Federal Reserve Private Information and the Stock Market

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November 3, 2016

Abstract

Measures of surprise changes in monetary policy constructed from futures data contain two components: an exogenous shock component and a component reflecting central bank private information. In this paper we isolate each component and examine their relationship with the stock market. We find that signalling shocks reflecting Fed private information have a unique effect on stock returns which is significantly different from the effect of an exogenous shock. The sign of the effect is conventional and the magnitude is moderate, except for unscheduled policy decisions in which case the sign reverses and magnitude increases. The response of stock returns to each type of shock are decomposed to study whether they are driven by cash-flow or discount rate news.

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1 Introduction

An important component of the monetary policy transmission mechanism is the reaction of the stock market. Changes in stock prices can have important effects on the economy by affecting wealth, cost of capital and overall expectations. Thus policymakers, market participants and the academic literature have all paid a large amount of attention to measuring the effect of monetary policy on the stock market. However, the behavior of the Federal Reserve has changed in important ways in the last few years.

Since the 1980s, the primary tool of the Federal Open Market Committee (FOMC) has been to target the federal funds rate, which has been accompanied with the release of a corresponding FOMC statement since the early 1990s. Analyzing changes in the stock market in a narrow window around these FOMC announcements is a simple way to measure the effect of monetary policy. Since stock prices should not react to policy changes that were already anticipated , the key challenge with this approach is to isolate an unexpected component. Bernanke and Kuttner (2005) used changes in the price of federal funds futures contracts to measure the unexpected component of monetary policy and found a negative relationship between stock prices and monetary policy. However, in more recent years the main component of the monetary policy surprise has not been about changes (or lack thereof) in the current fed funds rate target but rather about surprise future policy actions (so called forward guidance). Moreover, there is an ongoing debate in the macroeconomic literature regarding the specific nature of forward guidance that the Federal Reserve gives about future decisions. In two recent papers (Campbell, Evans, Fisher, and Justiniano (2012) and Campbell, Fisher, Justiniano, and Melosi (2016)) suggest that the Fed communication can be broken down into two categories: "Odyssean" and "Delphic". Odyssean forward guidance fits the conventional definition of forward guidance; a signal from the Fed about what it will do to short-term rates in the future that is unrelated to economic activity. While the Delphic component of the Fed's communication about their future intentions also embodies a signal about future economic conditions. If the Fed's communication is more about revealing information about economic activity, this may have potentially distinct implications for the monetary policy transmission mechanism.

In this paper we aim to study the stock market response by explicitly separating responses to Fed actions that are related to revelation of information from actions that are true exogenous shocks. We proxy for the Federal Reserve's asymmetric information by constructing a measure of private information using market survey data and the Fed's internal forecasts. Specifically, our measure is defined as the difference between the Greenbook forecasts produced by the Federal Reserve Board's staff and the consensus forecast from the Blue Chip survey. In constructing our measure of monetary policy surprise, we need to capture the surprise component from i)FOMC's current change (or lack thereof) to the fed funds rate target and ii)FOMC signals about future policy actions. We thus use data from Eurodollar futures contracts up to 4 quarters ahead in addition to the current month federal funds futures contracts.

Our estimation proceeds in two steps. In the first step, we regress the monetary policy surprise on our measure of private information. The fitted values from this regression is the component of the policy surprise that is related to the Fed's asymmetric information, we label them "signalling" shocks. The residual from the regression is a cleaner measure of a true exogenous monetary policy shock. In the second step we regress the change in the stock market in a narrow window around the FOMC announcement on the signalling and exogenous shocks.

Our baseline results use data from 1991 to 2010, being limited by the availability of the Greenbook forecast data. In this sample the effects of the exogenous shock is similar to that of Bernanke and Kuttner (2005). Specifically, a hypothetical surprise increase of 25 basis points in the expected 1 year ahead fed funds rate results in about a 1.25% fall in the S&P 500 index. More interestingly, we find that signalling shocks have a separate and negative effect on stock prices as well. The full sample results suggest that if the Fed decides to pursue a contractionary surprise action then the stock market perceives it as bad news (i.e. stock prices fall), even if this action is a signal about asymmetrically positive economic forecasts. However, we find that signalling shocks have a large effect of the opposite sign in the case of unscheduled FOMC meetings. Thus overall, our results suggest that in certain FOMC episodes, the stock market perceives contractionary monetary policy actions as good news (i.e. stock prices rise). Additionally, we find evidence that each type of shock has differential effects on cash-flow vs discount rate news.

2 Stock Prices and Monetary Policy

To identify the effect of monetary policy on stock prices, one cannot directly regress stock prices on the central bank's policy instrument (for example the short-term interest rate). The endogenous reaction of both stock prices and the central bank's policy instrument to common economic conditions leads to the classic simultaneous equation bias. Thus the literature has tried to isolate exogenous variation in the policy instrument to overcome this problem. Following the work of Bernanke and Kuttner (2005), an important strategy involves high-frequency identification using federal funds futures contracts. In this section we first outline a simple framework to understand futures based identification, with a special emphasis on why central bank private information can matter. This treatment is closely related to the framework laid out in Miranda-Agrippino (2016). Next we discuss how stock prices may respond differently to an interest rate change by the central bank depending on if the change reflects an exogenous monetary policy shocks or if it reflects a signal about the central bank's private information.

Let $p_t^{(h)}$ be the price of a futures contract at time t that matures in $t+h$. The underlying asset for this futures contract is the federal funds rate. Thus we can write

$$p_t^{(h)} = i_{t+h|t} + \zeta_t^{(h)} \tag{2.1}$$

where $i_{t+h|t} = E_t i_{t+h}$ is the expected fed funds rate at $t+h$ and $\zeta_t^{(h)}$ is the risk-premium. There is an ongoing debate in the literature about the relevance of risk-premia in fed funds futures markets, but they are not crucial to our analysis and we will set them to zero in the illustrative model.[1]

[1] Piazzesi and Swanson (2008) find that risk-premia are slow-moving and do not change much around FOMC

The next step is to consider a general monetary policy rule where the central bank changes the short-term interest rate i_t in response to current, lagged and forecasts of certain indicators of economic activity.

$$i_t = g\left(\widehat{\Omega}_{t|t}\right) + e_t \tag{2.2}$$

where e_t represents a monetary policy shock and $g(.)$ is the central bank's reaction function. $\widehat{\Omega}^{CB}_{t|t}$ contains the central bank information set available at time t, including any current information that is used to form forecasts. The hat denotes that not all economic data is available contemporaneously and must be estimated.

