991) and Campbell and Ammer (1993), we find that most of the effect of monetary policy on stock prices can be traced to its implications for forecasted equity risk premiums. Some effect can be traced to the implications of monetary policy surprises for forecasted dividends, but very little stems from the impact of policy on expectations of the real rate of interest.

Bernanke: Board of Governors of the Federal Reserve System and Princeton University; Kuttner: Federal Reserve Bank of New York. Correspondence to Kenneth Kuttner, Federal Reserve Bank of New York, 33 Liberty Street, New York, NY 10045 (e-mail: kenneth.kuttner@ny.frb.org). The authors extend thanks to John Campbell for his advice; to Jon Faust, Refet Gürkaynak, Martin Lettau, Sydney Ludvigson, Athanasios Orphanides, Glenn Rudebusch, Brian Sack, Chris Sims, and Eric Swanson for their comments; and to Peter Bondarenko for research assistance.

1 Introduction

The ultimate objectives of monetary policy are expressed in terms of macroeconomic variables such as output, employment, and inflation. However, the influence of monetary policy instruments on these variables is at best indirect. The most direct and immediate effects of monetary policy actions, such as changes in the federal funds rate, are on the financial markets; by affecting asset prices and returns, policymakers try to modify economic behavior in ways that will help to achieve their ultimate objectives. Understanding the links between monetary policy and asset prices is thus crucially important for understanding the policy transmission mechanism.

This paper is an empirical study of the relationship between monetary policy and one of the most important financial markets, the market for equities. According to the conventional wisdom, changes in monetary policy are transmitted through the stock market via changes in the values of private portfolios (the "wealth effect"), changes in the cost of capital, and by other mechanisms as well. Some observers also view the stock market as an independent source of macroeconomic volatility, to which policymakers may wish to respond. For these reasons, it will be useful to obtain quantitative estimates of the links between monetary policy changes and stock prices. In this paper we have two principal objectives. First, we measure and analyze in some detail the stock market's response to monetary policy actions, both in the aggregate and at the level of industry portfolios. Second, we try to gain some insights into the reasons for the stock market's response.

Estimating the response of equity prices to monetary policy actions is complicated by the fact that the market is unlikely to respond to policy actions that were already anticipated. Distinguishing between expected and unexpected policy actions is therefore essential for discerning their effects. A natural way to do this is to use the technique proposed by Kuttner (2001), which uses Fed funds futures data to construct a measure of "surprise" rate changes.[1] To explain the economic reasons for the observed market response to policy surprises requires an assessment of how those policy surprises affect expectations of *future* interest rates, dividends, and excess returns. To do this, we adapt the procedure developed by Campbell (1991) and Campbell and Ammer (1993), which uses a vector autoregression (VAR) to calculate revisions in expectations of these key variables.

The results presented in section 2 of the paper show that the market does indeed react strongly to surprise funds rate changes. For a sample consisting of the union of days with a change in the target funds rate target and days of meetings of the Federal Open Market Committee (FOMC), we estimate that the CRSP value-weighted index registers a one-day gain of roughly 1 percent in response to a surprise 25 basis point easing. The market reacts little, if at all, to the component of funds rate changes that are anticipated by futures market participants. A comparable reaction is observed at a monthly unit of observation.

Section 3 takes up the question of what explains equity prices' response. It turns out that only a modest portion of the effect of surprise funds rate changes on the variance of excess equity returns can be attributed to the effect of those changes on dividend forecasts, and still less to the effect on forecasts of real interest rates. Instead, most of the effect of funds rate surprises comes through their effect on expectations of future excess returns. In particular, we find that while an unanticipated rate cut (for example) generates an immediate rise in equity prices, it is also followed by an extended period of lower-than-normal excess returns. One interpretation of this result is that monetary policy surprises are associated with changes in the equity premium, a point we discuss further below. But in the absence of a fully-developed asset pricing model, it is impossible to distinguish this interpretation from a market overreaction.

[1] Cochrane and Piazzesi (2002) propose using the change in term eurodollar rates, while Rigobon and Sack (2002) utilize the eurodollar futures rate. While these measures provide informative gauges of interest rate expectations over a slightly longer horizon, Gürkaynak, Sack and Swanson (2002) show that Fed funds futures do the best job of forecasting target rate changes one to five months ahead.

This paper is not the first to estimate the impact of monetary policy on equity prices. Using several different gauges of the stance of monetary policy, including shocks from an identified VAR and one-day changes in the Fed funds rate, Thorbecke (1997) documented a connection between expansionary policy and above-average stock returns. Another set of papers in this vein are Jensen, Johnson and Mercer (1996) and Jensen and Mercer (1998), which examined the disaggregated response of stock prices to changes in the discount rate. Rigobon and Sack (2002) found a robust response of the stock market to interest rate surprises derived from eurodollar futures, using a novel estimator exploiting the heteroskedasticity introduced by unexpected policy actions to correct for possible endogeneity. Taking a less structured approach, Fair (2002) identified the largest changes in equity prices at 1- to 5-minute intervals, and found that nearly one-third of those were associated with news about monetary policy. Several other papers that have looked at this question are cited at various points below.

Fewer papers have tackled the question of *why* the stock market reacts to monetary policy. The results of Goto and Valkanov (2000) suggest that the covariance between equity prices and inflation induced by policy shocks from an identified VAR may be one reason for the response. Boyd, Jagannathan and Hu (2001) focus on equity prices' response to unemployment news, rather than monetary policy; but their explanation for the market's perverse reaction (i.e., the association of higher-than-expected unemployment with increases in equity prices) involves a presumed expansionary response of monetary policy to bad unemployment news. Patelis (1997) addresses the question using identified VAR shocks within the framework of (1991) and Campbell and Ammer (1993).

2 Estimating equities' reaction to target rate changes

This section focuses on the immediate impact of monetary policy on equity prices, both for broad stock market indices and for individual industries. As noted in the introduction, however, one difficulty inherent in measuring policy's effects is that asset markets are forward looking and hence tend to incorporate any information about anticipated policy changes. Some effort is therefore required to isolate the unexpected policy change which might plausibly generate a market response. This does not say that asset prices respond to monetary policy only when the Fed surprises the markets, of course. Naturally, asset prices will also respond to revisions in *expectations* about future policy, which in turn may be driven by news about changing economic conditions. Unexpected policy actions merely represent convenient exogenous events which allow us to discern more clearly the stock market's reaction to monetary policy.

One convenient, market-based way to identify unexpected funds rate changes relies on the prices of Fed funds futures contracts, which embody expectations of the effective Fed funds rate, averaged over the settlement month.[2] Krueger and Kuttner (1996) found that the Fed funds futures rates did a good job of forecasting, efficiently incorporating available information on the likely policy actions. Kuttner (2001) subsequently used these futures data to estimate the response of the term structure to monetary policy. The analysis in this section employs a similar method to gauge the response of equity prices to unanticipated changes in the Fed funds rate from 1989 through 2002.

2.1 Measuring the surprise element of policy actions

A measure of the surprise element of any specific change in the Fed funds target can be derived from the change in the futures contract's price relative to the day prior to the policy

[2] The Federal funds rate was either implicitly or explicitly the operating instrument of Federal Reserve policy over the period analyzed.

action. For an event taking place on day d of month m, the unexpected, or "surprise" target rate change can be calculated as the change in the rate implied by the current-month futures contract, scaled up by a factor related to the number of days in the month affected by the change,

$$\Delta i^u = \frac{D}{D-d}\left(f^0_{m,d} - f^0_{m,d-1}\right) \quad , \tag{1}$$

where Δi^u is the unexpected target rate change, $f^0_{m,d}$ is the current-month futures rate and D is the number of days in the month.[3] The expected component of the rate change is defined as the actual minus the surprise, or

$$\Delta i^e = \Delta i - \Delta i^u \quad . \tag{2}$$

Getting the timing right is, of course, crucial for event-study analysis. Before 1994, when the Fed instituted its current policy of announcing changes in the funds rate target, markets generally became aware of policy actions on the day after the FOMC's decision, when it was implemented by the Open Market Desk. Following Rudebusch (1995) and Hilton (1994), most rate changes prior to 1994 are assigned to the date of the Desk's implementation. As documented in Kuttner (2003), however, the sample contains several minor deviations from this pattern. Six of these correspond to days on which the Desk allowed the funds rate to drift downward in advance (and presumably in anticipation) of the FOMC's decision, with the full awareness that its inaction would be interpreted as an easing of policy. A seventh exception occurred on December 18, 1990, when the Board of Governors made an unusual late-afternoon announcement of a cut in the discount rate, from which market observers (correctly) inferred a 25 basis point rate cut.

The policy of announcing target rate changes, which began in February 1994, eliminates virtually all of the timing ambiguity associated with rate changes in the earlier part of the

[3]The implied futures rate is just 100 minus the contract price. When the rate change comes on the first day of the month, $f^1_{m-1,D}$ would be used instead of $f^0_{m,d-1}$. Also, to avoid amplifying any month-end noise, when the rate change falls on one of the last three days of the month, the unscaled change one-month futures rate is used instead of the change in the spot month rate. See Kuttner (2001) for details.

sample. Moreover, because the change in the target rate is usually announced prior to the close of the futures market, the closing futures price generally incorporates the day's news about monetary policy. The only exception is October 15, 1998, when a 25 basis point rate cut was announced after the close of the futures markets. In this case, the difference between the opening rate on the 16th and the closing rate on the 15th is used to calculate the surprise.

2.2 Baseline event study results

One approach to measuring the impact of Federal Reserve policy on the stock market is to calculate the market's reaction to funds rate changes on the day of the change. The market may of course also react to the *lack* of a change in the target, if a change had been anticipated. Because this approach involves looking at the response to specific events, it might be described as an "event-study" style of analysis. For the purpose of this paper, the relevant sample of "events" is defined as the union of all days when the funds rate target was changed, and days corresponding to FOMC meetings. The first "event" in the sample is the June 1989 25 basis point rate cut, and the last corresponds to the FOMC meeting in December 2002. The 17 September 2001 observation is excluded from the analysis, as that days' rate cut occurred on the first day of trading following the September 11 terrorist attacks. Altogether, the sample contains 131 observations.

Table 1 contains the baseline regression results for the event-study analysis. Column (a) reports the results from a simple regression of the CRSP value-weighted return on the raw change in the Fed funds target,

$$H_t = a + b\Delta i_t + \varepsilon_t \quad , \tag{3}$$

making no distinction between surprise and expected changes; H_t represents the stock return, and i_t is the funds rate target. The response to the raw target rate changes is negative,

Table 1: The response of equity prices to funds rate changes

	Full sample		Excluding outliers	
Regressor	(a)	(b)	(c)	(d)
Intercept	0.23	0.12	0.17	0.11
	(2.58)	(1.35)	(2.14)	(1.37)
Raw funds rate change	−0.61	...	−0.11	...
	(1.06)		(0.31)	
Expected change	...	1.04	...	0.67
		(2.17)		(1.62)
Surprise change	...	−4.68	...	−2.55
		(3.03)		(2.79)
Adjusted R-squared	0.007	0.171	−0.007	0.049

Notes: The dependent variable is the one-day CRSP value-weighted return, in percent. Parentheses contain t-statistics, calculated using heteroskedasticity-consistent estimates of the standard errors. The full sample consists of the 55 target rate changes and the 77 FOMC meeting dates over the period from June 1989 through December 2002, excluding the 17 September 2001 observation, for a total of 131 observations. The outliers excluded from the regressions in columns (c) and (d) correspond to the six observations with influence statistics in excess of 0.3, depicted in figure 2, leaving 125 usable observations.

as expected, but small and insignificant.

