Pre-announcement Premium

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Abstract

In this paper, we propose a rational expectations equilibrium (REE) model with pre-scheduled announcements to examine the role of information uncertainty for the pre-announcement premium. The model predicts that pre-announcement premium is positively related to information uncertainty of the upcoming announcements. Liquidity traders withdraw their trading if the information uncertainty is high, which leads informed investors to trade less aggressively. As a result, the price is less informative, which elevates pre-announcement premium. Empirically, we use VIX as a proxy of information uncertainty and show that empirical results are mostly consistent with model predictions.

Keywords: Pre-scheduled announcements; Excess return; Informed trading; Information heterogeneity; Liquidity shock.

JEL Classification: G12; G14; E52
I. Introduction

Existing literature documents large market excess returns prior to certain public announcements, including pre-scheduled FOMC announcements (Lucca and Moench, 2015), corporate earnings announcements (Frazzini and Lamont, 2007; Barber et al., 2013) and the releases of some macroeconomic data.¹ Such an excess return is referred to as pre-announcement premium. What’s more, it is typically associated with low return volatility, posing challenges for conventional asset pricing theory.² A public announcement is essentially the revelation of information, and hence information uncertainty should play an important role for pre-announcement premium. However, this seemingly plausible explanation is somehow unexplored in the literature.

In the paper, we propose a rational expectations equilibrium (REE) model with pre-scheduled economic news announcements to examine the determinants of pre-announcement premium. In particular, we focus on the role of information because a public announcement essentially reveals information for private to public. We consider an REE model (e.g. Grossman and Stiglitz, 1980) with two additional dates in which a public announcement happens. In the market, there is one risky asset whose payoff has two random components, and the public announcement is modelled by revealing one random component before the final dates. Informed traders can observe the noisy signal about the upcoming public announcement, but the uninformed traders can only observe the price. Thus, the trading equilibrium before the public announcement is a standard REE model. Consistent to the REE literature, we also introduce the liquidity trading in the model to prevent a fully revealed price.³ Moreover, we assume a non-zero mean of liquidity

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¹Savor and Wilson (2013) document excess returns for the releases for inflation, unemployment and various interest rates.
²For instance, Lucca and Moench (2015) show that realized volatility calculated from intraday returns during the pre-announcement period is actually lower than that during non-FOMC announcement days.
³As shown in Grossman and Stiglitz (1980), if the price is fully revealed, then no one has any incentive to acquire information, which will lead to the Grossman and Stiglitz paradox.
trading to analyze the price implications when liquidity traders withdraw their demand due to high information uncertainty.\textsuperscript{4}

The multi-period model is solved by backwards induction. Starting from the last period, we solve all the equilibrium prices, and from the prices before and on the public announcement day, we can derive the expression of the pre-announcement premium. In addition, we also solve the abnormal trading volumes during the per-announcement period. The model predictions mainly about the determinants of the pre-announcement premium and abnormal trading volume. We show that per-announcement premium is positively related to information uncertainty in the upcoming announcement and is negatively related to the mean of liquidity trading. For the abnormal trading volume, it is negatively related to information uncertainty in the upcoming announcement. Thus, it seems that the information uncertainty is the key driver for both per-announcement premium and abnormal trading volume, which has the potential to explain the puzzling fact that the high excess return is associated with the low realized volatility.

Using data on pre-scheduled macroeconomic news announcements during stock market trading hours, we perform empirical tests and show that the empirical results are mostly consistent with model predictions. Data used in our study includes macroeconomic news announcements and Bloomberg survey from Bloomberg, intraday observations of S&P 500 Index and the CBOE Volatility Index (VIX) from tickdata.com, TAQ data on S&P500 tracking ETF (SPY) from WRDS. In particular, we use VIX as a proxy of information uncertainty of the upcoming announcements. Empirically, we show that changes of VIX during the pre-announcement period have a significant explanatory power of pre-announcement premium and Changes in VIX also have a significantly negative relation with abnormal trading volume which, in turn, has a significantly negative effect

\textsuperscript{4} The analysis is conducted by doing comparative statics with respect to the mean of liquidity trading.
on the magnitude of pre-announcement premium. Moreover, information uncertainty measure constructed from Bloomberg surveys on macroeconomic news announcements also has significant explanatory power of pre-announcement premium.

We perform further analysis by decomposing trading activities into informed trading and liquidity shocks and test how liquidity shocks affect pre-announcement premium. Specifically, we employ the Lee and Ready (1991) algorithm combined with the Interpolated Time technique proposed by Holden and Jacobsen (2014) to classify transactions as buyer-initiated or seller-initiated. The trades are then classified as either informed or liquidity trading based on the level of S&P 500 index following macroeconomic news announcements. The results show that large negative liquidity shocks during the pre-announcement period are also responsible for large excess returns prior to pre-scheduled FOMC announcements. The effect of informed trading on pre-announcement premium is subject to the constraint of liquidity provision by uninformed traders and therefore is a function of liquidity shocks during the pre-announcement period. Thus, when information uncertainty is high, liquidity traders withdraw their trading, which leads informed investors to trade less aggressively and less information is incorporated into the price. As a result, the price is less informative, which elevates the pre-announcement premium.

Our paper focuses on the determinants of the pre-announcement premium, with an analysis of asset pricing implications from public announcements. In general, pre-announcement premium is identified either based on the public announcements about macroeconomic data such as inflation, unemployment and various interest rates, (e.g. Lucca and Moench, 2015; Savor and Wilson, 2013, Balduzzi and Moneta, 2017; Altavilla et al., 2017), or the public announcements about firm level information such as corporate earnings ((Barber et al., 2013; Bernard and Thomas, 1989; Frazzini, 2006, Dellavigna and Pollet, 2009). Moreover, as shown by Lucca and Moench (2015), pre-
announcement premium is normally accompanied by low realized volatility, which is inconsistent with the standard asset pricing models. Theoretically, Ai and Bansal (2016) propose an explanation based on the modification of utility functions. They show that some utility functions in class of revealed preferences can deliver pre-announcement premium. Our paper considers the pre-announcement premium of macro announcements such as FOMC announcements and investigates the determinants for pre-announcement premium from the information uncertainty perspective.

Our analysis is based on a competitive rational expectations equilibrium (REE) model, which is standard in the literature (e.g. Grossman and Stiglitz, 1980; Grossman, 1976; Hellwig, 1980; Diamond and Verrecchia, 1981). In order to analyze the pre-announcement premium, we need a multiple period model with a public announcement. The multiple period model is similar to Tetlock (2010) and Llorente et al. (2002). In particular, Tetlock (2010) also models the revelation of the public information like ours but does not focus on pre-announcement premium.

One important prediction of our theoretical model is that liquidity trading plays an important role in determining pre-announcement premium, we simply use a non-zero mean of liquidity trading to model the behavior of liquidity traders. The prediction is supported by evidence from our empirical analysis. Theoretically, we follow Admati and Pfleiderer (1988) and do not make liquidity traders silent. Empirically, we follow Lee and Ready (1991) algorithm and Holden and Jacobsen (2014) to identify the trades initiated by liquidity traders.

The rest of the paper is structured as follows. Section II proposes a model of pre-scheduled announcement and delivers theoretical predictions on the determinants of trading volume and pre-

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5 Admati and Pfleiderer (1988) introduces discretionary liquidity traders to explain the U-shaped pattern of daily volatility and trading volume observed in stock market.
announcement premium. Section III performs empirical tests of theoretical implications derived in the model, with further analysis in Section IV. Section V concludes.

II. The Model of Pre-scheduled Announcements

In this section, we build a rational expectations equilibrium (REE) model with a pre-scheduled announcement. Our purpose is to analyze the role of information for the determinants of pre-announcement premium.

A. Basic Model Setup

We consider a discrete time model with four dates, $t=0, 1, 2, 3$. There are one risky asset and a risk-free asset in the market. For simplicity, the interest rate of the risk-free asset is normalized to be zero. The risky asset has a constant supply 1 and pays off a liquidity value $v$ at $t=3$. The payoff of the risky asset $v$ has two random dividends, $e$ and $d$, which is

$$ v = e + d, $$

where $e$ and $d$ are independently normally distributed with $e \sim N(0, V_e)$ and $d \sim N(0, V_d)$. In the model, $e$ represents the public information about the risky asset payoff, which can be revealed before the final date. In particular, we assume that there is a public announcement at $t=2$, in which the random component $e$ is revealed. Thus, at $t=2$, only $d$ is a random variable, which will be fully revealed at $t=3$.

There are measure one of investors in the market. Among all investors, $m$ mess of investors are informed and $(1-m)$ are uninformed. Uninformed investors are composed of liquidity traders who assume a liquidity shock,

$$ U = \mu + u \text{ with } u \sim \mathcal{N}(0, V_u), $$
and competitive market makers. Note that the mean of noise trading is not zero, which differs from standard REE model, e.g. Grossman and Stiglitz (1980). By making this assumption, we try to model the behaviors of noise traders when they face a public announcement. We call those noise traders discretionary liquidity traders as in Admati and Pfleiderer (1988) because they can choose to withdraw from the market, i.e. $\mu$ decreases. In the model, it is equivalent to the change of market supply, that the market supply is not a constant 1 anymore but is effectively $c \equiv 1 - (1 - m)\mu$.