An important convention in the monetary policy literature is that e_t is assumed to be an exogenous shock, i.e. it is unrelated to economic activity. Thus if we can identify e_t, then we can regress stock prices on e_t to identify the effects of monetary policy. One strategy for identification is to study changes in fed funds futures data around FOMC announcements, following Bernanke and Kuttner (2005).

Consider the futures contract maturing at the end of the current month (i.e. $h = 0$). Specifically, consider the futures prices of this contract measured just before the FOMC announcement

$$p^{(0)}_{t-\varepsilon} = i_{t|t-\varepsilon} = g\left(\widehat{\Omega}^{M}_{t|t}\right) \tag{2.3}$$

The M superscript denotes the fact that the futures price will reflect expectations based on the market's information set, $\widehat{\Omega}^{M}_{t|t}$[2]. The key assumption in the futures based identification is that no other macro news announcements are released in the window between $t - \varepsilon$ and t. Thus we have that $\widehat{\Omega}_{t|t-\varepsilon} = \widehat{\Omega}_{t|t}$. Now consider the futures price after the FOMC announcement.

$$p^{(0)}_{t} = i_{t|t} = g\left(\widehat{\Omega}^{CB}_{t|t}\right) + e_t \tag{2.4}$$

announcements. However, recent work by Miranda-Agrippino (2016) discuss the importance of risk-premia vis-a-vis private information. In the online appendix we show how time-varying risk-premia do not hinder our main point and in fact they fit naturally into our analysis of controlling for private information.

[2]For simplicity, let us assume that the market has full knowledge of the central bank's reaction function.

Note that the information set that is relevant to the short rate set by the central bank is its own information set. The monetary policy surprise is measured as the change in the futures contract

$$\begin{aligned} p_t - p_{t-\varepsilon} &= g\left(\widehat{\Omega}_{t|t}^{CB}\right) - g\left(\widehat{\Omega}_{t|t}^{M}\right) + e_t \\ &= g\left(\widehat{\Omega}_{t|t}^{CB} - \widehat{\Omega}_{t|t}^{M}\right) + e_t \end{aligned} \tag{2.5}$$

where the second equality holds if we assume a linear reaction function $g(.)$ for the central bank. More generally, we can show that the analysis used to derive the last equation also applies to futures contracts that expire not in the current month, but in the future. These surprises likewise capture an exogenous component, which is a signal about exogenous shocks to the interest rate that are expected to occur in the future. But the surprises also capture a signal about future shocks to the interest rate that are related to central bank private information about macroeconomic fundamentals (which we will call signalling shocks).

Equation 2.5 makes it clear that in the special case that the information set of the central bank and the market coincide, the monetary policy surprise recovers the exogenous monetary policy shock. However the assumption of no asymmetric information may not be tenable. There is a growing body of literature suggesting a role for central bank signals about macro fundamentals. Nakamura and Steinsson (2015) find a "Fed information effect" where Fed communication affects agents' expectation of future economic activity. Melosi (2015) sets up a DSGE model with an explicit signalling channel of monetary policy and finds that it has empirically relevant effects. Finally, Tang (2015) also finds that the empirical patterns in the U.S. inflation data are consistent with the existence of a signalling channel. While this a nascent literature, it does seem to suggest that the "signalling/information" channel is important. In this paper we add to this literature by studying the response of the stock market and testing whether it responds differently to signalling shocks when compared to traditional exogenous monetary policy shocks.

In the first step of the estimation procedure we separate the monetary policy surprises into i) exogenous component and ii) private information component. Equation 2.5 suggests that a simple linear regression will suffice as long as we can construct a variable that measures the difference in the information sets of the central bank relative to the market. In section 3.2 below we discuss how we create a Fed private information variable that measures exactly this quantity, we label it PI_t. With PI_t in hand, we can just run the following regression.

$$mps_t = c + \gamma PI_t + e_t \tag{2.6}$$

Using this equation we construct the residual $\widehat{e}_t$ and the fitted values $\widehat{\gamma} PI_t$. In the next step of the estimation procedure we just regress the change in the stock price on the residual and fitted values.

$$\Delta S_t = \alpha + \beta_1 \widehat{e}_t + \beta_2 \widehat{\gamma} PI_t + u_t \tag{2.7}$$

where S_t is the stock price. What do we expect for the sign of the two coefficients β_1 and β_2? Here we layout a simple "model-free" theoretical framework that can help us understand the related issues.

The key intuition can be obtained by thinking broadly about stock prices depending on discount rates and cash-flow news. Consider a surprise increase in the interest rate by the central bank that is solely due to an exogenous monetary policy shock. In any model where monetary policy has real effects this should translate into bad news about future cash flows. Additionally, discount rates rise and thus we should expect stock prices to fall in response. This is the conventional channel of how monetary policy affects the stock market. But monetary policy can have an additional effect if the change in the interest rate is related to revelation of central bank private information. A surprise increase in the interest rate in this case has two distinct but opposing effects. First, a rise in the interest rate will increase the discount rate and should thus lower stock prices. However this decision to increase interest rates could be driven by the central bank having a more optimistic view of the economy relative to the market. If the central bank successfully signals this optimistic view, then the market may end up revising their expectations of economic activity upwards in response. This upward revision of expectations is good news about future cash flows and stock prices should go up. Thus whether stock prices actually rise or fall will depend on the relative strength of the two opposing effects.

