Distinct roles of risk and uncertainty: Evidence from trading around U.S. macro news

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Abstract

We provide evidence on distinct roles of risk and uncertainty in financial markets by examining trading activity around the U.S. macro news releases. We document a sustained increase in stock and option trading activity coupled with a rise in risk and a dramatic drop in uncertainty after the release of Federal Open Market Committee (FOMC) statements. Following non-FOMC macro news, we find little change in uncertainty and moderate increase in equity trading, even though risk increases. Our results suggest FOMC news helps resolve uncertainty. This resolution of uncertainty encourages more trading activity than increased risk. We also compare trading prior to news releases on event days with that on non-event days and find a significant reduction in both stock and option trades for FOMC news. For non-FOMC macro news, we find a surge in trading options only. Our results confirm that investors are willing to wait to trade in anticipation of resolution in uncertainty after the FOMC news. Knowing that uncertainty in the post-announcement of non-FOMC news does not change much, investors actively exploit their insights in options market prior to the news releases.

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1 Introduction

The effects of risk and uncertainty on trading activity have been investigated in two separate strands of the literature. A positive relation between risk (volatility) and trading activity (volume) is broadly documented; see Bollerslev et al. (2018) and references therein. The notion that high uncertainty limits market participation and reduces trading activity is established in a series of theoretical works (e.g. Cao et al., 2005; Ui, 2011, among others). However, empirical evidence on the effects of the interaction between risk and uncertainty on trading activity is not well-documented, even though both factors are evaluated simultaneously in the asset pricing topics (e.g. Bekaert et al., 2009; Brenner and Izhakian, 2018). Our aim is to examine how uncertainty influences trading activity differently from risk, which helps us understand better the distinct roles of risk and uncertainty in determining where and how investors trade.

Our examination is based on the assumption that the asset return distribution evolves with the release of new information. Macroeconomic (macro) news releases provide an ideal framework since they are typically considered to be a market-moving event (see Jones et al., 1998; Boyd et al., 1998; Balduzzi et al., 2001). Among the U.S. macro news releases, the Federal Open Market Committee (FOMC) meetings stand out because of their text-based nature. In addition to the target rate decision, the FOMC committee also explains the rationale of policy action and conveys the outlook for its future policy stance in statements. This is undertaken as an attempt to increase both transparency and policy effectiveness, which helps investors better understand the current state of the economy and potentially reduces uncertainty.[1] However, other macro news announcements, e.g. nonfarm payroll that is closely followed by financial press (often referred to as the "king" of announcements; see Andersen and Bollerslev, 1998), release only descriptive statistics and do not bring any insight to the numbers. As a consequence these announcements can create different interpretations on the current state of the economy for investors.[2] The current literature has also documented different impacts of the

[1] As an example, the Wall Street Journal (WSJ) dedicates a column (named "Parsing the FED") to outline changes in the wording of announcements from meeting to meeting (see `https://blogs.wsj.com/economics/tag/parsing-the-fed/`). The articles are available soon after the meeting, e.g. 40 minutes after the meeting on 30 April 2008, which was reduced to 3 minutes after the meeting on 18 December 2013 (based on story timestamps reported in Factiva). For example, the scheduled FOMC statement on 30 January 2008 was interpreted by the WSJ as follows: "credit crunch and market stress are core issues, housing and job markets still weaken"; "inflation is still on radar but not a prominent concern"; "this may be a time to pause on further (federal funds rate) reduction"; "FED may cut again if needed"; and "Richard W. Fisher (preferred no rate change and) voted against (the rate cut decision)."

[2] For instance, the news announcement on 4 January 2008 stated that "the unemployment rate rose to 5.0 percent in December, while nonfarm payroll employment was essentially unchanged (+18,000)", and

FOMC statements in financial markets, including market volatility (Rosa, 2013), liquidity (Smales and Apergis, 2017), or investors' attention (Tang, 2017). Lucca and Moench (2015) argue that "the increasing magnitude of the pre-FOMC equity price drift may potentially be related to the increased importance and clarity of information collected by investors at scheduled FOMC meetings". Hence, we conduct our analysis on the FOMC and non-FOMC macro news separately as the former offers a richer framework to study different roles of risk and uncertainty as suggested by current theories.

We investigate trading activity associated with risk and uncertainty from the S&P500 Exchange Traded Fund (SPY) surrounding FOMC meetings and 12 other macro news items released during the period January 2005 to December 2013.[3] Risk is commonly measured as the realized variance, or the sum of squared returns over a given time period, under the assumption that the underlying return distribution is known to investors. However, the true data generating process of asset returns potentially varies over time, so the realized returns can come from either a single (static) or mixture of different (time-varying) distributions. The higher the degree of time-variation in the underlying distribution, the greater the uncertainty faced by investors in determining the shape of the return distribution. To take this into account, we use a recent non-parametric method developed by Izhakian (2017) and adopted by Izhakian and Yermack (2017) and Brenner and Izhakian (2018) to estimate uncertainty. That is, uncertainty is measured as "the weighted average of variance of probabilities estimated for different return outcomes, where the weights are the associated likelihood of these outcomes."[4]

We use trading volume (in shares or contracts) and number of trades to measure trading activity in both stock and options markets. A number of recent studies document that some traders may have an information advantage prior to macro news releases due to either information leakage (Bernile et al., 2016) or superior forecasting by using proprietary data (Kurov et al., 2018). The options market, with implicit leverage, is often considered a key market for speculation (e.g. Back, 1992; Biais and Hillion, 1994). Hence, the options market is a potential venue for better informed investors to exploit their insights. Therefore, an analysis of trading activity in both stock and options markets helps us understand and distinguish the roles of risk and uncertainty, particularly in determining where better informed investors trade.

Our analysis focuses on two separate pre- and post-announcement time intervals of equal length, examined separately for FOMC and non-FOMC macro news. We find a

on 1 February 2008 that "both nonfarm payroll employment, at 138.1 million, and the unemployment rate, at 4.9 percent, were essentially unchanged in January."

[3]See Table 1 for the list of macro news items.

[4]See Brenner and Izhakian (2018) for a simple example of an asset with two possible return outcomes.

higher (lower) degree of uncertainty (risk) before FOMC news, and this pattern reverses in the post-announcement period. In addition, trading activity in both stock and options markets is low before the FOMC announcements but has a sustained increase post-announcement. These results align with an extensive body of literature that documents a positive relation between trading volume and volatility (Bollerslev et al., 2018, and references therein), but a negative relation between uncertainty and market participation (Cao et al., 2005; Ui, 2011). This is also consistent with the fact that FOMC statements explain the committee's rationale for its decision and economic outlook, which helps market participants learn about the state of the economy and reduces uncertainty .

When we repeat our analysis for non-FOMC macro news announcements, we find a moderate increase in risk and equity trading activity, with stable uncertainty in the post-announcement period. Since these macro announcements only convey particular variables' statistical descriptions, it is not clear that investors learn about the determinants or implications of reported numbers, as in the case of FOMC news. As a consequence it appears that the non-FOMC announcements do not reduce uncertainty. From a cross-comparison analysis of the two types of news, we find that the dynamics in risk, uncertainty and trading activity around FOMC meetings are stronger than those from non-FOMC macro news. Therefore, the clarity of information from FOMC statements, and not the target rate per se, helps reduce uncertainty to a greater extent, relative to non-FOMC macro news. Further, the resolution of uncertainty encourages more trading activity beyond activity driven by the influence of risk.

In addition to equity trades, we find that options are traded more frequently only before the non-FOMC news releases. In our context, two different factors potentially explain this result. If investors changed their perception of risk or uncertainty, they would adjust trading activity accordingly. Since uncertainty remains stable after non-FOMC news, the surge in pre-announcement option trades is likely to be driven by the perceived increase in risk after the announcement. Alternatively, recent literature has documented evidence of superior forecastability (e.g. Kurov et al., 2018) prior to macro news releases. Hence, investors could be more likely to trade in options market to exploit their information advantage. This is established in our analysis of option trades prior to non-FOMC macro news.

The conditions that encourage pre-announcement option trades also hold for FOMC meetings, namely the substantial increase in post-announcement volatility, and evidence of information leakage over a short time window in the equity market as in Bernile et al. (2016). However, we find no significant rise in pre-FOMC option trades, and we attribute this difference to the high level of uncertainty observed prior to FOMC meetings. At

times of high uncertainty, investors are reluctant to trade because they are unable to form the shape of the distribution of future returns. In other words, uncertainty plays a dominant role in determining whether and where the investors trade. High uncertainty offsets the benefits of both information advantage (speculative) and volatility trades, which leads to the marked reduction of both equity and option trades.