At $t=0$, investors are identical, and all of them establish their initial positions. We introduce information heterogeneity among informed investor groups by having $n$ informed groups who receive different but correlated private signals ($s_i, i = 1, \ldots, n$) at $t = 1$:

$$s_i = e + \epsilon_i, \quad i = 1, \ldots, n,$$

where $\epsilon \sim N(0, V_\epsilon)$, and is independent to $e$. Because $e$ will be revealed by a pre-scheduled public announcement at $t=2$, informed investors effectively receive a signal about the public information of the risky asset. All investors have Constant Absolute Risk Aversion (CARA) utility functions with risk aversion equal to one. Both informed and uninformed investors adjust their portfolio holdings based on their information set. Below is the timeline of the model:
In the model, we have four random variables, $e, d, \epsilon$ and $u$, which are summarized by the following expression

$$
\begin{pmatrix}
  e \\
  d \\
  \epsilon \\
  u
\end{pmatrix} \sim N
\begin{pmatrix}
  (0) \\
  (0) \\
  (0) \\
  (0)
\end{pmatrix},
\begin{pmatrix}
  V_e & 0 & 0 & 0 \\
  0 & V_d & 0 & 0 \\
  0 & 0 & V_\epsilon & 0 \\
  0 & 0 & 0 & V_u
\end{pmatrix}.
$$

**B. Solving the Model**

We solve the model by backward induction. First, start from the ending period $t = 3$. In each period, we first guess a linear pricing function, then derive the demand functions for both informed and uninformed traders based on their information sets. Then by the market clearing condition, we can obtain the equilibrium price. Second, based on the price at $t=2$, we solve the equilibrium price and the optimal demand at $t=1$. Finally, we solve the similar equilibrium at $t=0$. In the end, based on equilibrium prices and traders’ demands, we can derive closed form expected abnormal trading volume and pre-announcement premium and can investigate their properties with...
respect to the underlying parameters. We summarize our equilibrium price solutions of our model in the following proposition.  

Proposition 1: the equilibrium prices are:

At \( t = 3 \): \( p_3 = v = e + d \)

At \( t = 2 \): \( p_2 = e - V_d \)

At \( t = 1 \): \( p_1 = \alpha + \beta (s + \gamma u^*) \), where

\[
\alpha = -\frac{cV_e V_e (1 + V_{u^*} V_e)}{V_e + V_e + mV_e V_{u^*} V_e + V_{u^*} V_e^2} - V_d
\]

\[
\beta = \frac{V_e (1 + mV_{u^*} V_e)}{V_e + V_e + mV_e V_{u^*} V_e + V_{u^*} V_e^2}
\]

\( \gamma = V_e \)

At \( t = 0 \): \( p_0 = \alpha - \beta^2 (V_e + V_e + \gamma^2 V_{u^*}) \)

Note that the public announcement is at \( t = 2 \). Hence, in the model, we get the pre-announcement stock price \( p_1 \) at \( t = 1 \), which is the focus of our analysis.

C. Model Implications

In this sub section, we derive the pre-announcement abnormal trading volume ATV,

\[ \text{ATV} = m_0 \left[ x_t - x_0 - E \left[ x_t - x_0 \right] \right] = m_0 [\xi s + \eta u^*] \]

where

\[ m_0 = \frac{m}{c} \]

\[ \xi = \frac{1}{V_e} - \beta \frac{V_e + V_e}{V_e V_e}, \quad \eta = 1 - \beta \gamma \frac{V_e + V_e}{V_e V_e}. \]

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6 We only present the prices in the proposition and leave all the details in the Appendix.
ATV is the unexpected change in informed traders’ demand multiplied by informed traders’ fraction $m$. In ATV, absolute value is taken to make sure trading volume is positive. Because in our model trading takes place only between informed and uninformed traders, we can get the same solution of ATV from the uninformed traders’ demand side. We then derive the pre-announcement expected abnormal trading volume $\overline{ATV}$,

$$\overline{ATV} = E[ATV] = \sqrt{\frac{2}{\pi}} m^* \sqrt{\frac{\zeta^2 V_c + \zeta^2 V_e + \eta^2 V_u^*}{V_c + V_e + m V^* V_c V_e + V_u^* V_e^2}} = \frac{m^* (1-m)}{\sqrt{\pi}} \sqrt{\frac{V_c V_e V_c + V_c + V_u^* V_e^2}{V_c + V_e + m V^* V_c V_e + V_u^* V_e^2}}.$$

Based on the equilibrium stock price $p_2$ at the announcement and $p_1$ one-period preceding the announcement, we derive the pre-announcement risk premium $PaP$,

$$PaP = E[p_2 - p_1] = \frac{-V_d - \alpha}{V_c + V_e + m V^* V_c V_e + V_u^* V_e^2} = \frac{(1-(1-m)\mu) V_c (1 + V_u^* V_e)}{V_c + V_e + m V^* V_c V_e + V_u^* V_e^2}.$$

Taking derivatives of $\overline{ATV}$ or $PaP$ with respect to underlying parameters, we derive the model’s predictions of interest about pre-announcement abnormal trading volume and premium. We summarize our model’s predictions about abnormal trading volume and pre-announcement risk premium $PaP$ in the following two propositions.

**Proposition 2.** The pre-announcement expected abnormal trading volume $\overline{ATV}$ is decreasing with $n$ and $V_e$, increasing with $V_c$, $V_u$ and $\mu$:

$$\frac{\partial \overline{ATV}}{\partial n} < 0, \frac{\partial \overline{ATV}}{\partial V_c} < 0, \frac{\partial \overline{ATV}}{\partial V_e} > 0, \frac{\partial \overline{ATV}}{\partial V_u} > 0, \frac{\partial \overline{ATV}}{\partial \mu} > 0.$$

**Proposition 3.** The pre-announcement risk premium $PaP$ is positive, decreasing with $n$ and $\mu$, increasing with $V_c$, $V_e$ and $V_u$:

$$\frac{\partial PaP}{\partial \mu} < 0, \frac{\partial PaP}{\partial n} < 0, \frac{\partial PaP}{\partial V_c} > 0, \frac{\partial PaP}{\partial V_e} > 0, \frac{\partial PaP}{\partial V_u} > 0.$$
There are three sources of uncertainty in our model, information uncertainty $V_e$, signal noise $V_e$, and liquidity trading uncertainty $V_u$. Risk averse investors adjust their demands with these uncertainties. Specifically, informed investors are affected by $V_e$ and $V_e$, and uninformed investors are affected by $V_e$, $V_e$ and $V_u$. When one uncertainty increases, at least one group of investors’ demand decreases, resulting in lower total demand and higher pre-announcement premium PaP. That’s why PaP is positively related to $V_e$, $V_e$ and $V_u$.

We illustrate the effect of non-zero mean liquidity shock on PaP as follows. In anticipation of the upcoming public news announcement, some liquidity traders, so called discretionary liquidity traders, realize their information disadvantage relative to informed investors, and hence choose to withdraw from the market. When discretionary liquidity traders withdraw from the market,\(^7\) the total market demand for the risky asset decreases. Because we have a constant market supply, the pre-announcement asset price has to decrease to restore the market equilibrium. Due to the lower price, other investors buy more stocks, resulting in high pre-announcement premium.

Our model can help us further illustrate the mechanism in the retreat of discretionary liquidity trading. The modeling choice of discretionary liquidity traders effectively changes the total shares that are available to other market participants. If they choose to withdraw their trading, the supply of the risky asset to investors existing in the market is increased. Therefore, for the market to restore equilibrium, the pre-announcement asset price decreases, resulting in high pre-announcement premium.

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\(^7\) In the model, it means the mean of noise trading, $\mu$, decreases.
III. Empirical Tests

A. Data

We use data from several sources in our empirical tests: Macro news announcements and Bloomberg survey from Bloomberg terminal; intraday S&P 500 Index (SPX) level and CBOE Volatility Index (VIX) from tickdata.com; S&P500 ETF (SPY) TAQ data from WRDS. Our sample period spans from July 2003 to December 2016. Table I reports the summary statistics of pre-scheduled macroeconomic news announcements and variables constructed from Bloomberg market participant survey.

[Insert Table I about here]

Panel A of Table I lists basic information about the five types of macroeconomic news announcements used in our empirical analysis, which take place during stock market regular trading hours. There are 8 pre-scheduled FOMC announcements per year and 108 announcements in total during our sample period, and among them 66 times take place at 14:15, 31 times at 14:00, 8 times at 12:30, and 3 times around 14:15. For other macroeconomic news announcements, University of Michigan Consumer Sentiment Index is scheduled twice a month, and all other three, Consumer Confidence Index, ISM Manufacturing Index and New Home Sales are scheduled once a month. And all other macroeconomic news announcements take place at 10:00. In Panel B, #SP is the number of market participants. SUR is the announcement surprise, which is defined as the standardized surprise associated with a macroeconomic news announcement,

\[ SUR_t = \frac{A_t - \bar{F}_t}{\hat{\sigma}(A_t - \bar{F}_t)}, \]

(2)

where \( A_t \) is the actual value and \( \bar{F}_t \) is the median of market participants' forecasts. DIS is the dispersion of forecasts, which is defined by
\[ SD_t = \sqrt{\frac{1}{N_t - 1} \sum_{i=1}^{N_t} \left( F_{it} - \frac{1}{N_t} \sum_{i=1}^{N_t} F_{it} \right)^2}, \quad \text{DIS}_t = \frac{SD_t}{\sigma(SD_t)}, \tag{3} \]

where \( N_t \) is the number of forecasts at time \( t \), \( F_{it} \) is the forecast value from participant \( i \) at time \( t \).