Next we flesh out this intuition in a little more detail. Consider that stock prices S_t depend on interest rates i_t and news about future cash flows X_t. Both these terms in turn depend on (among other things) on the exogenous monetary policy shock and the revelation of private information by the central bank. Thus we have

$$S_t\left(i_t\left(e_t, PI_t\right), X_t\left(e_t, PI_t\right)\right)$$

Consider the derivative of stock price to the exogenous monetary policy shock

$$\frac{dS_t}{de_t} = \underbrace{\overbrace{\frac{\partial S_t}{\partial i_t}}^{<0}\overbrace{\frac{di_t}{de_t}}^{>0}}_{<0} + \underbrace{\overbrace{\frac{\partial S_t}{\partial X_t}}^{>0}\overbrace{\frac{dX_t}{de_t}}^{<0}}_{<0}$$

The first term $\frac{\partial S_t}{\partial i_t}$ is the partial derivative of stock prices to interest rates. This derivative is negative based on the idea that a higher discount rate should lower present value of expected future dividends and thus lower stock prices. The sign of the second term is trivially positive, recall that we define an increase in e_t as representing a contractionary shock to the interest rate in equation 2.2. Let's adopt the convention that an increase in X_t represents positive news about cash flows. This means that the sign of the third term $\frac{\partial S_t}{\partial X_t}$ is positive by construction. The last term $\frac{dX_t}{de_t}$ captures how an exogenous monetary policy shock affects cash flow news. In any model where monetary policy has real effects, we would expect a contractionary shock to reduce future output and thus imply bad news about future cash flow. Thus this last term should be negative. $\frac{dS_t}{de_t}$ is the sum of two negative numbers and must be negative itself. Hence we should expect β_1 in our regression from equation 2.7 to be negative. Next consider the response of stock prices to private information.

$$\frac{dS_t}{dPI_t} = \underbrace{\overbrace{\frac{\partial S_t}{\partial i_t}}^{<0} \overbrace{\frac{di_t}{dPI_t}}^{>0}}_{<0} + \underbrace{\overbrace{\frac{\partial S_t}{\partial X_t}}^{>0} \overbrace{\frac{dX_t}{dPI_t}}^{>0}}_{>0}$$

As discussed above, $\frac{\partial S_t}{\partial i_t} < 0$ and $\frac{\partial S_t}{\partial X_t} > 0$. For the private information variables, we will adopt the convention that a positive value for PI_t implies that the Fed's forecast of economic activity is more optimistic than the market's. Based on this convention, we would expect that if the Fed reveals that it has a more optimistic outlook for the economy (e.g. higher inflation forecast) then it is more likely to raise interest rates as a result. This implies that $\frac{di_t}{dPI_t}$ will be positive. In section 4.2 we show from the first step of our empirical estimation that this is indeed the case. Finally, what is the sign of $\frac{\partial X_t}{\partial PI_t}$? In conventional models of monetary policy, the typical assumption is that there is no asymmetric information and this derivative is zero. There is some recent empirical work suggesting that central bank signals can affect the private sectors beliefs about future economic activity. Melosi (2015) builds a model with an explicit signaling channel of monetary policy. The model incorporates a mechanism that could lead agents to expect higher inflation in response to a signal tied to an increase in the interest rate. In a similar vein, Nakamura and Steinsson (2015) sketch a model where the Fed can affect the markets expectations about the natural rate of interest. In their model an increase in interest rate can cause the market to revise upwards their expectation of the natural rate, leading to a rise in economic activity. Finally, in a recent paper Campbell, Fisher, Justiniano, and Melosi (2016) use similarly constructed private information variables and show that the component of the monetary policy surprises that is related to optimistic Fed private information predicts upward revisions of economy activity by forecasters. All these studies suggest that $\frac{\partial X_t}{\partial PI_t} > 0$. Thus we conclude that $\frac{dS_t}{dPI_t}$ is the sum of a negative term and a positive term. Whether β_2 from our regression in equatio 2.7 turns out to be negative or positive will depend on the relative strength of the two competing effects.

3 Data

We use the S&P 500 index to measure the response of the stock market. The prices are measured in a 30 minute window around FOMC announcements, starting at 10 minutes before the announcement and ending 20 minutes after the announcement. For our baseline results, we use the sample period 1991-2010. There are 180 total FOMC policy decisions over this time frame. We drop a total of four data points. We exclude 8/17/2007, 11/25/08 due to stock market data unavailability for those dates. We also drop 9/17/2001 and 3/18/09 following Campbell, Fisher, Justiniano, and Melosi (2016). This leaves 176 observations in our sample. In the next subsection we detail the construction of the monetary policy surprise and conclude this section by discussing the private information variables constructed from Greenbook and Blue Chip forecasts.

3.1 Monetary policy surprise Our measure of the surprise change in monetary policy is constructed from short term interest rate futures contracts, as in Kuttner (2001). Federal funds rate and Eurodollar futures contracts capture the market's expectations about future Federal Reserve actions. Changes in these futures contracts around FOMC announcements therefore serve as a measure of the change in policy that is unanticipated by the market. Since any expected change in policy will already be priced into financial assets, the reaction of asset prices to monetary policy should be entirely due to this surprise component. For the baseline results we use the change in the futures contracts in a 30 minute window around FOMC announcements. In ? we also discuss results obtained using end of day data.

As mentioned in the introduction, we want the monetary policy surprise measure to capture surprises to expectations about future fed funds rate, in addition to any surprise to the current month fed funds rate target. Thus to construct our baseline measure of the monetary policy surprise, we follow Gürkaynak, Sack, and Swanson (2005) and use five futures contracts: the current month's fed funds futures, the 3-month ahead fed funds futures, and the 2-quarter, 3-quarter, and 4-quarter ahead Eurodollar futures.[3] The surprise change in each contract is

[3] For comparison, Bernanke and Kuttner (2005) use only the current month fed funds futures contract in their

measured as the change in the futures rate in a 30 minute window around FOMC policy decisions (10 minutes before to 20 minutes after) as in Gürkaynak, Sack, and Swanson (2005). Taken together, the five contracts contain rich information about the short and medium term path of interest rates.

