When we leave the information on the table: information shock and stock price underreaction to monetary policy

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Abstract

I examine the effect of information shock on the immediate stock price response to monetary policy announcements. Analyzing information shocks which are defined as stochastic jumps, I find that the information shock mitigates the stock price impact of monetary policy surprises. Furthermore, the effect of information shock is more pronounced when the information shock is unable to attract investor attention, suggesting that the effect of information shock is driven by the information which is not incorporated into the stock price. I further show that the underreaction to earnings announcements also deters the information of monetary policy announcements from being incorporated into stock prices. The results of this paper imply that in the presence of underreacted information, information asymmetry between investors who have a different level of information processing capacities would be increased.

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1 Introduction

"…, the Federal Reserve, like many central banks around the world, has made significant progress in recent years in clarifying its goals and policy approach, and in providing regular information about the future path of policy that it views as most likely to attain its objectives. This increased transparency about the framework of policy has aided the public in forming policy expectations, reduced uncertainty, and made policy more effective. …"

-Ben S. Bernanke, pre-chairman of the Federal Reserve. November 19, 2013. [1]

"…, We will continue to strive to find better ways to enhance transparency around our approach to preserving financial stability. Efforts to engage with the public--including consumer groups, academics, and the financial sector--are likely to lead to improved policies. Moreover, ongoing dialogue will work to enhance public trust, as well as our ability to adapt to new threats as they emerge. …" -Jerome H. Powell, chairman of the Federal Reserve. May 25, 2008. [2]

As can be seen from the chairs' speeches, policymakers expect their policies to be revealed in financial markets more effectively by providing transparent information on monetary policy decisions. As part of this effort, the Federal Reserve which is the central bank of the U.S. has been changing their policy of announcement to more communicate with market participants and provide information more precisely, prior research has also reported that it can reduce the noise of monetary policy announcement. (Woodford, 2005; Blinder, Ehrmann, Fratzscher, Haan and Jansen, 2008) However, apart from the attempts to reduce the ambiguity of information, if market participants cannot interpret the information properly, the information will not be fully

[1] Ben S. Bernanke, Communication and monetary policy, Speech at the National Economists Club Annual Dinner, Herbert Stein Memorial Lecture, Washington, D.C., November 19, 2013.

[2] Jerome H. Powell, "350 years of Central Banking: The Past, the Present and the Future," A Sveriges Riksbank anniversary conference sponsored by the Riksbank and the Riksdag, Stockholm, Sweden, May 25, 2018

incorporated into the market, which can reduce the effectiveness of monetary policy decisions. A presence of information not fully evaluated and processed by investors can prevent investors' understanding of new information, and it may negatively affect the processing of the new information. In this paper, I examine whether information that is not fully incorporated into the stock price could hinder the immediate stock price response of monetary policy announcements. Many prior studies provide evidence for underreaction, suggesting a presence of information not fully processed in financial markets. In particular, it has been widely studied in corporate finance researches and has founded that investors may underreact to various corporate announcements such as earnings announcements, mergers and acquisitions, and stock split announcements. [3] Information that is not immediately incorporated into the stock price could be slowly diffused, indicating that information is continuously processed after the underreaction. In the spirit of rational inattention of Sims (2003), information processing capacity is finite, so the presence of prior information that requires continuous information processing could be friction that hinders the processing of new information. On the other hand, a large body of literature shows that limited investor attention contributes to underreaction to new information. [4] In a similar vein, if a firm's previous information event alters investors' firm-level attention, it may affect new information from being processed. [5] Therefore, the empirical challenge in examining whether the information not incorporated into the stock price could inhibit a price reaction to new

[3] There is extensive literature including Bernard and Thomas (1989, 1990) for earnings announcements, Agrawal, Jaffe, and Mandelker (1992) for mergers and acquisitions, and Desai and Jain (1997) and Ikenberry and Ramnath (2002) for stock split announcements.

[4] For instance, Hirshleifer and Teoh (2003), DellaVigna and Pollet (2009), Hirshleifer, Lim, and Teoh (2009), and many others.

[5] Ben-Rephael, Da, Israelsen (2017) show that news coverage gives a persistent but delayed impact on retail investor attention, measured by Google Search Volume Index in Da, Engelberg, Gao (2011), while the impact on institutional investor attention is not persistent. I will discuss more detail the construction of institutional investor attention in a later section.

information is to get rid of the effect of firm-level investor attention on the processing of new information.

I use the market-wide information event, monetary policy announcement of the FOMC, to demonstrate how prior underreaction hinders the immediate stock market response of new information. The firm-specific information event contains various quality, transparency, or complexity of information, and firm-level investor attention could influence the understanding of this information. On the other hand, estimating stock price responses to macroeconomic announcements makes it possible to more clearly gauge the impact of prior underreaction on the processing of new information. Since monetary policy announcements from the FOMC are released during stock market trading hours (around 2:15 p.m.), unlike other macroeconomic announcements, we can estimate the immediate response of the stock market to the released information. Another advantage of using monetary policy announcement is that expectations of future monetary policy decisions are traded in the futures market. It implies a lower information asymmetry between investors in monetary policy decisions than in other macroeconomic announcements and allows a more accurate estimate of the monetary policy surprise which is an unanticipated portion of the monetary policy decision.

A voluminous literature has reported the immediate impact of monetary policy on the stock market. Bernanke and Kuttner (2005) show that an unanticipated monetary policy target rate cut (hike) is associated with an entire U.S. stock market increase (decrease). To investigate the effect of underreacted information on the stock price impact of monetary policy announcement, I use a methodology of Jiang and Zhu (2017), which find that the stock price underreacts information shocks which are defined as a stochastic jump, and there exist price drift continuations in short-time periods after information shocks revealed. Following Jiang and Zhu

(2017), I estimate information shock by a jump in daily stock price series for a month and use it as a proxy of information not fully incorporated into the stock price. I also consider stock price jumps estimated for three months and firms' quarterly earnings announcements as measures of information shock for the robustness of the results. For the baseline analysis, I use the scheduled FOMC announcements from 1994 to 2008, and the sample includes 378,727 firm observations. [6]

I find that the impact of the stock price from a percent change of monetary policy surprise is about 0.7 percent lower in firms with information shock, and it is about a quarter of the impact on the entire stock market. Moreover, the effect of information shock does not come from transmission channels of monetary policy. Following Ozdagli and Velikov (2020), I consider firm characteristics related to firms' exposure to monetary policy and the results show that the effect of information shock remains significant after controlling the transmission channels. More interestingly, the lack of investor attention to information shock could increase the effect of information shock. Using the magnitude of immediate price response to information shock and the number of simultaneous information shocks as measures of investor attention and distraction, I find that the stock price response to monetary policy surprise could be lowered by investor's inattention and distraction to information shock. From the point that lower investor attention and more investor distraction are associated with more underreaction to information shock, the results suggest that information not incorporated into the market could interfere with the immediate pricing of monetary policy decisions, which are new information. Further, I provide evidence supporting the role of institutional investor attention in information processing. Consistent with Ben-Rephael, Da, and Israelsen (2017), high institutional investor attention is associated with immediate stock price responses to information events, suggesting that the

[6] The sample period starts in February 1994 when the FOMC started to announce its monetary policy decision right after the meeting at this time and ends before the zero-lower-bound monetary policy rate.

information shock accompanied with high institutional investor attention does not mitigate the impact of monetary policy decision on the stock price.

I then investigate whether valuation uncertainty could amplify the effect of information shock that mitigates immediate stock price response to monetary policy surprise. Many researchers provide evidence supporting that investor's behavior bias could be increased when a firm has difficulty in pricing. (Zhang, 2006; Jiang et al., 2005; Kumar, 2009). For a firm with high valuation uncertainty, underreaction to information shock could be increased by inattentive investors, and it results in increasing the effect of information shock. Using several firm characteristics representing the valuation uncertainty, I find consistent results with prior works. The results show that the information shock has a much greater impact on the stock price response to monetary policy decisions when the stock is difficult to price. Further, consistent with Kumar (2009), the effect of information shock is also pronounced during periods of high market-level uncertainty.

I also provide evidence supporting that underreaction to prior information events affects order flows with the arrival of new information. Through the intraday analysis, I find that there exists an order imbalance which is proportional to monetary policy surprise after the announcements, and it is much greater in firms with information shocks. Moreover, trading volumes of those firms are less affected by monetary policy surprises, while other firms could be traded more when the FOMC announces more unanticipated monetary policy decisions. The results also show that underreaction to information shock is positively associated with information asymmetry between investors with large and small information processing capabilities. Further, information on monetary policy announcements could be diffused later when it is not fully reflected in stock price at the announcement date. Investors gradually reflect the information of the monetary policy announcement underreacted at the announcement date, and I find that it could be lasted one or two days after the announcement.

This study investigates how the underreaction to prior information shock affects the processing of new information and immediate price impact by using the FOMC's monetary policy announcements. This study has a similarity to Cohen and Lou (2012) in that it analyzes different firms' stock price reactions to the same information shock. Cohen and Lou (2012) find that the stock prices of conglomerate firms that require a more complex understanding of information have more delayed responses to information than the stock prices of standalone firms. Their research analyzes the difficulty of information processing derived from firm characteristics, but I investigate whether the information that was not reflected in the stock price mitigates the stock price response of the new information.

This paper shows that the underreaction of prior information can deter new information from being priced. Information that is not fully reflected in the stock price can create friction for the processing of new information and make pricing for new information more difficult. The continuation of a price drift after the release of information, defined as underreaction to information, indicates that there is a significant difference between the realized and expected price of the asset, associated with high uncertainty of fundamental value. From the perspective of limited investor attention, Peng and Xiong (2006) construct the model and show how investors allocate their attention to market-wide, sector-wide, or firm-specific level information. They find that the optimal decision of investors is to allocate more attention to factors that generate higher uncertainty. In the light of limited investor attention, increased stock price uncertainty from the delayed information processing could hinder an allocation of attention to new market-wide information.

Similarly, in terms of rational inattention models, underreaction of prior information could be friction in the information process of new information. Sims (2003, 2006) suggests that investors have limited information processing capacity and it impedes information from being incorporated into prices. The presence of underreacted information that is not immediately reflected in the stock price and diffusing slowly suggests that information processing continues. As the underreacted prior information requires an investor's information processing capacity under the information processing constraint, the investors cannot put all their ability into processing the new information, and it leads to an impediment of the immediate price response to the new information.

This study proceeds as follows. Section 2 provides a more detailed description of related literature. Section 3 presents the data and methodologies used in this research. Section 4 contains the main results and Section 5 provides the results from the further analysis for robustness. Section 6 concludes.

2 Related literature

In a broad sense, this paper is related to two branches of studies. First, this study is related to the friction of information processing. Sims (2003, 2006) suggests that investors have limited information processing capacity. Under the limited information processing capacity, uninformed investors have lower information-processing capacity than informed investors, and they cannot fully employ information that is even freely available. Hirshleifer and Teoh (2003) examine the optimal choice of companies between various methods to provide information under the limited investor attention and processing ability. Peng and Xiong (2006) construct the model and show how investors allocate their attention. For empirical studies, Cohen and Lou (2012) examine the informational friction of conglomerate firms. Their results suggest that conglomerate firms require a more understanding of information due to their complex business areas and product chains. In an occurrence of new information on the single industry, they find that stock prices of conglomerate firms have more delayed responses to the information than stock prices of standalone firms do. Dong, Li, Lin, and Ni (2014) examine the effect of information processing cost on information processing through the XBRL (eXtensible Business Reporting Language) filings mandates. They find that providing more precise and standardized information could reduce firms' return synchronicity. Similar to those findings, this paper analyzes whether underreaction to the prior information event could be informational friction. Under the limited information processing capacity, underreacted information may deter other information from being processed because some portion of capacity would be aligned to the prior underreacted information.