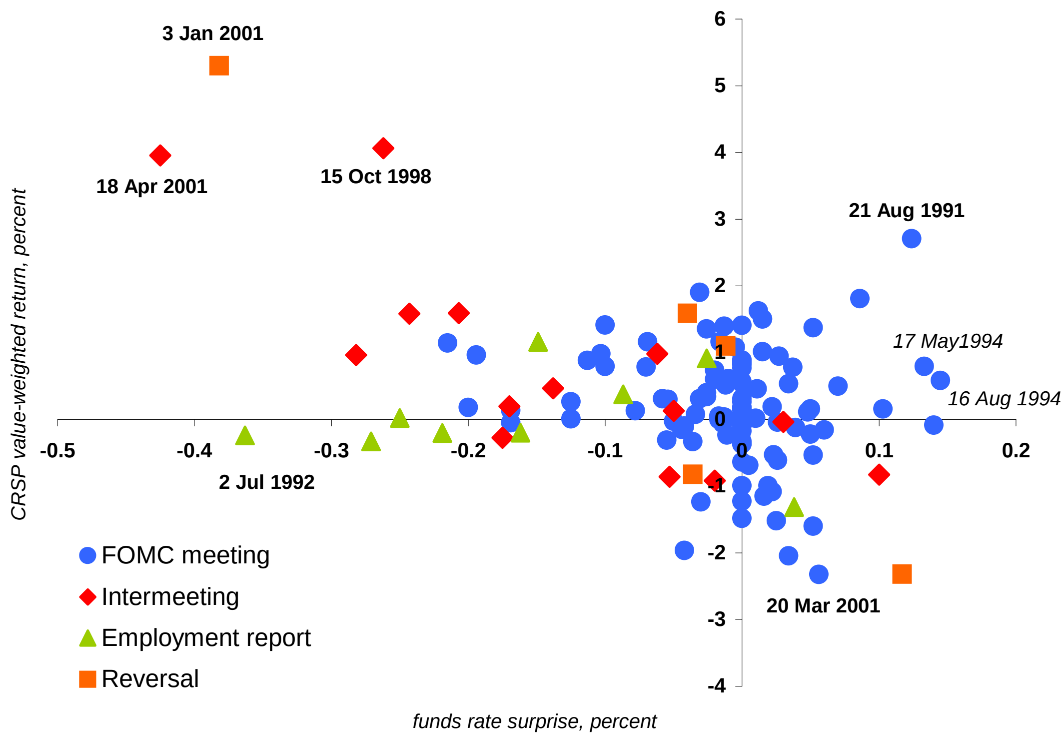
Column (b) shows the response when the funds rate change is broken down into the expected and surprise components. The regression used here is

$$H_t = a + b^e \Delta i_t^e + b^u \Delta i_t^u + \varepsilon_t \quad , \tag{4}$$

where the expected and unexpected changes, Δi_t^e and Δi_t^u, are computed as described above in section 2.1. The highly significant negative coefficient on the surprise coefficient implies a -4.68 percent one-day return in response to a 1 percentage point surprise rate cut.[4] The strength of the measured reaction is remarkable, given that much of the Fed funds surprises measured at a daily frequency represent changes to the likely *timing* of rate changes, rather than to the longer-term path of interest rates. Indeed, as shown below in section 2.6, eq-

[4]Very similar results are obtained using the S&P 500 in place of the CRSP value-weighted return.

Figure 1: Scatterplot of equity returns and Fed funds surprises, daily data

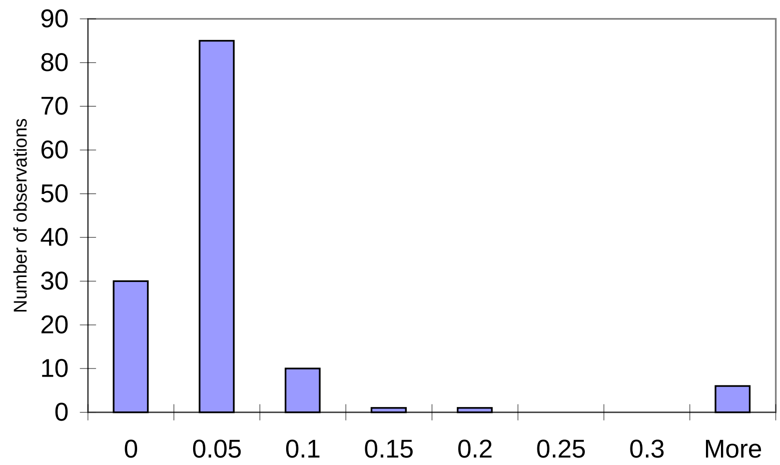


uities' response is even stronger to surprises that also affect expectations of the funds rate in the future. Also noteworthy is the R^2 of 0.17, which implies that 17 percent of the variance in equity prices on these "event" days is associated with monetary policy actions (or inactions, in the case of FOMC meetings that left the funds rate target unchanged).

The negative impact of surprise funds rate increases on the stock market is readily visible in the scatterplot shown in figure 1. Also apparent are a number of observations characterized by very large changes in equity prices — many well in excess of 2 percent. This naturally raises the question of whether the results reported in the first two columns of Table 1 are sensitive to the inclusion of these observations.

To determine which observations might be having the largest effect on the regression results, influence statistics were computed for each observation in the sample. These statis-

Figure 2: Distribution of influence statistics



tics are calculated as the quadratic form $\Delta\hat{b}_t'\hat{\Sigma}^{-1}\Delta\hat{b}_t$, where $\Delta\hat{\beta}_t$ is change in the regression coefficient resulting from dropping observation t, and $\hat{\Sigma}$ is the estimated covariance matrix of the coefficients. The distribution of these statistics, plotted in figure 2, confirms that six observations, all with statistics in excess of 0.3, exert an unusually large influence on the estimates; the comparable statistics for the remaining observations are all well below 0.20 and most are less than 0.10. The six observations associated with the large influence statistics are labeled in figure 1: 8 August 1991, 2 July 1992, 15 October 1998, 3 January 2001, 20 March 2001, and 18 April 2001. The first two of these are associated with events other than monetary policy actions, while the most recent four arguably represent unusual reactions to monetary policy actions. Each is in its own way is revealing.

Interestingly, three of the six candidate outliers occurred during the easing cycle that began in 2001. The surprise 50 basis point intermeeting rate reductions on 3 January and 18 April were both greeted euphorically, with one-day returns of 5.3 and 4.0 percent respectively. The 50 basis point rate cut on 20 March was received less enthusiastically, however. Even though the cut was more or less what the futures market had been anticipating, financial press reported that many equity market participants were “disappointed” the rate cut hadn't been an even larger 75 basis point action. Consequently, the market lost more than 2 percent.

Another unusually vehement reaction to a Fed action is associated with the 25 basis point intermeeting rate cut on 15 October 1998, which was taken in response to unsettled conditions in the financial markets — specifically, the deteriorating situations in Asia and Russia. For whatever reason, the unexpected intermeeting cut lifted equities over 4 percent.

The stock market fell less than 0.3 percent on 2 July 1992. What makes this reaction unusual, however, is the fact that it came on a day when the Fed unexpectedly cut the funds rate target by 50 basis points. The decision to cut was no doubt influenced by that day's unusually bleak employment report, in which reported payroll employment fell by 117 thousand. This raises the issue that some of the "surprise" rate changes in the sample may in fact represent endogenous responses to economic news, such as the employment report. This possibility is investigated in greater detail below in section 2.4.

The final candidate outlier is 21 August 1991, when the CRSP value-weighted index rose 2.7 percent on a day associated with an FOMC meeting. The futures market had apparently priced in some possibility of a rate cut on that day, but the FOMC's decision to leave rates unchanged generated a small, positive surprise. The financial press reported that the stock market jump was a response to the resolution of the attempted coup in Russia — clearly an event with no direct relation to that day's FOMC decision.

Two other observations are highlighted in figure 1: 17 May and 16 August 1994. While the influence statistics associated with these two dates are not extraordinarily high (0.05 and 0.04 respectively), they stand out as unusual instances in which equities rose in spite of significant, *positive* funds rate surprises. As noted in Kuttner (2001), a similarly anomalous response is observed in the response of bond yields on those dates. The reason seems to be that both of these larger-than-expected 50 basis point rate hikes were accompanied by statements by the FOMC suggesting that further rate increases were not imminent. Thus, expectations of the level of the funds rate in the future may have fallen, despite the increase in the current setting of the funds rate target.

Columns (c) and (d) of table 1 show what happens when the six candidate outliers associated with the large influence statistics are dropped from the sample. (The two observations from 1994 are retained.) The measured response to funds rate surprises is still negative and significant, but smaller in magnitude: -2.55, as opposed to -4.68. The response to the expected component is smaller (and now no longer significant at the 0.05 level), as is the response to the raw funds rate change in column (c). Interestingly, excluding the six outliers actually decreases the adjusted R-squared, presumably because the fitted regression was doing a good job of accounting for the variance contributed by the three observations in the extreme northwest of the scatterplot.

2.3 A comparison with results from other methods

The event-study method employed in section 2.2 above obviously relies heavily on the assumption that event-day changes in the futures rate reflect only changes in the stance of monetary policy, and are not "contaminated" by measurement error or other sources of variation. A number of recent studies have examined this assumption in detail, and proposed statistical methods for dealing with various sources of error. While there is some evidence suggesting the futures-based surprises are an imperfect measure of exogenous policy actions, the overall conclusion of these studies is that this error has only small effects on the estimated response of equity prices to monetary policy.

One potential source of contamination is simple measurement error resulting from ambient variation in the Fed funds futures rate, a possibility explored by Poole, Rasche and Thornton (2002) in a study of Treasury yields' response to monetary policy. Their analysis assumes the "noise" contaminating the futures rate in their analysis is uncorrelated with other factors affecting yields. As in the classical errors-in-variables problem, this sort of error tends to attenuate the estimated parameters. Poole et al. calculate the variance of the futures rate on days when the actual funds rate change was in line with the consensus market expectations reported by the *Wall Street Journal*, and use this as a gauge of the ambient variance of the futures rate.[5] Estimates obtained from their errors-in-variables procedure are slightly larger than the corresponding OLS estimates, with the difference between the two typically in the 5–10 percent range.

Another form of contamination could arise if the measured funds rate surprise were correlated with other factors affecting stock returns. This means the funds rate surprise would be correlated with the disturbance term in equation 4, and this would also bias the estimated parameters.

The most obvious source would be a contemporaneous response of the funds rate to equity prices. Since it is unlikely that the FOMC would respond within a day to stock market fluctuations, the use of daily data should in principle minimize this problem.[6] To the extent the FOMC *did* tend to cut rates when the stock market fell, however, such a contemporanous reaction would tend to reduce the size of the estimated response to the funds rate surprise.