To summarize this information in a parsimonious way we perform a principal components analysis. Let X denote a T x 5 matrix of the 30 minute change in the price of the 5 futures contracts, where T is the number of FOMC meetings. We can then perform a principal components analysis of the futures price changes

$$X = F\Lambda + \widetilde{\eta}$$

where F are factors, Λ are factor loadings, and $\widetilde{\eta}$ is an error term. The first principal component of F explains more than 80% of the total variation across all the contracts.[4] We therefore use this first principal component as our baseline measure of monetary policy surprises.[5] The blue line in figure 3 plots the monetary policy surprise.

Finally, to facilitate interpretation of our results below, we normalize the policy surprise such that its effect on the four quarter ahead Eurodollar futures contract is equal to unity. Thus the coefficient from a regression of stocks on the monetary policy surprise will measure the effect on the stock market of a 1% surprise rise in the fed funds rate that is expected 4 quarters from now.

3.2 Federal Reserve Private Information Our measure of Federal Reserve private information is constructed using the FOMC Greenbook forecasts and the private sector Blue Chip forecasts. Greenbook forecasts are constructed by the Federal Reserve Board's staff a week prior to every scheduled FOMC policy meeting and are released to the public following a roughly five year lag. Blue Chip forecasts are compiled from market professionals on a monthly basis and released on the 10th of every month. For each FOMC policy decision (t) the corresponding measure of Fed private info is calculated as the most recent Greenbook forecast minus the last

baseline results.

[4]This detailed principal component analysis is presented in the online appendix.

[5]This is essentially identical to the measure used in Nakamura and Steinsson (2015) which they call the "policy news shock"

Blue Chip forecast prior to the policy decision that is of the same forecast horizon as the relevant Greenbook forecast. In the online appendix, for each FOMC meeting we list the corresponding Greenbook and Blue Chip forecast dates.

Each set of forecasts predicts the values of future macroeconomic variables on a quarterly basis. For the 1991-2010 sample there are 5 common variables: real GDP, the GDP price index, CPI, industrial production, and the civilian unemployment rate. For each variable, both set of forecasts contain at least five different forecast horizons: the current quarter forecast, the quarter ahead forecast, two quarter ahead forecast, three quarter ahead forecast, and four quarter ahead forecast. Our measure of private information for variable i at forecast horizon j is:

$$PI_t^{i,j} = GB_t^{i,j} - BC_t^{i,j}$$

For the baseline results, we focus on forecasts for GDP, CPI and the unemployment rate. These are plotted in figure 2. A few interesting points stand out. Notice that these variables are persistent and that as the forecast horizon increases, the persistence rises. This suggests that the Federal Reserve's internal forecasts are not completely inferred by the market based on FOMC meeting actions and announcements. This is especially true for the longer-horizon forecasts. For a given variable, in addition to the autocorrelation for each individual forecast horizon, the forecasts for different horizons are also correlated with one another. Table **??** shows this cross-correlation between the different forecast horizons for the three macro variables. We can see that forecast horizons that are "closer" to each other are more highly correlated. For example, the 4 quarter ahead forecast is quite highly correlated with the 3 quarter ahead forecast but not with the nowcast.

These patterns guide us in choosing the private info measures that will be used in the regression analysis below. First, given the high cross-correlation among forecasts of different horizons we will use only the nowcast and the 4 quarter ahead forecast, for parsimony. Next, given the high persistence of the private information variables, we will include the first lag in our regression. Thus our baseline specification will have the contemporaneous and first lag of the nowcast (0 quarter ahead forecast) and 4 quarter ahead forecast for four macro variables: GDP, CPI, Industrial Production and Unemployment. Thus we have a total of 16 private information variables that capture the relevant information. A potential alternative is to follow the approach of Campbell, Fisher, Justiniano, and Melosi (2016) and construct a short and long factor for each variable using principal component analysis. We found that the short factor and long factors correlate very highly with the nowcast and the 4 quarter ahead forecasts.

4 Results

4.1 Stock prices and monetary policy surprise We start by exploring the relationship between change in S&P 500 index (S_t) and our measure of monetary policy surprise (mps_t) detailed in the previous section. Recall that they are both measured in a 30 minute window around FOMC announcements. The two are shown in a scatter plot in figure 1. We can see a clear negative relationship between the two. The black triangles show dates that represent dates other than the regularly scheduled FOMC meetings, labeled "Unscheduled". The red squares represent dates where the FOMC changed the fed funds rate in a direction opposite to the previous change, labeled "Turning Points". As we can see, some of the bigger monetary policy surprises occur at unscheduled and turning point FOMC meetings. This is reflected in the summary statistics in table 1 as well. The mean of both monetary policy surprises and stock returns are larger on unscheduled and turning point meetings than for all meetings. Table 2 presents the results from a simple regression of S_t on mps_t. Consistent with Bernanke and Kuttner (2005), the specification in column (1) reports a significant decline in the S&P 500 following a positive monetary policy surprise (i.e. an unexpected tightening of monetary policy). A 1% surprise rise in the fed funds rate that is expected 4 quarters from now, results in a 5.2% fall in stock prices. Columns (2) - (4) present regression results where the monetary policy surprise is interacted with dummy variables representing i) zero lower bound episode from 2008 onwards, ii)unscheduled FOMC meetings and iii)FOMC meetings with turning points. None of the interaction terms are statistically significantly different from zero. Note that the response of stock prices to the monetary policy surprise in specifications with the interactions is a little lower than the simple specification in column (1).

4.2 Monetary Policy Surprise and Private Information In section 3.2 we discussed the properties of the private information variables constructed from forecast data. An important implication was that the Federal Reserve does not seem to completely reveal all of its private info through the FOMC announcement. Thus we would like to use only the component of private information that is inferred by the market from the FOMC announcements. A natural way to proceed is to regress the monetary policy surprise measure on the private info variables and use the fitted value as the surprise component of monetary policy attributable to the Fed's private information. This residual from this regression becomes a clean measure of an exogenous monetary policy shock.

Table 3 shows this regression using the nowcast and 4 quarter ahead forecasts for the GDP, CPI, Unemployment and Industrial Production private information variables. Given the persistent nature of the private information variables, we also include the first lag. The p-value jointly tests the null hypothesis that the private information variables have no explanatory power. This is rejected at the 1% level. The R^2 from the regression is 0.17, which while being substantial, highlights the fact that a major part of the monetary policy surprise is exogenous with respect to the Fed's private information.