In this paper, I investigate the stock price response of the monetary policy announcement. Cook and Hahn (1989) analyze the effect of monetary policy change on the financial market empirically. They use changes in federal funds target rates to verify how monetary policy affects bond rates. However, since most of the target rate changes are already anticipated in the financial market, it is difficult to measure the exact impact of monetary policy. To overcome the limitations of a target rate change, Kuttner (2001) measures the unanticipated monetary policy decision which is referred to as the monetary policy surprise by using the federal funds futures. After this, Bernanke and Kuttner (2005) estimate how the stock market is affected by monetary policy surprise. They analyze the FOMC announcements from May 1989 to December 2002 using an event-study methodology and show that the unanticipated monetary policy rate cut is associated with the stock price increase. Moreover, there are several pieces of research investigating the transmission channel of monetary policy. For instance, Ozdagli (2018) examines whether financial friction lowers the monetary policy sensitivity of stock prices and Ozdagli and Velikov (2020) summarize various firm characteristics that might affect monetary policy sensitivity. This paper investigates whether underreaction to prior information interferes with the immediate stock price reaction to monetary policy announcements and proceeded according to the conventional methodologies of the prior studies.

3 Data and methods

3.1 Monetary policy surprise

Kuttner (2001) and Bernanke and Kuttner (2005) estimate the monetary policy surprise using market expectations of the monetary policy rate. Federal funds futures contracts are priced by 100 minus the 30-day averaged effective federal funds rate on the contract month. The monetary policy surprise can be estimated by using a daily difference of federal funds futures rates as follows:

$$\Delta s_t = \frac{D}{D-d}(FFR_t - FFR_{t-1}),$$

where FFR_t is a federal funds futures rate at the scheduled FOMC announcement date t, FFR_{t-1} is a federal funds futures rate of the prior date, D is the number of days in a current month, and d is the day of the FOMC announcement date. Unanticipated monetary policy rate change can only affect effective rates after the announcement day d. Because the underlying federal funds futures is the 30-day averaged effective federal funds rate on the current month, the daily difference of federal funds futures rates should be adjusted. Following Kuttner (2001) and Bernanke and Kuttner (2005), I use the difference of federal funds futures rates in the next month's contracts with no adjustment as the monetary policy surprise when the day of FOMC announcement is within the last 3 days of the month. It can remove the measurement error from the near-maturity futures.

3.2 Information shock

Different from the literature that studied public announcement events, several studies use large price changes as information shocks. For example, Conrad, Cornell, Landsman, and Rountree (2006) examine how analysts respond to information shock by using large stock price changes as a proxy for information shock. Further, Jiang and Zhu (2017) estimate stock price jumps which are large discontinuous price changes and suggest that the information shock could be underreacted by investors. Using a large stock price jump as a proxy for information shock is not limited to a specific news event, but may include a wide range of information events, and information shocks that are not publicly available, such as insider trades. Moreover, large stock price changes are generally caused by unforeseen information in the market, so they do not include information that is already expected or reflected in the financial market. I use stock price jumps as a proxy of the information shock for the main analysis. To estimate stock price jumps, I followed the procedure of Jiang and Oomen (2008) and Jiang and Zhu (2017). For this, a general asset price process is considered at first:

$$d \ln P_t = a_t dt + \sqrt{V_t} dW_t + J_t dq_t, \qquad (A.1)$$

where P_t is the stock price at time t, a_t is the drift, V_t is the variance for the no-random jump situation, W_t follows a standard Brownian motion, q_t is a counting process with finite intensity $\lambda_t (0 \leq \lambda_t < \infty)$, and J_t is a random jump in asset prices. After applying $It\hat{o}'s\ lemma$ and integrating over time T, formula $(A.1)$ can be expressed as follows:

$$2 \int_0^T \left[\frac{dS_t}{S_t} - d \ln P_t \right] = \int_0^T V_t dt + 2 \int_0^T (e^{J_t} - 1 - J_t) dq_t. \qquad (A.2)$$

Suppose the observed stock prices are $\{\mathrm{P}_0, \mathrm{P}_1, \ldots, \mathrm{P}_N\}$, N is the number of observations during $[0, \mathrm{T}]$, and r_t is the observed log returns of asset prices, $\mathrm{r}_\mathrm{t} = \ln(\mathrm{P}_t) - \ln(\mathrm{P}_{\mathrm{t}-1})$. The variance swap measure, which is a discretized form of $2\int_0^{\mathrm{T}} \left[\frac{\mathrm{dP_t}}{\mathrm{P_t}} - \mathrm{d}\ln \mathrm{P_t}\right]$, can be expressed as:

$$\mathrm{SWV}_T = 2\sum_{i=1}^{N}(R_i - r_i) = 2\sum_{i=1}^{N} R_i - 2ln(P_T/P_0), \qquad (\mathrm{A.3})$$

where $\mathrm{R}_t = \mathrm{P}_t/\mathrm{P}_{t-1} - 1$. Realized variance can be expressed as $\mathrm{RV}_T = \sum_{t=1}^{N} r_t^2$. Following Jiang and Oomen (2008), the test statistics for testing the presence of jumps can be constructed by using SWV and RV:

$$\frac{\int_0^1 \mathrm{V_t dt}\, N}{\sqrt{\Omega_{\mathrm{SWV}}}}\left(1 - \frac{RV_T}{SWV_T}\right) \rightarrow^d N(0,1), \qquad (\mathrm{A.4})$$

where $\Omega_{\mathrm{SWV}} = \frac{1}{9}\mu_6 \int_0^{\mathrm{T}} \mathrm{V_u^3 du}$, and $\mu_\mathrm{p} = 2^{\mu/2}\Gamma[(\mathrm{p}+1)/2]/\sqrt{\pi}$. By Barndorff-Nielsen and Shephard (2006), a consistent estimator of $\int_0^1 V_t dt$ is defined as:

$$\mathrm{BPV}_T = \frac{1}{\mu_1^2}\Sigma_{\mathrm{i}=1}^{N-1} \mid \mathrm{r_i} \mid\mid \mathrm{r_{i+1}} \mid. \qquad (\mathrm{A.5})$$

Finally, Jiang and Zhu (2017) shows that a consistent estimator of Ω_{SWV} can be defined as:

$$\widehat{\Omega_{\mathrm{SWV}}} = \frac{1}{9}\mu_6 \frac{\mathrm{N}^3 \mu_{6/\mathrm{p}}^{-\mathrm{p}}}{\mathrm{N} - \mathrm{p} + 1}\sum_{\mathrm{i}=0}^{T-\mathrm{p}}\prod_{k=1}^{p}|r_{i+k}|^{6/p}, \text{with } \mathrm{p} = 6. \qquad (\mathrm{A.6})$$

To capture information shocks that are expressed as jumps in asset price process, the jump statistics $(\mathrm{A.4})$ is used. The period between two connected scheduled FOMC announcement dates is considered to test the presence of information shocks before the FOMC announcement. To eliminate the effect of past monetary policy announcement, the next day of the last FOMC announcement date t-1 is used as a starting date of the period. The end of the estimation period is the day before yesterday of the current announcement date t to avoid the Pre-FOMC announcement day effect of Lucca and Moench (2015). Following the similar procedure of Andersen, Bollerslev, Frederiksen, and Nielsen (2010) and Jiang and Zhu (2017), in a return series, jump date and size can be estimated. First, the jump statistics for the selected period is calculated, and if it rejects the null hypothesis, we can argue that there is at least one jump in that period. To identify a jump among price series during the period, return r_i is changed as the median value of the return series, $\{r_0, r_1, \dots, r_N\}$, and then the jump test statistics is repeatedly calculated for each changed return series. The jump is identified as an observation whose absolute value of the difference between the jump statistics of original return series and the jump statistics of changed return series has the maximum value.

[TABLE 1]

3.3 Sample data

For the main analysis, I use 378,727 firm-event level observations from 1994 to mid-2008. Following Ozdagli (2018), I utilize firms traded in AMEX, NYSE, and NASDAQ on the FOMC announcement dates and exclude firm observations with their stock price are less than $5.[7] Firm information and daily return are extracted from the Compustat databases and the Center for Research in Security Prices (CRSP). The federal funds futures data and the Eurodollar futures data are obtained from Tickdata.com. I winsorize stock price returns at 1% level. The scheduled FOMC meeting history could be obtained from the Board of Governors of the Federal Reserve System database. Table 1 shows the summary statistics of the sample. I also consider firm-specific information events as an additional information shock measure for robustness. Here,

[7] The results are estimated by sample firms in every industry. Excluding observations of financial and utility firms does not corrupt the results.

I use earnings announcements which are periodically released-firm specific events. From the firms' responsibility to release their earnings information, it is possible to get sufficient unbiased information events. The underreaction to firms' quarterly earnings announcements has been widely discussed in the literature. Following DellaVigna and Pollet (2009), I use their identification procedure to verify earnings announcement dates. As in related literature, I only consider firms that have at least one analyst forecast of earnings announcement, and the sample starts from 1995 for complete announcement date matching. I use quarterly earnings announcement data from the COMPUSTAT and I/B/E/S and generate 80,467 observations from 1995 to mid-2008.

4 Empirical results

4.1 Information shocks and the effect of monetary policy surprises

Firstly, I analyze whether the information shock is associated with the stock price impact of monetary policy surprise. As described in the previous section, the information shock is defined as a positive or negative jump in the stock price return series. Using the information shock and its interaction term with monetary policy surprise, I do the regression analysis. The described regression model is as follows:

$$\mathrm{r}_{\mathrm{i,t}} = \beta_1 + \beta_2 \times \Delta \mathrm{s}_{\mathrm{t}} + \beta_3 \times \text{Information Shock}_{\mathrm{i,t}} + \beta_4 \times \Delta \mathrm{s}_{\mathrm{t}} \times \text{Information Shock}_{\mathrm{i,t}} + \text{Controls}_{\mathrm{i,t}} + \epsilon_{\mathrm{i,t}},$$

where $\mathrm{r}_{\mathrm{i,t}}$ is log return of firm i at FOMC announcement date t, $\Delta \mathrm{s}_{\mathrm{t}}$ is monetary policy surprise at the same day, $\text{Information Shock}_{\mathrm{i,t}}$ is the indicator variable which is equal to 1 if there is an information shock from prior FOMC announcement date t-1 to present FOMC announcement date t in firm i. The regression model controls firm fixed effects, 10 Fama-French industry fixed effects, and year fixed effects. In line with Ozdagli (2017), I also include interaction terms of industry fixed effects and monetary policy surprises, which could absorb industry-specific monetary policy sensitivities.

[TABLE 2]

In Table 2, columns 1 and 2 show the stock price response to monetary policy shocks. As in many studies including Bernanke and Kuttner (2005), stock prices are increased by expansionary monetary policy shock. The result shows that an unanticipated 1 percent point cut of the monetary policy rate is associated with about a 2.6 percent increase in stock prices on average. Next, I investigate whether the information shock mitigates the stock price impact of monetary policy surprise by including an interaction term between the information shock and monetary policy surprise. Column 3 demonstrates that stock price responses to monetary policy surprises are much weaker in firms with information shocks than in other firms Coefficient of interaction term of information shock and monetary policy shock expressed as β_4 in the regression model is 0.74 which is significantly positive. It can be interpreted that for a hypothetical unanticipated 1 percentage-point cut of federal funds target rate, immediate stock price response of firms with information shock is, on average, 0.74 percentage point lower than the price response of other firms. The magnitude of the effect is about a quarter of the entire stock market response which is shown in column 1. This result suggests that a presence of information shock may hinder the information of monetary policy announcements from being incorporated into the stock price. the results are also robust after controlling various fixed effects: firm fixed effects, industry fixed effects, and their interaction with monetary policy surprise. In columns 4 and 5, coefficients of the interaction term between information shock and monetary policy surprises are positive and significant.