Following the distinct dynamics of risk and uncertainty around two types of macro news, we investigate their explanatory power on trading activity through regression analysis. We find that trading and volatility (risk) are positively related, but a rise in uncertainty depresses trading and *vice versa*. These results hold for both FOMC and non-FOMC macro news. In addition, the low level of pre-FOMC trades becomes insignificant, and excessive trades over the post-announcement period fall for all types of macro news. With uncertainty as a control variable, we find that the effect of risk on trading activity falls by 7% to 27% on average. These results indicate the separate and significant role of uncertainty in explaining trading activity around macro news.

Our findings are consistent with several strands of the literature. It is important to study the distinct impacts of risk and uncertainty in financial markets simultaneously; see also Izhakian and Yermack (2017) and Brenner and Izhakian (2018). We provide evidence to support the theoretical predictions about the market participation-uncertainty relation, and more importantly, the crucial role of uncertainty in determining whether and where investors with an information advantage trade. We also expand the literature on trading with superior information prior to macro news (e.g. Bernile et al., 2016; Kurov et al., 2018), and add to recent findings on the importance of FOMC statements on investors' behavior (e.g. Rosa, 2013; Lucca and Moench, 2015; Tang, 2017).

The paper is organized as follows. Section 2 discusses past research, and Section 3 documents the data and variable construction. The empirical results in Section 4-6 discuss dynamics of risk, uncertainty, and trading activity around the macro news releases and the explanatory power of risk and uncertainty on trading activity and returns. Section 7 provides a summary.

2 Background

2.1 The effects of FOMC news

The FOMC meetings have recently been the central topic of a series of research papers on macro news announcements. The initial focus of this literature stream is on explanations of market reactions to FOMC news. For example, Bernanke and Kuttner (2005) find

that the positive effects of unanticipated Federal funds rate (FFR) changes on stock market prices originates mainly from increases in expected future dividends, and not differences in expected real interest rates.

FOMC news announcements are also associated with pre-announcement price drifts in financial markets. Lucca and Moench (2015) document positive returns in both U.S. and global equity markets before FOMC meetings. While the pre-FOMC equity volatility and trading volume remain low, both of these variables show sustained increases once the FOMC target rate decisions are made. This is consistent with Rosa (2013) who reports a greater sensitivity of bond and stock market volatilities to FOMC statements relative to non-farm payroll and other news. Brusa et al. (2018) find that FOMC announcements, not those from other central banks, uniquely generate positive excess returns in global stock markets in the two-day window around scheduled FOMC meetings, and Cieslak et al. (2018) explain the equity premium in the U.S. and other countries (realized even weeks in advance of the FOMC meeting cycle) by the Fed's informal communication with the media and financial sector. Mueller et al. (2017) study the currency markets and find large excess returns around the FOMC meetings. More specifically, the trading strategy that shorts the U.S. dollar and longs other currencies yields both positive pre- and post-announcement returns. Brooks et al. (2017), however document a price drift in the U.S. bond market following the announcements of target rate changes, but no evidence of pre-FOMC under-reaction.

Current research investigates the impact of FOMC informativeness on financial markets. This is because the text-based nature of FOMC statements helps market participants to better understand the rationale behind policy action. Non-FOMC macro news only releases a statistical description of the macro variables. Tang (2017) finds that information released through FOMC meetings determines the types of macro news to which financial markets pay attention. In particular, the intensity of labor-related keywords measured from FOMC statements and minutes are related to the magnitude of interest rate responses to labor news, relative to other news. Smales and Apergis (2017) document that bond trading volume increases with the linguistic complexity and length of FOMC statements.

Gu et al. (2018) document that after FOMC meetings associated with the release of the Summary of Economic Projections (SEP) and press conferences there are substantial, positive average stock returns. This is thought to be associated with a resolution of uncertainty. Boguth et al. (2018) study the unintended economic consequences of press conferences following only some FOMC meetings. That is, the concentration of investor attention on these meetings reduces the frequency at which important monetary policy

news is released to the public, which may reduce transparency and social welfare. In addition, the press conferences convey little new information to the market and do not reduce monetary policy uncertainty. With VIX as the proxy of uncertainty, Gu et al. (2018) and Boguth et al. (2018) find differences in VIX evolution after news from FOMC meetings. In summary, the results of this research support the Lucca and Moench (2015) assessment that "the increasing magnitude of the pre-FOMC drift may potentially be related to the increased importance and clarity of information collected by investors at scheduled FOMC meetings."

2.2 Market reaction to macroeconomic news

The literature has documented the separate dynamics of risk and uncertainty around macro news releases. Beber and Brandt (2009) study whether the pre-announcement macroeconomic uncertainty, i.e. implied volatility of economic derivatives introduced by Goldman Sachs and Deutsche Bank, explains the resolution of financial market uncertainty, i.e. implied volatility of stock and bond markets, around macro news. In particular, Goldman Sachs and Deutsche Bank launched a market for economic derivatives (calls, puts, and digital options) before a scheduled macro news announcement, whose underlying is the initial release of forthcoming macroeconomic statistics. The macro variables include non-farm payrolls, the Institute for Supply Management (ISM) manufacturing index, retail sales ex-autos, and initial jobless claims. Beber and Brandt (2009) find that the higher pre-announcement macroeconomic uncertainty, the greater reduction in implied volatility and open interest in stock and bond options, but more pronounced trading volume in the post-announcement period.

A large body of literature has documented the responses of financial markets to macroeconomic news, starting with a few macro news releases (see initial works in Jones et al., 1998; Boyd et al., 1998; Fleming and Remolona, 1999), and a large set of macro news more recently (see Balduzzi et al., 2001; Andersen et al., 2003; Chordia et al., 2017). Balduzzi et al. (2001) study a set of 26 macro announcements and the U.S. Treasury market to document a persistent increase in volatility and volume up to 60 minutes after the news, but instantaneous price adjustment to news of less than a minute. The bid-ask spreads of Treasury bonds initially widen at announcement time and then quickly revert to normal levels in the next 5 to 15 minutes. Andersen et al. (2003) analyze the asymmetric effect of news on the foreign exchange market to report the greater impact of bad news relative to good news. Jiang et al. (2011) document a positive relation between announcement surprises and bond price jumps, where the jumps can be predicted by

pre-announcement liquidity shocks. Bollerslev et al. (2018) recently demonstrate the co-movement between trading and spot volatility in stock markets for a comprehensive set of macro news.

Savor and Wilson (2013) document higher daily stock market returns, marginal risk (measured by realized volatility) changes, and lower risk-free returns on macro announcement days (relative to non-event days). Their sample covers the release of inflation, unemployment, and FOMC news over an extended period from 1958 through 2009. Under the assumption of a positive correlation between stock returns and state variables, stocks perform poorly at times of negative news on the state of the economy, which makes stocks riskier than their volatility suggests. Savor and Wilson (2013) argue that the state variable risk is deterministically higher when scheduled macro announcements reveal important information about the economy. Hence, the positive equity premium on announcement days is compensation for exposure to such macroeconomic risk, and the heightened precautionary saving demand by macro risks reduces risk-free returns.

We note that there are no previous studies that evaluate the effects of both risk and uncertainty on trading activity around macro news releases. Beber and Brandt (2009) study the impact of pre-announcement macro uncertainty on implied volatility in financial markets over a short time period. Savor and Wilson (2013), Lucca and Moench (2015), and Bollerslev et al. (2018) focus on the explanatory power of risk on market returns and trading volume on macro announcement days. Given that Beber and Brandt (2009) also work closely on uncertainty, it is worth noting that this paper differs from theirs in three aspects. We cover a longer sample period (2005-2013 versus 2002-2006), which is a consequence of the short-lived economic derivatives data. We focus on a large number (more than four) of macroeconomic news announcements. Importantly, we also study distinct patterns in risk and uncertainty and their relation to trading activity before and after news releases. Beber and Brandt (2009) evaluate the effects of pre-announcement macro uncertainty on the post-announcement resolution of financial uncertainty.