In the theoretical motivation sketched out in section 2, we emphasized that the response of stock prices to private information depends crucially on how interest rates respond to private information. Specifically, we are interested in the sign of the derivative $\frac{di_t}{dPI_t}$. Note that a positive value for the private information variable for GDP, CPI and IP means that the Fed has a relatively optimistic forecast for the economy. For unemployment a positive sign implies the opposite. The first step regression is reported in table 3, where 0Q refers to the nowcast and 4Q refers to the four quarter ahead forecast. The sign of all the coefficients on the private information nowcast variables suggest that the sign of $\frac{di_t}{dPI_t}$ is positive.[6] But not all the signs on the lagged variables have the signs consistent with this interpretation. For example, the coefficient on the lagged 4 quarter ahead forecast of IP implies that if the Fed has a more positive outlook for IP, that is related to an expansionary monetary surprise. This is most likely a combination of some noise and the fact that there is a high amount of correlation in the content of the different private information variables. We have run the first step regression with different combination of private information variables (including using principal component analysis) and find that most of the coefficients are consistent with $\frac{di_t}{dPI_t} > 0$. Another reassuring aspect is that the resulting fitted values and residuals are quite similar regardless of the exact combination of private information variables used.

Figure 3 displays the monetary policy surprises, fitted values, and residuals over time. Notice the fitted value is typically of a smaller magnitude than the residual and the residual typically tracks movements in the monetary policy surprise more closely. This is unsurprising given that Fed private information explains only a minor part of monetary policy surprises. There are cases, such as the end of the sample in 2010, where the majority of the policy surprise is driven by the fitted value however. Overall, the largest monetary policy surprises appear to be driven by factors exogenous to Fed private information. It is also interesting to note there are periods (e.g. the late 1990's and early 2000's) in which the fitted value and residual are of opposite signs with the monetary policy surprise falling between the two.

4.3 Response of Stock Prices accounting for Private Information Now we are ready to run our second step regression. We will regress the change in the S&P 500 index in the 30 minute window on the fitted value and residual from the first step, as discussed above in equation 2.7. For ease of exposition we reproduce the equation here.

$$\Delta S_t = \alpha + \beta_1 \widehat{e}_t + \beta_2 \widehat{\gamma} PI_t + u_t$$

[6] To clarify, a positive (negative) coefficient in front of GDP, CPI and IP (Unemployment) variables implies a positive sign for the derivative $\frac{di_t}{dPI_t}$

Since the regressors in this second step are generated in the first step, we have to account for the added sampling uncertainty. This is done by bootstrapping the standard errors using $10,000$ replications. The key idea is to perform the resampling at the beginning and thus both steps of the two-step regression procedure are done for every bootstrap sample. The results are presented in table 4 with the bootstrapped standard errors in parentheses. Column 1 shows that the residual has a negative and significant effect on stock returns with a slightly larger magnitude than the monetary policy surprise in table 2. Specifically, a 1% surprise rise in the fed funds rate that is expected 4 quarters from now, results in a 5.2% fall in stock prices. The effect of the fitted value is also negative but much lower at -1.9%. Note that this coefficient is not statistically significantly different from zero. However, the test for whether this coefficient is equal to that on the residual is rejected at the 5% level (with a p-value of .043). Thus, an important implication is that Federal Reserve decisions and announcements that are related to revelation of their private information have a statistically significantly lower effect on the stock market. Since the sign of the coefficient is negative, the analysis from section 2 suggests that the effect of a higher discount rate dominates that of the positive signal about economic fundamentals.

The second column shows the results with an interaction added for the unscheduled FOMC meetings. Allowing for a different coefficient on unscheduled FOMC meetings has some important consequences. First, the coefficient on regularly scheduled meetings is lower in magnitude for the residual and higher in magnitude for the fitted value. These differences are not statistically significant and also not economically very important. More interestingly, the response of the stock market to private information induced monetary policy surprises is highly positive. Specifically, a 1% private information induced surprise rise in the fed funds rate that is expected 4 quarters from now, results in a 16% rise in stock prices. Notice that the related standard error is quite large and this is driven by the fact that we have only 17 unscheduled meetings. Going back to the analysis from section 2, we can conclude that the effect coming from positive signals about economic fundamentals is dominating discount rate changes.

5 Understanding the response of stock prices

Monetary policy may impact stock prices through one of three sub-components of excess equity returns: expected future dividends, real interest rates, and expected future excess returns. Bernanke and Kuttner (2005) show how to estimate the impact of monetary policy surprises on each of these components. In this section we perform a similar analysis to study how exogenous and signalling shocks impact stock returns.

Campbell and Shiller (1988) show how unexpected excess equity returns can be expressed in terms of the revision of the expectation of discounted future dividends, the real interest rate, and future excess returns. Campbell and Ammer (1993) show how this relationship can be modeled using the variables of interest and any other variables that might be helpful in forecasting. Therefore, a six-variable one-lag VAR is used which includes the excess stock return, real interest rate, relative 3-month T-bill rate, change in the 3-month T-bill rate, dividend-price ratio, and spread between the 10-year and 1-month Treasury yields:

$$z_t = Az_{t-1} + w_t$$

For comparability with Bernanke and Kuttner (2005) and Campbell and Ammer (1993) we first report the variance decomposition of excess equity returns in table 5. The results show that the majority of variation in excess returns is accounted for by the variance in expected dividends and expected future excess returns. Our results contrast with the previous two papers in that they found the variance in expected future excess returns to be the dominant component, whereas we find the variance in expected dividends explains a somewhat larger share.