Is there an asymmetric effect for a negative and positive information shock? Prior literature suggests that investors often react to new information differently depending on whether it is positive or negative news for stock prices. (Chan, 2003; Engelberg, Reed, and Ringgenberg, 2012; Jiang and Zhu, 2017) Table 3 contains coefficient estimates with a dummy variable which equals one if there is negative information shock, otherwise zero.

[TABLE 3]

Results show that information shock could affect the stock price response to monetary policy surprise asymmetrically. In column 1, Information shock is associated with the low impact of monetary policy surprises on the stock price. However, this amount is relatively smaller in negative information shock than in positive information shock. The interaction variable with the negative information shock dummy generates its coefficient as about -0.5. This result is closely related to the findings of Jiang and Zhu (2017) that investors underreact more to the positive information shock than the negative information shock. By constructing a monthly portfolio, they find that the positive information shock shows a larger and more persistent price drift after the shock than the negative one, which is consistent with Epstein and Schneider (2008). Their findings also suggest that the positive shock includes more information that is not incorporated into stock price than the negative stock. From this point of view, the results of Table 3 suggest that underreacted prior information deters the immediate processing of the monetary policy surprise, which is new information. In columns 2 and 3, the results are consistent controlling firm fixed, industry fixed, and their interaction effects with monetary policy surprise.

4.2 Firm characteristics of monetary policy transmission

Previous results show that the information shock is negatively associate with the impact of monetary policy announcements on stock prices. Next, I consider transmission channels of monetary policy on the stock price and analyze whether the effect of information shock could be explained by firm characteristics related to the transmission channels of monetary policy. Many researchers have studied the way stock prices are affected by monetary policy theoretically and empirically. Using various measures related to firms' financial constraints, Ehrmann and Fratzscher(2004) examine the impact of monetary policy announcements on the stock price of constrained firms. Their results show that among the firms in the S&P 500 index, financially constrained firms are less affected by monetary policy surprises than others. Further, Ozdagli (2018) employs financial constraint indexes of Whited and Wu (2006) and Hadlock and Pierce (2010). He also shows that the impact of monetary policy surprise is lower in financially constrained firms. Based on prior studies, I estimate whether the effect of information shock is driven by the financial constraints channel. Following Ozdagli (2018), I also use Whited and Wu (2006) index and Hadlock and Pierce (2010) index as financial constraint measures.

[TABLE 4]

For Table 4, I generate percentile ranks for financially constraint measures at every year-end and do regression analysis with percentile ranks variable of financial constraint variable and their interaction term with monetary policy surprise. The results demonstrate that the effect of information shock is not driven by including financial constraint measures. Column 1 shows consistent results with the prior studies, more financially constrained firms are less exposed to monetary policy surprises. Using the financial constraint dummy variable indicating whether a firm's financial constraint index is above median or not, Ozdagli (2018) shows that financially constrained firms are less affected by monetary policy surprise. I also find that a higher WW index could dampen the effect of monetary policy surprise by using percentile ranks of the firm's WW index. The results of HP index are marginally significant, but still positive. Returning to this paper, even if we consider the impact of financial constraints on firms' monetary policy sensitivity, information shock reduces the stock price responses of monetary policy surprises. The results are observed in both analyses using two different financial constraint measures.

Next, I address other transmission channels of monetary policy. Firstly, we consider corporate cash holdings which firms may hoard for precautionary motives (Opler et. al., 1999). Cash holdings can reduce the potential risk from volatile corporate cash flows, suggesting that the impact of monetary policy may also be lower in firms with higher cash holdings. Second, change of monetary policy rate has a greater impact on firms with high equity duration. Equity duration measures how much a firm's cash flow is concentrated in the future. Therefore, sensitively to monetary policy rate changes could be high in firms with high equity duration because of their discounted future cash flows. Third, firms with high cash flow volatility are more likely to be affected by monetary policy as they rely more on external financing. Finally, operating profitability could capture nominal rigidities. Similar to the prior analysis with the financial constraint indexes, I include firm characteristics related to monetary policy transmission channels and their interaction with monetary policy surprises in the regression model. Each channel variable is standardized to have a mean of 0 and a standard deviation of 1.

[TABLE 5]

Table 5 contains the result of considering the firm characteristics. Column 1 shows that stock price sensitivity to monetary policy surprise is increased by the firm's cash holdings. Consistent with prior studies, stock prices of firms with high cash holdings are affected more by unanticipated monetary policy changes. Nevertheless, the stock price response of monetary policy surprise is significantly lower in firms with information shock. Coefficient of interaction variable between information shock and monetary policy surprise is significantly positive. Next, Column 2 shows results with implied equity duration and its interaction with monetary policy surprise. I find that stock prices of firms with higher implied equity duration are more affected by monetary policy surprises. An increase in equity duration by 1 standard deviation suggests an additional stock price hike of about 0.65 percent by 1 percent-point monetary policy rate cut. The coefficient of interaction between monetary policy surprise and equity duration is -0.65, which is significantly negative. Column 3 contains a firm's cash flow volatility and its interaction term with monetary policy surprise. Consistent with prior literature, cash flow volatility is positively related to firm's exposure to monetary policy change. I find that firm's cash flow volatility could increase the effect of monetary policy surprises on firm value. Column 4 shows positive coefficient of the interaction term with operating profitability and monetary policy surprise, which is not significant. Despite that, the effects of information shock are still persistent. Interaction terms between information shock and monetary policy surprise have positive coefficient estimates which are statistically and economically significant even after controlling various firm characteristics indicating monetary policy transmission channels. The results suggest that the effect of information shock on the stock price impact of monetary policy is not due to the transmission channels of monetary policy shock on the firm value.

4.3 Information shock and size

Through the previous analysis, I show that information shock reduces the immediate price response of monetary policy surprises, and it is not driven by the transmission channels. If information not fully incorporated into the price causes the effect of information shock, the higher level of underreaction to information shock, the greater the effect should be. In this subsection, I examine how the effect of information shock changes depending on investor attention to information shocks. Limited investor attention suggests that investors' limited cognitive resource and amount of time deters new information to be fully reflected in stock prices. In line with it, information that is not reflected in the market increases when the investor is more underreact to information shock, and low investor attention to information shock is positively associated with information that is not reflected in the market. It suggests that the lack of investor attention to information shock increases the effect of it. To estimate investor attention to information shock, I consider two variables, the number of simultaneous information shocks and the magnitude of information shock. First, investors cannot fully incorporate multiple information which is occurred simultaneously. Hirshleifer, Lim, and Teoh (2009) suggest that limited investor attention could drive such distraction of information in the existence of extraneous information releases. They find that the stock market more underreacts to a firm's earnings announcement when there are a large number of earnings announcements from other firms. According to their arguments, I consider how many information shocks occur simultaneously on the same day to estimate the distraction of investors. Second, the magnitude of information shock measures whether it is salient news or not. From Barber and Odean (2008), a large stock price movement is likely to grab more investor attention. Furthermore, salient and attention-grabbing information could be less underreacted by investors. On the contrary, less salient information shock which has a smaller magnitude may generate more underreaction. Besides, Jiang and Zhu (2017) show that a larger magnitude of information shock is associated with weaker underreaction to information shock. Their results also support that investors give more attention to a large magnitude of information shock, which results in the information being quickly reflected in prices. Following the prior studies, I investigate whether the effect of information shock is associated with investor attention and distraction to the information shocks. I estimate the following regression models:

$$
\begin{aligned}
\mathrm{r}_{\mathrm{i,t}} = \beta_1 + \beta_2 \times \Delta \mathrm{s}_{\mathrm{t}} + \beta_3 \times \text{Information Shock}_{\mathrm{i,t}} + \beta_4 \times \Delta \mathrm{s}_{\mathrm{t}} \times \text{Information Shock}_{\mathrm{i,t}} \\
+ \beta_5 \times \Delta \mathrm{s}_{\mathrm{t}} \times \text{Information Shock}_{\mathrm{i,t}} \times \text{Shock Size}_{\mathrm{i,t}} \\
+ \beta_6 \times \text{Information Shock}_{\mathrm{i,t}} \times \text{Shock Size}_{\mathrm{i,t}} + \text{Controls}_{\mathrm{i,t}} + \epsilon_{\mathrm{i,t}},
\end{aligned}
$$

$$
\begin{aligned}
\mathrm{r}_{\mathrm{i,t}} = \beta_1 + \beta_2 \times \Delta \mathrm{s}_{\mathrm{t}} + \beta_3 \times \text{Information Shock}_{\mathrm{i,t}} + \beta_4 \times \Delta \mathrm{s}_{\mathrm{t}} \times \text{Information Shock}_{\mathrm{i,t}} \\
+ \beta_5 \times \Delta \mathrm{s}_{\mathrm{t}} \times \text{Information Shock}_{\mathrm{i,t}} \times \text{Simultaneous Shock}_{\mathrm{i,t}} \\
+ \beta_6 \times \text{Information Shock}_{\mathrm{i,t}} \times \text{Simultaneous Shock}_{\mathrm{i,t}} + \text{Controls}_{\mathrm{i,t}} + \epsilon_{\mathrm{i,t}},
\end{aligned}
$$

where Shock Size is the decile rank of an absolute magnitude of the information shock, and Simultaneous Shock is the decile rank of number of simultaneous information shock on the same day. Both two variables equal to zero if there is no information shock, so interaction terms of two variables with monetary policy surprise are absorbed by β_5.

[TABLE 6]

Table 6 contains evidence supporting that information not fully incorporated into the price mitigates the stock price response to monetary policy surprise. In columns 1 to 3, I use the size rank of information shock which is estimated by the absolute magnitude of information shock. For this measure, I divide information shocks into 10 deciles based on its magnitude. For example, an information shock rank of 10 (1) is the highest (lowest) 10% of the magnitude of information shock among all information shocks during the estimation period. Using the decile rank without using the magnitude of the information shock not only reduces biased estimates due to extreme values but also allows intuitive interpretation of estimation results. The result of column 1 shows that a higher magnitude of the information shock has a lesser impact on the stock price response to monetary policy surprise. The coefficient estimate on the triple interaction term, β_5, is significantly negative, which is the opposite sign of \beta_4. The results support the findings of Jiang and Zhu (2017) that investors are less underreacted as the larger the magnitude of information shock is, and the argument of this study that information not fully incorporated into the stock price impedes investors' accurate information processing. Moreover, the results are robust regardless of methods of grouping the magnitude of the information shock. I find that dividing the magnitude of information shock into two groups, above the median and below the median, or using continuous values does not affect the results. Next, I sort the information shocks into decile ranks by the number of simultaneous information shocks on the same day. Increasing simultaneous shock indicates that the information shock is co-occurred with many other firms' information shocks, on the same day. Columns 4 to 6 show that other firms' simultaneous information shocks can amplify the effect of information shock. I find that the coefficient of triple interaction term of monetary policy surprise, the information shock, and simultaneous shock is 0.133, which is significantly positive. This result indicates that the effect of information shock could be increased by a greater number of other information shocks on the same day increases. Consistent with Hirshleifer, Lim, and Teoh (2009), simultaneous shocks could distract investor attention to specific information shock, and it inhibits the information shock from being incorporated into the stock price. In other words, the results of columns 4 to 6 show that underreacted information caused by distracted investor attention deters the immediate stock market response to monetary policy surprise. Moreover, the investor attention attracting effect of the magnitude of information shock and distract the investor attention distracting effect of simultaneous shocks could be observed simultaneously. In column 7, I find significant effects of attracted and distracted investor attention.