One way to eliminate the problem of same-day feedback is to use intra-day data, as in D'Amico and Farka (2003), who examined the equity price response in a ten-minute window following policy announcements. Their results are quite similar to those reported above. An alternative approach is that of Rigobon and Sack (2002), who propose a novel estimator based on exploiting the heteroskedasticity introduced by monetary policy actions. Their hetroskedasticity-based estimator yields slightly larger estimates of the stock market's respose to Fed funds surprises: -3.7 to -4.0 (depending on the form of the estimator

[5] In a similar vein, Ehrmann and Fratzscher (2003) use the results from a Reuters poll as a direct proxy for policy expectations, and obtain results quite similar to ours.

[6] Even in monthly data, it is hard to find evidence of a systematic response of monetary policy; see, for example, Bernanke and Gertler (1999) and Fuhrer and Tootell (2003). Some evidence to the contrary is provided by Rigobon and Sack (2003), however.

used), compared with -3.2 for the OLS event-study estimate.

The joint response of policy and the stock market to new information is a second source of possible contamination. For example, the release of data indicating weaker-than-expected economic growth would plausibly cause the stock market, and make a cut in the funds rate target more likely.[7] As in the case of a direct policy response to the stock market, the resulting tendency for rate cuts to be associated with stock market declines would lead to a downward bias in the size of policy's estimated market impact. A similarly attenuated reaction would be observed if surprise policy actions were thought to reveal private information about the state of the economy, as suggested by Romer and Romer (2000).

Instances of direct, same-day policy responses to economic news are rare in our sample — at least in recent years, when the FOMC meeting schedule dictated the timing of most policy actions. During the earlier pre-1994 portion of the sample, however, it was not uncommon for the FOMC to cut rates on the heels of weaker-than-expected employment data. In fact, 8 of the 23 rate cuts from June 1989 through July 1992 were intermeeting actions that coincided with the release of the employment report. The analysis below in section 2.4 addresses this issue directly, by allowing the response to policy to vary depending on whether the action coincided with an employment report.

To allow for the possibility that measured funds rate surprises also contain "information shocks," Craine and Martin (2003) estimated the response of asset prices using an innovative factor model approach. In their model, the entire vector of asset returns is allowed to depend on a common unobserved component, representing a market-wide response to non-policy news. In the end, however, their multivariate factor estimate of the stock market's response to policy turns out to be virtually identical to that based on the event-study approach.

[7] The 17 September 2001 is an extreme example of just such a joint response: the Fed's 50 basis point rate cut and the stock market's sharp drop were both clearly spurred by the previous week's terrorist attacks.

Overall, the alternative econometric methods that have been used to correct for mismeasurement of the funds rate surprises uniformly yield results similar to those using the event-study methodology used in section 2.2. Moreover, to the extent that the event-study results are biased, that bias tends to *understate* the true response to monetary policy. Thus, it seems safe to proceed using the event-study approach, bearing in mind that these probably represent conservative estimates of the stock market's reaction to monetary policy.

2.4 Endogeneity and subsample stability

This section investigates the robustness of the results reported in section 2.2 along two dimensions. One issue has to do with the joint response of monetary policy and the stock market to economic news. As noted above, in the early, 1989–92 portion of the sample, changes in the funds rate (all rate cuts during this period) often occurred on the same day as the employment report. After 1994, with rate changes more or less dictated by the exogenous scheduling of FOMC meetings, this becomes less of an issue. These pre-1994 employment report-related observations are distinguished in figure 1 by triangles. These observations are characterized by little, if any, correlation between the funds rate surprise and the stock return. In these instances, the "good news" for the stock market represented by the Fed's actions seems to have been almost exactly offset by the "bad news" about economic activity contained in the employment report.

Another issue concerns the stability of the estimated relationship. The avoidance of a same-day response to employment reports (and other economic news) is one possible reason the relationship might have changed in the early 1990s. The FOMC's practice of explicitly announcing rate changes, which began in February 1994, may also have altered the stock market's response to monetary policy.

To explore the possibility of different responses either post- 1994, or on days associated with employment releases, we interact the surprise rate change with dummy variables: one

Table 2: Tests for subsample stability and endogeneity

	Full sample		Excluding outliers	
Regressor	(a)	(b)	(c)	(d)
Intercept	0.16	0.16	0.12	0.12
	(1.80)	(1.76)	(1.43)	(1.43)
Expected change	1.09	1.09	0.69	0.69
	(2.26)	(2.24)	(1.68)	(1.67)
Surprise change	−1.25	−2.55	−2.29	−3.57
	(1.14)	(1.70)	(2.28)	(3.77)
Surprise change ×				
post-1994	−6.87	−5.58	−0.78	0.50
	(3.59)	(2.61)	(0.45)	(0.29)
employment report	...	2.67	...	3.33
		(1.82)		(2.55)
Adjusted R-squared	0.280	0.283	0.042	0.054

Notes: The dependent variable is the one-day CRSP value-weighted return, in percent. Parentheses contain t-statistics, calculated using heteroskedasticity-consistent estimates of the standard errors. The post-1994 dummy is set to 1 for observations beginning with 4 February 1994. The employment dummy is set to 1 for pre-1994 observations when a change in the target funds rate coincided with an employment release. See also notes to table 1.

equal to 1 starting with the 4 February 1994 observation, and another equal to 1 on the days of pre-1994 employment releases. Table 2 reports the response of the CRSP value-weighted index to surprise rate changes in the presence of these interactive dummies. Like table 1, columns (a) and (b) give the results for the full sample, and columns (c) and (d) give the results for the sample excluding the six candidate outliers identified above.

Judging from the results in column (a), it would appear that the entire equity price response can be traced to the post-1994 period. The coefficient on the surprise itself is only −1.25 and insignificant; that on the surprise interacted with the post-1994 dummy is a highly significant −6.87. But this regression neglects the possibility of endogeneity in the policy response prior to 1994. Including the surprise interacted with the employment release dummy as in column (b), increases the magnitude of the surprise response, and the positive interaction term implies a near-zero response to policy when it coincides with an employment release. These coefficients are statistically significant at only the 0.10 level however, and the post-1994 interaction term remains large and highly significant.

These results turn out to be heavily influenced by the six outliers identified above. With those observations excluded, as in column (c), post-1994 rate surprises have only a slightly larger effect, and the difference is not statistically significant. The coefficient on the surprise itself -2.29, and significant at the 0.05 level. But when the employment interaction term is included, the surprise coefficient grows to -3.57. This effect is almost exactly offset for employment release days by the 3.33 coefficient on the interaction term. Both are now highly significant, and the post-1994 dummy remains insignificant. Thus, if the six candidate outliers are discarded as unrepresentative of the sample, there is no evidence of a break in 1994. Furthermore, the results confirm that the endogeneity problem discussed above tends to reduce the measured response of equity prices to Fed funds surprises.

2.5 Asymmetries

Another set of questions concerns asymmetries, broadly defined: the possibility that the equity price response to monetary policy depends somehow on the direction of the action, or on the context in which it occurred. As above in section 2.4, interactive dummy variables are used in the regression to investigate these questions.

One possibility is that the magnitude of the stock market response depends on whether the surprise itself was positive or negative. To allow for this, a dummy variable was set to 1 for those observations with positive surprises. An interaction term involving this dummy and the surprise rate change was then included in the regression. The interactive term involving the employment release is also included, in order to pick up the smaller impact of funds rate surprises on employment release days. As above, the regressions are run with and without the six candidate outliers identified earlier. The results reported in table

Table 3: Tests for asymmetries

	Full sample			Excluding outliers		
Regressor	(a)	(b)	(c)	(d)	(e)	(f)
Intercept	−0.02	0.12	0.14	0.12	0.12	0.13
	(0.17)	(1.34)	(1.72)	(1.32)	(1.42)	(1.63)
Expected change	0.84	1.56	1.03	0.72	0.97	0.72
	(1.58)	(3.24)	(2.24)	(1.67)	(2.00)	(1.76)
Surprise change	−7.57	−8.34	−3.97	−3.26	−4.49	−3.67
	(4.67)	(5.73)	(2.98)	(3.30)	(4.91)	(3.14)
Surprise change ×						
employment	7.05	8.11	2.54	3.05	4.14	3.46
	(4.43)	(5.26)	(1.47)	(2.36)	(3.19)	(2.35)
positive surprise	7.39	…	…	−0.34	…	…
	(1.59)			(0.10)		
no rate change	…	10.42	…	…	4.00	…
		(3.81)			(2.25)	
positive rate change	…	3.05	…	…	0.58	…
		(0.76)			(0.15)	
FOMC meeting	…	…	4.25	…	…	0.67
			(2.75)			(0.39)
reversal	…	…	−6.33	…	…	−17.62
			(3.09)			(4.08)
post-1994	…	…	−4.61	…	…	0.80
			(2.48)			(0.44)
Adjusted R-squared	0.260	0.323	0.369	0.053	0.065	0.098

Notes: The dependent variable is the one-day CRSP value-weighted return, in percent. Parentheses contain t-statistics, calculated using heteroskedasticity-consistent estimates of the standard errors. The positive surprise dummy is set to 1 when the surprise change in the funds rate is greater than zero. The no rate change and positive rate change dummies equal 1 when the funds rate target is unchanged or increased. The FOMC meeting dummy is set to 1 for those observations coinciding with FOMC meetings. The reversal dummy equals 1 for rate changes that reverse the direction of the previous change. See also notes to tables 2 and 1.

3 provide weak support at best for this form of asymmetry. For the full sample, in column (a) of the table, the coefficient on the interaction term indicates a smaller effect of positive surprises, but the difference is not statistically significant. There is virtually no difference for the no-outlier sample, shown in column (d).

A related kind of asymmetry can be modeled by including interactive dummies for rate changes associated with increases in the funds rate, and with surprises associated with no change in the funds rate (i.e., when the futures market expected a change, but none occurred). The results of this exercise appear in columns (b) and (e) of the table for the full and no-outlier samples. Again, the statistically insignificant coefficient in the rate increase interaction variable suggests the direction of movement is not an important determinant of the market's reaction. The positive and statistically significant estimated coefficient on the "no change" interaction variable does, however, indicate that the market responds very little, if at all, to policy "inactions." This presumably means that the failure to move at any specific FOMC meeting may be viewed largely as postponing the inevitable.

A third sort of asymmetry has to do with the context of the rate decision: whether it was taken at an FOMC meeting, or represented a change in the direction of short-term interest rates. Again, these effects are captured through the use of suitable dummy variables, interacted with the surprise rate change variable. The sign of the FOMC interaction term is unclear a priori. Decisions taken at FOMC meetings may be less subject to the sort of endogeneity issues discussed above, which would tend to increase the impact of rate changes on these days. On the other hand, intermeeting changes (at least those not associated with employment reports) may convey an urgency on the part of the FOMC which would tend to increase the size of the response. What is clear, however, is that interest rate reversals — the first rate increase after a series of decreases, or vice versa — may have larger implications for future interest rates than other rate changes, and thus elicit a larger stock market response. These "reversal" and FOMC observations are distinguished in figure 1 by squares and circles, respectively.