We follow Pasquariello and Vega (2007) to calculate SUR and DIS. In Panel B of Table I, we see that the FOMC announcement has on average 86 survey participants, which is largest among all the five macroeconomic news announcements. The number of survey participants varies from 60 to 74 for other four macroeconomic news announcements. This reflects the importance of the FOMC announcement. Panel B also reports the number and the percentage of announcement surprises deviating away from 0 with one to three standard deviations. Moreover, the FOMC announcement has only 3 (2.78%) SURs deviating from 1 standard deviation, the least among all the macroeconomics news announcements.

[Insert Table II about here]

In Table II, we report both the one-day and the half-day returns of pre-announcement period, VIX level and its changes, excess realized volatility, and abnormal trading volume for the FOMC announcement and other macro news announcements during the pre-announcement period. The one-day pre-announcement return \( \text{Ret}_{[t-d,t]} \) is computed as,

\[ \text{Ret}_{[t-d,t]} = \ln P_t - \ln P_{t-d}, \tag{4} \]

where \( P_t \) is the SPX level on the announcement day 15 minutes before the announcement time, \( P_{t-d} \) is the SPX level 24 trading hours prior \( t \). The one-day pre-announcement VIX level change \( \Delta \text{VIX}_{[t-d,t]} \) is computed as,

\[ \Delta \text{VIX}_{[t-d,t]} = VIX_t - VIX_{t-d}, \tag{5} \]
where $VIX_t$ is the VIX level on the announcement day 15 minutes before the announcement time, $VIX_{t-d}$ is the VIX level 24 trading hours before $t$.

For each announcement day $t$, we compute the excess realized volatility of one-day pre-announcement period as follows: First, we sum up the squared 1-minute log returns of SPX during the one-day pre-announcement period (with the 15-minute lag as above), to compute the one-day pre-announcement realized volatility $RV_t$; then we move back 1 trading day and similarly compute $RV_{t-1}$; the difference between these two RV quantities is our excess realized volatility,

$$ExRV_{[t-d,t]} = RV_t - RV_{t-1}. \quad (6)$$

We follow the similar procedures above to compute abnormal trading volume of one-day pre-announcement period. Specifically, for each announcement day $t$, we compute the abnormal trading volume as follows: First, we sum up the trading volume (size $\times$ transaction price) of each transaction during the one-day pre-announcement period (with the 15-minute lag as well), to compute the one-day pre-announcement trading volume $TV_t$; then we move back 1 trading day and similarly compute $TV_{t-1}$; the difference between these two TV quantities is our abnormal trading volume,

$$ATV_{[t-d,t]} = TV_t - TV_{t-1}. \quad (7)$$

When $d$ is replaced with $d/2$ in these variables, we computed the half-day variables, using 12 trading hours SPX and VIX level prior to $t$.

In Table II, the FOMC announcement has high pre-announcement return, on average 33.6 basis points for the one-day pre-announcement period and 79% of it is realized in the first half-day. Corresponding to the increase of price, as a measure of information uncertainty, VIX level significantly drops on average 0.35 basis point during the one-day pre-announcement period, indicating significant uncertainty resolution. Moreover, the FOMC announcement has low realized
volatility and trading volume during the pre-announcement period: one-day realized volatility drops 0.129 and trading volume drops 1.25 billion on average relative to prior 24 trading hours. The high pre-announcement mean return, low realized volatility and low trading volume are consistent with the empirical facts in Lucca and Moench (2015). Other macroeconomic news announcements’ pre-announcement mean returns, drops in VIX, realized volatility and trading volume are dwarfed by the FOMC announcement: The one-day pre-announcement mean return is only 2.5 basis points, the drops in VIX and realized volatility are insignificant, and the trading volume is even positive although insignificant. And the one-day and half-day numbers are similar.

In Figures 2 to 4, we differentiate the FOMC announcement (Panel A) and other macroeconomic news announcements (Panel B) and compare the cumulative mean return, realized volatility, and VIX level changes during two consecutive trading days for announcement and non-announcement. The patterns in these figures about cumulative mean return, realized volatility, and VIX level change are consistent with the numbers presented in Table II.

B. Determinants of Trading Volume and Pre-announcement Premium

We have a 12 (month) × 5 (news) panel dataset per year by the following procedure. There are 8 pre-scheduled FOMC announcements in a year. We use the average value in a year of all the variables in the regression as the value of the other 4 months with no announcements. For University of Michigan Consumer Sentiment Index (CSI), there are two announcements per month. We take the average value of these two announcements in a month, then let this average value to be the value in that month. For other 3 news, CSI, ISM, and New Home Sales, they are monthly announcements and so we just keep the original values.
Table III reports the results of panel regression of abnormal trading volume (ATV) against potential determinant variables: VIX\textsubscript{t-d}, -ΔVIX\{t-d,t\}, #SP, |SUR|, and DIS, where VIX\textsubscript{t-d} and -ΔVIX\{t-d,t\} are proxies of information uncertainty \(V_e\), #SP is the proxy for the number of informed traders groups \(n\), |SUR| and DIS are proxies for forecast uncertainty \(V_e\). As we can see from the results in Table III, the only important determinant of ATV is information uncertainty, and the result is robust for different proxies (e.g. VIX\textsubscript{t-d} and -ΔVIX\{t-d,t\}). Column (5) shows that if the VIX level reduces one more point during the pre-announcement period, the pre-announcement trading volume on average reduces 0.715 $billion relative to non-announcement days. Forecast variables have no significance in explaining ATV.

Table IV reports the results of panel regression of pre-announcement premium (Ret\{t-d,t\}) against potential determinant variables including VIX\textsubscript{t-d}, -ΔVIX\{t-d,t\}, ExRV\{t-d,t\}, #SP, |SUR|, DIS, and ATV. VIX\textsubscript{t-d}, -ΔVIX\{t-d,t\} and ExRV\{t-d,t\} are proxies of information uncertainty \(V_e\), #SP is the proxy for the number of informed traders groups \(n\), |SUR| and DIS are proxies for forecast uncertainty \(V_e\). As we can see from the results in Table IV, the most important determinant of pre-announcement premium is information uncertainty, and the result is robust for different proxies. Column (5) shows that if VIX level reduces one more point during the pre-announcement period, the pre-announcement return on average increases 0.547 basis points relative to non-announcement days. Moreover, the adjusted \(R^2\) is 0.663, which is much larger than other explanatory variables. In column (9), consistent with existing empirical facts, excess realized volatility ExRV\{t-d,t\} is negatively associated with pre-announcement return, indicating the puzzling empirical fact that high pre-announcement return is accompanied by low realized volatility.
volatility. Columns (4) and (5) provide an explanation for this puzzle if we use proper proxies from VIX, VIX_{t-d} or -ΔVIX_{[t-d,t]}, for information uncertainty. Furthermore, column (10) shows if we throw both -ΔVIX_{[t-d,t]} and ExRV_{[t-d,t]} into the regression, the effect -ΔVIX_{[t-d,t]} on pre-announcement return remains significant, but the effect of ExRV_{[t-d,t]} is subsumed by -ΔVIX_{[t-d,t]}.

Moreover, the results in Table IV show other factors matter in determining pre-announcement return even after we control information uncertainty. In columns (7) and (8), forecast variable DIS also has significance in explaining pre-announcement premium and is positively associated with it. However, other forecast variables have no explanatory power.

Given extant empirical evidence, there is no surprise that ATV is significantly negatively associated with pre-announcement return as shown in column (6). But columns (7) and (8) show that although the magnitude is not so large, after controlling information uncertainty and forecast variables, the effect of ATV on pre-announcement return is still significant, indicating ATV contains information that cannot be subsumed by information uncertainty and participants’ forecast, potentially information about liquidity shocks, which we will test in the next subsection. The results with and without news type fixed effects are very similar, which indicates the regression coefficient is driven by variation over time within each news, not by variation across different news.

C. Informed Trading and Liquidity Trading

For each announcement day t, we compute uninformed abnormal trading volume and informed abnormal trading volume according to the following procedures:
1. We identify every trading activity during normal trading hours as buyer-initiated or seller-initiated by Lee and Ready (1991) algorithm. 

2. For one day prior to the announcement time, denote the transaction price of a pre-announcement trading as $P_{t-}$, the transaction price 15 minutes after the announcement time as $P_{t+15}$. A pre-announcement trading is identified as an informed trading if it is buyer-initiated and $P_{t-} < P_{t+15}$ or it is seller-initiated and $P_{t-} > P_{t+15}$. Transactions that are not informed trading is then identified as uninformed trading. Compute both total informed and uninformed trading during the one-day pre-announcement period, denoted as TVI$_t$ and TVU$_t$.

3. Move backwards one day and do the same thing for the trading day before the announcement day, and get both total informed and uninformed, denoted as TVI$_{t-1}$ and TVU$_{t-1}$.