4.4 Valuation uncertainty

This subsection explores whether the effect of information shock could vary between firms' valuation uncertainty. The valuation uncertainty denotes how difficult information is to be reflected in the stock price, and it could interfere with investors from fully understanding the information shock. Prior literature finds that investor's behavior bias is more pronounced in the firm which is difficult to value. For instance, Zhang (2006) finds that uncertain information could attribute the investor's behavior bias. He shows that stocks with high information uncertainty have greater price drifts after the earnings announcements and price momentum, and it suggests that firms with low information uncertainty reflect new information more immediately in stock prices than firms with high uncertainty. Jiang et. al. (2005) also find that price and earnings momentum effects increase in firms that are difficult for investors to evaluate.

Similarly, using investor-level trading and holding data, Kumar (2009) finds that firms with higher valuation uncertainty result in greater investors' behavior bias. The more difficult it is for investors to evaluate a firm value, the slower the new information about the firm is reflected in the stock price and the greater the behavioral bias of investors. In this study, I define an information shock as the price jump that occurs when new information has a significant impact on stock prices. From the prior findings, in firms with low valuation uncertainty, the new information could be priced more immediately, and it suggests that underreaction to the information shock is much lower in those firms. On the other hand, the information shock of the firms with high valuation uncertainty could include underreacted information more than other firms. Considering the previous results that information related to information shock that is not reflected in the market hinders immediate stock price reactions to monetary policy surprises, the effect of information shock would be greater and significant for firms with high valuation uncertainty. I examine whether the effect of information shock differs between firms with high and low valuation uncertainty. Following Kumar (2009), I use firm age (AGE), idiosyncratic volatility (IVOL), volume turnover (TURNOVER) as valuation uncertainty measures. Because idiosyncratic volatility and volume turnover could be correlated with information shock, both measures are estimated based on the 30-day period prior to the prior FOMC announcement, which does not overlap an estimation period of information shock. Firm age is calculated by the year of first registration in the CRSP database, and other control variables are the same as in Table 6.

[TABLE 7]

Table 7 shows estimation results after dividing firms into high and low valuation uncertainty based on the median value of the measures. I find that the effect of information shock is greater in firms with higher valuation uncertainty. In Column 1 and 2, the results show that the effect of information shock is much greater in younger firms. Consistent with the prior studies, the results suggest that in younger firms that have higher information uncertainty, their stock price response more slowly to new information, so the information shock contains more underreacted information. Columns 3 and 4 show that the results using idiosyncratic volatility are also consistent with the prior results. Firms with high idiosyncratic volatility have a larger and significant effect on information shock than other firms. The coefficient of the interaction term between information shock and monetary policy surprise is significantly positive only in high IVOL firms. Meanwhile, the results using share turnover show that the effect of information shock also exists in firms with low share turnover, but the estimated coefficient is small and marginally significant. This result could be attributed to the fact that the share turnover indicates not only valuation uncertainty but also investor attention. Hirshleifer, Hsu, Li (2018) also argue for ambiguity about using stock turnover as a measure of valuation uncertainty. Nevertheless, the results present that the effect of information shock is greater and more significant in firms with high turnover, suggesting that share turnover could better express a level of valuation uncertainty than a level of investor attention.

Next, I examine the relationship between market uncertainty and the effect of information shock. Because the level of market-wide uncertainty is also associated with underreaction to information shock, the effect of information shock could be increased in uncertain market conditions. Kumar (2009) also finds that behavior biases are much stronger in higher market uncertainty. I consider the Chicago Board Options Exchange volatility index (VIX) and the monetary policy uncertainty index (MPU) as market uncertainty measures. The VIX index measures an expectation of the U.S. stock market volatility for 30-day from the S&P 500 index futures, and it is widely used for measuring a stock market volatility. Because it is a daily-based measure, I consider that the market is in a high uncertainty when an average of VIX index prior to 15-day is greater than an average of VIX index for the past 3 years. The MPU index is a sub-index of the economic policy uncertainty index (Baker, Bloom, and Davis, 2016) which is a newspaper-based uncertainty index. It estimates a monthly-basis uncertainty, so I compare a prior month's MPU index to an average MPU index for the past 3 years.

[TABLE 8]

The estimation results are reported in Table 8. I find that market uncertainty is positively related to the effect of information shock. Columns 1 and 2 shows that the stock price reaction to monetary policy surprise is hindered by information shock in uncertain market circumstances. The coefficient of interaction variable between information shock and monetary policy surprise is positive and highly significant when the VIX index is high. Moreover, I find similar results using the MPU index as a measure of market uncertainty. Consistent with the prior studies suggesting that a higher level of market uncertainty is associated with more investor's behavior bias, the results of columns 3 and 4 indicate that information shock mitigates the impact of monetary policy surprises on the stock price during the periods when the market uncertainty is high.

4.5 Intraday analysis

So far, I have estimated stock price response of monetary policy announcements using daily stock returns. In this section, the short-term price reaction to monetary policy surprise is estimated by intraday stock returns, and I examine whether the effect of information shock even exists in a short-time interval. The intraday response of stock price can lower the likelihood that factors other than monetary policy announcement may influence, which is more in line with the goal of the event study. I analyze intraday stock returns from 2003 to mid-2008 using NYSE Trade and Quote (TAQ) data. By mid-2011, when FOMC's official announcement time was changed to 12:30 PM or 2:15 PM, FOMC has announced its policy rate decisions around 2:15 PM. During the sample period, the earliest release of the FOMC announcement is at 2:09 PM on June 25, 2008, and the latest release is at 2:19 PM on September 16, 2003 (Bernile, Hu, and Tang, 2016). I calculated the intraday stock price return using the stock price in the 30-minute window based on the official announcement release time of 2:15 PM. Similarly, intraday monetary policy surprise is also estimated using intraday Federal Funds Futures rates at the same time as follows,

$$\Delta s_t^{intra} = \frac{D}{D-d}\left(FFR_{t,2:30} - FFR_{t,2:00}\right),$$

where $FFR_{t,2:30}$ is a federal funds futures rate traded first after 2:30 pm, $FFR_{t,2:00}$ is a federal funds futures rate which is traded last before 2:00 pm, D is the number of days in a current month, and d is the day of the FOMC announcement date.

[TABLE 9]

Table 9 contains the effect of information shock on intraday stock price reaction to monetary policy surprise. First, column 1 shows how the entire stock market affected by monetary policy surprise during a 30-minute window. The estimated coefficient of monetary policy surprise is larger than the magnitude of the coefficient from Table 2, suggesting that the stock price impact of monetary policy surprise increases during the estimation period. However, it is not because the results are estimated by an intraday stock price response. The daily stock price reaction to monetary policy surprise during the same period from 2003 to mid-2008 is also greater than the estimations in Table 2. Intraday analysis confirms that the information shock reduces the impact of monetary policy surprise on stock prices. Columns 4 to 6 show that the presence of information shock reduces the stock price impact of monetary policy surprise.

4.6 Abnormal trading behavior

Next, I investigate abnormal order flows caused by information shock. Underreaction to information shock implies that there is information not incorporated into stock prices, and the previous results show that the presence of the information could reduce the immediate impact of monetary policy announcement on the stock price. If some traders have better ability or capacity to process information, they might take an advantage of it when the monetary policy announcement is released. I investigate that abnormal trading behavior due to information shock exists in transactions immediately after the monetary policy announcements. Besides, we estimate order imbalances and abnormal trading volumes from transactions occurred after the latest announcement time of 2:19 PM, in order not to be affected by information leakage during the pre-announcement period. The order imbalance measures how many trades are initiated by a buyer or seller, and it is constructed as the ratio of buyer-initiated trading volume and seller-initiated trading volume during the estimation period. I use the trade direction classification algorithm of Ellis, Michaely, and O'Hara (2000). As in Bernile, Hu, and Tang (2016), I also employ the number of trades and the dollar value of trades to measure trading volume. Likewise, the abnormal trading volume is defined as the logarithm of trading volume during the estimation period divided by the 1-month average trading volume before the information shock estimation period.

[TABLE 10]

Table 10 includes order imbalances of stock transactions right after the FOMC's monetary policy announcement. Contrary to the results of Bernile et. al. (2016), the results find an abnormal order imbalance in trades of individual stocks after the monetary policy announcements. After expansionary monetary policy shock, there are more trades initiated by buyers than seller-initiated trades, and this ratio increases as the magnitude of the monetary policy surprise increases. Comparing with the results of Bernile et al. (2016), it may suggest that the speed of information process is slower than index futures in individual stocks, which is consistent with Hasbrouck (2003). The difficulty in short sale of individual stocks could be another considerable reason. I also find that the magnitude of order imbalance is greater in stocks with information shock. The coefficient of the interaction term between information shock and monetary policy surprise is positively significant, and its direction is the same as the effect of monetary policy surprise. Firms with information shock have greater abnormal order imbalance which is caused by monetary policy surprises than other firms, which also suggests that information shock could increase information asymmetry between investors. The result is significant in the analysis using both trade volume-based order imbalance and dollar trade volume-based order imbalance. The effect of information shock on the abnormal order imbalance also exists in the 60-minute window after the FOMC announcement. The results of panel B show that the 60-minute order imbalance is significantly decreased by the monetary policy surprise, and this effect is much greater in the presence of information shock.

[TABLE 11]

The trading volume of stock market index futures and individual stocks could be increased rapidly after the FOMC announcement (Chung, Elder, and Kim, 2013; Lucca and Moench, 2015). I find that abnormal trading volume of individual stocks could be increased by the unanticipated portion of the monetary policy rate decision. Table 11 presents that abnormal trading volume which may increase due to the magnitude of monetary policy surprise exists after the FOMC announcement. I find that the coefficients of the absolute value of monetary policy surprises are significantly positive. On the other hand, abnormal trading volumes of firms with information shock are relatively less affected by the magnitude of monetary policy surprises. Columns 1 to 3 present that information shock diminishes the positive impact of absolute value of monetary policy shock on the abnormal trading volume. Further, the effect of information shock on abnormal trading volume is significant even using transactions in 60 minutes windows after the announcement. In column 4, 5, and 6, analyses using abnormal dollar trading volume also give consistent results with the prior.

The intraday results of Tables 10 and 11 demonstrate that information shock is positively associated with investors' information asymmetry. Some informed traders who have higher information processing capacity or advantage than uninformed traders can utilize their ability by trading stocks with informational friction. On the other hand, uninformed traders with low information processing ability are not willing to buy stocks with information friction at the risk of their information disadvantages, which will result in a larger magnitude of abnormal order imbalances and a smaller abnormal trade volume. It suggests that underreaction to information shock could exacerbate information asymmetry between investors with large and small information processing capabilities.

4.7 Delayed stock price reaction to monetary policy announcements

Through the prior analysis, I show results that firms with information shocks are less affected by monetary policy surprises on the FOMC announcement date. Here, a natural question is whether there is a delayed response to monetary policy surprises in these firms. In this subsection, I estimate the delayed stock price reaction to monetary policy surprise. To eliminate other macroeconomic announcement effects, I control date fixed effects, which subsume the impact of monetary policy surprise. As in prior analysis, I also control industry fixed effect and its' interaction with the monetary policy surprise. Table 12 contains the stock price reaction to monetary policy surprises from the following day of the monetary policy rate announcement. Column 1 provides evidence of delayed response by showing that stock prices with information shock are negatively affected by the surprise of monetary policy announced the day before. Although delayed stock price response on the following day is not significant, the results for cumulative returns for two days after the announcement indicate that in firms with informational friction, information of monetary policy surprise could be incorporated into stock prices after the announcement date.