NOTE: this section needs to be updated, the below uses an alternative specification

To estimate the impact of the exogenous and signalling shocks on the components of excess returns we add them into the VAR as exogenous variables:

$$z_t = Az_{t-1} + \beta mp_t^e + \gamma mp_t^f + \tilde{w}_t$$

We include the two signalling shocks related to the unemployment rate since they were the only significant signalling shocks in the previous section. The results are presented in table 6. Each column shows how an exogenous shock, signalling shock related to current quarter unemployment, and signalling shock related to 4-quarter ahead unemployment impacts excess stock returns and its three components. Note that the magnitudes do not have a clear interpretation. We are simply interested in the decomposition of the current excess return's response into the response of the three components.

Column 1 shows that the effect of a an exogenous shock on stock returns is mainly driven by the impact of the shock on expected future dividends. The results in columns 2 and 3 for the signalling shocks are mixed however, as both future excess returns and dividends respond strongly. For each, the impact of the signalling shock on future excess returns explains slightly more of the current return's response than the impact on dividends. This is interesting, as it suggests that exogenous shocks and signalling shocks impact stock returns through somewhat different channels.

6 Conclusion

By exploiting differences in central bank and private sector forecasts we constructed a measure of Federal Reserve private information. We use this measure to separate monetary policy surprises into exogenous shocks and signaling shocks. Exogenous shocks are surprise changes in monetary policy which are unrelated to macroeconomic fundamentals whereas signalling shocks are surprise changes in policy attributable to the Fed's asymmetric information about the state of the economy. We regress the return on the S&P 500 in a narrow window around monetary policy announcements on the signalling and exogenous shocks in order to estimate the relationship between Federal Reserve private information and the stock market.

Our baseline results for 1991-2010 show that exogenous shocks have a similar effect on stock prices as composite monetary policy surprises do. Specifically, a surprise increase of 25 basis points in the expected 1 year ahead fed funds rate is associated with a significant 1.25% decline in the S&P 500. Signalling shocks also have a negative effect on the stock market. Specifically, a positive signalling shock (monetary tightening) related to Fed asymmetric information is associated with a decrease in stock prices, though this decrease is statistically significantly smaller in magnitude than the decline caused by an exogenous shock. Interestingly, this means that the stock market perceives a monetary tightening to be bad news even if it signals that the Fed forecasts more favorable economic conditions than the private sector (i.e. positive asymmetric information).

For unscheduled FOMC meetings we find an effect of signalling shocks with the opposite sign. When a policy action occurs at an unscheduled meeting signalling shocks actually have a positive effect on stock returns. Moreover, the absolute value of the magnitude of the effect is much larger in these cases. This implies that under certain conditions the stock market may perceive a monetary tightening as good news when the tightening is related to the Fed's asymmetrically positive assessment of economic conditions.

These results have important implications for how monetary policy is transmitted to the real economy. Intriguing possibilities for future work include analyzing firm and industry level responses to the exogenous and signalling shocks. Heterogeneous firm-level responses may be informative about what kind of firms/industries are particularly sensitive to Fed private info. Additionally, investigating whether similar results hold for financial assets other than stocks may be of interest.

References

Bernanke, B. S., and K. N. Kuttner (2005): "What explains the stock market's reaction to Federal Reserve policy?," *The Journal of Finance*, 60(3), 1221–1257.

Campbell, J., J. Fisher, A. Justiniano, and L. Melosi (2016): "Forward Guidance and Macroeconomic Outcomes Since the Financial Crisis," in *NBER Macroeconomics Annual 2016, Volume 31.* University of Chicago Press.

Campbell, J. R., C. L. Evans, J. D. Fisher, and A. Justiniano (2012): "Macroeconomic effects of federal reserve forward guidance ," *Brookings Papers on Economic Activity*, pp. 1–80.

Campbell, J. Y., and J. Ammer (1993): "What moves the stock and bond markets? A variance decomposition for long-term asset returns," *The Journal of Finance*, 48(1), 3–37.

Campbell, J. Y., and R. J. Shiller (1988): "The dividend-price ratio and expectations of future dividends and discount factors," *Review of financial studies*, 1(3), 195–228.

Gürkaynak, R. S., B. Sack, and E. T. Swanson (2005): "Do Actions Speak Louder Than Words? The Response of Asset Prices to Monetary Policy Actions and Statements," *International Journal of Central Banking.*

Kuttner, K. N. (2001): "Monetary policy surprises and interest rates: Evidence from the Fed funds futures market," *Journal of monetary economics*, 47(3), 523–544.

Melosi, L. (2015): "Signaling effects of monetary policy," .

Miranda-Agrippino, S. (2016): "Unsurprising Shocks: Information, Premia, and the Monetary Transmission," *Unpublished Manuscript, Bank of England.*

Nakamura, E., and J. Steinsson (2015): "High frequency identification of monetary non-neutrality," Discussion paper, National Bureau of Economic Research.

Piazzesi, M., and E. T. Swanson (2008): "Futures prices as risk-adjusted forecasts of monetary policy," *Journal of Monetary Economics*, 55(4), 677–691.

Tang, J. (2015): "Uncertainty and the signaling channel of monetary policy," Discussion paper, Federal Reserve Bank of Boston.

VARIABLES	(1)	(2)	(3)
MP Surprise	0.0000		
	(0.005)		
Stock Return	-0.0149		
	(0.048)		
MP Surprise x Unscheduled		-0.0095***	
		(0.004)	
Stock Return x Unscheduled		0.0510	
		(0.031)	
MP Surprise x Turning Point			-0.0018
			(0.002)
Stock Return x Turning Point			0.0314
			(0.027)
Observations	176	176	176

Table 1: The table reports the mean of monetary policy surprises and stock returns from 1991-2010 around i) all FOMC policy decisions, ii) unscheduled FOMC policy decisions, and iii) FOMC decisions that reversed the direction of policy. Standard errors are in the parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

	S&P 500 (30 minute window)			
VARIABLES	(1)	(2)	(3)	(4)
MP Surprise	-5.1713***	-5.0516***	-4.6802***	-4.3655***
	(0.940)	(1.017)	(0.843)	(0.839)
ZLB Dummy		0.2544**		
		(0.100)		
MP Surprise x ZLB		-1.2908		
		(1.193)		
Unscheduled FOMC Dummy			-0.0168	
			(0.166)	
MP Surprise x Unscheduled			-1.1080	
			(1.748)	
Turning Point Dummy				0.3817
				(0.281)
MP Surprise x Turning Point				-4.7095
				(3.819)
Constant	-0.0149	-0.0385	-0.0238	-0.0405
	(0.039)	(0.042)	(0.039)	(0.035)
Observations	176	176	176	176
R-squared	0.328	0.343	0.331	0.389
Adjusted R-squared	0.324	0.331	0.319	0.378
Robust F-statistic	30.25	184.7	15.06	11