2.3 Volatility and trading activity

The literature has reported the positive relation between trading volume and volatility (see Karpoff, 1987, for a survey of early empirical evidence). Several theoretical works have provided different explanations for this strong contemporaneous volume-volatility relation, including the mixture-of-distribution hypothesis (Tauchen and Pitts, 1983), rational-expectations (Kim and Verrecchia, 1991), and differences-in-opinion (Kandel

and Pearson, 1995). With a focus on macro news releases, a significant increase in post-announcement volatility and volume is well established in Lucca and Moench (2015) and Bollerslev et al. (2018) for stock markets, and Balduzzi et al. (2001) and Jiang et al. (2011) for bond markets. However, the positive volume-volatility relation has not been evaluated in the presence of other economically meaningful variables that contribute to trading activity. For example, Bollerslev et al. (2018) propose a differences-in-opinion model where an elasticity measure, i.e. the percentage change in volume relative to that in volatility, should be less than unity. The authors document a significant dependence of volume-volatility elasticity on economic uncertainty, where it becomes closer to unity when their analysis controls for economic uncertainty, conflicting beliefs, and textual-based sentiment expressed in FOMC statements. Without considering these additional measures, the contribution of volatility to trading volume would be misunderstood. We confirm this potential overestimation bias and document a significant link between uncertainty and trading activity.

2.4 Volatility, uncertainty, and market participation

A negative relation between uncertainty and market participation has been well established in theoretical works. Cao et al. (2005) adopt the framework in Gilboa and Schmeidler (1989) to demonstrate two important findings: the limited participation in the presence of heterogeneous uncertainty-averse investors, and the negative relation between uncertainty and risk premiums. At times of high ambiguity, not all agents participate in the market, as uncertainty-averse investors will choose not to enter. The remaining traders perceive low uncertainty on the stock's payoff distribution and hence are willing to accept a lower uncertainty premium. However, they have to bear all the risk, so the risk premium could be high to induce them to hold stocks. The dominant low uncertainty premium therefore helps to explain why equity premia under limited market participation can be lower than that under the full participation case, i.e. with ambiguity-averse investors also active in the market.

Ui (2011) identifies other instances when the equity premium increases with limited market participation by incorporating asymmetric information, or private signals to investors. He first shows that limited market participation is driven by either high uncertainty or low stock return variance. If high uncertainty is the main driver of market participation, the equity premium increases when the difference in ambiguity between limited and full participation cases is higher than some threshold (if this difference is larger than a smaller threshold, and the precision of private signals is large enough).

Easley and O'Hara (2010a) study how the presence of different investor types results in limited market participation. They separate participants into sophisticated traders with correct beliefs, and inexperienced traders whose ambiguity aversion affects their willingness to participate in the market. As unsophisticated investors are heavily influenced by the worst return distribution, they can opt to not participate in markets. Alternatively, Easley and O'Hara (2010b) use the approach of Bewley (2000) to explore non-participation. In this setting an agent is allowed to have incomplete preferences, and one portfolio is ranked over another if and only if it yields greater expected utility for every belief in the set representing their preferences. When the agent cannot rank order some portfolios because of extreme uncertainty this leads to neither a buy nor a sell decision. This insight helps to explain behavior during the financial crisis of 2008; at this time there were no trades in some financial products, although uncertainty-averse investors could be inclined to leave the market by selling and closing their positions.

3 Data and variable construction

3.1 Data

We obtain information about macroeconomic announcements from Bloomberg. This includes release dates and times, announced values, number of estimates, the median consensus estimate, and standard deviation across estimates. We use announcement data for the sample of macroeconomic data series studied in Balduzzi et al. (2001) and Chordia et al. (2017). These events are from the period of January 2005 through December 2013. This sample period is a consequence of availability of intraday option data from the Chicago Board Option Exchange (CBOE)[5] which is only available from 2005. Equity and options trade from 9:30 to 16:00 and to 16:15, respectively, so we focus on the announcements during this time period. We present the relevant macro news in Table 1. The typical announcement time of FOMC releases and our sample of 12 non-FOMC macro news announcements is 14:15 and 10:00, respectively. The non-FOMC news releases include ISM (non-)manufacturing, construction spending, factory orders, wholesale (business) inventories, leading indicator, existing (new) home sales, consumer sentiment (confidence), and Chicago PMI. A large number of estimates are reported in the forecast surveys. For example, there are 82 forecasts for FOMC announcements. Non-FOMC announcements also have considerable variation in the number of estimates, ranging from 32 (wholesale inventories) to 75 (ISM manufacturing) estimates across

[5]See `https://datashop.cboe.com/`

series. In addition, the percentages of positive and negative surprises are approximately equal over the sample period.[6]

To proxy for equity returns we focus on the largest and most heavily traded equity ETF, SPY, which is also studied in Chordia et al. (2017), Bollerslev et al. (2018), and Brenner and Izhakian (2018). High frequency data for SPY and its options are obtained from the Trade and Quote (TAQ) database and CBOE, respectively. Following Bollerslev et al. (2016), an entry is excluded if it satisfies at least one of the following criteria: a time stamp outside the exchange trading hours, a price less than or equal to zero, a trade size less than or equal to zero, corrected trades, and abnormal sale condition. If one or multiple trades occur in a second, we calculate the sum of volumes, trades, and the volume-weighted average price within that second. For option data, we first retain the observations that satisfy the trade conditions similar to those in equity, and only keep those options with maturities between 10 and 100 days with an absolute delta between 0.02 and 0.98.[7] This sampling procedure helps us avoid thinly traded options in our analysis.

3.2 Risk and uncertainty measures

We first discuss risk and uncertainty as presented in the theoretical work of Izhakian (2017). Izhakian and Yermack (2017) and Brenner and Izhakian (2018) introduce an empirical measure of uncertainty and find evidence consistent with differences between risk and uncertainty. Over a fixed time period, risk is measured by realized variance, and uncertainty is computed as the weighted average of the variance of probabilities estimated for different return outcomes, where the weights are the likelihood of these outcomes. That is, given T time intervals with M observed returns in each time interval (i.e. the stock returns r_t for time $t = 1, ..., T \times M$), risk and uncertainty are calculated as follows:

$$Risk = \Sigma_{t=1}^{T\times M} r_t^2,$$

$$\begin{aligned} Uncertainty = \frac{1}{\omega(1-\omega)} \big\{ & E\big[\Phi(r_0;\mu_\tau,\sigma_\tau)\big] Var\big[\Phi(r_0;\mu_\tau,\sigma_\tau)\big] \\ & + \Sigma_{i=1}^{N} E\big[\Phi(r_i;\mu_\tau,\sigma_\tau) - \Phi(r_{i-1};\mu_\tau,\sigma_\tau)\big] Var\big[\Phi(r_i;\mu_\tau,\sigma_\tau) - \Phi(r_{i-1};\mu_\tau,\sigma_\tau)\big] \\ & + E\big[1 - \Phi(r_N;\mu_\tau,\sigma_\tau)\big] Var\big[1 - \Phi(r_N;\mu_\tau,\sigma_\tau)\big] \big\}, \end{aligned} \tag{1}$$

[6] We follow the literature to calculate announcement surprises, i.e. standardizing the difference between released and median forecast estimates by its time series standard deviation

[7] We retain the observations with trade condition ID of 0, 18, 35, 36, 37, 38, 95, and 106.

where $r_i, i = 0, ..., N$ are the fixed points with width $\omega = r_i - r_{i-1}$ covering the domain of returns distributions. Given a certain return outcome or fixed $i = 0, ..., N$, the normal cumulative distribution function $\Phi(r_i; \mu_\tau, \sigma_\tau)$ is computed for each time interval $\tau = 1, ..., T$, where μ_τ and σ_τ are the mean and standard deviation of M returns observations in the corresponding time interval.[8]

Given our focus on macro news releases at the intraday level, stock returns are sampled at one-minute frequency, similar to Bollerslev et al. (2018). We compute risk and uncertainty over periods of 150 minutes before and after a news announcement, equivalent to T=10 intervals of M=15 observations of one-minute returns. This is because we need a sufficient number of return observations for the uncertainty calculation around macro news releases. As a robustness check, we also consider 200, 225, and 300 minute intervals, equivalent to T=10 20-minute intervals, T=15 15-minute intervals, and and T=10 30-minute intervals. Each 15-, 20-, and 30-minute interval must have at least M=10, 13, or 20 available one-minute returns, respectively, to be included in the estimation of uncertainty.[9] Following equation (1), risk is equal to the sum of one-minute squared returns. To measure uncertainty, we first divide a wide range of one-minute returns from $r_0 = -1\%$ to $r_N = 1\%$ into bins of width $\omega = 0.002\%$. From the unconditional one-minute returns distribution over the sample period, the 0.01^{st} and 99.99^{th} percentiles are -0.8% and 0.8%, respectively, and the difference between the 45th (55th) percentile and median is approximately 0.002%, so this construction covers a large number of re-

[8]The M returns in each time interval are assumed to follow a normal distribution, whose mean and variance are different across T time intervals. Hence, the returns are not identically distributed over the time period of $T \times M$ observations. This assumption helps to compute a cumulative distribution function $\Phi(.; \mu_\tau, \sigma_\tau)$ and hence uncertainty. It does not affect the calculation of risk, which is the sum of squared returns over the sample of $T \times M$ observations.