4. The difference between (un)informed trading volume of t and t-1 is abnormal (un)informed trading volume:

$$ATVI_t = TVI_t - TVI_{t-1},$$ (5)

$$ATVU_t = TVU_t - TVU_{t-1},$$ (6)

[Insert Table V about here]

Table V reports summary statistics of ATVI and ATVU, proxies for informed and uninformed abnormal trading volume. Panel A shows that for the FOMC announcement, both abnormal informed and uninformed trading volume drop significantly during the one-day period of pre-announcement, but ATVI drops more. On average, ATVI drops 0.8 $billion per announcement and ATVU drops 0.45 $billion, so that ATVI drops 35 $million more than ATVU

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8 We use the SAS code provided by Holden and Jacobsen (2014) to process the SPY TAQ data.
during the one-day period of pre-announcement. For other macro news, there is no such significant drops about trading volume during the pre-announcement period.

[Insert Table VI about here]

Table VI reports the results of panel regression of liquidity shock ATVU against potential determinants. The results show that the forecast variables have no significant effect on liquidity shock. The only important determinant of liquidity shock is information uncertainty of the upcoming announcement. Moreover, liquidity shock is negatively related to information uncertainty. Column (5) shows that one point increase of the information uncertainty⁹ results in 391 $million decrease in uninformed trading volume during the pre-announcement period.

Our explanation of this result is that the high uncertainty before the pre-scheduled announcement deters discretionary liquidity traders. Admati and Pfleiderer (1988) model discretionary liquidity traders’ behavior and show that discretionary liquidity traders tend to concentrate their trading on equilibrium. Admati and Pfleiderer (1988) use their model to explain the U-shape of intraday trading volume and volatility: discretionary liquidity traders concentrate their trading at market open and close, resulting high trading volume and volatility at market open and close. Here we provide evidence that discretionary liquidity traders avoid to concentrate their trading in anticipation of important pre-scheduled announcement, resulting low trading volume and volatility during the pre-announcement period. Because all market participants are risk-neutral in Admati and Pfleiderer (1988) model, risk premium is not their objective to examine. We provide evidence that enriches the implications of discretionary liquidity traders’ behavior.

[Insert Table VII about here]

---

⁹ It is measured by VIX level change during the pre-announcement period.
Table VII reports the results of panel regression of informed trading ATVI against potential determinants. We add liquidity shock ATVU as an explanatory variable because its lubricant role in facilitating informed trading in our model. Columns (2) and (3) show that information uncertainty is negatively associated with informed trading, but after we add liquidity shock, the effects of information uncertainty on informed trading are either substantially reduced in column (7) or subsumed in column (8). Moreover, the adjust $R^2$ with liquidity shock as explanatory variable is as high as 0.79. Consistent with our model’s prediction, results in Table VII show that liquidity shock is the most important factor that drives informed trading: one dollar uninformed liquidity trading is on average accompanied by about 80 cents informed trading. Based on this relation, we can predict that if liquidity provision is constrained by the retreatment of discretionary liquidity traders. Then informed traders will reduce their trading and there will be less information incorporated into prices, resulting in lower resolution of uncertainty and hence high pre-announcement premium.

[Insert Table VIII about here]

Table VIII reports the results of panel regression of pre-announcement premium ($\text{Ret}_{[t-d,t]}$) against proxies for informed trading and liquidity shock and other potential determinants. ATVI is informed abnormal trading volume, a proxy for informed trading. ATVU is uninformed abnormal trading volume, a proxy for liquidity shock. Columns (1) to (4) show both ATVU and ATVI are negatively associated with pre-announcement premium. Column (5) shows this result is robust even after we add information uncertainty and forecast variables into the regression. In addition to information uncertainty and forecast uncertainty, negative liquidity shock also plays an important role in generating high pre-announcement premium.
The results in Table VIII support our prediction that if liquidity provision is constrained by
the retreatment of discretionary liquidity traders, the informed traders will reduce their trading and
there will be less information incorporated into prices, resulting in lower resolution of uncertainty
and high pre-announcement premium. In addition to the important role of discretionary liquidity
traders in generating high trading volume and volatility as described in Admati and Pfleiderer
(1988), we provide evidence that discretionary liquidity traders’ behavior can also have effects on
risk premium.

D. What Drives Lower RV?

By definition, realized volatility is the sum of squared changes in log prices. Price changes
either due to information flow or noise, such as bid-ask spread, price discreteness, market maker’s
inventory adjustment, etc. Therefore, realized volatility can be decomposed into two parts: realized
volatility due to information flow and due to noise. In this subsection, we examine the driver of
realized volatility

[Insert Table IX about here]

Table IX reports the results of panel regression of excess realized volatility (ExRV_{t-d,t})
against several potential determinants, ATV, ATVI, and ATVU. In column (2) of Table IX, |SUR|
is significantly negatively associated with ExRV_{t-d,t}, which means that high forecast uncertainty
results in less information generated realized volatility. Column (4) show that the trading volume
is positively associated with pre-announcement excess realized volatility and the large portion
comes from trading volume, with adj. R^2 about 16%. When we decompose trading activities into
informed trading and liquidity shocks, columns (5) and (6) show that both of them have
significantly explanatory power of the pre-announcement realized volatility. However, when we
throw both informed trading and liquidity shocks into the regression, column (7) show that the
effect of liquidity shocks on excess realized volatility is subsumed by informed trading. The results of column (7) indicate that both |SUR| and informed trading drive the pre-announcement realized volatility, and high |SUR| and low informed trading result in lower pre-announcement realized volatility.

V. Conclusion

In this article, we propose a rational expectations equilibrium (REE) model with pre-scheduled announcement to examine the role of information for pre-announcement premium and trading volume. Our model predicts that pre-announcement premium is positively related to information uncertainty in the upcoming announcements. Informed trading attenuates pre-announcement premium as it helps incorporate information into asset prices. However, the effect of informed trading is subject to the constraint of liquidity provision by uninformed investors. Thus, if liquidity provision is constrained, informed traders reduce their trading, so less information is incorporated into prices, resulting in lower resolution of uncertainty and hence high pre-announcement premium.

The results of our empirical test are largely consistent with model predictions. Specifically, using VIX as a proxy of information uncertainty, we show that changes of VIX during the pre-announcement period have significant explanatory power of pre-announcement premium. Moreover, abnormal trading volume has a negative effect on the magnitude of pre-announcement premium. Further decomposing trading activities into informed trading and liquidity shocks, we show that large negative liquidity shocks during the pre-announcement period are also responsible for large excess returns prior to pre-scheduled FOMC announcements.
References


Appendix A: Model Solutions

We solve the model backward, starting from the ending period $t = 3$, then stepping back one period at a time, all the way back to the initial period $t = 0$. Specifically, at each period $t$, we first identify the information sets $\mathcal{F}_t^I$ and $\mathcal{F}_t^U$ of informed and uninformed traders, then derive their demands $x_t^I$ and $x_t^U$ for the stock,

$$x_t^I = \frac{\mathbb{E}[p_{t+1} | \mathcal{F}_t^I] - p_t}{\text{Var}[p_{t+1} | \mathcal{F}_t^I]}, \quad x_t^U = \frac{\mathbb{E}[p_{t+1} | \mathcal{F}_t^U] - p_t + U}{\text{Var}[p_{t+1} | \mathcal{F}_t^U]},$$

where $U = \mu + u$ with $u \sim \mathcal{N}(0, V)$ represents liquidity shock when there is a liquidity shock at $t$, otherwise $u^*$ is zero. We finally solve the equilibrium price $p_t$ of the stock by the market clearing condition:

$$mx_t^I + (1-m)x_t^U = 1.$$

Based on the stock demands at pre-announcement periods $t = 0$ and $t = 1$, we derive the pre-announcement abnormal trading volume ATV of the stock, which is defined by

$$\text{ATV} = m^* \left[ x_1^I - x_0^I - \mathbb{E} \left[ x_1^I - x_0^I \right] \right],$$

where $m^* = m/(1 - (1 - m)\mu)$ with the fraction $m$ of informed investors adjusted by $1 - (1 - m)\mu$ due to non-zero mean liquidity shock.

We then derive its expectation, the pre-announcement expected abnormal trading volume $\overline{\text{ATV}}$.

We also derive how Pap and $\overline{\text{ATV}}$ change with respect to change in model's underlying parameters.