Table 2: The table reports the regression of the change in the S&P 500 index on the monetary policy surprise, both measured in a 30 minute window around FOMC announcements. The ZLB dummy is set to 1, post November 2008. The Unscheduled dummy is set to 1 for FOMC meetings occurring outside the regularly scheduled dates. The Turning Point dummy is set to 1 if the policy decision changed the fed funds rate in the opposite direction of the previous change. Robust standard errors are in the parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

	(1)
VARIABLES	MP Surprise
CPI0Q	0.0086**
	(0.004)
U0Q	-0.0095
	(0.053)
GDP0Q	0.0178*
	(0.009)
IP0Q	0.0036
	(0.003)
CPI4Q	0.0091
	(0.023)
U4Q	0.0279
	(0.030)
GDP4Q	0.0150
	(0.016)
IP4Q	0.0063
	(0.011)
CPI0Q Lag	-0.0032
	(0.007)
U0Q Lag	0.0332
	(0.045)
GDP0Q Lag	-0.0087
	(0.010)
IP0Q Lag	0.0013
	(0.003)
CPI4Q Lag	0.0054
	(0.023)
U4Q Lag	-0.0517*
	(0.029)
GDP4Q Lag	0.0173
	(0.018)
IP4Q Lag	-0.0219*
	(0.011)
Constant	0.0137
	(0.009)
Observations	175
R-squared	0.167
Adjusted R-squared	0.083
P-Value	0.010

Table 3: The table reports the regression of the monetary policy surprise on the private information variables (constructed as the difference between the Greenbook forecasts and Blue Chip forecasts). "0Q" and "4Q" refer to the nowcast and 4 quarter ahead forecast, see the main text for more details. The robust F-statistic and p-values test the joint significance of all the private info variables included in the regression. Robust standard errors are in the parentheses.

VARIABLES	S&P 500 (30 minute window)	
Residual	-5.81	-5.29
	(1.01)	(0.87)
Fitted	-1.97	-2.48
	(1.87)	(1.82)
Unscheduled FOMC Dummy		0.17
		(0.33)
Residual x Unscheduled FOMC Dummy		-2.80
		(3.13)
Fitted x Unscheduled FOMC Dummy		21.32
		(16.87)
Constant	-0.02	-0.02
	(0.04)	(0.04)
Observations	175	175
R-squared	0.35	0.39
Adjusted R-squared	0.34	0.37

Table 4: The table reports the regression of the change in the S&P 500 index on the residual and fitted value of the policy surprise from the first step, both measured in a 30 minute window around FOMC announcements. The ZLB dummy is set to 1, post November 2008. The Unscheduled dummy is set to 1 for FOMC meetings occurring outside the regularly scheduled dates. The Turning Point dummy is set to 1 if the policy decision changed the fed funds rate in the opposite direction of the previous change. Bootstrapped standard errors are in the parentheses

Table 5: Variance Decomposition of Excess Equity Return

	1991:2010	
	Total	Share (%)
Var(excess return)	19.42542	
Var(dividends)	8.126162	41.83262
Var(real rate)	0.245556	1.264098
Var(future returns)	5.527729	28.45616
-2*Cov(dividends, real rate)	0.422366	2.174298
-2*Cov(dividends, future excess returns)	5.035774	25.92363
2*Cov(future excess returns, real rate)	0.067832	0.34919

Table 6: Impact of Shocks on Excess Return Components

	MP Surprise	U0Q Fit	dU4Q Fit
current excess return	-13.9817	131.8745	-99.514
future excess return	3.6998	-80.4629	62.99
real interest rate	1.0792	16.7708	-5.1
dividends	-9.2027	68.1825	-41.63