[TABLE 12]

5 Robustness of the results

5.1 Alternative information shock measure

In this section, information shock is measured differently to verify that the results from the previous analyses are robust. While the information shock is estimated during the period from the prior FOMC announcement date t-1 to the current announcement date t in the prior results, I estimate information shock by extending the estimation period as about 3 months (From the FOMC announcement on t-2 to the FOMC announcement on t). A 3-day window around the FOMC announcement date on t-1 is excluded from the estimation period. Moreover, both 95% and 99% of significance levels are considered in the calculation of jump statistics. Table 13 shows that information shock estimated by longer periods still significantly mitigates the immediate stock price impact of monetary policy surprise, and this effect is also not affected by the significance level of jump statistics.

[TABLE 13]

Table 14 contains the results of alternative information shock measures using the analysis for Table 6. Regardless of using other metrics to estimate information shock, the effect of information shock is higher when it receives lower investor attention. High investor distraction also increases the effect of information shock. In addition to this, I examine whether more recently occurred information shock can decrease the impact of monetary policy surprises on the stock price more. Given the gradual diffusion of information, old information shock may already be reflected in the stock price, and there may be less information not included in the stock price than the new information shock. Through the previous findings that information that is not incorporated into the price could mitigate immediate price response to monetary policy announcements, I expect that the recent information shock can reduce the impact of monetary policy surprises on the stock price more than the old information shock does. Column 3 shows the results. To investigate the effect of recent information shock, the information shock that occurred within a 1-month is considered as the recent information shock. In line with the conjecture, I find that the recent information shock has a greater impact on mitigating stock price reaction to monetary policy surprise. The coefficient of interaction variable between the recent information shock and the monetary policy surprise is 0.583, which is significantly positive, while the overall effect of entire information shocks is estimated as 0.403. The results indicate that the effect of information shock could be weakened over time, and it is also consistent with the process by which information is reflected in the stock price.

[TABLE 14]

Next, I revisit one of the most representative corporate information disclosures, the quarterly earnings announcement. The investor underreaction to the quarterly earnings announcement, as I mentioned earlier, has been well documented by a voluminous literature. The short-term price continuation in the same direction as the earnings surprise implies that information of the earnings announcement is not fully incorporated into the stock price. I investigate whether information on earnings announcements that are not fully reflected in the stock price could deter immediate stock price response to monetary policy surprises. From the findings of prior studies, I use three variables indicating underreaction to earnings announcements. First, earnings announcements released on Friday are less attentive to investors (Dellavigna and Pollet, 2009). The low investor attention to Friday earnings announcement makes it difficult for earnings announcement information to be immediately reflected in the stock price. Therefore, firms with a Friday earnings announcement may contain greater underreacted information than other firms that release their earnings announcements on other days. Next, a small number of analyst coverage is associated with delayed stock price reaction to earnings announcements, and it may increase underreaction to earnings announcement information. Finally, similar to the previous analysis, I use the recent earnings announcement. I consider earnings announcements released for a month prior to the FOMC announcement date as the recent earnings announcement and construct a dummy variable indicating this.

[TABLE 15]

Table 15 shows that underreaction to earnings announcement affects the stock price response to monetary policy surprise. Consistent with the previous results, I find that underreaction to earnings announcements could mitigate the immediate impact of monetary policy surprises on stock prices. Column 1 and 2 show that the impact of monetary policy surprise on the stock price is lower in firms which release earnings announcements on Friday and in firms with a small number of analyst coverage. Because the Friday earnings announcement and lower number of analyst coverage are associated with investor underreaction to earnings announcements, its information cannot be fully reflected in the stock price in these conditions. Moreover, I find that recent earnings announcement has a greater impact on mitigating the stock price response to monetary policy surprise. The result of column 3 presents that the coefficient of the interaction term between recent earnings announcement and monetary policy surprise is significantly positive. At last, column 4 considers three variables which can affect investor underreaction to earnings announcement and shows that they have significant effects on immediate stock price reaction to monetary policy surprise.

5.2 Extended period

Next, I analyze the effects of information shock after the global financial crisis. Since the financial crisis, FOMC adhered to the Zero Lower Bound policy rate for a while, the Federal Funds Futures rate cannot reflect the monetary policy rate expectation for this period. To overcome this limitation, Ozdagli and Velikov (2020) estimate the changes in short-term expectations for the FOMC's interest rate decision by using the Eurodollar futures, following Rigobon and Sack (2004) and Gurkaynak et al. (2005). In this subsection, I also use the changes in short-term interest rate expectations as the unanticipated FOMC's decision. The short-term interest rate expectation change is defined as the difference between two intraday Eurodollar futures rates before and after the FOMC announcement,

$$\Delta EDS_t = \mathrm{EFR}_{\mathrm{t,2:45}} - \mathrm{EFR}_{\mathrm{t,12:00}}$$

where ΔEDS_t measures unexpected monetary policy decision of FOMC at the announcement date t after 2008 and the EFR is the 3-month Eurodollar futures rates which maturity lefts a one-quarter. From April 27, 2011, FOMC have started to release the monetary policy announcement around either 12:30 pm or 2:15 pm. To avoid potential time effect which is not intended, I use the first traded rates after 2:45 pm and the last traded rates before 12:00 pm rather than changing the time window for each announcement. Table 15 contains the results of this regression model,

$$r_{i,t}^{intra} = \beta_1 + \beta_2 \times \Delta EDS_t + \beta_3 \times \text{Information Shock}_{i,t} + \beta_4 \times \Delta EDS_t \times \text{Information Shock}_{i,t} + \text{Controls}_{i,t} + \epsilon_{i,t},$$

where $r_{i,t}^{intra}$ is intraday return of firm i at the scheduled FOMC announcement date t, ΔEDS_t is the monetary policy surprise estimated by the Eurodollar futures, and other variables are equivalent. Results of Table 16 show that unanticipated expansionary monetary policy shock is also associated with increases in the stock market during the post-2008 period. Moreover, the effect of information shock is significant, statistically and economically. In column 2 to 4, the regression coefficients of the interaction variable between monetary policy surprises from Eurodollar futures and information shock is about 6 to 5, which are about half of the impact of the monetary policy surprises on the entire stock markets.

[TABLE 16]

One advantage of extending the estimation period to post-2008 is that I can apply various methods used in recent research. Recent work by Ben-Rephael, Da, and Israelsen (2017) proposes a procedure to directly measure abnormal institutional investor attention. They measure the firm-level institutional investor attention by using news reading and searching activities on Bloomberg terminals. In line with the many pieces of research suggesting the importance of institutional investors on information processing into the stock price, they find that high institutional investor attention can reduce a stock price underreaction to new information, such as earnings announcements and changes of analyst recommendation. In this work, I show that information shock can mitigate the stock price reaction to monetary policy surprise, and this effect is driven by information that is not incorporated into the stock price. From the findings of

Ben-Rephael et al. (2017), abnormal institutional investor attention can boost the speed of information processing and reduce stock price underreaction to news. Therefore, if information shock can attract high institutional investor attention, the effect of information shock will be decreased. I estimate whether high institutional investor attention can reduce the effect of information shock by using the abnormal institutional investor attention of Ben-Rephael et al. (2017). To measure whether the information shock received high institutional investor attention, I construct a dummy variable indicating whether Bloomberg's investor attention measure is 3 or 4 on the day of the information shock. I reproduce the results of Table 6 using the sample of the extended period, and also perform the following regression:

$$
\begin{aligned}
r_{i,t}^{intra} = {} & \beta_1 + \beta_2 \times \Delta EDS_t + \beta_3 \times \text{Information Shock}_{\text{i,t}} + \beta_4 \times \Delta EDS_t \times \text{Information Shock}_{\text{i,t}} \\
& + \beta_5 \times \Delta EDS_t \times \text{Information Shock}_{\text{i,t}} \times \text{High Institutional Attention}_{\text{i,t}} \\
& + \beta_6 \times \text{Information Shock}_{\text{i,t}} \times \text{High Institutional Attention}_{\text{i,t}} + \text{Controls}_{\text{i,t}} \\
& + \epsilon_{\text{i,t}},
\end{aligned}
$$

where $r_{i,t}^{intra}$ is intraday return, ΔEDS_t is the monetary policy surprise from the Eurodollar futures, and $\text{High Institutional Attention}_{\text{i,t}}$ is the dummy variable which is equal to 1 if the information shock is covered by high institutional investor attention, and zero otherwise.

[TABLE 17]

I find that underreaction to information shock due to the lack of investor attention mitigates immediate stock price reaction to monetary policy surprise, regardless of the sample period after 2008. Columns 1 and 2 of Table 16 show that the effect of information shock could be decreased by high investor attention. Moreover, results are robust after considering more direct measures of investor attention. I find that the abnormal institutional investor attention is related to instantaneous stock price reaction to monetary policy surprises in firms with information shocks. Column 3 reports that high institutional investor attention can resolve the stock price underreaction to monetary policy surprise caused by information shock. As with other investors' attention, high institutional investors' attention accelerates the processing of information shock and reduces underreaction to information shock, consistent with the findings of Ben-Rephael et al. (2017). Information shock reflected in the stock price due to high attention of institutional investors does not affect the immediate pricing of new information related to monetary policy announcements.

6 Conclusion

In financial markets, there are several pieces of evidence of frictions that can drive real markets away from the theoretical world. Market makers and market participants have been transforming markets in the direction that financial markets can operate more efficiently. Similarly, policymakers have been trying to implement more accurate and efficient monetary policy decisions. Nevertheless, many studies support that there are still many anomalies in the markets. In this paper, I analyze how if the information is not properly reflected, it affects the processing and pricing of the following information. To my knowledge, this is the first study to analyze the effect of underreaction to information shock on the processing of new information. The results show that the impact of information shock could be amplified by investor inattention and investor distraction, suggesting that the processing power of the information could be continuously buried in the information that is not fully incorporated into the stock price.

Under the limited information processing capacity, an informed trader and an uninformed trader have differences in the processing of information, and their optimal trading strategies would be different. Through the intraday results, I find that the underreaction to information shock is associated with high abnormal order imbalance and low abnormal trading volume after the FOMC announcement is released. The results suggest that information left behind the table could exacerbate information asymmetry between investors with large and small information processing capabilities. The results of using the corporate earnings announcements as the information shock are also consistent with my main argument. More inattentive earnings announcements, such as the Friday announcement and a low number of analyst coverage, can lead to more underreaction and make the immediate processing of new information laborious. How long this sustained underreaction can last and whether it can be transferred to companies in the same industry remains for future research.