Based on the equilibrium prices before and at the public announcement period, $t = 1$ and $t = 2$, we derive the pre-announcement risk premium PaP of the stock, which is defined by

$$\text{PaP} = \mathbb{E} [p_2 - p_1].$$

At $t = 3$, all uncertainty is resolved and hence the stock price is equal to its liquidation value,

$$p_3 = v = e + d.$$

At $t = 2$, the information sets are
\[ \mathcal{F}_2^I = \mathcal{F}_2^U = \{ e, p_2 \} \]

We derive the conditional expectation and conditional variance of \( p_3 \) for both informed and uninformed traders,

\[
\mathbb{E}[p_3 | \mathcal{F}_2^I] = \mathbb{E}[p_3 | \mathcal{F}_2^U] = e, \quad \text{Var}[p_3 | \mathcal{F}_2^I] = \text{Var}[p_3 | \mathcal{F}_2^U] = V_d.
\]

Substitute these conditional moments into the market clearing condition, we get

\[ p_2 = e - V_d \]

At \( t = 1 \), we guess the equilibrium price \( p_1 \) has the following linear form,

\[ p_1 = \alpha + \beta(s + \gamma u^*) \]

To solve the pre-announcement stock price, we use a little trick to make the form of our model’s solution simpler and easier to derive implications. First we write down the market clearing condition at the pre-announcement time \( t = 1 \),

\[
m \cdot \left( \frac{\mathbb{E}[p_{t+1} | \mathcal{F}_t^I] - p_t}{\text{Var}[p_{t+1} | \mathcal{F}_t^I]} \right) + (1 - m) \cdot \left( \frac{\mathbb{E}[p_{t+1} | \mathcal{F}_t^U] - p_t}{\text{Var}[p_{t+1} | \mathcal{F}_t^U]} + \mu + u \right) = 1,
\]

where the LHS is the total demand for the risky asset and the RHS is the supply, a constant 1. By introducing non-zero mean in liquidity shock, we depart from the models in Llorente et al. (2002) and Tetlock (2010). Then we transform it into

\[
m \cdot \left( \frac{\mathbb{E}[p_{t+1} | \mathcal{F}_t^I] - p_t}{\text{Var}[p_{t+1} | \mathcal{F}_t^I]} + u^* \right) + (1 - m) \cdot \left( \frac{\mathbb{E}[p_{t+1} | \mathcal{F}_t^U] - p_t}{\text{Var}[p_{t+1} | \mathcal{F}_t^U]} \right) = c.
\]

where

\[ u^* \equiv \frac{1 - m}{m} u, \quad c \equiv 1 - (1 - m) \mu. \]

And we have \( u^* \sim \mathcal{N}(0, V_{u*}) \) with \( V_{u*} = V_u (1 - m)^2 / m^2 \). The above market clearing condition corresponds to a Tetlock type model. In this transformed model, liquidity shock has zero mean and
is combined with informed demand, and the supply of the risky asset is not a fixed number 1 but a function of mean liquidity trading \( \mu \), varying \( \mu \) is equivalent to varying asset supply. To make sure the transformed model has positive asset supply, we assume \( c > 0 \).

At \( t=1 \), both informed and uninformed traders observe the market price \( p_1 \), but only informed traders receive a private signal \( s \). Hence, the information sets are

\[
\mathcal{F}_t^I = \{s, p_1\} = \{s, u^*\}, \quad \mathcal{F}_t^U = \{p_1\} = \{s + \gamma u^*\}
\]

We derive the conditional expectation and conditional variance of \( p_2 \) for informed traders,

\[
E[p_2 | \mathcal{F}_t^I] = -V_d + \frac{sV_e}{V_e + V_e}, \quad \text{Var}[p_2 | \mathcal{F}_t^I] = \frac{V_eV_d}{V_e + V_e},
\]

and for uninformed traders,

\[
E[p_2 | \mathcal{F}_t^U] = -V_d + \frac{(s + \gamma u^*)V_e}{V_e + \gamma^2V_u^* + V_e}, \quad \text{Var}[p_2 | \mathcal{F}_t^U] = V_e - \frac{V_e^2}{V_e + \gamma^2V_u^* + V_e}.
\]

Substitute these conditional moments into the market clearing condition, we get

\[
p_1 = \alpha + \beta(s + \gamma u^*),
\]

where

\[
\alpha = -\frac{cV_eV_e(1 + V_u^*V_e)}{V_e + V_e + mV_eV_u^*V_e + V_u^*V_e} - V_d
\]

\[
\beta = \frac{V_e(1 + mV_u^*V_e)}{V_e + V_e + mV_eV_u^*V_e + V_u^*V_e^2}
\]

\[
\gamma = V_e
\]

At \( t = 0 \), the information sets are

\[
\mathcal{F}_0^I = \mathcal{F}_0^U = \emptyset.
\]

We derive the conditional expectation and conditional variance of \( p_1 \) for both informed and uninformed traders,

\[
E[p_1 | \mathcal{F}_0^I] = E[p_1 | \mathcal{F}_0^U] = \alpha, \quad \text{Var}[p_1 | \mathcal{F}_0^I] = \text{Var}[p_1 | \mathcal{F}_0^U] = \beta^2(V_e + V_e + \gamma^2V_u^*).
\]

Substitute these conditional moments into the market clearing condition, we get

\[
p_0 = \alpha - \beta^2(V_e + V_e + \gamma^2V_u^*).
\]

We derive the pre-announcement abnormal trading volume ATV,
\[
\text{ATV} \equiv m^* \left[ x^1 - x^0_0 - E \left[ x^1 - x^0_0 \right] \right] = m^* \left[ \xi s + \eta u^* \right],
\]

where
\[
m^* = \frac{m}{c}, \quad \xi = \frac{1}{V_c} - \beta \frac{V_c + V_e}{V_c V_e}, \quad \eta = 1 - \beta \gamma \frac{V_c + V_e}{V_c V_e}.
\]

We then derive the pre-announcement expected abnormal trading volume \( \text{EATV} \),
\[
\text{ATV} = E[\text{ATV}] = \sqrt{\frac{2}{\pi}} m^* \sqrt{\xi^2 V_c + \xi^2 V_e + \eta^2 V_u^*} = \frac{m^* (1 - m) \sqrt{2 V_c V_e \sqrt{V_c + V_e + V_u^* V_e^2}}}{V_c + V_e + m V_c V_u^* V_e + V_u^* V_e^2}
\]

Then we get EATV’s derivatives with respect to underling parameters. The pre-announcement expected abnormal trading volume \( \text{ATV} \) is non-determinant with \( m \), decreasing with \( V_c \), increasing with \( \mu, V_c \) and \( V_u \):
\[
\frac{\partial \text{ATV}}{\partial m} = -m^* \sqrt{\frac{2}{\pi}} V_c V_e \sqrt{V_c + V_e} + V_e \left( V_c \left( m V_u V_e + 2 m - 1 \right) + (2 m - 1) V_e (V_u V_c + 1) \right) \left( m V_c V_u V_e + V_e + V_u^* V_e^2 + V_e^2 \right)^2
\]
\[
\frac{\partial \text{ATV}}{\partial V_c} = \frac{(1 - m) V_c \left( 2 m V_u V_e + (m + 2)V_u V_e + 3 + 2 V_e + V_c \right)^2}{\sqrt{2} \pi \sqrt{V_c + V_u V_e^2} + V_e \left( m V_c V_u V_e + V_e + V_u^* V_e^2 + V_e^2 \right)^2}
\]
\[
\frac{\partial \text{ATV}}{\partial V_e} = \frac{(1 - m) V_c \left( 2 m V_u V_e + (m + 2)V_u V_e + 3 + 2 V_e + V_c \right)^2}{\sqrt{2} \pi \sqrt{V_c + V_u V_e^2} + V_e \left( m V_c V_u V_e + V_e + V_u^* V_e^2 + V_e^2 \right)^2}
\]
\[
\frac{\partial \text{ATV}}{\partial V_u} = \frac{m^3 V_c \left( m V_u^2 V_e^2 + 3 V_u V_e + 4 \right) + 2 V_e \left( V_u^2 V_e^2 + 3 V_u V_e + 2 \right)^2}{(1 - m) \sqrt{2} \pi \sqrt{V_c + V_u V_e^2} + V_e \left( m V_c V_u V_e + V_e + V_u^* V_e^2 + V_e^2 \right)^2}
\]

We derive the pre-announcement risk premium \( \text{PaP} \),
\[
\text{PaP} \equiv E[p_2 - p_1] = -V_d - \alpha = \frac{c V_c V_e \left( 1 + V_u V_e \right)}{V_c + V_e + m V_c V_u V_e + V_u^* V_e} = \frac{(1 - (1 - m) \mu) V_c V_e \left( 1 + V_u V_e \right)}{V_c + V_e + m V_c V_u V_e + V_u^* V_e} > 0.
\]
The pre-announcement risk premium \( \text{PaP} \) is positive, decreasing with \( m \), increasing with \( V_c, V_e \) and \( V_u \):

\[
\frac{\partial \text{PaP}}{\partial \mu} = -\frac{(1-m)V_cV_e(1+V_uV_e)}{V_c+V_e+mV_cV_uV_e+V_uV_c^2} < 0
\]

\[
\frac{\partial \text{PaP}}{\partial V_c} = \frac{cV_c^2(1+V_uV_c)^2}{\left(V_c+V_e+mV_cV_uV_e+V_uV_c^2\right)^2} > 0
\]

\[
\frac{\partial \text{PaP}}{\partial V_e} = \frac{cV_e^2(1+2V_uV_e+mV_uV_c^2)}{\left(V_c+V_e+mV_cV_uV_e+V_uV_c^2\right)^2} > 0
\]

\[
\frac{\partial \text{PaP}}{\partial V_u} = \frac{c(1-m)V_cV_u^2V_e^2}{\left(mV_cV_uV_e+V_c+V_uV_c^2+V_e\right)^2} > 0
\]

**The model with information heterogeneity**

When there are \( n \) informed groups, we denote the information set of informed group \( i(i=1,\cdots,n) \) at \( t \) by

\[ \mathcal{F}_t^i(i), \]

and the demands for the stock by

\[
x_t^i(i) = \frac{1}{n} \frac{\mathbb{E}[p_{t+1} | \mathcal{F}_t^i(i)] - p_t}{\text{Var}[p_{t+1} | \mathcal{F}_t^i(i)]},
\]

where \( u = 0 \) when there is no liquidity shock at \( t \). The market clearing condition at \( t \) is

\[
m \sum_{i=1}^n x_t^i(i) + (1-m)x_t^U = 1.
\]