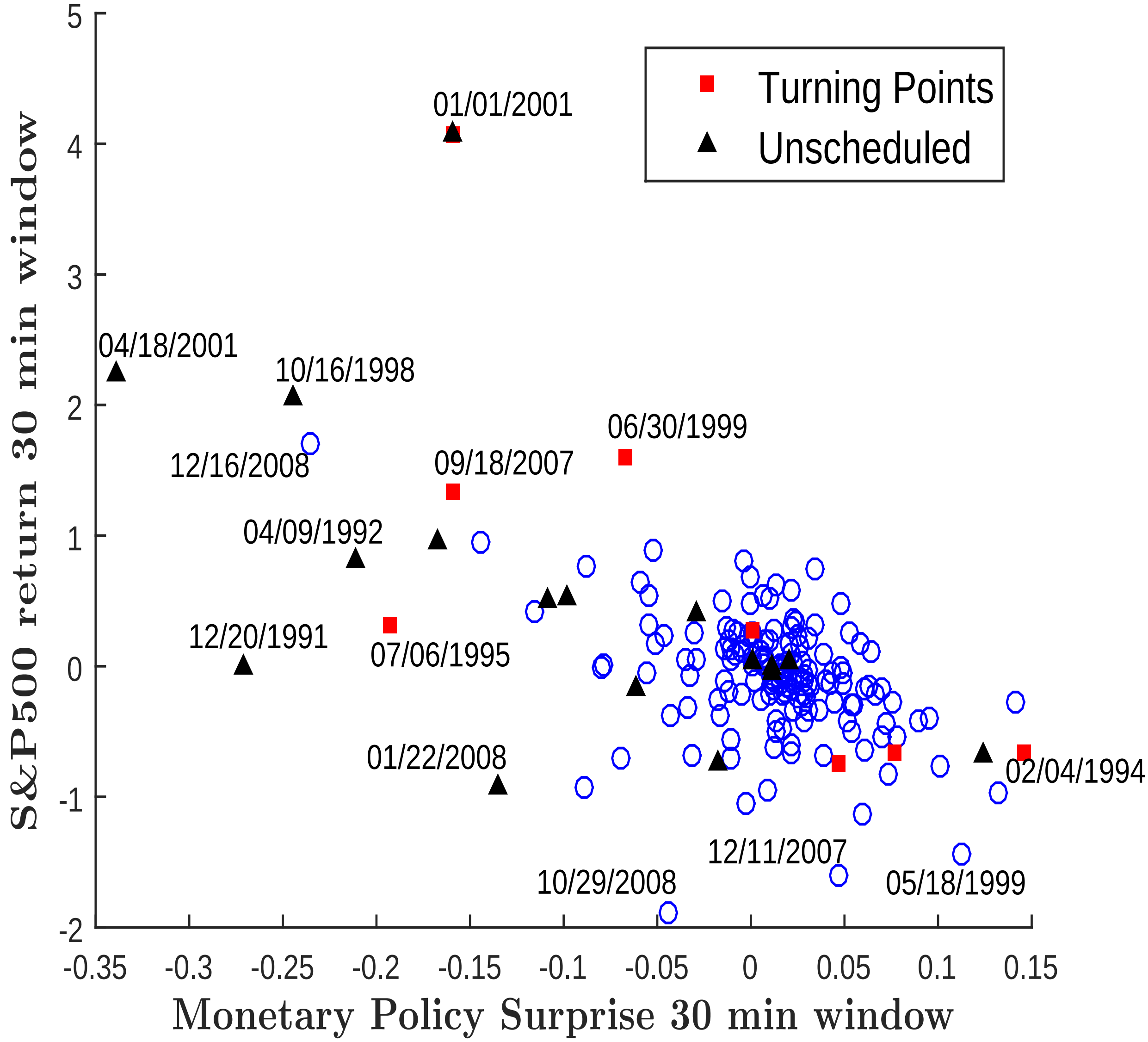

Figure 1: Stock Returns vs Monetary Policy Surprises

Figure 2: Private information variables for GDP, CPI and unemployment, representing the difference between the Greenbook and Blue Chip forecasts. See the main text for more details.

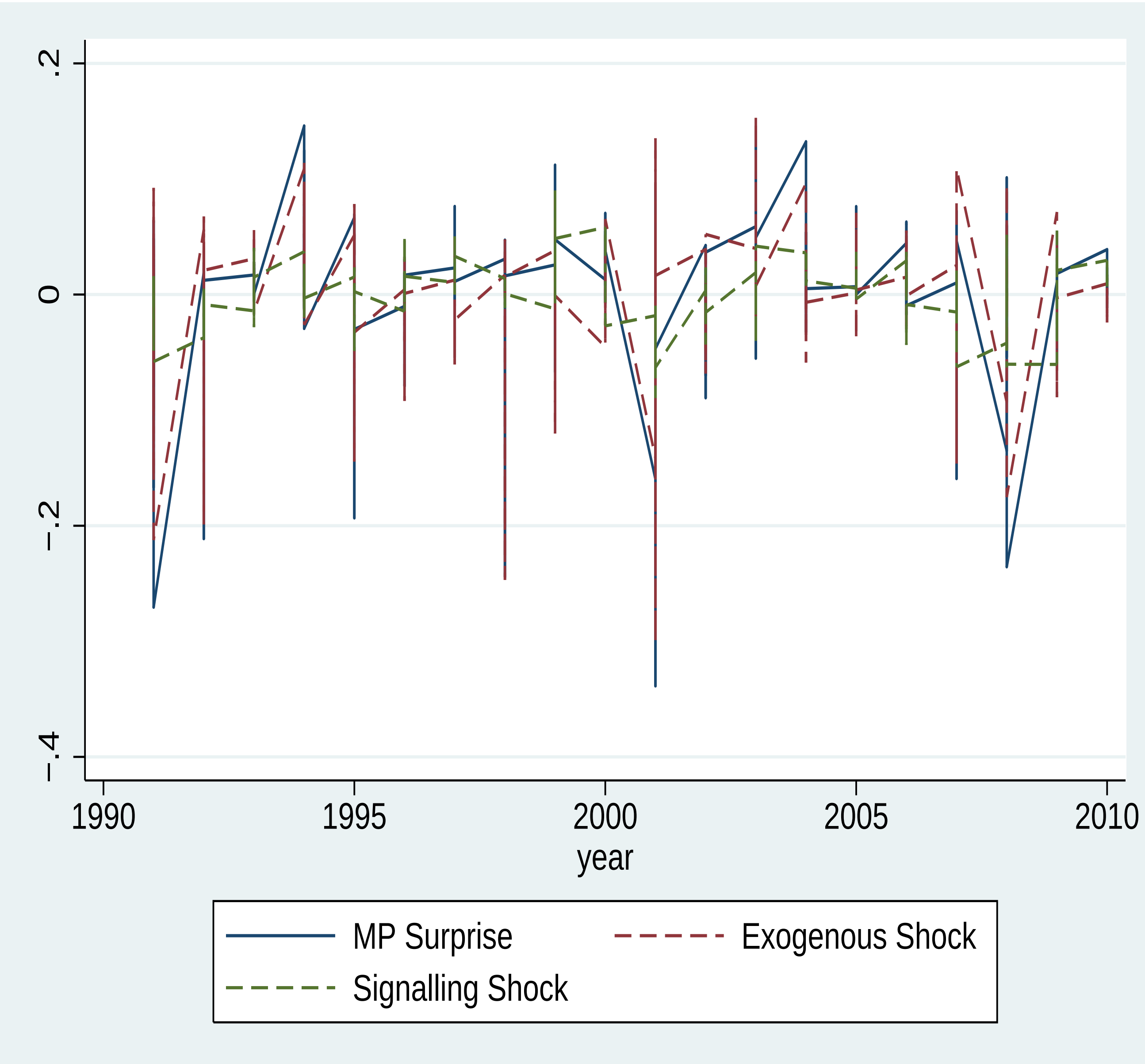

Figure 3: Decomposition of Monetary Policy Surprises