Columns (c) and (f) of table 3 show the results from a regression containing these two interaction terms, along with the employment interaction variable and (just for good measure) the post-1994 interaction term. The coefficient on the surprise term remains an economically and statistically significant -3.97 or -3.67, depending on whether the full or no-outlier sample is used. Relative to this baseline response, there is no meaningful difference in either case between FOMC and non-FOMC days, controlling for the employment release. But reversals seem to have a large additional impact on the stock market: -6.33 for the full sample, and -17.62 for the no-outlier sample. In the latter case, the implausibly large estimate is driven almost entirely by the single observation in the southeast corner of the diagram, corresponding to the first rate increase in 1994. (The inclusion of the 3 January 2001 "outlier" actually shrinks the estimate to something more reasonable.) Thus, it appears that the stock market response to interest rate reversals may be larger than for other changes — although with so few of these reversals in the sample, this result should be treated with caution.

Taken together, the results presented above provide compelling evidence for a strong one-day reaction of the stock market to unanticipated changes in Federal funds rate. Just *how* strong this response is depends on whether the handful of potentially anomalous observations are viewed as representative, or discarded as outliers. The estimated response is stable over time, once the tendency for the FOMC to react to employment news in the early part of the sample is controlled for. And finally, there is some evidence of a larger response to reversals in the direction of rate changes, and a smaller response to unanticipated decisions to leave the funds rate target unchanged.

2.6 Timing versus level surprises

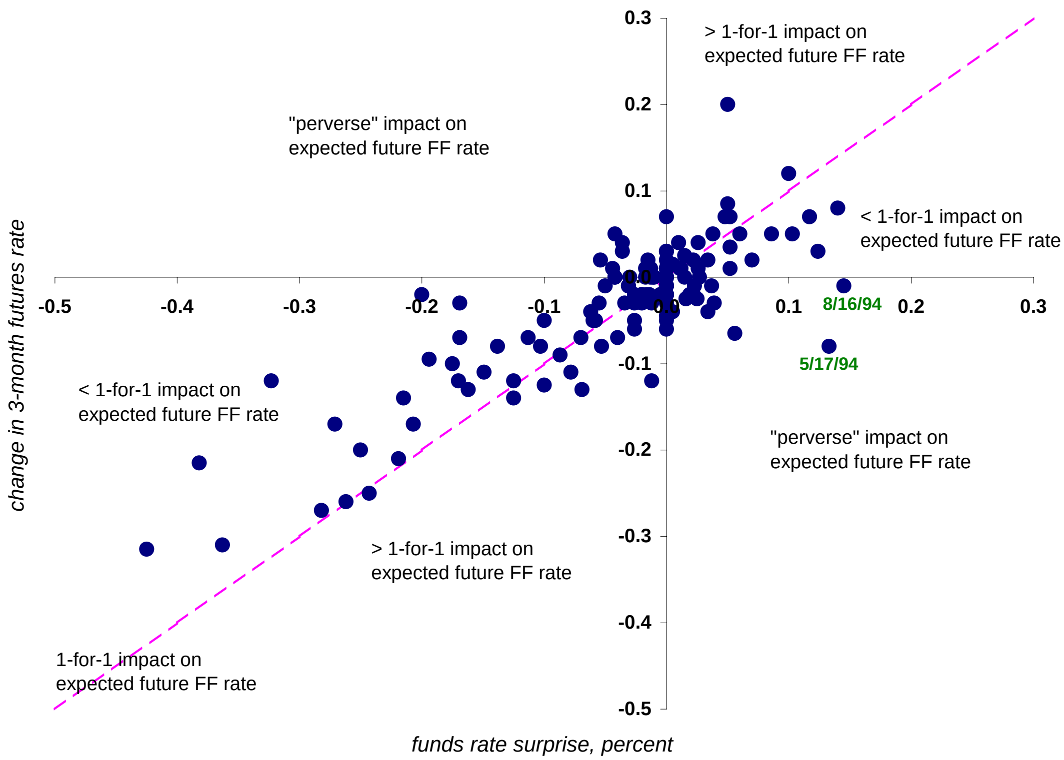
While the results described above point to a strong, systematic response of equity returns to funds rate surprises, there is a great deal of variation in this response. In some cases, the reaction is quite muted, while in others the reaction seems quite out of proportion with the size of the measured surprise. Apparently, not all funds rate surprises are created equal, at least in terms of their impact on the stock market.

One explanation for the observed variation in equities' response is that not all of the measured funds rate surprises have the same impact in the expected trajectory of monetary policy. Many of the surprises in the sample were in all likelihood interpreted as an advancement or postponement of a more-or-less inevitable change in policy. By contrast, others may have been interpreted as altering the expected path of the funds rate for months to come. Surprises with a more durable on policy expectations would naturally tend to have a larger effect on equity prices than those which merely alterted the *timing* of policy actions.

One way to see this is to look at the relation between the current-month fed funds surprises used in the preceding analysis, and the change in the fed funds futures rates for the months ahead, representing the change in policy expectations at that horizon. Chart 3 plots the change in the three-month-ahead futures rate against the funds rate surprise for the 131 observations in our June 1989 through December 2002 sample. The 45 degree line is also plotted, corresponding to a one-for-one response of the 3-month futures rate to the current month funds rate surprise.

The results from regressions of the change in the 3-month-ahead futures rate on the current month surprise are presented in table 4. The estimated slope coefficient of 0.65 in the first column says that on average, a 100 basis point funds rate surprise increases the three-month-ahead expectation by only 62 basis points. This is considerably less than

Figure 3: Fed funds surprises versus funds rate expectations



the one-for-one response indicated in the scatterplot, and the difference is significant at the 0.01 level. As noted in Kuttner (2001), this is consistent with the view that many of these unexpected changes are to a large extent surprises about the timing of policy actions. As shown in the remaining three columns, FOMC meetings and “no change” surprises tend to be associated with an even smaller response of expectations. Interestingly, the handful of reversals in the sample are not systematically associated with a larger impact on expectations — just the opposite, in fact.

It is revealing to categorize the observations according to where they fall relative to the 45 degree line in Chart 4. Those lying along a shallower line (i.e., those below the 45 degree line in the northeast quadrant and above in the southwest quadrant) represent observations where the impact on expectations is less than one-for-one. Those lying along a steeper line

Table 4: The impact on funds rate expectations of rate surprises

Regressor	(a)	(b)	(c)	(d)
Intercept	−0.01	−0.01	−0.01	−0.01
	(1.46)	(1.55)	(1.34)	(1.40)
Expected change	0.07	0.05	0.07	0.07
	(2.10)	(1.32)	(2.29)	(2.08)
Surprise change	0.65	0.70	0.73	0.66
	(13.37)	(14.71)	(14.54)	(12.83)
Surprise change ×				
no rate change	...	−0.36	...	...
		(3.24)		
FOMC meeting	...	...	−0.21	...
			(2.07)	
reversal	...	...	...	−0.12
				(2.24)
Adjusted R-squared	0.726	0.745	0.744	0.727

Notes: The dependent variable is the one-day change in the three-month-ahead Federal funds futures rate, in percent. Parentheses contain t-statistics, calculated using heteroskedasticity-consistent estimates of the standard errors. See also notes to tables 1 and 3.

are associated with a greater-than one-for-one reaction. There are even a few "perverse" reactions in the northwest and southeast quadrants, notably the two observations from May and August 1994 where unexpectedly-large rate hikes reduced (or left largely unchanged) expectations about future policy.

This raises the natural question of whether these differing impacts on expectations can help explain the dispersion in equities' response to surprise changes in the target rate. A straightforward way to address this is to include in the regression (4) a term reflecting the *difference* between the change in the 3-month-ahead futures rate and the current surprise, i.e., the vertical difference between each observation in Chart 3 and the 45 degree line. This "timing surprise" term might be interpreted as reflecting the degree to which the rate surprise was merely one of timing: a zero value implies a one-for-one movement in ex-

Table 5: The stock market response to level versus timing surprises

Regressor	Full sample (a)	Full sample (b)	Excluding outliers (c)	Excluding outliers (d)
Intercept	0.12	0.09	0.11	0.09
	(1.35)	(1.09)	(1.37)	(1.11)
Expected change	1.05	1.34	0.67	0.94
	(2.17)	(2.92)	(1.62)	(2.46)
Surprise change	−4.68	−6.20	−2.55	−4.17
	(3.03)	(3.80)	(2.79)	(4.20)
Timing surprise	...	−4.29	...	−4.27
		(2.20)		(3.25)
Effect of "pure" timing surprise	...	−1.91	...	0.09
		(0.91)		(0.08)
Adjusted R-squared	0.171	0.192	0.049	0.085

Notes: The dependent variable is the one-day change in the CRSP value-weighted return, in percent. Parentheses contain *t*-statistics, calculated using heteroskedasticity-consistent estimates of the standard errors. The "timing surprise" is the difference between the change in the three-month-ahead futures rate and the current month's surprise. The effect of the "pure" timing surprise is the difference between the coefficient on the surprise change, and that on the timing surprise. See also notes to table 1.

pecatations, while a value equal in magnitude to the surprise itself but with the opposite sign would be a pure timing surprise, with no effect on expectations three months out. Results for stock return regressions that include this timing surprise term appear in table 5.

For comparison purposes, columns (a) and (c) of the table simply reproduce the baseline results reported earlier in table 1, with and without the six extreme observations. Columns (b) and (d) report the regression results when the timing surprise term is added to the regression. The inclusion of this term increases the magnitude of the coeffient on the current-month surprise, which goes from −4.68 to −6.20 for the full sample. Because this coefficient can now be interpreted as the impact of a funds rate surprise that changes expectations by the same amount (i.e., with the timing surprise equal to zero), this implies a larger stock price response to those policy surprises that affect the level of interest rates expected to prevail three months hence.

Similarly, the statistically significant, negative coefficient on the timing surprise term says that surprises with a less-than one-for-one impact on expectations (i.e., those for which the change in the 3-month futures rate is smaller than the current-month surprise) have a correspondingly smaller effect on stock prices. In the extreme case of a "pure" timing surprise with *no* effect on the expected level of rates, the response is given by the difference between the two coefficients: -1.91 for the full and 0.09 for the no-outlier sample. Neither is statistically significant at even the 0.10 level, suggesting that policy actions affect stock returns only to the extent that they alter the expected level of rates.

2.7 Results based on monthly data

An alternative way to define the policy surprise is to focus on the expected change in policy at a regular, monthly horizon. Unlike the event study approach, the regular timing is amenable to the time series analysis employed below in section 3 to assess the causes of the market's response. It is worth noting that in this approach, any month could potentially contain a surprise policy action, and that a failure to change the funds rate target in any month could represent a policy surprise. Consequently, the monthly time-series approach is probably less susceptible to any sample selection issues that might arise in the context of the event-study methodology.