At \( t=3 \), all uncertainty is resolved and hence the stock price is its liquidation value,

\[
p_3 = v = e+d
\]

At \( t=2 \), the information sets are

\[ \mathcal{F}_2^i(i) \equiv \mathcal{F}_2^i = \mathcal{F}_2^U = \{e, p_2\}, i=1,\cdots,n. \]

We derive the conditional expectation and conditional variance of \( p_3 \) for both informed and uninformed traders,

\[
\mathbb{E}[p_3 | \mathcal{F}_2^i(i)] = \mathbb{E}[p_3 | \mathcal{F}_2^U] = e, \quad \text{Var}[p_3 | \mathcal{F}_2^i(i)] = \text{Var}[p_3 | \mathcal{F}_2^U] = V_d, \quad i=1,\cdots,n.
\]

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Substitute these conditional moments into the market clearing condition, we get
\[ p_2 = e - V_d \]

At \( t = 1 \), we guess the equilibrium price \( p_1 \) has the following linear form,
\[ p_1 = \alpha + \beta(\bar{s} + \gamma u^*) \]
where
\[ \bar{s} = \frac{1}{n} \sum_{i=1}^{n} s_i = \frac{1}{n} \sum_{i=1}^{n} (e + \epsilon_i) = e + \frac{1}{n} \sum_{i=1}^{n} \epsilon_i \equiv e + \bar{\epsilon} \]

We have
\[ V_e \equiv \text{Var}[\bar{\epsilon}] = \frac{1}{n^2} \text{Var}\left[ \sum_{i=1}^{n} \epsilon_i \right] = \frac{1}{n^2} n \cdot V_\epsilon = \frac{V_\epsilon}{n}, \]
and we see \( V_e \) is decreasing with \( n \).

And the information sets are
\[ \mathcal{F}_1^i(i) = \{ s, u^*, p_1 \} = \{ s, \bar{s}, u^* \} \quad i = 1, \ldots, n; \quad \mathcal{F}_1^U = \{ p_1 \} = \{ \bar{s} + \gamma u^* \}. \]

Denote \( \mathcal{F}_1^i = \{ \bar{s}, u^* \} \). We have the aggregate informed investors demand:
\[ \sum_{i=1}^{n} \left[ \frac{1}{n} \text{Var}[p_2 | \mathcal{F}_1^i(i)] - p_1 \right] = \frac{\text{Var}[p_2 | \mathcal{F}_1^i] - p_1}{\text{Var}[p_2 | \mathcal{F}_1^i]}. \]

Comparing to the previous model without multiple informed groups, we see the only difference of this model is that \( s \) in information sets of informed investors is replaced by \( \bar{s} \). And the difference of \( \bar{s} \) from \( s \) is that \( \epsilon \) is replaced by \( \bar{\epsilon} \). We have \( V_e \) is decreasing with \( n \). Intuitively, when there are more informed investor groups (\( n \) is greater), the informed investors as a whole group has more information and hence informed trading incorporate more information into the market price.

Therefore, substitute \( V_e = V_\epsilon \) into the solution of \( p_1 \) in the previous model, we obtain the solutions of the prices at \( t = 1 \) and \( t = 0 \), the pre-announcement risk premium PaP, and the pre-announcement expected abnormal trading volume \( \overline{ATV} \).

Based on the above argument and the relationship between \( V_e \) and \( V_\epsilon \), we can infer the properties of \( \overline{ATV} \) and PaP:
The pre-announcement expected abnormal trading volume $\overline{ATV}$ is non-determinant with $m$, decreasing with $n$ and $V_e$, increasing with $V_e$, $V_u$ and $\mu$:

$$\frac{\partial \overline{ATV}}{\partial n} < 0, \frac{\partial \overline{ATV}}{\partial V_e} < 0, \frac{\partial \overline{ATV}}{\partial V_u} > 0, \frac{\partial \overline{ATV}}{\partial \mu} > 0.$$  \hfill (A1)

The pre-announcement risk premium $PaP$ is positive, decreasing with $n$ and $\mu$, increasing with $V_e$, $V_e$ and $V_u$:

$$\frac{\partial PaP}{\partial \mu} < 0, \frac{\partial PaP}{\partial n} < 0, \frac{\partial PaP}{\partial V_e} > 0, \frac{\partial PaP}{\partial V_e} > 0, \frac{\partial PaP}{\partial V_u} > 0.$$ \hfill (A2)

Based on the results in (A1) and (A2), we get the model predictions of interest summarized in proposition 2 and 3.
Table I: Summary statistics of macroeconomic news announcements

Panel A lists the five pre-scheduled macro news announcements during trading hours of US stock markets: FOMC Announcement (FOMC), Consumer Confidence Index (CCI), University of Michigan Consumer Sentiment Index (CSI), ISM Manufacturing Index (ISM), and New Home Sales. Day and time denote the day of month and the time of the announcement. N denotes the number of announcements during our sample period from July 2003 to December 2016. Panel B reports summary statistics of Bloomberg survey. #SP is the number of survey participants, SUR is the standardized announcement surprise, DIS is the standardized dispersion of forecasts. We also report the number (percentage) of announcements with surprise greater than 2 and 3 standard deviations.

Panel A: List of pre-scheduled macroeconomic news announcements

<table>
<thead>
<tr>
<th>Macro News</th>
<th>Day</th>
<th>Time</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>FOMC</td>
<td>Eight regularly scheduled meetings per year</td>
<td>14:15*</td>
<td>108</td>
</tr>
<tr>
<td>CCI</td>
<td>Around 25th of the month</td>
<td>10:00</td>
<td>162</td>
</tr>
<tr>
<td>CSI</td>
<td>Second and fourth Friday (revised) of the month</td>
<td>10:00</td>
<td>323</td>
</tr>
<tr>
<td>ISM</td>
<td>Around 16th of the month</td>
<td>10:00</td>
<td>162</td>
</tr>
<tr>
<td>New Home Sales</td>
<td>17th workday of the month (around 25th/26th)</td>
<td>10:00</td>
<td>161</td>
</tr>
</tbody>
</table>

*From July 2003 to Dec. 2016, FOMC pre-scheduled announcements took place 66 times at 14:15, 31 times at 14:00, 8 times at 12:30, and 1 time each at 14:14, 14:17 and 14:19. Data Source: www.bloomberg.com.

Panel B: Summary statistics of market surveys

| Variable | Mean    | Median  | Std Dev  | Min    | Max    | |SUR|>2 | |SUR|>3 |
|----------|---------|---------|----------|--------|--------|--------|--------|
| FOMC: N = 108 |         |         |          |        |        | |      |      |      |
| #SP      | 85.519  | 93.000  | 24.602   | 33.000 | 143.000|        |        |      |
| SUR      | -0.098  | 0.000   | 1.000    | -6.960 | 3.341  | 3 (2.78%) | 3 (2.78%)|
| DIS      | 0.504   | 0.000   | 1.000    | 0.000  | 4.790  |        |        |      |
| CCI: N = 162 |         |         |          |        |        | |      |      |      |
| #SP      | 68.049  | 68.000  | 6.516    | 48.000 | 81.000 |        |        |      |
| SUR      | 0.037   | 0.071   | 1.000    | -2.825 | 2.492  | 4 (2.47%) | 0 (0.00%)|
| DIS      | 3.492   | 3.311   | 1.000    | 1.742  | 7.411  |        |        |      |
| CSI: N = 323 |         |         |          |        |        | |      |      |      |
| #SP      | 60.424  | 61.000  | 6.290    | 44.000 | 74.000 |        |        |      |
| SUR      | -0.083  | 0.000   | 1.000    | -3.442 | 3.198  | 25 (7.74%) | 3 (0.93%)|
| DIS      | 2.518   | 2.410   | 1.000    | 0.983  | 7.551  |        |        |      |
| ISM: N = 162 |         |         |          |        |        | |      |      |      |
| #SP      | 74.673  | 75.000  | 7.298    | 55.000 | 88.000 |        |        |      |
| SUR      | 0.118   | 0.080   | 1.000    | -3.201 | 3.948  | 7 (4.32%) | 2 (1.23%)|
| DIS      | 3.495   | 3.340   | 1.000    | 1.784  | 7.455  |        |        |      |
| New Homes Sales: N = 161 |         |         |          |        |        | |      |      |      |
| #SP      | 69.174  | 72.000  | 7.131    | 50.000 | 82.000 |        |        |      |
| SUR      | 0.029   | -0.051  | 1.000    | -2.833 | 4.164  | 8 (4.97%) | 3 (1.86%)|
| DIS      | 1.633   | 1.196   | 1.000    | 0.513  | 5.486  |        |        |      |
Table II: Summary statistics of pre-announcement return on SPX and VIX variables.