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Table 1
Summary statistics

Variables	N	Mean	Std. Dev.	Q1	Median	Q3
Daily Return	378727	0.214	2.948	-1.22	0.00	1.53
Monetary Policy Surprise	114	-0.006	0.057	-0.03	0.00	0.01
Size	374587	6.000	1.851	4.62	5.83	7.18
WW Index	325869	-0.292	0.097	-0.36	-0.29	-0.22
HP Index	378727	-3.527	0.697	-4.04	-3.46	-3.05
Cash Holdings	344476	0.168	0.221	0.03	0.09	0.22
Cash Flow Volatility	237801	0.072	0.068	0.03	0.05	0.09
Equity Duration	352107	16.604	2.697	15.25	16.59	17.83
Return Volatility	378727	0.028	0.016	0.02	0.02	0.04
Firm Age	378727	16.591	16.106	5.00	11.00	24.00
Operating Profitability	371869	0.046	0.039	0.01	0.04	0.07
Information Shock	378727	0.339	0.473	0.00	0.00	1.00
Size of negative information shock	46194	-0.166	0.128	-0.21	-0.13	-0.08
Size of positive information shock	90169	0.152	0.117	0.08	0.12	0.19

This table contains firm characteristics and monetary policy surprise. Daily return is stock price return with a daily basis, size is the logarithm of market capitalization, WW index is Whited and Wu (2006) index, HP index is Hadlock and Pierce (2010) index, cash flow volatility is estimated as the standard deviation of operating cash flow for the last 20 quarters, equity duration is estimated by the methodology of Dechow, Sloan, and Soliman (2004), idiosyncratic volatility is measured as the standard deviation of firm's market excess returns based on the 30-day period prior to the prior FOMC announcement, firm age is calculated by the year of first registration in the CRSP database, operating profitability is calculated by sales minus cost of goods sold deflated by market value of total assets, information shock is the indicator variable which is equal to 1 if there is an information shock from prior FOMC announcement date t-1 to present FOMC announcement date t in firm i, and size of negative and positive information shocks shows the magnitude of negative and positive information shocks.

Table 2

Stock price response to monetary policy surprise and the effect of information shock

VARIABLES	(1)	(2)	(3)	(4)	(5)
ΔS	-2.603***	-3.156***	-2.826***	-3.340***	-2.696***
	(-32.531)	(-36.235)	(-29.115)	(-32.405)	(-8.971)
Information shock			-0.005	-0.022**	-0.021**
			(-0.505)	(-2.065)	(-2.017)
ΔS × Information shock			0.738***	0.619***	0.683***
			(4.051)	(3.396)	(3.730)
Constant	0.196***	-0.023	0.197***	-0.016	-0.012
	(39.274)	(-0.322)	(32.879)	(-0.230)	(-0.174)
Observations	378,727	378,727	378,727	378,727	378,727
Adjusted R-squared	0.003	0.009	0.003	0.009	0.009
Firm FE	No	Yes	No	Yes	Yes
Year FE	No	Yes	No	Yes	Yes
Industry FE	No	Yes	No	Yes	Yes
Industry X surprise	No	No	No	No	Yes

This table contains the following regression model:

$$r_{i,t} = \beta_1 + \beta_2 \times \Delta s_t + \beta_3 \times \text{Information Shock}_{i,t} + \beta_4 \times \Delta s_t \times \text{Information Shock}_{i,t}$$

$$+\text{Controls}_{i,t} + \epsilon_{i,t},$$

where $r_{i,t}$ is log return of firm i at FOMC announcement date t, Δs_t is monetary policy surprise at the same day, $\text{Information Shock}_{i,t}$ is the indicator variable which is equal to 1 if there is an information shock from prior FOMC announcement date t-1 to present FOMC announcement date t in firm i. Column 2, 4, and 5 controls firm fixed effects, 10 Fama-French industry fixed effects, and year fixed effects. In column 5, interaction terms of industry fixed effects and monetary policy surprise are also included. Robust standard errors with clustering at the firm levels are used in reporting the *t* -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 3

Asymmetric impact of information shock

VARIABLES	(1)	(2)	(3)
ΔS	-2.823***	-3.340***	-2.688***
	(-29.088)	(-32.406)	(-8.937)
Information shock	-0.013	-0.027**	-0.027**
	(-1.087)	(-2.223)	(-2.178)
$\Delta S \times$ Information shock	0.940***	0.824***	0.906***
	(4.418)	(3.879)	(4.244)
$\Delta S \times$ Negative shock	-0.523*	-0.522*	-0.566*
	(-1.669)	(-1.665)	(-1.804)
Negative shock	0.009	0.014	0.014
	(0.526)	(0.803)	(0.794)
Constant	0.153***	-0.017	-0.013
	(18.916)	(-0.232)	(-0.176)
Observations	378,727	378,727	378,727
Firm FE	No	Yes	Yes
Year FE	No	Yes	Yes
Industry FE	No	Yes	Yes
Industry X surprise	No	No	Yes
Adjusted R-squared	0.003	0.009	0.009

This table contains the following regression model:

$$r_{i,t} = \beta_1 + \beta_2 \times \Delta s_t + \beta_3 \times \text{Information Shock}_{i,t} + \beta_4 \times \Delta s_t \times \text{Information Shock}_{i,t} + \beta_5 \times \Delta s_t \times \text{Negative Shock}_{i,t} + \beta_6 \times \text{Negative Shock}_{i,t} + \text{Controls}_{i,t} + \epsilon_{i,t},$$

where $r_{i,t}$ is log return of firm i at FOMC announcement date t, Δs_t is monetary policy surprise at the same day, Information $\text{Shock}_{i,t}$ is the indicator variable which is equal to 1 if there is an information shock from prior FOMC announcement date t-1 to present FOMC announcement date t in firm i. Negative $\text{Shock}_{i,t}$ is a dummy variable which is equal to 1 if the information shock is negative. Robust standard errors with clustering at the firm levels are used in reporting the *t* -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 4
Financial Constraint index and the effect of information shock

VARIABLES	(1)	(2)
ΔS	-2.970***	-2.894***
	(-8.694)	(-9.181)
Information shock	-0.021*	-0.021**
	(-1.849)	(-2.013)
ΔS × Information shock	0.524***	0.676***
	(2.654)	(3.688)
ΔS × WW index	0.011***	
	(2.883)	
WW index	0.002***	
	(3.476)	
ΔS × HP index		0.005
		(1.506)
HP index		0.001
		(1.584)
Constant	-0.093	-0.084
	(-1.201)	(-0.998)
Observations	325,869	378,727
Adjusted R-squared	0.009	0.009
Firm FE	Yes	Yes
Year FE	Yes	Yes
Industry FE	Yes	Yes
Industry X surprise	Yes	Yes

This table includes the coefficient estimates of Whited Wu (2006) index and Hadlock and Pierce (2010) index. Both indexes are estimated as:

$$\text{WW index} = -0.091 * CF/AT - 0.062 * I_{DVC+DVP\geq 0} + 0.021 * DLTT/AT - 0.044 * \log(AT) + 0.102 * SGI - 0.35 * SG,$$

$$\text{HP index} = -0.737 * \log(AT_{adj}) + 0.043 * \log(AT_{adj})^2 - 0.04 * \text{Age},$$

where CF is the cash flow, AT is total assets, DVC+DVP is total amount of dividends for common and preferred stocks, $I_{DVC+DVP\geq 0}$ is a dummy variable which is equal to 1 if the dividends is positive, otherwise 0, DLTT is the long-term debt, SGI is the average sales growth of firms' industry by three-digit Standard Industrial Classification (SIC), SG is the sales growth, AT_{adj} is the inflation-adjusted total assets, and Age is the firm year from when the firm listed on COMPUSTAT database. Following Hadlock and Pierce (2010), I set limits of the inflation-adjusted total assets as 4.5 billion dollars and firm years as 37 years. I use percentile ranks of both indexes. Robust standard errors with clustering at the firm levels are used in reporting the t -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively. Robust standard errors with clustering at the firm levels are used in reporting the t -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 5

Monetary policy transmission channel and the effect of information shock

VARIABLES	(1) Cash	(2) Equity Duration	(3) Cash Flow Volatility	(4) Operating Profitability
ΔS	-2.741***	-1.600***	-2.841***	-2.756***
	(-8.534)	(-4.385)	(-8.554)	(-9.051)
Information shock	-0.022**	-0.021**	-0.040***	-0.021**
	(-2.040)	(-1.972)	(-2.933)	(-1.980)
ΔS × Information shock	0.655***	0.704***	0.744***	0.643***
	(3.372)	(3.640)	(3.130)	(3.461)
ΔS × Cash holdings	0.214**			
	(2.289)			
Cash holdings	0.044***			
	(4.867)			
ΔS × Equity duration		-0.023***		
		(-6.435)		
Equity duration		-0.001**		
		(-2.418)		
ΔS × Cash flow volatility			-0.286**	
			(-2.323)	
Cash flow volatility			0.003	
			(0.251)	
ΔS × Operating profitability				0.092
				(0.862)
Operating profitability				0.068***
				(5.898)
Constant	-0.062	-0.040	-0.045	-0.006
	(-0.895)	(-0.568)	(-0.616)	(-0.079)
Observations	344,476	352,107	237,801	371,869
Adjusted R-squared	0.010	0.009	0.010	0.009
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Industry X surprise	Yes	Yes	Yes	Yes

This table contains firm characteristics related to the transmission channel of monetary policy. Equity Duration is estimated by the methodology of Dechow et al. (2004), cash flow volatility is estimated as the standard deviation of operating cash flow for the last 20 quarters, and Operating profitability is calculated by sales minus cost of goods sold deflated by market value of total assets. All variables are winsorized at 1% level. Robust standard errors with clustering at the firm levels are used in reporting the t -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 6

Investor inattention, distraction, and the effect of information shock

VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)	(7)
ΔS	-2.826***	-3.340***	-2.714***	-2.826***	-3.341***	-2.694***	-2.713***
	(-29.115)	(-32.405)	(-9.052)	(-29.115)	(-32.411)	(-8.959)	(-9.045)
Information shock	-0.037**	-0.015	-0.016	-0.023*	-0.037***	-0.037***	-0.029
	(-2.253)	(-0.873)	(-0.936)	(-1.853)	(-2.899)	(-2.870)	(-1.588)
ΔS × Information shock	1.743***	1.664***	1.502***	0.401*	0.241	0.291	1.158***
	(5.990)	(5.701)	(5.124)	(1.838)	(1.101)	(1.325)	(3.700)
ΔS × Information shock	-0.181***	-0.188***	-0.149***				-0.163***
× Shock Size	(-3.306)	(-3.425)	(-2.654)				(-2.904)
Information shock	0.006*	-0.001	-0.001				-0.002
× Shock Size	(1.894)	(-0.404)	(-0.318)				(-0.496)
ΔS × Information shock				0.135***	0.149***	0.155***	0.166***
× Simultaneous Shock				(2.776)	(3.040)	(3.157)	(3.387)
Information shock				0.006**	0.005**	0.005**	0.006**
× Simultaneous Shock				(2.508)	(2.134)	(2.155)	(2.207)
Constant	0.197***	-0.017	-0.013	0.197***	-0.017	-0.013	-0.013
	(32.879)	(-0.239)	(-0.182)	(32.879)	(-0.234)	(-0.178)	(-0.188)
Observations	378,727	378,727	378,727	378,694	378,694	378,694	378,694
Adjusted R-squared	0.003	0.009	0.009	0.003	0.009	0.009	0.009
Firm FE	No	Yes	Yes	No	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	No	Yes	Yes	No	Yes	Yes	Yes
Industry X surprise	No	No	Yes	No	No	Yes	Yes