The use of monthly data calls for a slightly different gauge of unanticipated policy actions. Since the price of the Fed funds futures contract is based on the monthly average Fed funds rate, a natural definition of the month-t surprise would be

$$\bar{\Delta} i_t^u \equiv \frac{1}{D} \sum_{d=1}^{D} i_{t,d} - f_{t-1,D}^1 \ , \qquad (5)$$

where $i_{t,d}$ is the funds rate target on day d of month t, and $f_{t-1,D}^1$ is the rate corresponding to the one-month futures contract on the last (Dth) day of month $t-1$.[8] The expected funds

[8]The settlement price of the Fed funds futures contract is determined by the average over the calendar

rate change is defined analogously as

$$\bar{\Delta} i_t^e \equiv f_{t-1,D}^1 - i_{t-1,D} \ . \tag{6}$$

The sum of the two is the average funds rate target in month t minus the target on the last day of month $t-1$. (The notation $\bar{\Delta}$ is used to distinguish this from the conventionally-defined first difference operator.)

This definition of the funds rate surprise raises a time aggregation issue. Measuring the surprise in terms of the average funds rate will tend to attenuate the size of the policy surprises, as discussed in detail in Evans and Kuttner (1998). Unfortunately, without making specific assumptions about the days of possible rate changes, there is no clean way to correct for this problem.[9] Consequently, some caution is required when interpreting the magnitude of the surprises measured in this way.

It is also important to note that the endogeneity issue discussed above in section 2.4 is almost certainly going to be more relevant to monthly funds rate surprises than it was for the day-ahead surprises. Rate changes that were unanticipated as of the end of the prior month may well include a systematic response to economic news, such as employment, output and inflation.

The results shown in table 6 confirm this suspicion. The table reports the parameter estimates and R-squared from a regression of the monthly policy surprises on the surprise element of key economic reports, calculated as the difference between the number released and the consensus expectation for that number, compiled by Money Market Services.[10] Over the full May 1989 through December 2002 sample, there appears to be a significant within-month impact of several data releases on the funds rate target: nonfarm payrolls,

month, carrying the prior business day's rate over to weekends and holidays.

[9]One solution would have been to assume that post-1994 rate changes were always expected to occur at scheduled FOMC meetings. The three intermeeting rate cuts in 2001 have made this assumption less plausible, however.

[10]We are indebted to Eric Swanson for his assistance with these data.

Table 6: The impact of economic news on funds rate surprises

Data surprise	Full sample	Subsample 5/89–9/92	Subsample 2/94–12/02
Headline CPI	0.016	−0.124	−0.010
Core CPI	−0.058	−0.012	0.152
Headline PPI	0.001	−0.027	−0.024
Core PPI	−0.085**	−0.304***	−0.022
Nonfarm payrolls	0.203**	0.624***	−0.009
Industrial production	0.069*	0.136	0.028
Retail sales	−0.031**	−0.061	−0.035***
Retail sales, x autos	0.023	0.093	0.021
R-squared	0.128	0.454	0.087
Adjusted R-squared	0.082	0.304	0.012

Notes: Asterisks denote statistical significance: *** for the 0.01 level, ** for the 0.05 level, and * for the 0.01 level. The dependent variable is the unexpected change in the funds rate, defined by equation 5. The Money Market Services data are used to calculate the surprise elements of the economic releases.

industrial production, retail sales, and core PPI (although these latter two have the "wrong" sign).

This relationship seems to be much stronger in the early part of the sample, however. The second column of the table shows the results for the same regression estimated over the May 1989 through September 1992 sample. The Fed's reaction to bad payroll employment news is now particularly pronounced. Moreover, the regression accounts for nearly half of the variance of the funds rate surprises. By contrast, in the more recent February 1994 through December 2002 subsample, there is very little evidence of a within-month reaction to economic news, as shown in the third column of the table. Only retail sales is significant, and the regression now accounts for a much smaller share of the variance of funds rate surprises.[11]

[11] Again, retail sales is significant with the "wrong" sign. But this result is due entirely to an anomalous 7 percent jump in retail sales in November 2001, which happened to occur in a month in which the Fed also

Table 7 reports the results from a regression of the monthly CRSP value-weighted return the expected and unexpected components of monthly funds rate changes,

$$H_t = a + b^e \overline{\Delta} i_t^e + b^u \overline{\Delta} i_t^u + \varepsilon_t \quad . \tag{7}$$

Column (a) reports the estimates for the full sample, consisting of all 164 months from May 1989 through December 2002. As in the earlier results, there is a strong, statistically significant negative response to unanticipated rate increases, and little or no response to the anticipated actions. The $\bar{R}^2$ indicates that nearly seven percent of the monthly stock return variance can be traced to unanticipated policy actions.

It is interesting to note that the magnitude of the response, -11.43, is over twice that found in the event-study analysis. This difference in magnitudes is readily explained by the time aggregation issue alluded to earlier. In fact, if funds rate changes on average take place in the middle of the month (for example, if rate changes were distributed uniformly over the days of the month), then the magnitude of the estimated monthly surprises will be attenuated by one-half, and this would explain the doubling of the estimated response of the stock price.

The negative relationship between policy surprises and stock returns is also evident in the scatterplot of the data in figure 4. As in the daily data, a number of observations stand out as potential outliers, again raising the question of whether the results are sensitive to their inclusion. As above, influence statistics were calculated for each observation in the sample; those with statistics in excess of 1.5 are flagged as outliers in the plot. (The most conspicuous of these is the data point deep in the southwest quadrant, which corresponds to September 2001.) Dropping these ten observations makes little difference to the results, however. In fact, as shown in column (b) of table 7, the estimated coefficient of -14.26 is somewhat larger than it is for the full sample, and the $\bar{R}^2$ rises to 0.096.

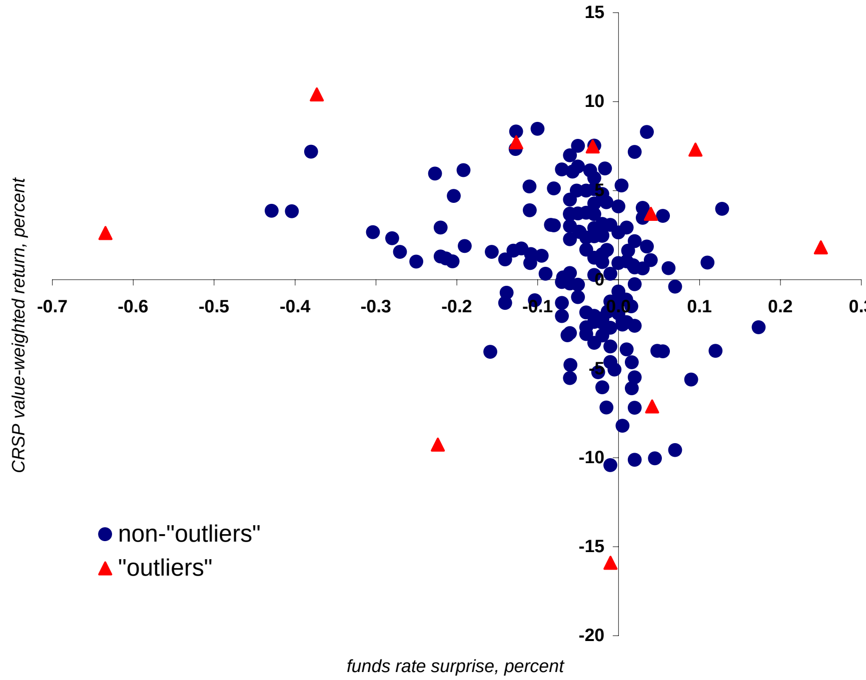
cut the funds rate target.

Table 7: The monthly response of equity prices to funds rate surprises

Regressor	Full sample (a)	No outliers (b)	Tests for asymmetries (c)	(d)	(e)
Intercept	0.13	−0.03	−0.01	−0.07	0.10
	(0.32)	(0.09)	(0.02)	(0.16)	(0.24)
Expected change	−1.11	0.96	−1.07	−2.72	−1.09
	(0.37)	(0.35)	(0.36)	(0.72)	(0.36)
Surprise change	−11.43	−14.26	−12.46	−11.01	−10.49
	(3.95)	(5.43)	(3.69)	(3.46)	(2.53)
Surprise change ×					
positive surprise	...	...	6.82	...	...
			(0.63)		
no rate change	...	...		−4.88	...
				(0.75)	
positive rate change	...	...	...	6.59	...
				(0.52)	
reversal	...	...	...	...	3.52
					(0.50)
post-1994	...	...	...	...	−3.77
					(0.50)
Employment surprise	...	...	...	...	−0.69
					(0.10)
Adjusted R-squared	0.065	0.096	0.061	0.056	0.049
Standard error	4.28	3.85	4.30	4.30	4.31
Durbin-Watson statistic	2.02	2.09	2.02	2.02	2.03

Notes: Parentheses contain t-statistics. The dependent variable is the monthly return on the CRSP value-weighted portfolio, expressed in percent. The unanticipated and anticipated components of the change in the Fed funds rate are given by equations 5 and 6, and are expressed in percent. The full sample includes 164 monthly observations spanning May 1989 through December 2002. The no-outlier sample contains 154 observations.

Figure 4: Scatterplot of equity returns and Fed funds surprises, monthly data



The monthly data contain very little evidence for the sorts of asymmetries uncovered in the daily data. As shown in columns (c) and (d), there is no indication that the stock price response depends on the sign of the surprise, or on the direction of the rate change. Nor is there any evidence of a different response to policy reversals, or to the MMS employment surprises.[12]

There is considerable cross-industry variation in the response of stock prices to monetary policy. Table 8 reports estimates of equation 7 for the ten industry portfolios constructed from CRSP returns by Fama and French. The most responsive industries are high tech and telecommunications, with coefficients half again as large that for the overall value-weighted index. On the other end of the spectrum, energy and utilities are only half as re-

[12]Interestingly, the employment surprise is negative and significant in a univariate regression (not reported), but becomes insignificant once the Fed funds surprise is included. This is consistent with the findings of Boyd et al. (2001), and corroborates their conjecture that the policy response accounts for equities' perverse response.

Table 8: Response of Fama-French industry portfolios

Index	Response to target change: anticipated	Response to target change: unanticipated	$\bar{R}^2$	SE	DW	Market beta
CRSP value weighted	−1.11	−11.43	0.065	4.28	2.02	1
	(0.37)	(3.95)				
Nondurables	−0.85	−9.65	0.046	4.17	2.00	0.60
	(0.25)	(2.88)				
Durables	−1.47	−12.45	0.048	5.56	1.97	1.02
	(0.38)	(3.04)				
Manufacturing	−2.02	−8.82	0.035	4.26	2.03	0.85
	(0.61)	(2.81)				
Energy	0.20	−4.03	−0.003	4.71	2.12	0.55
	(1.02)	(1.24)				
High tech	0.06	−14.73	0.025	8.22	2.00	1.61
	(0.01)	(2.72)				
Telecommunications	0.35	−16.10	0.065	6.16	1.85	1.16
	(0.60)	(3.31)				
Wholesale/retail	−4.75	−11.97	0.056	4.85	1.95	0.90
	(1.47)	(3.64)				
Health care	−1.04	−8.04	0.017	4.96	2.15	0.72
	(0.29)	(1.80)				
Utilities	−1.24	−5.42	0.006	4.21	1.97	0.32
	(0.48)	(1.55)				
Other	−1.21	−11.08	0.051	4.62	2.09	0.92
	(0.35)	(3.61)				

Notes: Parentheses contain t-statistics. The dependent variable is the monthly return on the Fama-French industry portfolios, expressed in percent. The unanticipated and anticipated components of the change in the Fed funds rate are given by equations 5 and 6, and are expressed in percent. The regressions also include an intercept (not reported). The sample includes 164 monthly observations spanning May 1989 through December 2002.

sponsive as the overall market, and the relevant coefficients are statistically insignificant.[13] The low R-squareds indicate that very little of those industries' variance is associated with unexpected policy actions.