[9]Given a macro news item, the pre-(post-) announcement time window over which risk and uncertainty are measured can overlap with the trading hours in the previous or following day, e.g. those released at 10:00 or 14:15. This raises a concern that overnight information may affect the dynamics of risk and uncertainty. We address this issue by studying the patterns of overnight returns and volatility around the announcement and present the results in Table 2, where the overnight volatility is measured either as squared or absolute overnight returns from opening and closing prices. For non-FOMC news, both the overnight returns and volatility before and after news are not significantly different from those in non-event days. For FOMC meetings, we document a rise in pre-FOMC overnight returns relative to non-event days or those before non-FOMC news (with positive γ_1 and γ_5 significant at the 5% and 10% levels, respectively), a reduction in post-FOMC returns relative to that in the pre-FOMC period (with negative γ_3 significant at the 10% level), and unchanged overnight volatility. The pre-FOMC overnight returns contributes to positive price drift documented in Lucca and Moench (2015) and does not significantly distort the measurement of risk and uncertainty. That is, the typical FOMC release time ranges from 12:30 to 14:15, so the shorter time intervals of 150, 200, or 225 minutes in which the pre-FOMC results hold do not overlap with trading hours in the previous day. In the post-FOMC period, both the overnight returns and volatility remain similar to those in non-event days, and the results are available upon request. Overall, we find no evidence of overnight information driving the market around macro news releases.

turn outcomes. For each 15-minute interval, we calculate the returns probabilities of different outcomes, i.e. each bin and returns less than -1% or higher than 1%. We then compute the mean (likelihood) and variance of probabilities for each return outcome over 150 minutes before and after the news announcement, and hence degree of uncertainty. We also take the natural logarithm (log) of risk and uncertainty measured in equation (1) to avoid the effects of extreme values in our analysis.

3.3 Trading activity measures

To measure trading activity, we follow Chordia et al. (2001) to employ total trading volume and number of trades aggregated over the same time window used in measuring risk and uncertainty. We further take the natural logarithm of these variables to mitigate outlier effects. We study abnormal trading activity around macro news to avoid confounding effects from regular intraday patterns in trading activity unrelated to the macro news.[10] Given the log level of trading activity (in event and non-event days), we follow Bernile et al. (2016) and Bollerslev et al. (2018) and subtract the log of moving average in the last 20 non-event days from current values. For example, the pre-FOMC trading volume on the event day is adjusted by its moving average in the prior 20 trading days without FOMC news. The trading volume is computed over a time window before the scheduled announcement time of the upcoming FOMC meeting. This adjustment is similar to computing a first-order difference to obtain time series stationarity; see Naes et al. (2011). For the option-to-equity trade ratio, we divide a current value by the ratio of moving averages of option and equity trades in the last 20 non-event days, and log transform the adjusted ratio to attenuate the influence of outliers.

4 The dynamics of risk, uncertainty, and trading activity

We first investigate the dynamics of risk, uncertainty, and trading activity around macro news announcements. We illustrate the magnitude of these variables in the pre- and post-announcement windows during the event and non-event days separately in Figures 1 and

[10]Figures 3 and 4 illustrate the intraday pattern of squared returns, trading volume, and number of trades at the one-minute frequency over the trading day. These show a well-documented U-shape pattern with high volatility and trading activity at the start and close of trading hours. For example, Lucca and Moench (2015) document a sustained increase in trading volume and volatility in the equity market following the FOMC announcements, e.g. 14:15. We also observe a high intraday level of these variables after 14:15 in Figure 3. Taken together, the intraday effect may intensify or conceal the true dynamics of these variables around macro news releases. The literature has also reported market frictions, (e.g Chordia et al., 2001), and the trading behavior bias from overconfident investors, (e.g Odean, 1998; Grinblatt and Keloharju, 2009) that may also result in trades unrelated to macro announcement effects.

2.

We use the difference-in-difference approach to compare effects on event days with outcomes on non-event days and examine the post-announcement effect on event days. We introduce two dummy variables: one dummy variable $event_t$ (equal to 1 on event days and zero otherwise) to separate event from non-event days, and a second dummy variable $after_t$ (equal to 1 in the post-announcement window and zero otherwise) to separate pre-announcement from post-announcement windows on a given day. In order to have a balanced sample, we use a fixed time window, e.g. 150 minutes, before and after the announcement time to compute the key variables in our analysis. Risk, uncertainty, and trading activity are separately considered as a dependent variable y_t in a regression on the dummy variables $event_t$ and $after_t$, and their interaction is as follows:

$$y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 after_t + \gamma_3 event_t * after_t + \epsilon_t. \tag{2}$$

We are primarily interested in coefficients γ_1 and γ_3. While γ_1 measures the difference in y_t between event and non-event days in the pre-announcement window, γ_3 represents the effects of news releases on y_t following the news relative to the pre-announcement window on event days. The coefficients γ_0 and γ_2 measure the average magnitude of y_t in the pre-announcement window and the mean differential between the post- and pre-announcement window on non-event days, respectively. As previously discussed, we consider FOMC releases separately, given their reported distinct effects on the financial market. Hence, we estimate equation (2) twice: once for FOMC meetings and again for non-FOMC news releases. The results are reported in Table 2.

Insert Table 2 here

The first column of Table 2 lists the dependent variable, namely risk (Rvar), uncertainty (U2), trading volume, and number of trades in equity and option markets, and stock returns. We adjust the variables to study their abnormal movements by taking the difference between the current value and its moving average over the previous 20 non-event days. The second column presents the time window before (after) announcement time over which the dependent variable is calculated, namely 150, 200, 225, and 300 minutes to serve as robustness checks. The uncertainty measure is computed from 10- (15-) time intervals of 15 (20, 30) observations of one-minute returns. The coefficient estimates and t-statistics (t-stat) of γ_1 and γ_3 of Equation (2) are reported under "FOMC releases" and "non-FOMC releases", respectively. The last two columns present the estimates and

t-stat of γ_5 and γ_7 of Equation (3) to be discussed in Section 4.4. Tables 10 and 11 in the Appendix present the summary statistics in the pre- and post-announcement time window of FOMC (other macro news) days and non-event days for the main variables in our analysis. We refer interested readers to these tables.

4.1 Macro news effects on risk and uncertainty

The results of dynamics in risk and uncertainty around FOMC releases are reported in the first two panels of Table 2 and the first row of Figures 1 and 2. Over the 300-minute window, the mean differential coefficients γ_1 and γ_3 equal -0.4 (t-stat=-4.5) and 1.24 (t-stat=10.44), respectively, significant at the 1% level. When the time window contracts to 225, 200, and 150 minutes, the coefficients are still significant with t-stats greater than 3 in magnitude. This implies that on average, risk before FOMC meetings is lower by 35-40% than that on non-event days, but rises by 124-133% after news. However, the results of uncertainty provide a contrasting view. Over the 300-minute window, the mean differential coefficients γ_1 and γ_3 are 0.71 (t-stat=6.87) and -0.86 (t-stat=-5.82), respectively, both significant at the 1% level. The results are robust to different, shorter time intervals as the coefficients retain their sign and statistical significance with t-stats above 3 in magnitude. Taken together, this shows that the pre-FOMC uncertainty is greater by 68-71% on event days, relative to non-event days. Further, FOMC uncertainty is dramatically lower (by 86-135%) following FOMC announcements.

For non-FOMC news, there appears to be no drastic change in risk and uncertainty before and after announcements. Over the 300-minute window, the estimates of γ_1 and γ_3 in risk regression are 0.03 (t-stat=0.99) and 0.06 (t-stat=1.54), respectively, insignificant at conventional significance levels. These results persist when the time window contracts to 225, 200, and 150 minutes. However, the positive coefficient γ_3 becomes weakly significant at the 10% level. For example, with a 150-minute interval, both γ_1 and γ_3 estimates are 0.04 (t-stat=1.41) and 0.07 (t-stat=1.94), respectively. In general, the post-announcement risk (volatility) increase is consistent with the existing literature on market reactions to macro news, e.g. Lucca and Moench (2015) and Bollerslev et al. (2018) for equity and Balduzzi et al. (2001) for bond markets. With respect to uncertainty, the coefficients γ_1 and γ_3 are essentially zero across different time windows. For example, over the 300-minute interval, their corresponding values are -0.01 (t-stat=-0.15) and 0.00 (t-stat=-0.09), respectively, insignificant at the 10% level.