This table reports results from the following regression models:

$$
\begin{aligned}
r_{i,t} = \beta_1 + \beta_2 \times \Delta s_t + \beta_3 \times \text{Information Shock}_{i,t} + \beta_4 \times \Delta s_t \times \text{Information Shock}_{i,t} \\
+ \beta_5 \times \Delta s_t \times \text{Information Shock}_{i,t} \times \text{Shock Size}_{i,t} \\
+ \beta_6 \times \text{Information Shock}_{i,t} \times \text{Shock Size}_{i,t} + \text{Controls}_{i,t} + \epsilon_{i,t},
\end{aligned}
$$

$$
\begin{aligned}
r_{i,t} = \beta_1 + \beta_2 \times \Delta s_t + \beta_3 \times \text{Information Shock}_{i,t} + \beta_4 \times \Delta s_t \times \text{Information Shock}_{i,t} \\
+ \beta_5 \times \Delta s_t \times \text{Information Shock}_{i,t} \times \text{Simultaneous Shock}_{i,t} \\
+ \beta_6 \times \text{Information Shock}_{i,t} \times \text{Simultaneous Shock}_{i,t} + \text{Controls}_{i,t} + \epsilon_{i,t},
\end{aligned}
$$

where Shock Size is the decile rank of an absolute magnitude of the information shock, and Simultaneous Shock is the decile rank of number of simultaneous information shock on the same day. Both two variables equal to zero if there is no information shock, so interaction terms of two variables with monetary policy surprise are absorbed by β_5. Robust standard errors with clustering at the firm levels are used in reporting the t -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 7
Valuation uncertainty and the effect of information shock

	AGE		IVOL		TURNOVER	
	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Low	High	Low	High	Low	High
ΔS	-3.663***	-2.012***	-1.429***	-4.435***	-1.714***	-4.497***
	(-6.543)	(-5.983)	(-4.867)	(-7.476)	(-4.393)	(-7.584)
Information shock	-0.026	-0.017	-0.007	-0.042**	-0.019	-0.028*
	(-1.563)	(-1.303)	(-0.655)	(-2.363)	(-1.376)	(-1.645)
$\Delta S \times$ Information shock	1.070***	0.315	0.110	1.264***	0.454*	1.120***
	(3.714)	(1.385)	(0.592)	(4.034)	(1.765)	(3.916)
Constant	0.022	-0.040	-0.056	0.050	-0.102	-0.045
	(0.153)	(-0.475)	(-0.802)	(0.325)	(-1.202)	(-0.325)
Observations	184,095	194,632	189,366	189,361	172,926	172,978
Adjusted R-squared	0.008	0.010	0.009	0.010	0.006	0.014
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes	Yes
Industry X surprise	Yes	Yes	Yes	Yes	Yes	Yes

This table reports estimates from subsamples divided by valuation uncertainty of firms. Firm age (AGE) is calculated by the year of first registration in the CRSP database. Because idiosyncratic volatility (IVOL) and volume turnover (TURNOVER) could be correlated with information shock, both measures are estimated based on the 30-day period prior to the prior FOMC announcement, which does not overlap an estimation period of information shock. Other control variables are the same as in Table 6. Robust standard errors with clustering at the firm levels are used in reporting the t -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 8

Market uncertainty and the effect of information shock

	VIX		MPU	
VARIABLES	Low	High	Low	High
ΔS	-1.550***	-3.723***	-0.979***	-4.129***
	(-3.521)	(-8.601)	(-2.596)	(-8.347)
Information shock	-0.064***	0.030*	-0.031**	0.020
	(-4.300)	(1.902)	(-2.424)	(1.048)
$\Delta S \times$ Information shock	0.217	1.014***	0.241	1.078***
	(0.816)	(3.788)	(0.983)	(3.763)
Constant	-0.067	0.090	-0.080	0.103
	(-0.512)	(0.877)	(-0.855)	(0.861)
Observations	170,161	208,566	235,645	143,082
Adjusted R-squared	0.014	0.010	0.013	0.020
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Industry X surprise	Yes	Yes	Yes	Yes

This table presents the effect of information shock in high and low market uncertainty. I use Chicago Board Options Exchange volatility index (VIX) and the monetary policy uncertainty index (MPU) as market uncertainty measures. I consider that the market is in a high uncertainty when an average of VIX index prior 15-day is greater than an average of VIX index for past 3 years. I also compare a prior month's MPU index to an average MPU index for the past 3 years to divide sample into high and low market uncertainty. Robust standard errors with clustering at the firm levels are used in reporting the t - statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 9

intraday stock price response to monetary policy surprise and the effect of information shock

	Intraday Return					
VARIABLES	(1)	(2)	(3)	(4)	(5)	(6)
ΔS^{intra}	-5.570***	-7.055***	-7.862***	-5.970***	-7.407***	-8.168***
	(-66.544)	(-68.308)	(-42.363)	(-60.677)	(-64.024)	(-43.026)
Information shock				0.020***	0.023***	0.022***
				(3.954)	(4.306)	(4.228)
$\Delta S^{\text{intra}} \times$ Information shock				1.406***	1.251***	1.201***
				(7.304)	(6.476)	(6.212)
Constant	-0.089***	-0.106**	-0.095**	-0.097***	-0.119***	-0.107**
	(-42.707)	(-2.448)	(-2.197)	(-33.515)	(-2.705)	(-2.456)
Observations	82,347	82,347	82,347	82,347	82,347	82,347
Adjusted R-squared	0.092	0.137	0.138	0.094	0.138	0.139
Firm FE	No	Yes	Yes	No	Yes	Yes
Year FE	No	Yes	Yes	No	Yes	Yes
Industry FE	No	Yes	Yes	No	Yes	Yes
Industry X surprise	No	No	Yes	No	Yes	Yes

This table reports intraday stock price response to monetary policy surprise and the effect of information shock. Intraday return is calculated by using the stock price in the 30-minute window based on the official announcement release time of 2:15 PM. Robust standard errors with clustering at the firm levels are used in reporting the *t* -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 10
Order imbalance after the monetary policy announcement.

PANEL A	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES		OI 30-min.			OID 30-min.	
ΔS^{intra}	-0.357***	-0.561***	-0.449***	-0.369***	-0.545***	-0.430***
	(-9.869)	(-14.341)	(-2.845)	(-10.206)	(-13.939)	(-2.718)
Information shock	-0.001	0.000	0.000	-0.001	-0.000	-0.000
	(-0.314)	(0.058)	(0.073)	(-0.316)	(-0.093)	(-0.079)
$\Delta S^{\text{intra}} \times$	-0.097	-0.206***	-0.190**	-0.093	-0.197***	-0.182**
Information shock	(-1.334)	(-2.754)	(-2.534)	(-1.286)	(-2.642)	(-2.430)
Constant	0.014***	0.051	0.052	0.012***	0.048	0.048
	(6.424)	(1.497)	(1.507)	(5.395)	(1.380)	(1.390)
Observations	79,629	79,629	79,629	77,806	77,806	77,806
Adjusted R-squared	0.001	0.007	0.007	0.002	0.006	0.006
Firm FE	No	Yes	Yes	No	Yes	Yes
Year FE	No	Yes	Yes	No	Yes	Yes
Industry FE	No	Yes	Yes	No	Yes	Yes
Industry X surprise	No	No	Yes	No	No	Yes
PANEL B	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES		OI 60-min.			OID 60-min.	
ΔS^{intra}	-0.103***	-0.309***	-0.269**	-0.105***	-0.315***	-0.264**
	(-3.157)	(-8.827)	(-2.075)	(-3.207)	(-8.994)	(-2.034)
Information shock	-0.002	-0.002	-0.002	-0.003	-0.002	-0.002
	(-0.852)	(-0.649)	(-0.629)	(-0.949)	(-0.789)	(-0.772)
$\Delta S^{\text{intra}} \times$	-0.078	-0.183***	-0.171***	-0.078	-0.185***	-0.173***
Information shock	(-1.235)	(-2.905)	(-2.685)	(-1.246)	(-2.922)	(-2.714)
Constant	0.026***	0.044	0.044	0.026***	0.048	0.047
	(12.910)	(1.171)	(1.163)	(12.936)	(1.270)	(1.263)
Observations	82,936	82,936	82,936	81,036	81,036	81,036
Adjusted R-squared	0.000	0.009	0.009	0.000	0.009	0.009
Firm FE	No	Yes	Yes	No	Yes	Yes
Year FE	No	Yes	Yes	No	Yes	Yes
Industry FE	No	Yes	Yes	No	Yes	Yes
Industry X surprise	No	No	Yes	No	No	Yes

This table presents order imbalances during 30-minutes and 60-minutes after the FOMC announcements. Trade directions are classified by algorithm of Ellis, Michaely, and O'Hara (2000). Order imbalance (OI) is constructed as the ratio of buyer-initiated trading volume and seller-initiated trading volume during the estimation period, and OID is calculated by dollar trading volume. Robust standard errors with clustering at the firm levels are used in reporting the *t* -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 11

Abnormal trading volume and the effect of information shock

PANEL A	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES		Avol 30-min.			Avold 30-min.	
$\text{abs}(\Delta S^{\text{intra}})$	1.759***	1.093***	0.658**	1.319***	0.811***	0.408
	(21.503)	(13.601)	(2.090)	(15.739)	(9.858)	(1.295)
Information shock	-0.000	0.043***	0.042***	0.022***	0.067***	0.066***
	(-0.008)	(5.710)	(5.582)	(2.682)	(8.506)	(8.315)
$\text{abs}(\Delta S^{\text{intra}}) \times$	-0.901***	-0.569***	-0.534***	-1.098***	-0.747***	-0.693***
Information shock	(-4.990)	(-3.347)	(-3.105)	(-5.899)	(-4.289)	(-3.937)
Constant	0.746***	0.502***	0.510***	0.754***	0.551***	0.558***
	(110.970)	(7.190)	(7.330)	(109.638)	(7.496)	(7.603)
Observations	79,581	79,581	79,581	77,758	77,758	77,758
Adjusted R-squared	0.005	0.029	0.029	0.002	0.025	0.025
Firm FE	No	Yes	Yes	No	Yes	Yes
Year FE	No	Yes	Yes	No	Yes	Yes
Industry FE	No	Yes	Yes	No	Yes	Yes
Industry X surprise	No	No	Yes	No	No	Yes

PANEL B	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES		Avol 60-min.			Avold 60-min.	
$\text{abs}(\Delta S^{\text{intra}})$	1.436***	0.750***	0.568*	1.004***	0.448***	0.292
	(18.637)	(9.816)	(1.916)	(12.742)	(5.735)	(0.986)
Information shock	0.001	0.041***	0.040***	0.022***	0.065***	0.064***
	(0.085)	(5.874)	(5.789)	(2.891)	(8.907)	(8.761)
$\text{abs}(\Delta S^{\text{intra}}) \times$	-0.665***	-0.431***	-0.408**	-0.853***	-0.613***	-0.572***
Information shock	(-4.037)	(-2.744)	(-2.569)	(-5.022)	(-3.791)	(-3.500)
Constant	1.467***	1.290***	1.293***	1.474***	1.341***	1.343***
	(240.849)	(19.126)	(19.275)	(236.726)	(18.777)	(18.885)
Observations	82,886	82,886	82,886	80,986	80,986	80,986
Adjusted R-squared	0.003	0.017	0.018	0.001	0.013	0.013
Firm FE	No	Yes	Yes	No	Yes	Yes
Year FE	No	Yes	Yes	No	Yes	Yes
Industry FE	No	Yes	Yes	No	Yes	Yes
Industry X surprise	No	No	Yes	No	No	Yes

This table contains abnormal trading volume after the announcement. The abnormal trading volume (Avol) is defined as the logarithm of trading volume during the estimation period divided by the 1-month average trading volume before the information shock estimation period, and Avold is calculated by dollar trading volume. $\text{abs}(\Delta S^{\text{intra}})$ is an absolute value of intraday monetary surprise. Robust standard errors with clustering at the firm levels are used in reporting the *t* -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 12