A natural question to consider is the degree to which this pattern of industry responses is consistent with the implications of the CAPM — that is, whether the observed responses are proportional to the industries' market "betas". A straightforward way to do this is first to calculate industry betas using the usual regression method,

$$y_{i,t} = \alpha + \beta_i y_{M,t} + \nu_t$$

where $y_{i,t}$ is the industry i excess return, and $y_{M,t}$ is the overall market excess return.[14] The industry response implied by the CAPM could then be expressed as:

$$\hat{b}_i^u = \hat{\beta}_i \times \hat{b}^u \tag{8}$$

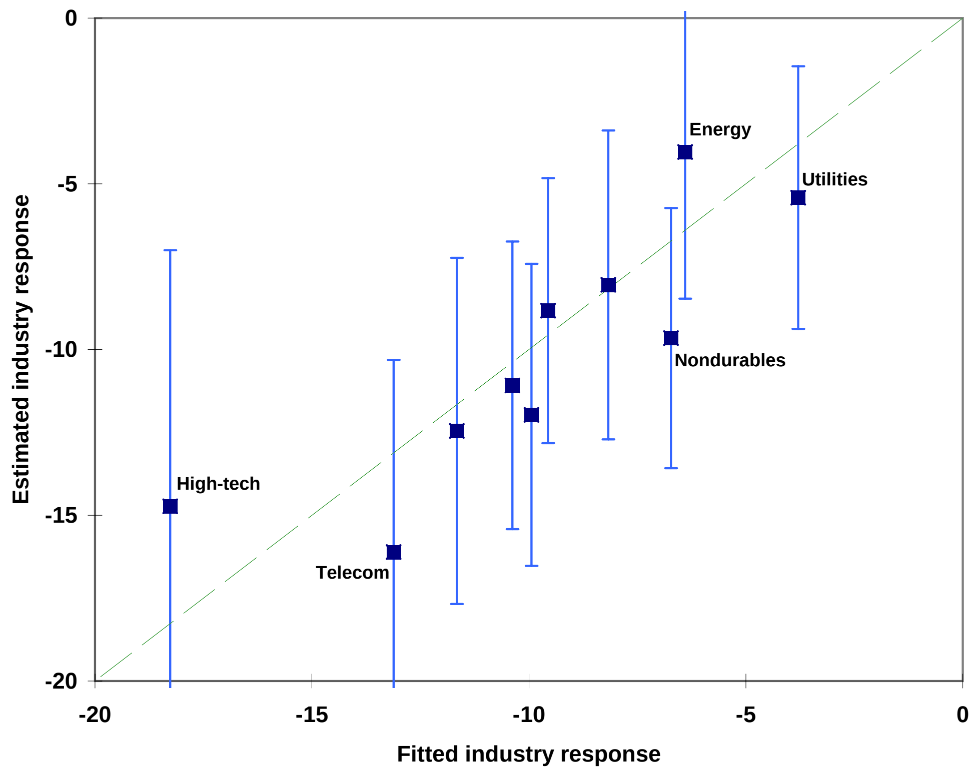
where $\hat{b}^u$ is the estimated response of the CRSP value-weighted excess return to funds rate surprises.

Figure 5 plots these fitted responses to monetary policy against the estimated responses, $\hat{b}_i^u$, reported in table 8, along with the 80 percent confidence intervals associated with those estimates. Also plotted is the 45-degree line that the points would lie on if the CAPM perfectly accounted for variation across industries. Although the fit is not perfect, the points line up reasonably well along the 45 degree line, suggesting that the one-factor CAPM does a good job of explaining the observed industry variation. High-tech's measured sensitivity to monetary policy is in fact somewhat less than its beta would imply, while telecommunications' is somwehat greater. On the other end of the spectrum, the utilities and energy

[13] Using methods similar to ours, Guo (2002) found that the impact of monetary policy on stock prices does not seem to depend on firm capitalization.

[14] Using betas based on the sum of contemporaneous and lagged market covariances, as in Campbell and Vuolteenaho (2003), makes virtually no difference to the results.

Figure 5: Estimated industry responses and CAPM implications



Notes: The horizontal axis values are the the fitted industry stock price responses from equation 8. The vertical axis values are the estimated industry stock price responses, corresponding to those in table 8. The plotted error bands are the 80 percent confidence intervals associated with the estimated industry responses.

industries' low market betas for the most part account for their muted response to monetary policy. The 45 degree line lies well within the 80 percent confidence intervals.

3 Policy, fundamentals and stock prices

Having documented the reaction of equity returns to Federal Reserve policy in section 2 above, we now turn to the more difficult question of what explains the observed reaction. There are three broad reasons why an unexpected funds rate increase may lead to a decline in stock prices: it may be because of a decline in expected future dividends, an increase in the expected real interest rate used to discount those dividends, or it may increase the expected excess return (i.e., the equity premium) associated with holding stocks. Simple regressions of equity returns on surprise changes in the funds rate target are silent on the question, so a more structured approach is required to disentangle the various effects.

The approach in this paper is an adaptation of the method used by Campbell (1991), and Campbell and Ammer (1993). In brief, the first element of their method is a log-linear decomposition of excess equity returns into components attributable to news about real rates, dividends, and future excess returns; the second element is the use of a vector autoregression (VAR) to calculate the relevant expectations.[15] We take the Campbell-Ammer framework one step further, however, by relating these components in turn to the news about the path of monetary policy embodied in the surprises derived from Fed funds futures. This allows us to estimate the impact of Fed funds surprises on expected future dividends, real interest rates, and expected *future* excess returns. It turns out that the largest effects come from revisions to expectations of future excess returns, and to expectations of future dividends. Real interest rates have a very small direct impact.

The object of this analysis is the (log) excess return on equities, denoted y_{t+1}. This is defined as the total return on equities (price change plus dividends), minus the risk-free rate (taken to be the one-month Treasury bill yield). The return dated $t+1$ is measured over period t, i.e., from the beginning of period t to the beginning of period $t+1$. Let e^y_{t+1} represent the unexpected (relative to expectations formed at the beginning of period t) excess return during period t, i.e., $y_{t+1} - E_t y_{t+1}$.

Using the linearization developed by Campbell and Shiller (1988), the period t unexpected excess return on equity can be expressed in terms of the revision the expectation of discounted future dividends, the real interest rate, and future excess returns. (A sketch of

[15]Because VARs require periodic time series data, the subsequent analysis will use the monthly measure of the funds rate surprises.

the derivation can be found in the appendix.) The decomposition can be written as:

$$e^{y}_{t+1} = \tilde{e}^{d}_{t+1} - \tilde{e}^{r}_{t+1} - \tilde{e}^{y}_{t+1} \tag{9}$$

where the es represent the revision in expectations between periods t and $t+1$, and the tilde denotes a discounted sum, so that

$$\begin{aligned}
\tilde{e}^{d}_{t+1} &= (E_{t+1} - E_t) \sum_{j=0}^{\infty} \rho^j \Delta d_{t+1+j} \\
\tilde{e}^{r}_{t+1} &= (E_{t+1} - E_t) \sum_{j=0}^{\infty} \rho^j r_{t+1+j} \\
\tilde{e}^{y}_{t+1} &= (E_{t+1} - E_t) \sum_{j=1}^{\infty} \rho^j y_{t+1+j} \quad .
\end{aligned}$$

The ρ discount factor, which comes out of the linearization, represents the steady-state ratio of the equity price to the price plus dividend; following Campbell and Ammer (1993), this is set to 0.9962. As emphasized by Campbell (1991), equation 9 is really nothing more than a dynamic accounting identity relating the current excess return to revisions in expectations. As such, it contains no real economic content, much less any specific asset pricing model; such a model would be required to provide a link between the conditional expectations of future returns and economic variables (e.g., consumption).

Implementing this decomposition obviously requires empirical proxies for the expectations appearing in equation 9. The approach of Campbell (1991) and Campbell and Ammer (1993) is to model expectations using a Vector Autoregression (VAR) involving the variables of interest (excess returns and the real interest rate) along with any other indicators that might be helpful in forecasting those variables. Calculating the discounted sum of the revisions in expectations is straightforward; to do so involves requires writing the n variable, p lag VAR as a first-order system,

$$z_{t+1} = Az_t + w_{t+1} \quad , \tag{10}$$

where z_{t+1} is an appropriately stacked $np \times 1$ vector containing the excess equity return, the real interest rate, and any additional indicators. With the VAR expressed in this form, the ingredients of equation 9 are given by

$$\begin{aligned}
e^y_{t+1} &= s_y w_{t+1} \ , \\
\tilde{e}^y_{t+1} &= s_y \rho A(1-\rho A)^{-1} w_{t+1} \ , \\
\tilde{e}^r_{t+1} &= s_r(1-\rho A)^{-1} w_{t+1} \text{ and} \\
\tilde{e}^d_{t+1} &= e^y_{t+1} + \tilde{e}^y_{t+1} - \tilde{e}^r_{t+1} \ ,
\end{aligned}$$

where s_y and s_r are appropriate $1 \times np$ selection matrices.

Two features of the Campbell-Ammer method deserve further comment. One is its parametric approach to constructing long-horizon expectations of stock returns: one has to assume that the dynamics of equity returns many years in the future are adequately captured by a parsimonious VAR model. To a large extent, this parametric approach is forced upon us, as the relatively short, 13-year experience with Fed funds futures is not sufficient to directly estimate the long-horizon impact on stock asset returns, particularly in light of the questionable small-sample properties of long-horizon regressions [see Nelson and Kim (1993)]. But as discussed below, the use of the VAR *does* allow us to estimate the dynamics of stock returns over a longer sample than the period for which futures data are available.

A second important feature of the approach is that dividends are not included explicitly as a variable to be forecast; given e^y_{t+1}, $\tilde{e}^y_{t+1}$ and e^r_{t+1}, e^d_{t+1} is backed out from the equation 9. In principle, it would be possible to forecast dividends directly in the VAR, and instead back out an implied $\tilde{e}^y_{t+1}$. In practice, however, this is complicated by a strong seasonal pattern, and a root near unity in the dividend process. It is important to note that to the extent that the VAR understates the predictability of excess returns, treating dividends as a residual means that the method will end up attributing *too much* of the return volatility to dividends.[16]

3.1 The forecasting VAR

The first step is to set up a VAR to capture the dynamic correlations between the excess equity return and the real interest rate (calculated as the one-month bill yield minus the log difference in the non-seasonally-adjusted CPI). The VAR must therefore include these two variables at a minimum, plus whatever other variables that might be useful in forecasting them. (One important constraint, of course, is that these variables are available in real time.) We follow Campbell and Ammer (1993) in using a six-variable one-lag system that included, besides the real rate and equity return: the relative bill rate (defined as the three-month bill rate minus its 12-month lagged moving average), the *change* in the bill rate, the (smoothed) dividend price ratio, and the spread between the 10-year and one-month Treasury yields.