This table reports summary statistics of the return, VIX level and its change, excess realized volatility, and abnormal trading volume for FOMC announcement and other macro news announcement during one-day pre-announcement period in Panel A and those of the same variables during half-day pre-announcement period in Panel B. \( R_{t-d,t} \) is the one-day pre-announcement return, \( \Delta VIX_{t-d,t} \) is the one-day pre-announcement change of VIX level, \( VIX_{t-d} \) is the VIX level one day prior to the announcement, \( ExRV_{t-d,t} \) is the one-day pre-announcement excess realized volatility and \( ATV_{t-d,t} \) is the one-day pre-announcement abnormal trading volume. Both one-day and half-day pre-announcement return are expressed in percentage. (Sample period is from 2003/07 to 2016/12.)

### Panel A: One-day pre-announcement period

<table>
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<tr>
<th>Variable</th>
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<th>Std Dev</th>
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<th>Max</th>
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<tbody>
<tr>
<td>( R_{t-d,t} )</td>
<td>0.336</td>
<td>0.142</td>
<td>1.229</td>
<td>-2.152</td>
<td>9.566</td>
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<tr>
<td>( VIX_{t-d} )</td>
<td>19.713</td>
<td>17.025</td>
<td>9.471</td>
<td>10.050</td>
<td>75.380</td>
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<tr>
<td>( \Delta VIX_{t-d,t} )</td>
<td>-0.349</td>
<td>-0.205</td>
<td>1.397</td>
<td>-7.230</td>
<td>3.220</td>
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<tr>
<td>( ExRV_{t-d,t} )</td>
<td>-0.129</td>
<td>-0.062</td>
<td>0.477</td>
<td>-2.695</td>
<td>1.654</td>
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<tr>
<td>( ATV_{t-d,t} )</td>
<td>-1.254</td>
<td>-1.044</td>
<td>4.137</td>
<td>-21.915</td>
<td>11.738</td>
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<table>
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<th>Std Dev</th>
<th>Min</th>
<th>Max</th>
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</thead>
<tbody>
<tr>
<td>( R_{t-d,t} )</td>
<td>0.033</td>
<td>0.079</td>
<td>1.055</td>
<td>-4.638</td>
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<tr>
<td>( VIX_{t-d/2} )</td>
<td>19.243</td>
<td>16.490</td>
<td>9.171</td>
<td>9.980</td>
<td>85.460</td>
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<tr>
<td>( \Delta VIX_{t-d/2,t} )</td>
<td>-0.007</td>
<td>-0.010</td>
<td>1.598</td>
<td>-12.930</td>
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<td>( ExRV_{t-d/2,t} )</td>
<td>-0.016</td>
<td>-0.004</td>
<td>1.274</td>
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<td>( ATV_{t-d/2,t} )</td>
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<td>-0.060</td>
<td>5.948</td>
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### Panel B: Half-day pre-announcement period

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<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>( R_{t-d/2,t} )</td>
<td>0.072</td>
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<td>0.389</td>
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<td>( VIX_{t-d/2} )</td>
<td>19.421</td>
<td>16.755</td>
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<td>( \Delta VIX_{t-d/2,t} )</td>
<td>-0.057</td>
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<td>( ExRV_{t-d/2,t} )</td>
<td>-0.087</td>
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<th>Std Dev</th>
<th>Min</th>
<th>Max</th>
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<tr>
<td>( R_{t-d/2,t} )</td>
<td>0.024</td>
<td>0.090</td>
<td>0.962</td>
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<td>9.321</td>
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<td>( VIX_{t-d/2} )</td>
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<td>( ExRV_{t-d/2,t} )</td>
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<td>-0.006</td>
<td>0.868</td>
<td>-10.473</td>
<td>9.797</td>
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<tr>
<td>( ATV_{t-d/2,t} )</td>
<td>0.129</td>
<td>-0.019</td>
<td>4.116</td>
<td>-16.801</td>
<td>23.136</td>
</tr>
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</table>
Table III: Determinants of Trading Volume

This table reports the results of panel regression of abnormal trading volume (ATV) against several potential determinants, VIX\textsubscript{t-d}, -Δ VIX\textsubscript{t-d,t}, #SP, |SUR|, and DIS. VIX\textsubscript{t-d} is the VIX level one day prior to the announcement, Δ VIX\textsubscript{t-d,t} is the one-day pre-announcement change of VIX level, #SP is the number of survey participants, |SUR| is the absolute value of forecast surprise, and DIS is the forecast dispersion. We model news type fixed effects and report within estimators for coefficients. Below each coefficient estimate is the corresponding standard error. *** denotes significant at 1% level; ** denotes significant at 5% level; * denotes significant at 10% level.

<table>
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<tr>
<th></th>
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<td>#SP</td>
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<td>0.015</td>
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<tr>
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<tr>
<td>DIS</td>
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<td>0.049</td>
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<tr>
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<td>(0.199)</td>
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<td>VIX\textsubscript{t-d}</td>
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<td>-0.054***</td>
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<td>(0.021)</td>
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<td>-Δ VIX\textsubscript{t-d,t}</td>
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<td>-0.715***</td>
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<td>Yes</td>
<td>Yes</td>
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<td>803</td>
</tr>
<tr>
<td>Adj. R\textsuperscript{2}</td>
<td>-0.005</td>
<td>-0.006</td>
<td>-0.006</td>
<td>0.003</td>
<td>0.035</td>
<td>0.0004</td>
<td>0.033</td>
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</table>
### Table IV: Determinants of Pre-announcement Premium

This table reports the results of panel regression of pre-announcement premium ($\text{Ret}_{t-d,t}$) against several potential determinants, $\text{VIX}_{t-d}$, $-\Delta \text{VIX}_{t-d}$, $\text{ExRV}_{t-d}$, $\#SP$, $|\text{SUR}|$, DIS, and ATV. $\text{VIX}_{t-d}$ is the VIX level one day prior to the announcement, $-\Delta \text{VIX}_{t-d}$ is the one-day pre-announcement change of VIX level, $\text{ExRV}_{t-d}$ is the one-day pre-announcement excess realized volatility, $\#SP$ is the number of market participants, $|\text{SUR}|$ is the absolute value of forecast surprise, DIS is the forecast dispersion and ATV is the abnormal trading volume. We model news type fixed effects and report within estimators for coefficients. Below each coefficient estimate is the corresponding standard error. *** denotes significant at 1% level; ** denotes significant at 5% level; * denotes significant at 10% level.

| Dependent variable: $\text{Ret}_{t-d,t}$ | \( \#SP \) | \( |\text{SUR}| \) | DIS | $\text{VIX}_{t-d}$ | $-\Delta \text{VIX}_{t-d}$ | ATV | ExRV | News type | N | Adj. R² |
|---|---|---|---|---|---|---|---|---|---|---|
| (1) | -0.002 | 0.086* | 0.116*** | 0.020*** | 0.547*** | -0.031*** | -0.285*** | Yes | 803 | -0.006 |
| (2) | -0.001 | 0.027 | 0.074* | 0.016*** | 0.545*** | -0.028*** | -0.016 | Yes | 803 | -0.003 |
| (3) | -0.002 | 0.001 | 0.064*** | 0.004 | 0.543*** | 0.001 | -0.016 | Yes | 803 | 0.006 |
| (4) | (0.003) | (0.053) | (0.031) | (0.004) | (0.014) | (0.007) | (0.034) | Yes | 803 | 0.006 |
| (5) | (0.002) | (0.031) | (0.022) | (0.004) | (0.014) | (0.007) | (0.022) | Yes | 803 | 0.006 |
| (6) | (0.003) | (0.038) | (0.022) | (0.004) | (0.014) | (0.007) | (0.022) | Yes | 803 | 0.006 |
| (7) | (0.002) | (0.031) | (0.022) | (0.004) | (0.014) | (0.007) | (0.022) | Yes | 803 | 0.006 |
| (8) | (0.003) | (0.031) | (0.022) | (0.004) | (0.014) | (0.007) | (0.022) | Yes | 803 | 0.006 |
| (9) | (0.002) | (0.031) | (0.022) | (0.004) | (0.014) | (0.007) | (0.022) | Yes | 803 | 0.006 |
| (10) | (0.002) | (0.031) | (0.022) | (0.004) | (0.014) | (0.007) | (0.022) | Yes | 803 | 0.006 |
Table V: Summary Statistics of Informed Trading and Liquidity Trading

This table reports summary statistics of informed trading and liquidity trading. ATVI is abnormal informed trading volume, a proxy for informed trading. ATVU is uninformed abnormal trading volume, a proxy for liquidity shock. The unit of ATVI and ATVU is in $billion. (Sample period is from 2003/07 to 2016/12.)