4.2 Macro news effects on equity trading activity

In the second row of Figures 1 and 2, the distinct effect of FOMC statements relative to non-FOMC macro news is also apparent in trading activity measured by trading volume and number of trades. Over the 300-minute window in Panel 3 of Table 2, the coefficient estimates of γ_1 and γ_3 in the trading volume regression are -0.19 (t-stat=-5.25) and 0.61 (t-stat=12.35), significant at the 1% level. In general, the results with different time intervals and an alternate measure for trading activity, number of trades, remain similar, and the t-stats are all greater than 3 in magnitude. For instance, over the 300-minute interval in Panel 4 of Table 2, the coefficients for γ_1 and γ_3 in the number-of-trades regression are -0.17 (t-stat=-4.83) and 0.56 (t-stat=12.11), respectively. This implies that on average, the pre-FOMC trading volume (number of trades) in the equity market is 19-21% (17-20%) lower than that on non-event days. Following the FOMC announcements, the trading volume (the number of trades) increases by 61-80% (56-75%).

Shifting the focus to non-FOMC news releases, equity trades increase weakly during the post-release period. Over the 300-minute window, the coefficient estimates of γ_1 and γ_3 in the volume regression are 0.00 (t-stat=-0.32) and 0.03 (t-stat=1.65), respectively. As the time interval shortens, only the coefficient for γ_3 becomes significant at the 5% level. For instance, over the shortest window (150-minute window), the coefficient values of γ_1 and γ_3 in the volume regression are 0.00 (t-stat=0.13) and 0.04 (t-stat=2.35), respectively. Taken together, the evidence suggests that investors refrain from equity trade prior to FOMC meetings but trade aggressively once the FOMC news is made public. Meanwhile, equity trades increase moderately following the non-FOMC announcements. The substantially lower level of trading in pre-FOMC equity trades suggests that this may be the case in related derivative markets. To explore this issue, we consider the options market motivated by three reasons: the implicit leverage in options may maximize profits; volatility trading, given the post-announcement rise in volatility; and trades from informed investors may be placed in the options markets.

4.3 Macro news effects on options trading activity

The patterns of option trades around FOMC meetings follow those documented for the equity market (see Panels 5 to 8 of Table 2 and the third and fourth rows of Figure 1). For the number of trades over the 300-minute window, the coefficient estimates of γ_1 and γ_3 are -0.11 (t-stat=-2.39) and 0.5 (t-stat=7.97) for calls; and -0.15 (t-stat=-3.35) and 0.55 (t-stat=8.78) for puts, significant at the 5% level. These results hold across

different time intervals and option types with statistical significance at the 5% level. The only exception is that the coefficient γ_1 is negative but insignificant at the 10% level for volume in calls. For example, for trading volume over the 300-minute window, the coefficients for γ_1 and γ_3 are -0.09 (t-stat=-0.07) and 0.4 (t-stat=5.72) for calls; and -0.16 (t-stat=-2.94) and 0.55 (t-stat=7.22) for puts. Therefore, the pre-FOMC trading volume (number of trades) in the options market is lower by 3-5% (11-12%) for calls and 8-16% (13-16%) for puts. Following the FOMC statements, the trading volume (number of trades) increases by 40-59% (50-65%) for calls and 53-58% (55-67%) for puts.

With respect to non-FOMC announcements, option trading demonstrates a distinct pattern from equity as shown in the third and fourth row of Figure 2. For the number of trades over the 300-minute window, the coefficient estimates of γ_1 and γ_3 are 0.05 (t-stat=3.23) and 0.00 (t-stat=0.15) for calls; and 0.05 (t-stat=3.44) and -0.01 (t-stat=-0.29) for puts. Hence, only the coefficient for γ_1 is significant at the 1% level. This conclusion remains unchanged across different time windows and option types, except that put volume has an insignificant γ_1 coefficient. For instance, the trading volume measured over the 300-minute window has coefficients γ_1 and γ_3 of 0.05 (t-stat=2.78) and -0.01 (t-stat=-0.29) for calls; and 0.02 (t-stat=1.24) and 0.02 (t-stat=0.69) for puts. These results imply that prior to non-FOMC announcements, there is a surge in option trades by 5-6% for both number of trades and volume of calls and puts, while equity trades remains similar to those on non-event days.

Overall, we document that over the pre-FOMC period, uncertainty is higher, but risk and trading activity is lower than during non-event days; this pattern is reversed following the FOMC news releases.[11] For non-FOMC news, both risk and trading activity moderately increase, while uncertainty remains stable in the post-announcement period. The results align with theoretical works whereby high uncertainty depresses market participation and hence reduces trading activity (e.g. Easley and O'Hara, 2010a, b; Ui, 2011). The option trading activity, however, exhibits a surge prior to non-FOMC news, so we analyze what drives this abnormal increase in option trades in Section 4.5.

[11]Boguth et al. (2018) and Gu et al. (2018) find uncertainty (measured by VIX) resolution only after FOMC meetings followed by press conferences and release of a Summary of Economic Projections. The use of VIX as an uncertainty proxy however is controversial, since by construction, it represents the market's expectation of 30-day forward-looking volatility, and Lucca and Moench (2015) use VIX as a measure of stock market volatility (risk). By measuring uncertainty separately from risk, our results of FOMC meetings without press conferences and Summary of Economic Projections in the same announcement day also hold (see Table 13 in the Appendix).

4.4 FOMC vs. non-FOMC news

To compare the magnitude of various dependent variables, y_t, between FOMC and non-FOMC news releases, we merge the two samples and use a difference-in-difference-in-difference estimation strategy. That is, we add in Equation (2) a third dummy variable $type_t$ (equal to 1 for FOMC releases and zero otherwise) and its interactions with other dummy variables as follows:

$$\begin{aligned} y_t =& \gamma_0 + \gamma_1 event_t + \gamma_2 after_t + \gamma_3 type_t + \gamma_4 event_t * after_t \\ &+ \gamma_5 event_t * type_t + \gamma_6 after_t * type_t + \gamma_7 event_t * after_t * type_t + \epsilon_t. \end{aligned} \tag{3}$$

The coefficient γ_5 represents the mean differential in the pre-announcement window between FOMC and non-FOMC news days. The γ_7 measures the average difference in post-announcement window (relative to that in pre-announcement period) between FOMC and non-FOMC news days. The results of Equation (3) are presented in the last two columns of Table 2.[12]

The patterns of risk and uncertainty around FOMC meetings continue to hold. Over the 300-minute window, the mean differential coefficients γ_5 and γ_7 in risk regression equal -0.42 (t-stat=-4.58) and 1.18 (t-stat=9.47), respectively. For uncertainty as the dependent variable, the coefficient estimates of γ_5 and γ_7 are 0.72 (t-stat=6.58) and -0.85 (t-stat=-5.47), respectively. The results are also significant at the 1% level in other shorter time intervals with t-stats greater than 3 in magnitude. On average the pre-FOMC risk is lower by 38-42% than that before non-FOMC news, but higher by 118-125% in the post-announcement period. Regarding uncertainty, the pre-FOMC level is higher by 67-72% than that prior to non-FOMC releases, but lower by 85-136% following the announcements. In summary, the dynamics of risk and uncertainty around FOMC meetings are stronger than those of non-FOMC news.

Trading activity around FOMC announcements exhibits stronger dynamics when compared with non-FOMC news releases. For the number of equity trades over the 300-minute window, the coefficient estimates of γ_5 and γ_7 are -0.17 (t-stat=-4.63) and

[12]Equation (3) also works on days with both FOMC and non-FOMC macro news because their announcement times are different, but in this instance there is overlap between the pre-FOMC period and post-non-FOMC period. For example, given the typical release time of 10:00am for non-FOMC macro news, the pre-(post-) announcement window of 150 minutes ranges from 2:00pm the previous day to just before 10:00am the current day (from 10am to 12:30pm the current day). Meanwhile, with the release time of 2:00pm for FOMC macro news, the pre-(post-) announcement window of 150 minutes ranges from 11:30am to just before 2:00pm the current day (from 2:00pm the current day to 10:00am the next day). We show that results are strongest (with the largest coefficient magnitude) over the shortest 150-minute window, where there is minimal overlap as described above.