3.2 A variance decomposition of equity returns

Equation 9 expresses this month's excess equity returns into three components, which may be correlated with one another. The variance of the current excess return can therefore be broken down into the sum of the three variances, plus (or minus) the relevant three covariances,

$$\begin{aligned} \mathrm{Var}(e^{y}_{t+1}) \quad &= \quad \mathrm{Var}(\tilde{e}^{d}_{t+1}) + \mathrm{Var}(\tilde{e}^{r}_{t+1}) + \mathrm{Var}(\tilde{e}^{y}_{t+1}) - \\ & \quad\quad 2\mathrm{Cov}(\tilde{e}^{d}_{t+1}, \tilde{e}^{r}_{t+1}) - 2\mathrm{Cov}(\tilde{e}^{d}_{t+1}, \tilde{e}^{y}_{t+1}) + 2\mathrm{Cov}(\tilde{e}^{y}_{t+1}, \tilde{e}^{r}_{t+1}) \ , \end{aligned} \tag{11}$$

giving a sense of the relative contributions of news about real interest rates, dividends, and expected future excess returns to fluctuations in the current excess return. The results of

[16] A useful check on the Campbell-Ammer procedure would be to compare its implied dividend forecasts with the observed behavior of dividends. Such a comparison is beyond the scope of the present paper, however.

this decomposition appear in table 9. For comparison, the table displays results for the full 1973–2002 sample and for the subsample beginning in May 1989, when the Fed funds futures data became available. The columns labeled "total" show the total contribution, and those labeled "share" expresses that contribution as a percentage of the excess return variance, i.e., normalizing by $\text{Var}(e^y_{t+1})$.

The results for the full 1973–2002 sample are similar to those reported by Campbell and Ammer (1993) for their 1973–87 sample. In particular, the variance in expected *future* excess returns accounts for the majority of the variance of the current equity return: 76 percent, compared with Campbell and Ammer's 101 percent. Dividends make a correspondingly larger contribution of 24.5 percent, as opposed to Campbell and Ammer's 14 percent. In both cases, the contribution of the real interest rate is negligible (0.3 and 3 percent respectively) and statistically insignificant.

The truncated 1989–2002 subsample yields somewhat different results, as shown in the right-hand portion of the table. Considerably less variance is attributed to revisions in expectations of future excess returns, and the dividend component now plays a somewhat larger role. The main reason for this seems to be a decline in the forecastability of equity returns in recent years, consistent with the observed fall in the adjusted *R*-squared from 0.04 to basically zero. With returns less forecastable, the Campbell-Ammer methodology by default assigns more of the excess return variance to dividend news.

3.3 The effects of Fed funds surprises

The most straightforward way to analyze the impact of monetary policy within the framework introduced above is to include the Fed funds surprises in the VAR as an exogenous variable

$$z_{t+1} = Az_t + \phi \overline{\Delta i}^u_{t+1} + w^{\perp}_{t+1} \tag{12}$$

Table 9: Variance decomposition of excess equity returns

	1973–2002		1989–2002	
	Total	Share (%)	Total	Share (%)
Var(excess return)	21.5		19.0	
Var(dividends)	5.3	24.5	6.1	31.9
		(6.2)		(1.8)
Var(real rate)	0.3	1.4	0.1	0.6
		(2.4)		(1.5)
Var(future returns)	16.4	76.0	7.2	38.0
		(1.8)		(1.2)
-2 Cov(dividends, real rate)	-0.4	-2.1	-0.6	-3.2
		(0.8)		(0.7)
-2 Cov(dividends, future excess return)	0.2	1.0	7.2	-37.7
		(0.0)		(2.3)
2 Cov(future excess return, real rate)	-0.2	0.8	1.0	5.1
		(0.1)		(1.1)
$\bar{R}^2$ from excess return equation	0.040		-0.003	

Notes: The equity return used is the CRSP value-weighted index. Parentheses contain t-statistics, calculated using the delta method.

where ϕ is an $n \times 1$ vector capturing the contemporaneous response of the elements of z_{t+1} to the unanticipated rate change period $t+1$. The new disturbance term $w^{\perp}_{t+1}$ is by construction orthogonal to the funds rate surprise. This effectively breaks the VAR's one-month-ahead forecast error into a component having to do with news about monetary policy, $\phi\bar{\Delta} i^u_{t+1}$ and a component incorporating information about things other than policy.

An important point is that because Δi^u_{t+1} represents a prediction error from a rational forecast made at time t, it should be orthogonal to z_t.[17] Consistent estimates of both A and ϕ can therefore be obtained by first estimating the usual VAR (equation 10), and then regressing the VAR's one-step-ahead forecast errors on the funds rate surprises. Normally, there would be no advantage to the two-step procedure over simply estimating equation

[17]Krueger and Kuttner (1996) showed that in practice, the Fed funds futures prediction errors are generally uncorrelated with lagged information.

12 directly. But in our case, using the two-step procedure allows us to estimate the VAR dynamics (i.e., the coefficients in the A matrix) over a sample *longer* than the period for which Fed funds futures are available.[18] This will of course tend to improve the precision of our estimates.

3.3.1 The dynamic response to funds rate surprises

Incorporating the Fed funds surprises into the VAR in this way allows us to do two things. First, because it extracts an orthogonal element from the w_t forecast error, we can use it to calculate the dynamic responses of the variables in the VAR to the orthogonal component. The k-month response to a one-percentage-point surprise increase in the funds rate can be calculated quite simply as $A^k \phi$.

An obvious question to arise at this point concerns the relationship between these futures-based funds rate surprises and the more familiar monetary policy shocks derived from an identified VAR. The methods used to construct the one-month-ahead funds rate forecasts differ, of course, with one using the futures market's implicit forecast, and the other using a reduced-form econometric model. Forecast methodologies aside, however, the orthogonalization procedure described above is conceptually equivalent to ordering the funds rate first in a VAR system. Since this precludes any contemporaneous reaction of the funds rate to economic news, the surprises calculated in this way may well incorporate an endogenous policy response to information arriving within the month. Consequently, the impulse responses may represent the effects of things other than monetary policy *per se*.

One way to minimize this problem would be to purge the futures-based funds rate surprises of any contemporaneous response to the economy by projecting them onto the relevant information variables, such as the data news obtained from the MMS survey. Alternatively, since the results above in section 2.7 indicate there has been little, if any, correlation

[18] Faust, Swanson and Wright (2002) use a similar trick: they estimate the VAR parameters over the full sample, but choose an orthogonalization based on the response of interest rates over the post-1989 subsample.

between the funds rate surprises and data news since 1994, the ϕ estimated only on the post-1994 subsample should be relatively free from this endogeneity problem. This is the approach taken in the results presented below.

The upper-left-hand panel of figure 6 displays the dynamic response of excess returns calculated in this way. The initial decline of 11.6 percent (not shown, because of the difference in scale) is followed by another month of negative returns, and then by several months of near-zero excess returns.[19] After six months, equities start to exhibit small *positive* excess returns, peaking at 0.16 percent per month (1.9 percent at an annual rate), and continuing for a period measured in years.

The contractionary funds rate surprise also leads to a sizable increase in the relative bill rate, which persists several months (by construction). The real T-bill rate rises sharply at first, but the increase is relatively short-lived, and all but disappears after four months. In the near term, the dynamics of equity excess returns are dominated by the effects of rising interest rates. But as these effects die out, the long-run effect of the dividend-price ratio, which rises as a result of the fall in equity prices, reasserts itself. It is this that leads to the highly persistent, positive excess returns visible in the impulse response function.

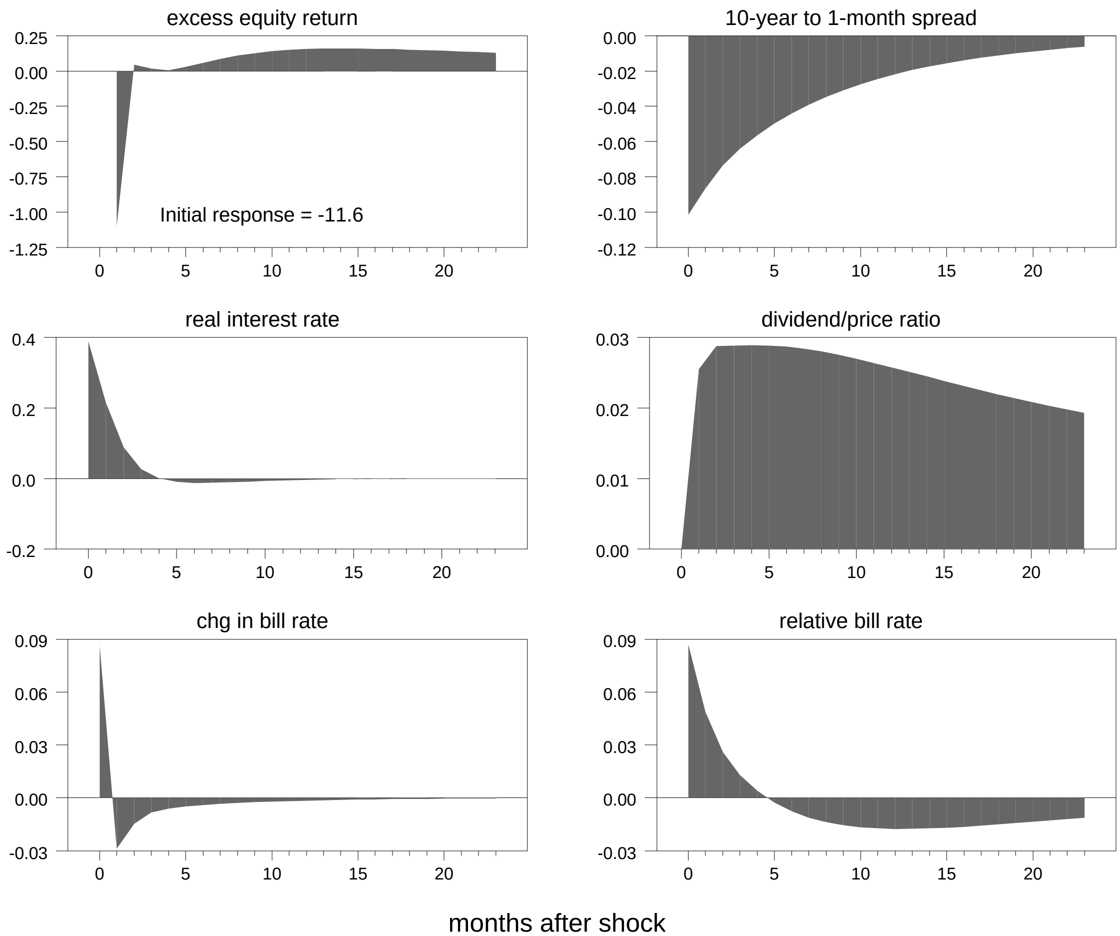
3.3.2 Explaining the stock market's reaction to Fed policy

The second thing this approach allows us to do is calculate the impact of the Fed funds surprises on the *discounted sums* of expected future excess returns, interest rates, and dividends. And since it is these sums that are related to the current excess return through equation 9, this provides a natural way to determine the source (or sources) of the stock market's reaction to monetary policy.