Panel A: One-day pre-announcement period

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Median</th>
<th>Std Dev</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATVI</td>
<td>-0.803</td>
<td>-0.687</td>
<td>2.267</td>
<td>-12.773</td>
<td>6.337</td>
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<tr>
<td>ATVU</td>
<td>-0.453</td>
<td>-0.341</td>
<td>2.171</td>
<td>-10.679</td>
<td>5.853</td>
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</table>

Other macro news announcement (N = 749)

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<th>Max</th>
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<tbody>
<tr>
<td>ATVI</td>
<td>0.091</td>
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<td>2.903</td>
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<tr>
<td>ATVU</td>
<td>0.007</td>
<td>-0.043</td>
<td>3.204</td>
<td>-12.424</td>
<td>14.940</td>
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Panel B: Half-day pre-announcement period

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<th>Variable</th>
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<th>Std Dev</th>
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<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATVI</td>
<td>-0.612</td>
<td>-0.348</td>
<td>1.218</td>
<td>-4.318</td>
<td>2.767</td>
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<tr>
<td>ATVU</td>
<td>-0.620</td>
<td>-0.399</td>
<td>1.381</td>
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Other macro news announcement (N = 749)

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<th>Max</th>
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<tr>
<td>ATVI</td>
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<td>ATVU</td>
<td>0.043</td>
<td>-0.012</td>
<td>2.211</td>
<td>-9.595</td>
<td>10.685</td>
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Table VI: Determinants of Liquidity Trading

This table reports the results of panel regression of liquidity trading (ATVU) against several potential determinants, VIXt-d, -ΔVIX [t-d,t], #SP, |SUR|, and DIS. VIXt-d is the VIX level 24 hours prior to the announcement, ΔVIX[t-d,t] is the one-day pre-announcement change of VIX level, #SP is the number of market participants, |SUR| is the absolute value of forecast surprise, and DIS is the forecast dispersion. We model news type fixed effects and report within estimators for coefficients. Below each coefficient estimate is the corresponding standard error. *** denotes significant at 1% level; ** denotes significant at 5% level; * denotes significant at 10% level.

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<td>(0.152)</td>
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<td>DIS</td>
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<td>-0.024**</td>
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<td>(0.011)</td>
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<tr>
<td>-ΔVIX [t-d,t]</td>
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<tr>
<td>Adj. R²</td>
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<td>-0.006</td>
<td>-0.006</td>
<td>-0.0005</td>
<td>0.035</td>
<td>-0.004</td>
<td>0.032</td>
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</table>
Table VII: Determinants of Informed Trading

This table reports the results of panel regression of informed trading (ATVI) against several potential determinants, VIX_{t-d}, -ΔVIX \_[t-d,t], #SP, |SUR|, DIS and ATU. VIX_{t-d} is the VIX level 24 hours prior to the announcement, ΔVIX_{[t-d,t]} is the one-day pre-announcement change of VIX level, #SP is the number of market participants, |SUR| is the absolute value of forecast surprise, DIS is the forecast dispersion, and ATU is liquidity shock. We model news type fixed effects and report within estimators for coefficients. Below each coefficient estimate is the corresponding standard error. *** denotes significant at 1% level; ** denotes significant at 5% level; * denotes significant at 10% level.

<table>
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<tr>
<td></td>
</tr>
<tr>
<td>(1)  (2)  (3)  (4)  (5)  (6)  (7)  (8)</td>
</tr>
<tr>
<td>#SP  0.013*  0.011***  0.011***</td>
</tr>
<tr>
<td>(0.008)  (0.003)  (0.003)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>(0.134)  (0.063)  (0.063)</td>
</tr>
<tr>
<td>DIS  -0.029  0.054  0.035</td>
</tr>
<tr>
<td>(0.095)  (0.046)  (0.045)</td>
</tr>
<tr>
<td>VIX_{t-d}  -0.029***  -0.010**</td>
</tr>
<tr>
<td>(0.010)  (0.005)</td>
</tr>
<tr>
<td>-ΔVIX _[t-d,t]  -0.326***  -0.016</td>
</tr>
<tr>
<td>(0.060)  (0.028)</td>
</tr>
<tr>
<td>ATU  0.794***  0.791***  0.792***</td>
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<tr>
<td>(0.015)  (0.014)  (0.015)</td>
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<td>News type</td>
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<tr>
<td>Adj. R² -0.002  -0.005  -0.006  0.005  0.030  0.787  0.791  0.790</td>
</tr>
</tbody>
</table>
Table VIII: Determinants of Pre-announcement Premium – Effect of Informed Trading and Liquidity Trading

This table reports the results of panel regression of pre-announcement premium ($\text{Ret}_{t-d,t}$) against proxies for informed trading and liquidity trading and other potential determinants. ATVI is informed abnormal trading volume, a proxy for informed trading. ATVU is uninformed abnormal trading volume, a proxy for liquidity trading. $\text{VIX}_{t-d}$ is the VIX level 24 hours prior to the announcement, $\Delta \text{VIX}_{t-d,t}$ is the one-day pre-announcement change of VIX level, #SP is the number of market participants, $|\text{SUR}|$ is the absolute value of forecast surprise, DIS is the forecast dispersion and ATV is the abnormal trading volume. We model news type fixed effects and report within estimators for coefficients. Below each coefficient estimate is the corresponding standard error. *** denotes significant at 1% level; ** denotes significant at 5% level; * denotes significant at 10% level.

<table>
<thead>
<tr>
<th>Dependent variable: $\text{Ret}_{t-d,t}$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td>(1)         (2)        (3)        (4)        (5)        (6)</td>
</tr>
<tr>
<td>#SP         -0.0004     -0.001     -0.001     -0.002     (0.003)     (0.003)     (0.003)     (0.002)</td>
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<tr>
<td>DIS         0.107***    0.105***   0.073*     0.064***   (0.038)     (0.038)     (0.038)     (0.022)</td>
</tr>
<tr>
<td>$\text{VIX}_{t-d}$       0.016***   (0.004)</td>
</tr>
<tr>
<td>$-\Delta \text{VIX}_{t-d,t}$   0.545***   (0.014)</td>
</tr>
<tr>
<td>ATVI         -0.060***   -0.060***   -0.006     -0.003     (0.014)     (0.014)     (0.030)     (0.017)</td>
</tr>
<tr>
<td>ATVU         -0.057***   -0.056***   -0.048*    0.003      (0.012)     (0.012)     (0.026)     (0.016)</td>
</tr>
<tr>
<td>News type FE Yes Yes Yes Yes Yes Yes</td>
</tr>
<tr>
<td>N            803         803         803         803         803         803</td>
</tr>
<tr>
<td>Adj. $R^2$   0.018       0.020       0.027       0.030       0.050       0.666</td>
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</tbody>
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Table IX: Determinants of Excess Realized Volatility – Effect of Informed Trading and Liquidity Trading

This table reports the results of panel regression of excess realized volatility (ExRV[t-d,t]) against several potential determinants, #SP, |SUR|, DIS, ATV, ATVI, and ATVU. ATV is the abnormal trading volume, ATVI is informed abnormal trading volume, a proxy for informed trading, and ATVU is uninformed abnormal trading volume, a proxy for liquidity shock. We model news type fixed effects and report within estimators for coefficients. Below each coefficient estimate is the corresponding standard error. *** denotes significant at 1% level; ** denotes significant at 5% level; * denotes significant at 10% level.

<table>
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<th>(1)</th>
<th>(2)</th>
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<tr>
<td>#SP</td>
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<td></td>
<td>SUR</td>
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<td>(0.035)</td>
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<td>ATV</td>
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<tr>
<td>ATVI</td>
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<td>0.164***</td>
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<td>0.152***</td>
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<td>ATVU</td>
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<tr>
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<tr>
<td>Adj. R²</td>
<td>-0.006</td>
<td>0.012</td>
<td>-0.006</td>
<td>0.159</td>
<td>0.169</td>
<td>0.134</td>
<td>0.181</td>
</tr>
</tbody>
</table>

Dependent variable: ExRV[t-d,t]
Figure 2: Cumulative returns of the S&P 500 index.

This figure reports the average cumulative returns on the S&P 500 index during two consecutive trading days, announcement vs non-announcement period. We report FOMC announcement in panel A and other macroeconomic news announcement in panel B. In each panel, the x-axis is calendar time, and the y-axis is cumulative mean return in percentage; the solid line is the cumulative mean return during announcement period, and the dashed line is the cumulative mean return during non-announcement period; for announcement period, day t is the announcement day, and day t-1 is the prior trading day; the vertical dash line indicates the announcement time, 14:15 for FOMC announcement and 10:00 for other macroeconomic news announcement.

Panel A FOMC announcement

Panel B Other macro news announcement
Figure 3: Intraday realized volatility of S&P 500 index returns.

This figure reports the average realized volatility on the S&P 500 index during two consecutive trading days, announcement vs non-announcement period. We report FOMC announcement in panel A and other macroeconomic news announcement in panel B. In each panel, the x-axis is calendar time, and the y-axis is average 5-minute realized volatility in squared percentage; the solid line is the realized volatility during announcement period, and the dashed line is the realized volatility during non-announcement period; for announcement period, day t is the announcement day, and day t-1 is the prior trading day; the vertical dash line indicates the announcement time, 14:15 for FOMC announcement and 10:00 for other macroeconomic news announcement.

Panel A FOMC announcement

Panel B Other macro news announcement
Figure 4: Intraday VIX level change around Macroeconomic News Announcements.

This figure reports the average VIX level during two consecutive trading days, announcement vs non-announcement period. We report FOMC announcement in panel A and other macroeconomic news announcement in panel B. In each panel, the x-axis is calendar time, and the y-axis is 1-minute mean VIX level; the solid line is the mean VIX level during announcement period, and the dashed line is the mean VIX level during non-announcement period; for announcement period, day $t$ is the announcement day, and day $t-1$ is the prior trading day; the vertical dash line indicates the announcement time, 14:15 for FOMC announcement and 10:00 for other macroeconomic news announcement.

Panel A FOMC announcement

Panel B Other macro news announcement