Delayed response to monetary policy

VARIABLES	(1) Day 1 return	(2) Day 2 return	(3) Day 1 and 2 return	(4) Day 0 to 2 return
Information shock	0.016	0.062***	0.073***	0.055**
	(1.098)	(4.222)	(3.614)	(2.224)
$\Delta S^{intra} \times$ Information shock	-1.107***	-0.042	-1.195***	-0.683
	(-3.507)	(-0.127)	(-2.646)	(-1.293)
Constant	1.497***	0.361***	1.835***	2.583***
	(10.725)	(2.808)	(10.040)	(9.832)
Observations	167,700	167,441	171,623	171,623
Adjusted R-squared	0.179	0.093	0.152	0.134
Firm FE	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Industry X surprise	Yes	Yes	Yes	Yes

This table reports stock returns after the announcement date. Column 1 and 2 use daily returns and column 3 and 4 estimates 2-day and 3-day cumulative returns. Following Cieslak, Morse, and Vissing-jorgensen (2019), the intraday monetary policy surprise begins from 2000 and ends before the 2008 financial crisis. Robust standard errors with clustering at the firm levels are used in reporting the *t* -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 13

The effect of information shocks estimated by different methods

VARIABLES	Daily Return (1)	(2)	(3)	(4)
ΔS	-2.655***	-2.646***	-2.624***	-2.616***
	(-8.823)	(-8.784)	(-8.766)	(-8.732)
Information shock^{3m}	-0.017	-0.011		
	(-1.598)	(-0.900)		
$\Delta S \times$ Information shock^{3m}	0.558***	0.825***		
	(3.018)	(3.772)		
$\Delta S \times$ Negative information shock^{3m}		-0.688**		
		(-2.197)		
Negative information shock^{3m}		-0.017		
		(-0.969)		
Information shock^{3m,99}			-0.026**	-0.019
			(-2.303)	(-1.471)
$\Delta S \times$ Information shock^{3m,99}			0.591***	0.837***
			(3.025)	(3.585)
$\Delta S \times$ Negative information shock^{3m,99}				-0.626*
				(-1.819)
Negative information shock^{3m,99}				-0.019
				(-0.962)
Constant	-0.009	-0.009	-0.011	-0.011
	(-0.131)	(-0.130)	(-0.149)	(-0.148)
Observations	374,431	374,431	375,093	375,093
Adjusted R-squared	0.009	0.009	0.009	0.009
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Industry X surprise	Yes	Yes	Yes	Yes

This table contains results for alternative information shock measures. Information shock^{3m} is estimated by extending the estimation period as about 3 months (From the FOMC announcement on t-2 to the FOMC announcement on t). A 3-day window around the FOMC announcement date on t-1 is excluded from the estimation period. 95% and 99% of significance levels are considered in calculation of jump statistics of Information shock^{3m} and Information shock^{3m,99}. Robust standard errors with clustering at the firm levels are used in reporting the *t* -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 14

Alternative information shocks and robustness

Panel A VARIABLES	(1)	(2)	(3)	(4)
ΔS	-2.670***	-2.647***	-2.711***	-2.720***
	(-8.894)	(-8.793)	(-8.996)	(-9.050)
Information shock^{3m}	-0.013	-0.056**	-0.021*	-0.055**
	(-0.797)	(-2.561)	(-1.949)	(-2.111)
ΔS × Information shock^{3m}	1.385***	-0.134	0.403**	0.606
	(4.801)	(-0.370)	(2.090)	(1.360)
ΔS × Information shock^{3m} × Shock Size^{3m}	-0.153***			-0.157***
	(-2.742)			(-2.818)
Shock Size^{3m}	-0.001			-0.001
	(-0.233)			(-0.232)
ΔS × Information shock^{3m} × Simultaneous Shock^{3m}		0.136**		0.126**
		(2.204)		(2.044)
Simultaneous Shock^{3m}		0.007**		0.007**
		(2.047)		(1.988)
ΔS × Information shock^{3m} × Recent Shock^{3m}			0.583**	0.607***
			(2.545)	(2.646)
Recent Shock^{3m}			0.017	0.016
			(1.308)	(1.278)
Constant	-0.010	-0.003	-0.011	-0.005
	(-0.137)	(-0.039)	(-0.151)	(-0.069)
Observations	374,431	374,431	374,431	374,431
Adjusted R-squared	0.009	0.009	0.009	0.009
Panel B VARIABLES	**(5)**	**(6)**	**(7)**	**(8)**
ΔS	-2.639***	-2.617***	-2.689***	-2.698***
	(-8.834)	(-8.740)	(-8.966)	(-9.018)
Information shock^{3m,99}	-0.026	-0.062***	-0.032***	-0.067**
	(-1.465)	(-2.651)	(-2.721)	(-2.354)
ΔS × Information shock^{3m,99}	1.498***	-0.015	0.422**	0.786
	(4.799)	(-0.039)	(2.071)	(1.627)
ΔS × Information shock^{3m,99} × Shock Size^{3m,99}	-0.167***			-0.170***
	(-2.755)			(-2.803)
Shock Size^{3m,99}	0.000			0.000
	(0.008)			(0.010)
ΔS × Information shock^{3m,99} × Simultaneous Shock^{3m,99}		0.120*		0.110
		(1.782)		(1.631)
Simultaneous Shock^{3m,99}		0.006*		0.006*
		(1.774)		(1.720)
ΔS × Information shock^{3m,99} × Recent Shock^{3m,99}			0.609***	0.621***
			(2.665)	(2.717)
Recent Shock^{3m,99}			0.021	0.020
			(1.634)	(1.589)
Constant	-0.011	-0.006	-0.013	-0.009
	(-0.158)	(-0.079)	(-0.177)	(-0.119)
Observations	375,093	375,093	375,093	375,093
Adjusted R-squared	0.009	0.009	0.009	0.009

[continued]

This table contains the results of alternative information shock measures using the analysis for Table 6. Recent Shock^{3m} and Recent Shock^{3m,99} are the information shock that occurred within a 1-month. Other characteristics are same as Table 6. Robust standard errors with clustering at the firm levels are used in reporting the *t* -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 15

Earnings announcement and the effect of underreaction

	Daily Return			
VARIABLES	(1)	(2)	(3)	(4)
ΔS	-5.437***	-4.874***	-7.886***	-7.741***
	(-7.447)	(-6.380)	(-9.726)	(-9.057)
$\Delta S \times$ Friday announcement	1.967**			2.109**
	(2.409)			(2.568)
Friday announcement	-0.000			0.006
	(-0.008)			(0.160)
$\Delta S \times$ Number of analyst forecasts		-0.079*		-0.073*
		(-1.841)		(-1.689)
Number of analyst forecasts		-0.008***		-0.008***
		(-2.953)		(-3.021)
$\Delta S \times$ Recent announcement			3.722***	3.767***
			(7.386)	(7.468)
Recent announcement			0.054***	0.055***
			(2.643)	(2.700)
Constant	0.542***	0.588***	0.504***	0.547***
	(4.435)	(4.781)	(4.097)	(4.418)
Observations	80,467	80,467	80,467	80,467
Adjusted R-squared	0.025	0.025	0.026	0.026
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Industry X surprise	Yes	Yes	Yes	Yes

This table presents the effect of underreaction to earnings announcement on stock price reaction to monetary policy surprise. Dataset contains observations of a firm with at least one analyst forecasts. Friday announcement is equal to one if the latest earnings announcement of the firm is released on Friday, otherwise zero, Number of analyst forecasts count the number of forecasts, and Recent announcement is equal to one if the firm's earnings announcement is released within the past month. Robust standard errors with clustering at the firm levels are used in reporting the *t* -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 16

The effect of information shock after the financial crisis

	Intraday Return			
VARIABLES	(1)	(2)	(3)	(4)
ΔEDS	-10.840***	-13.491***	-12.475***	-13.705***
	(-44.214)	(-45.821)	(-40.889)	(-15.416)
Information shock		-0.047***	-0.058***	-0.062***
		(-5.284)	(-6.313)	(-6.653)
ΔEDS × Information shock		6.396***	5.387***	5.098***
		(13.340)	(11.429)	(10.757)
Constant	0.347***	-0.006	0.358***	0.328***
	(4.948)	(-1.162)	(5.127)	(4.747)
Observations	112,834	112,834	112,834	112,834
Adjusted R-squared	0.086	0.048	0.089	0.092
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	No	Yes	Yes
Industry X surprise	No	No	No	Yes

This table shows results from the following regression:

$$r_{i,t}^{intra} = \beta_1 + \beta_2 \times \Delta EDS_t + \beta_3 \times \text{Information Shock}_{i,t} + \beta_4 \times \Delta EDS_t \times \text{Information Shock}_{i,t} + \text{Controls}_{i,t} + \epsilon_{i,t},$$

where $r_{i,t}^{intra}$ is intraday return of firm i at the scheduled FOMC announcement date t, ΔEDS_t is the monetary policy surprise estimated by the Eurodollar futures, and other variables are equivalent. $r_{i,t}^{intra}$ and ΔEDS_t are calculated by the first traded price and rates after 2:45 pm and the last traded price and rates before 12:00 pm. Robust standard errors with clustering at the firm levels are used in reporting the *t* -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.

Table 17

High institutional attention and the effect of information shock

	Intraday Return			
VARIABLES	(1)	(2)	(3)	(4)
ΔEDS	-13.735***	-13.732***	-7.810***	-7.851***
	(-15.491)	(-15.424)	(-7.564)	(-7.632)
Information shock	-0.008	-0.012	-0.098***	0.007
	(-0.544)	(-1.157)	(-8.175)	(0.358)
ΔEDS × Information shock	6.674***	3.501***	2.723***	1.824**
	(9.148)	(6.170)	(5.842)	(2.512)
ΔEDS × Information shock × Shock Size	-0.287**			-0.005
	(-2.054)			(-0.039)
Shock Size	-0.010***			-0.012***
	(-3.323)			(-3.188)
ΔEDS × Information shock × Simultaneous Shock		0.792***		0.518***
		(7.084)		(4.624)
Simultaneous Shock		-0.023***		-0.028***
		(-8.888)		(-8.667)
ΔEDS × Information shock × AIA			-3.630***	-4.510***
			(-4.537)	(-5.344)
AIA			0.054***	0.114***
			(2.687)	(5.370)
Constant	0.331***	0.317***	0.481***	0.480***
	(4.775)	(4.653)	(5.311)	(5.428)
Observations	112,834	112,829	65,498	65,855
Adjusted R-squared	0.092	0.094	0.073	0.077
Firm FE	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes
Industry X surprise	Yes	Yes	Yes	Yes

This table contains results from the regression:

$$r_{i,t}^{intra} = \beta_1 + \beta_2 \times \Delta EDS_t + \beta_3 \times \text{Information Shock}_{i,t} + \beta_4 \times \Delta EDS_t \times \text{Information Shock}_{i,t} + \beta_5 \times \Delta EDS_t \times \text{Information Shock}_{i,t} \times \text{High Institutional Attention}_{i,t} + \beta_6 \times \text{Information Shock}_{i,t} \times \text{High Institutional Attention}_{i,t} + \text{Controls}_{i,t} + \epsilon_{i,t},$$

where $r_{i,t}^{intra}$ is intraday return, ΔEDS_t is the monetary policy surprise from the Eurodollar futures, and $\text{High Institutional Attention}_{i,t}$ is the dummy variable which is equal to 1 if the information shock is covered by high institutional investor attention, and zero otherwise. Column 3 and 4 only contains firms with at least one AIA observation. Robust standard errors with clustering at the firm levels are used in reporting the *t* -statistics in parentheses *, **, and *** denote significance at the 1%, 5%, and 10% levels, respectively.