0.54 (t-stat=10.84), significant at the 1% level. The results are robust to different time intervals, trading volume as a proxy of trading activity, and equity or options markets, with statistical significance at the 1 to 5% levels. An exception is that the coefficient γ_5 is weakly significant for trading volume of call options. On average, the pre-FOMC trading volume (number of trades) is lower than that before non-FOMC releases by 18-22% (17-21%) and 15-18% (16-21%) in equity and options markets, respectively. Once the news is released, the post-FOMC trading volume (number of trades) in the equity market increases by 58-75% (54-70%) relative to that after non-FOMC news. The corresponding values in option markets are 41-59% and 49-65% for trading volume and number of trades, respectively.

4.5 Abnormal trading in option market before non-FOMC releases

Sections 4.2 and 4.3 have reported an increase in option trades associated with no significant change in equity trading before non-FOMC macro news. We argue that if high uncertainty is perceived by option investors, whether their motivation is for bets on future volatility or trades based on private information, they would not trade at this time due to concerns of working with an unidentified returns distribution. The literature has documented an increase in post-announcement equity volatility (e.g. Balduzzi et al., 2001; Bollerslev et al., 2018), and evidence of information leakage (e.g. Bernile et al., 2016) and superior forecastability (e.g. Kurov et al., 2018) prior to news releases. However, the options market offers a great venue to traders to exploit their insights given the implicit leverage to maximize profit (e.g. Back, 1992; Biais and Hillion, 1994). To formally test if trades of investors with superior information contribute to the rise in option trades prior to non-FOMC news, we first calculate the option-to-equity trade ratio. This is defined as the natural logarithm of the ratio between volume (number of trades) in option and equity markets over the time window prior to news releases. This option-to-equity trade ratio then serves as the dependent variable in a regression on a dummy variable $event_t$ (equal to 1 on event days):

$$y_t = \gamma_0 + \gamma_1 event_t + \epsilon_t. \tag{4}$$

The coefficient γ_1 presents the mean differential between event and non-event days, and the constant γ_0 is interpreted as the average of log option-to-equity trade ratio on non-event days. Table 3 presents regression estimates of Equation (4), where the first column presents the length of time over which the pre-announcement window for the option-to-equity trade ratio is calculated, e.g. 150, 200, 225, and 300 minutes. The second column

lists the option-to-equity trade ratio for calls, puts, and total options, and the next (last) two columns exhibit the coefficient estimates and t-stats of γ_1 for (non-) FOMC releases.

Insert Table 3 here

We first discuss the results for FOMC meetings. For the number-of-trades ratio over the 300-minute window, the coefficient estimate of γ_1 is 0.06 (t-stat=1.63) for calls, 0.02 (t-stat=0.49) for puts, and 0.03 (t-stat=1) for all options, where all of these estimates are insignificant. The results do not change across different time intervals with γ_1 mostly insignificant. When trading activity is proxied by volume, the statistical significance of coefficient γ_1, however, varies with option type and time window. For example, comparing the 300- vs. 150-minute windows, the estimate of γ_1 is 0.18 (t-stat=3.71) vs. 0.19 (t-stat=3.1) for calls; 0.03 (t-stat=0.63) vs. 0.13 (t-stat=1.74) for puts; and 0.08 (t-stat=1.81) vs. 0.15 (t-stat=2.39) for all options. In general, the results does not consistently support a higher option-to-equity trade ratio before the FOMC releases.

Moving to non-FOMC news, the coefficient for γ_1 is positive and statistically significant. For the number-of-trades ratio over the 300-minute window, the coefficient estimate of γ_1 is 0.05 (t-stat=3.89) for calls, 0.05 (t-stat=4.34) for puts, and 0.05 (t-stat=4.26) for all options, and all are significant at the 1% level. These significant results are robust to different time intervals, option type, and using volume as another proxy of trading activity. For example, for the volume ratio over the 300-minute window, the coefficient for γ_1 is 0.05 (t-stat=3.58) for calls, 0.03 (t-stat=1.82) for puts, and 0.04 (t-stat=2.85) for all options. In general, options are traded more frequently than equity prior to non-FOMC announcements.

Next we evaluate whether the increase in the pre-announcement option-to-equity trade ratio is explained by trades from informed investors. The initial work of Roll et al. (2010) looks at the ratio of option to equity trades and investigates whether traders act on the options market to exploit their insights around earnings announcements. Roll et al. (2010) argue that if the pre-announcement option-to-equity trade ratio is due to investors with an information advantage, it should predict the post-announcement returns, and that this relation depends on the size of pre-announcement equity returns. That is, profit-taking by these traders could induce larger absolute pre-announcement returns and hence noisier returns after news. This would imply that post-announcement equity returns are less sensitive to the pre-announcement option-to-equity trade ratio. We follow Roll et al. (2010) and run a regression on the sample restricted to observations

on event days:

$$|ret|_{post,t} = \gamma_0 + \gamma_1 ln(O/E)_{pre,t} + \gamma_2 ln(O/E)_{pre,t}|ret|_{pre,t} + \epsilon_t, \tag{5}$$

where the coefficients for γ_1 and γ_2 are expected to be positive and negative, respectively. Table 4 presents regression estimates of Equation (5), where the first and second columns list the time length of the pre-announcement window and the explanatory variables associated with γ_1 and γ_2, respectively. The next columns present the estimates and t-stats of coefficients in the regression for calls, puts, and all options.

Insert Table 4 here

With regard to FOMC meetings, the results do not support the notion that investors with an information advantage trade in option markets. For the number-of-trades ratio over the 300-minute window, the coefficient estimates of γ_1 and γ_2 are -0.012 (t-stat=-1.87) and 2.963 (t-stat=2.74) for calls; -0.008 (t-stat=-1.12) and 1.041 (t-stat=1.16) for puts; and -0.013 (t-stat=-1.84) and 2.789 (t-stat=2.3) for all options. The significant coefficients are of opposite signs, which contradicts the discussion above. The coefficient signs remain robust across different time intervals, option types, and volume as another proxy of trading activity. We document that both pre-FOMC option and equity trades are lower than those on non-event days, although the option-to-equity trade ratio is inconsistently higher before FOMC meetings. This indicates that the decreasing rate of option trades is lower than that of equity trades.

However, we find strong evidence that investors with an information advantage trade in option markets before non-FOMC announcements. For the number-of-trades ratio over the 225-minute window, the estimates of γ_1 and γ_2 are 0.002 (t-stat=3.97) and -0.183 (t-stat=-3.8) for calls; 0.002 (t-stat=4.32) and -0.178 (t-stat=-4.05) for puts; and 0.002 (t-stat=4.18) and -0.183 (t-stat=-4.04) for all options, and all are significant at the 1% level. These results hold across different time intervals and trade volume, and the statistical significance varies between 1 and 5% levels in most cases. The only exception is for the 300-minute window because the coefficients become insignificant, although their signs are still positive for γ_1 and negative for γ_2. For example, for the number-of-trades ratio over 300 minutes, the coefficient values of γ_1 and γ_2 are 0.001 (t-stat=1.52) and -0.065 (t-stat=-0.91) for calls; 0.002 (t-stat=2.14) and -0.089 (t-stat=-1.28) for puts; and 0.001 (t-stat=1.89) and -0.079 (t-stat=-1.13) for all options.

Our evidence on informed investors and their activities prior to non-FOMC news

aligns with recent empirical work. Kurov et al. (2018) document a price drift in the 30 minutes before U.S. macroeconomic news over January 2008-March 2014. They argue that this originates from a combination of information leakage and superior forecasting of market participants that incorporates proprietary data. In particular, the pre-announcement market prices move in the "correct" direction predicted by announcement surprise; that is, stock prices increase and bond prices decrease before good economic news, and vice versa for bad news. Since our sample period overlaps that of Kurov et al. (2018), we explore further their results. Kurov et al. (2018) report that the "correct" direction of the pre-release price movement is significant prior to 4 news releases, but insignificant with a "correct" sign for another 4 macro announcements among our 12 common non-FOMC news items. Our sample of non-FOMC macro news is also relevant to financial markets. For example, in Kurov et al. (2018), stock and bond market prices react to news surprises in 8 out of 12 non-FOMC news releases (this is for a time window from 30 minutes before to 5 minutes after the announcement). Similarly, the surprise components in 10 out of our common 12 non-monetary policy news impact stock market returns over 5 minutes before and after news releases during 2008-2014 as in Chordia et al. (2017). Taken together, our findings are consistent with literature on information leakage and superior forecastability prior to macro news releases, but we focus on options trading over the longer pre-announcement time window between 150 to 300 minutes before news release.