One way to assess policy's effect on these discounted sums is simply to use the VAR to calculate $\tilde{e}^d_{t+1}$, $\tilde{e}^r_{t+1}$, and $\tilde{e}^y_{t+1}$, which represent the revisions in expectations of the relevant

[19] This 11.6 percent response differs slightly from the results in section 2.7 because the dependent variable is the forecast error in the log excess return, rather than the raw nominal return.

Figure 6: The estimated responses to monetary policy surprises



Notes: Each panel represents the response to a 1 percent funds rate surprise, as defined in equation 5, calculated from the VAR using value-weighted CRSP returns and estimated over the 1973–2002 sample. The period-zero response to the funds rate surprises (ϕ) is estimated on the February 1994 to December 2002 subsample. The initial excess return response is not shown, because of the large difference in scale.

present values, and regress these variables in turn on Δi^u_{t+1}. Although this would provide the answer we are after, the standard errors would be misleading, as they would fail to take into account the dependence of the $\tilde{e}$s on the estimated parameters of the VAR.

An alternative way to do the same calculation is to write out the $\tilde{e}$s in terms of the VAR coefficients. Taking $\tilde{e}^y_{t+1}$ as an example:

$$\begin{aligned}\tilde{e}^y_{t+1} &= s_y \rho A(1-\rho A)^{-1} w_{t+1} \text{ or} \\ &= s_y \rho A(1-\rho A)^{-1}(\phi \bar{\Delta} i^u_{t+1} + w^{\perp}_{t+1}) \ .\end{aligned}$$

The response of the present value of expected future excess returns to the FF surprise is just

$$s_y \rho A(1-\rho A)^{-1}\phi \ .$$

Thus, the response of expected future excess returns depends not only on the ϕ vector, but also on the VAR dynamics represented by A. Similarly, the response of the present value of current and expected future real returns is

$$s_r(1-\rho A)^{-1}\phi \ ,$$

and the implied response of the present value of current and expected future dividends is

$$s_y\phi + s_y \rho A(1-\rho A)^{-1}\phi + s_r(1-\rho A)^{-1}\phi$$

or alternatively

$$(s_y + s_r)(1-\rho A)^{-1}\phi \ .$$

The standard errors for these responses can be calculated in the usual way, using the delta method.

The results of these calculations appear in table 10. With the VAR estimated over the entire 1973–2002 sample, funds rate surprises have a large, marginally significant impact on the discounted sum of future excess returns, accounting for just over half of the -11.55

Table 10: The impact of monetary policy on dividends, interest rates, and future returns

	Sample used for VAR	
	1/73–12/02	5/89–12/02
Current excess return	−11.55	−11.01
	(3.87)	(3.72)
Future excess returns	6.10	3.29
	(1.74)	(1.10)
Real interest rate	0.64	0.77
	(1.03)	(1.87)
Dividends	−4.82	−6.96
	(1.73)	(2.35)

Notes: Parentheses contain *t*-statistics. The VAR is estimaed over the sample indicated, and the period-zero response to the funds rate surprises (ϕ) is estimated on the February 1994 to December 2002 subsample.

contemporaneous excess return response. The reason for this large contribution is readily understood in terms of the impulse responses plotted in figure 6. Though small, funds rate shocks are estimated to have a highly persistent positive effect on excess returns. Discounting these future positive excess returns back using a discount factor near unity yields a large negative impact on the current excess return.

The −4.82 impact on dividends is nearly as large as that of future excess returns, and it too is significant at the 0.10 level. The impact on the discounted sum of real rates is very small, however, and accounts for less than one percentage point of the excess return response. This is to be expected, however, as real rates play a small role overall in the Campbell-Ammer variance decomposition.

The results are qualitatively similar when the VAR is estimated over the shorter 1989–2000 sample. The only noteworthy difference is the smaller impact on expected future excess returns, which now account for a statistically insignificant 3.29 percentage points of the −11.01 percent response. The reason for this can be traced to the smaller amount of long-run forecastability in excess returns in the post-1989 sample. In fact, the impulse response functions from this truncated sample (not shown) are nearly identical to those for the full 1973–2002 sample, shown above. The main difference is that the response of the excess return is negligible after six months or so, and it is this difference that accounts for the smaller contribution of future excess returns.

4 Conclusions

This study has documented a relatively strong and consistent of the stock market to unexpected monetary policy actions, using Fed funds futures data to gauge policy expectations. For broad stock market gauges like the CRSP value-weighted index, an unexpected 25 basis point rate cut would typically lead to an increase in stock prices on the order of 1 percent. The result is robust to the exclusion of outliers and to the choice of windows for measuring the stock market's response. There is some evidence of a larger market response to policy changes that are perceived to be relatively more permanent, a larger response to reversals in the direction of funds rate movements, and a smaller response to unexpected inaction on the part of the FOMC. Another finding is that the reactions differ considerably across industries, with the most sensitive high-tech and telecommunications sectors exhibiting a response half again as large as that of the broad market indices. Other sectors, such as energy and utilities, seem not to be significantly affected by monetary policy. The industry responses to monetary policy changes seem broadly consistent with the predictions of the standard CAPM.

Although we have found an effect of monetary policy on the stock market of reasonable size, we should emphasize that monetary policy surprises are responsible for only a small portion of the overall variability of stock prices. Our method also does not allow us to determine the role played by anticipated monetary policy in stock price determination.

Stocks are claims to real assets, so if monetary neutrality holds stock values should be independent of monetary policy in the very long run. In the medium term, however, real and nominal volatility induced by the form of the monetary policy rule may well influence stock values.

A more difficult question is *why* stock prices respond as they do to monetary policy. We have tried to make progress on this question by asking whether monetary policy affects stock values through its effects on real interest rates, expected future dividends, or expected future stock returns. The results presented in this paper showed, perhaps surprisingly, that the reaction of equity prices to monetary policy is, for the most part, not directly attributable to policy's effects on the real interest rate. This finding is the result of the relatively transitory movements in real interest rates induced by surprise policy actions. Instead, the impact of monetary policy surprises on stock prices seems to come either through its effects on expected future excess returns or on expected future dividends. (The exact breakdown between these two channels depends somewhat on the choice of sample, which appears to affect the long-horizon forecastability of excess returns.)

Economically, how should we interpret the result that monetary policy affects stock prices in significant part by affecting expected excess returns? Taken literally, this result suggests that tight money (for example) lowers stock prices by raising the expected equity premium. This could come about in at least two ways. First, tight money could increase the riskiness of stocks directly, for example, by raising the interest costs or weakening the balance sheets of publicly owned firms. Second, tight money could reduce the willingness of stock investors to bear risk, for example by reducing expected income or wealth or increasing the probability of unemployment as in Campbell and Cochrane (1999). These linkages open up the possibility of new ways in which monetary policy may affect real activity-for example, by affecting the level of precautionary saving.

An alternative interpretation of our results is that the large movements in excess returns associated with monetary policy changes reflect excess sensitivity or overreaction of stock prices to policy actions. A more tightly structured analysis that encompasses a wider class of assets may help to differentiate these interpretations. In any case, further exploration of the link between monetary policy and the excess return on equities is an intriguing topic for future research.

Appendix: deriving equation 9

This appendix provides a brief sketch of the derivation of the log-linearized relationship between the current excess return, expected future excess returns, dividend growth, and real interest rates given in equation 9. The derivation roughly follows Campbell and Shiller (1988) and Campbell (1991).

The starting point is simply the definition of the stock return, H_{t+1}:

$$1 + H_{t+1} \equiv \frac{P_{t+1} + D_t}{P_t}$$

where P is the stock price and D is the dividend. Taking logs and letting $h_{t+1} = \ln(1 + H_{t+1})$ yields:

$$h_{t+1} = \ln(P_{t+1} + D_t) - \ln(P_t) \ .$$

The next step is to derive a log-linear approximation to $\ln(P_{t+1} + D_t)$. One way to do this is to first-difference, and express the change in the log of the sum as the weighted sum of the log differences

$$\Delta \ln(P_{t+1} + D_t) \approx \rho \Delta p_{t+1} + (1 - \rho) \Delta d_t$$

where ρ is the steady-state $P/(D + P)$. "Integrating" this expression gives

$$\ln(P_{t+1} + D_t) \approx k + \rho p_{t+1} + (1 - \rho) d_t \ ,$$

substituting this into the expression for h_{t+1}, substituting δ_t for $d_{t-1} - p_t$, and combining terms gives

$$\begin{aligned} h_{t+1} &\approx k - \rho \delta_{t+1} + \delta_t + \Delta d_t \\ &\approx k + (1 - \rho L^{-1}) \delta_t + \Delta d_t \ . \end{aligned} \tag{13}$$

The next step is to solve forward, giving

$$\begin{aligned} \delta_t &= (1 - \rho L^{-1})^{-1} (h_{t+1} - \Delta d_t - k) \\ &= \sum_{i=0}^{\infty} \rho^i (h_{t+1+i} - \Delta d_{t+i}) - k/(1 - \rho) \ . \end{aligned}$$

Substituting this, and a similar expression for δ_{t+1}, into equation 13 and collecting terms yields:

$$h_{t+1} - E_t h_{t+1} = -\sum_{i=1}^{\infty} \rho^i (E_{t+1} - E_t) h_{t+1+i} + \sum_{i=0}^{\infty} \rho^i (E_{t+1} - E_t) \Delta d_{t+1+i}$$

which corresponds to equation 1 in Campbell (1991).

A breakdown of *excess* returns can then be derived by expressing the equity return h_{t+1} as the sum of a risk-free rate and an excess return

$$h_{t+1} = r_{t+1} + y_{t+1} \quad .$$

Because it is assumed that r_{t+1} is known at time t, the "excess return surprise" $y_{t+1} - E_t y_{t+1}$ is the same as the overall return surprise $h_{t+1} - E_t h_{t+1}$. So the risk-free rate can be included in the two-way breakdown as follows:

$$y_{t+1} - E_t y_{t+1} = -\sum_{i=1}^{\infty} \rho^i (E_{t+1} - E_t)(y_{t+1+i} + r_{t+1+i}) + \sum_{i=0}^{\infty} \rho^i (E_{t+1} - E_t)\Delta d_{t+1+i}$$

or as

$$\begin{aligned} y_{t+1} - E_t y_{t+1} \quad = \quad & -\sum_{i=1}^{\infty} \rho^i (E_{t+1} - E_t) y_{t+1+i} - \\ & \sum_{i=1}^{\infty} \rho^i (E_{t+1} - E_t) r_{t+1+i} + \sum_{i=0}^{\infty} \rho^i (E_{t+1} - E_t)\Delta d_{t+1+i} \quad . \end{aligned} \tag{14}$$

Again, because $E_t r_{t+1} = r_{t+1}$, it doesn't matter whether the summation involving the rs begins at 0 or 1. Finally, letting e^y_{t+1} represent the "excess return surprise" and replacing the summations with the corresponding $\tilde{e}$s yields equation 9.

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