Overall, for non-FOMC news, the rise in pre-announcement option trades may be due to investors with information advantage or trades to exploit the surge in post-announcement volatility, and uncertainty remains stable after news. For FOMC meetings, the option trades instead reduce before the release time, and the post-announcement uncertainty dramatically drops from the excessively high pre-announcement level. This suggests that high uncertainty offsets the benefits of superior information or volatility trades and discourages investors from exploiting their insights in option markets prior to FOMC news.

5 The relation between risk, uncertainty, and trading activity

In this section, we investigate how risk and uncertainty around macro news releases can explain trading activity. The literature has documented a positive relation between volatility (risk) and volume, e.g. Bollerslev et al. (2018) and references therein. Recent

theoretical works (see Easley and O'Hara, 2010a, b) demonstrate how high uncertainty limits market participation and hence trading activity, and Cao et al. (2005) and Ui (2011) study both risk and uncertainty effects on financial markets in a consolidated framework.[13] Hence, we are interested in how perceived risk and uncertainty are associated simultaneously with trading activity. Therefore, we estimate the following regression of trading activity $volume_t(trade_t)$ on a dummy variable $event_t$ (equal to 1 on event days), risk $Rvar_t$, uncertainty $U2_t$, and their interactions with $event_t$. The data sample includes observations calculated over the pre-announcement period on (non-) event days, separately for FOMC meetings and non-FOMC macro news. We repeat this for the post-announcement observations. The resulting regression is:

$$volume_t = \gamma_0 + \gamma_1 event_t + \gamma_2 Rvar_t + \gamma_3 U2_t + \gamma_4 Rvar_t event_t + \gamma_5 U2_t event_t + \epsilon_t. \quad (6)$$

The variables $Rvar_t$ and $U2_t$ are interpreted as the shocks to risk and uncertainty since they are adjusted by the 20-day moving average presented in Section 4.[14] For ease of interpretation, all variables are divided by their sample standard deviation so that the coefficients present the effect of one standard deviation (sigma) in explanatory variable on that in dependent variable. We also present the benchmark regression with only dummy variable $event_t$ to see how its coefficient and the adjusted R^2 change as we add risk and uncertainty to the regression. Tables 5 through 8 present regression estimates of Equation (6) with the dependent variables being volume around the FOMC and non-FOMC news releases.[15] The first column lists the market (namely equity, calls and puts) and the second column presents the Adj-R^2 (%) and the regressors associated with coefficients γ_1 to γ_5. Different time windows over which the variables are calculated are shown under column "range", and the next columns report the coefficient estimates and t-stats of Equation (6).

[13] We note that this stream of literature has mainly focused on the relation between returns and risk and uncertainty; see Bekaert et al. (2009) and Brenner and Izhakian (2018), among others.

[14] Lucca and Moench (2015) raise the importance of decomposing volatility into innovation and expectation terms and report the statistical significance only for innovation term. They use the VIX innovation as a measure of risk, although VIX also commonly proxies for uncertainty; see Bloom (2009).

[15] Tables 14 through 17 present results using the number of transactions as the dependent variable.

5.1 Pre-announcement results

5.1.1 FOMC news

We present the results of trading activity prior to FOMC announcements in Table 5.

Insert Tables 5

When only $event_t$ is included in the regression of pre-FOMC volume (see column (1) in Table 5), the coefficient γ_1 is consistently negative across different time intervals and equity and put option markets, and is significantly different from zero at the 1 to 5% levels. For example, over the 300-minute window or 10 intervals of 30 minutes, the coefficient estimate of γ_1 is -0.61 (t-stat=-5.25) for equity, -0.01 (t-stat=-0.07) for calls, and -0.32 (t-stat=-2.94) for puts. On average, pre-FOMC trading volume is lower by 54% to 61% in the equity market, 1% to 10% in calls, and 12% to 32% in puts.

With the addition of volatility shocks to the model specification, as reported in column (2), the dummy coefficient γ_1 falls in magnitude and statistical significance. This effect is maintained with a 300-minute time interval. In column (2) of Table 5, the coefficient for γ_1 is -0.16 (t-stat=-2.39) for equity, 0.2 (t-stat=2.02) for calls, and -0.1 (t-stat=-1.03) for puts. In general, γ_1 in the volume regression reduces to -16 or -26% for equity and is insignificant for puts. This value becomes positive but is only significant at the 5 to 10% levels over the 300-minute window for call volume. The volatility coefficient γ_2 is positive and significant at the 1% level. In the volume regression of Table 5, the estimate of γ_2 is 0.79 (t-stat=40.94) for equity, 0.38 (t-stat=18.25) for calls, and 0.4 (t-stat=19.57) for puts over the 300-minute window. Also, the adjusted R^2 rises from 1.1% to 63.27% for equity, -0.04% to 14.24% for calls, and 0.27% to 16.48% for puts. This implies that an increase in one sigma of risk shock increases the trade volatility by 74% to 79% in equity and 34% to 40% in options, and the adjusted R^2 also rises sharply from less than 1% to more than 55% in equity, and more than 12% in options.

With regard to the stand-alone uncertainty shocks reported in column (3) of Table 5, the coefficient γ_1 becomes insignificant with a smaller magnitude in the equity regression, relative to values from column (2). For the 300-minute interval, γ_1 is -0.09 (t-stat=-0.97) for equity, 0.24 (t-stat=2.51) for calls, and -0.04 (t-stat=-0.38) for puts. Overall, γ_1 in the volume regression falls to -16% to -18% for equity and is insignificant for puts (but becomes positive and significant at the 5% level only for the 300-minute window for calls). The uncertainty coefficient γ_3 is negative and significant at the 1% level. Regarding the volume regression, the estimate of γ_3 is -0.63 (t-stat=-30.66) for equity, -0.31 (t-stat=-

14.1) for calls, and -0.35 (t-stat=-16.17) for puts over the 300-minute window; and the adjusted R^2 also improves from column (1), i.e. 40.2% from 1.1% in equity, 9.12% from -0.04% in calls, and 12.15% from 0.27% in puts options. On average, an increase of one sigma in uncertainty shock decreases the trade sigma by 53% to 63% in equity and 25% to 35% in options. The adjusted R^2 increases substantially from less than 1% to at least 29% in equity and 5% in options.

Uncertainty shocks also help reduce the statistical significance of γ_1 across different time intervals, as shown in column (4). Over the 300-minute window, the coefficient of γ_1 becomes -0.04 (t-stat=-0.68) for equity, 0.26 (t-stat=2.7) for calls, and -0.02 (t-stat=-0.2) for puts; and the adjusted R^2 increases by 1% to 4% in column (2) of Table 5. This supports the important role of uncertainty in explaining the magnitude of γ_1. The adjusted R^2 continues to increase by 3% to 5% in equity and by 1 to 2% in options overall.[16]

The inclusion of uncertainty shocks does not affect the positive relation between risk and trading activity. Over the 300-minute window, γ_2 reduces from 0.79 to 0.65 (t-stat=27.88) for equity, from 0.38 to 0.31 (t-stat=12.31) for calls, and from 0.4 to 0.31 (t-stat=12.07) for puts in the volume regression. The decrease in magnitude of γ_2 is similar over different time intervals, with statistical significance at the 1% level. More importantly, the sign coefficient for γ_3 remains significantly negative, which aligns with theoretical works on the relation between market participation and uncertainty. Following the example above with volume regression, the estimate of γ_3 is -0.25 (t-stat=-12.54) for equity, -0.12 (t-stat=-5.14) for calls, and -0.17 (t-stat=-6.57). On average, a one sigma increase in uncertainty shocks suppresses the trade sigma by 19% to 27% for equity, 9% to 13% for calls, and 13% to 18% for puts.

When we consider the effect of interaction terms, reported in column (5), we note that their coefficients are close to zero and insignificant, so this implies the robust negative (positive) relations between trading activity and uncertainty (volatility) on FOMC days. For instance, in the case of the 300-minute interval, the coefficients for γ_4 and γ_5 are at most 0.2 in magnitude, and their statistical significance is greater than 10% for equity and option markets. We note that without considering the uncertainty measure, the role of risk is overestimated by 14-27% for equity and option trades.

[16] In the number-of-trade regression reported in the Appendix, the coefficient γ_1 is essentially zero in columns (2) to (4).

5.1.2 Non-FOMC news

We next discuss the results prior to non-FOMC news in Table 6.

Insert Table 6

In column (1) of Table 6 with stand-alone $event_t$ in the regression, the coefficient for γ_1 is not significant for equity. Further, it is consistent with no significant changes in equity trades as reported in Table 2. However, there is a significant increase in trading activity in options before non-FOMC news, where the coefficient of γ_1 is positive and significant at the 1% level for options. Over the 300-minute window, the estimate of γ_1 in the volume regression is -0.01 (t-stat=-0.32) for equity, 0.1 (t-stat=2.78) for calls, and 0.04 (t-stat=1.24) for puts. When volatility and uncertainty shocks are added, the coefficient for γ_1 remains insignificant for equity as expected, and is relatively unchanged (as reported in column (1) across different time intervals) for options. In column (4), the estimate of γ_1 is -0.03 (t-stat=-1.37) for equity, 0.09 (t-stat=2.73) for calls, and 0.03 (t-stat=1.02) for puts in the volume regression.

The coefficient signs of γ_2 and γ_3 of volatility and uncertainty shocks yield results similar to those reported for the pre-FOMC regression and they are significant at the 1% level. Over the 300-minute window, the estimate of γ_2 is 0.65 (t-stat=38.11) for equity, 0.38 (t-stat=24.77) for calls, and 0.4 (t-stat=24.54) for puts; and the corresponding values of γ_3 across markets are -0.23 (t-stat=-16.48), -0.09 (t-stat=-6.18), and -0.08 (t-stat=-5.18) in the volume regression. The adjusted R^2 also improves, e.g. from -0.02% to 58.47% for equity, from 0.13% to 17.65% for calls, and from 0.01% to 18.81% for puts in the same example. The risk effect is also overestimated by 7-16% without controlling for uncertainty.

The interaction terms in column (5) are however only insignificant at the shorter time window in the volume regression. In particular, over the 300-minute window, the coefficient γ_4 in Table 6 is positive at 0.08 to 0.1 (t-stat between 1.85 and 2.17) for equity, 0.07 (t-stat=1.68) for calls, and 0.1 to 0.11 (t-stat between 2.26 and 2.31) for puts. The coefficient γ_5 in Table 6 is estimated at 0.06 (t-stat=2.01) for equity, 0.05 (t-stat=1.57) for calls, and 0.07 (t-stat=1.79) for puts, with a magnitude much lower than γ_3.[17] Therefore, either a positive volatility shock or negative uncertainty innovation is associated with an increase in option trades. These effects, however, are unable to explain fully the surge in option trades prior to non-FOMC announcements, since on average

[17] In the number-of-trades regression in the Appendix, the interaction terms in column (5) are also insignificant.

option trading activity increases by 7% to 13%, even with volatility and uncertainty controls.

5.2 Post-announcement results

5.2.1 FOMC news

In regard to the post-announcement period, we present the results in Eq.(6) for FOMC news in Table 7.

Insert Table 7

Shifting the focus to post-FOMC trading activity presented in Table 7, the general relation between trading and volatility or uncertainty is maintained. In column (1), the coefficient for γ_1 is 1.33 (t-stat=12.37) for equity, 0.82 (t-stat=8.06) for calls, and 0.82 (t-stat=7.28) for puts over the 300-minute window or 10 30-minute intervals. The results hold in other time windows and are significant at the 1% level, which implies that after FOMC news, volume increasesa by 133% to 159% in equity and 80% to 100% in options.

The addition of volatility shocks in column (2) of Table 7 halves the value of γ_1 and improves the reported adjusted R^2. Over the 300-minute window, the estimate of γ_1 in Table 7 becomes 0.54 (t-stat=6.85) for equity, 0.4 (t-stat=4.26) for calls, and 0.38 (t-stat=3.61) for puts; and the adjusted R^2 increases from 5.44% to 59.48% for equity, from 2.03% to 16.81% for calls, and from 2% to 18.34% for puts. On average, the dummy coefficient γ_1 reduces to 51-70% in equity and 34-53% in options, which are all significant at the 1% level. The goodness-of-fit improves from about 5-8% to 49-60% for equity and from 2-3% to 14-18% for options across different time intervals. On the other hand, the coefficient for γ_2 of volatility shocks is positive and significant at the 1% level, and its estimate is close to that reported in column (2) of Table 5. For example, the estimate of γ_2 is 0.75 (t-stat=27.86) for equity, 0.39 (t-stat=17.17) for calls, and 0.41 (t-stat=17.66) for puts over the 300-minute interval in Table 7.

With the inclusion of uncertainty shocks in column (3) of Table 7, the coefficient γ_1 falls in magnitude and is associated with a substantial increase in adjusted R^2. In the 300-minute window example, γ_1 becomes 1.25 (t-stat=11.13) for equity, 0.78 (t-stat=7.51) for calls, and 0.77 (t-stat=6.76) for puts; and the adjusted R^2 improves from 5.44% to 30.79% for equity, from 2.03% to 8.33% for calls, and from 2% to 8.43% for puts. Overall, the dummy γ_1 moderately reduces to 113-131% in equity and 68-86% in options, which are all significant at the 1% level. In addition, the regression explanatory power increases to 24-31% for equity and 6-9% for options with different time intervals.

The coefficient for γ_3 is still negative and significant at the 1% level, whose estimates are similar to those documented in the pre-announcement period. Over the 300-minute window example in Table 7, γ_3 is estimated at -0.5 (t-stat=-18.49) for equity, -0.25 (t-stat=-10.12) for calls, and -0.25 (t-stat=-10.24) for puts.

In column (4) with both risk and uncertainty shocks, both the coefficients for γ_1 and γ_2 marginally change their statistical significance. The estimate of γ_1 in Table 7 is 0.61 (t-stat=7.48) for equity, 0.44 (t-stat=4.53) for calls, and 0.41 (t-stat=3.86) for puts; and the corresponding γ_2 across markets are 0.65 (t-stat=24.21), 0.34 (t-stat=14.37), and 0.37 (t-stat=14.99) over the 300-minute window. The uncertainty coefficient γ_3 is negative, significant at the 1% level, and very close to that in column (4) of Table 5. The adjusted R^2 also increases on average by 6% for equity and 1-2% for options in column (2). In the example above, the estimate of γ_3 is -0.24 (t-stat=-12.41) for equity, -0.11 (t-stat=-5.43) for calls, and -0.11 (t-stat=-4.96) for puts; and the adjusted R^2 rises to 64.43%, 17.86%, and 19.26%, respectively, for volume regression.

To assess the volatility and uncertainty coefficients on event days, we include their interaction terms with the dummy variable $event_t$ and report the outcomes in column (5) of Table 7. For the equity market, the coefficients for γ_1 to γ_3 carry the same values as in column (4). The interaction term of uncertainty, however, yields different results from those in the pre-FOMC period. In the volume regression, the coefficient γ_5 becomes positive and significant at the 10% level in one case and at the 5% level in the other cases.[18] For example, the estimate of γ_5 in Table 7 is 0.23 (t-stat=3.46) over the 300-minute window, but 0.15 (t-stat=1.7) over the 225-minute time interval. Meanwhile, γ_4 is insignificant at conventional levels, and it is 0.08 (t-stat=0.89) over the 300-minute window. Taken together, a one sigma decrease in uncertainty shocks intensifies volume by 2-9% ($\gamma_3 + \gamma_5$); whereas a one sigma increase of volatility shocks increases trading by 59-64%. With respect to option markets, the coefficient for γ_5 is larger in magnitude than γ_3, where it is mostly insignificant over different time windows for puts but statistically significant at the 1 to 5% levels in two cases for calls.[19] For example, the estimate of γ_5 is 0.14 (t-stat=1.68) for calls and 0.15 (t-stat=1.51) for puts over the 300-minute interval in Table 7.

[18] In the number-of-trades regression, the coefficient γ_5 turns positive and significant at the 5% level in three cases and marginally significant (t-stat above 1.49) in the other two cases.

[19] The coefficient γ_5 is mostly insignificant in the number-of-trades regression.

5.2.2 Non-FOMC news

We present the results on trades following non-FOMC news in Table 8.

Insert Tables 8

Section 4 documents a weak increase in post-announcement equity trade for non-FOMC news. We continue to explain this in terms of risk and uncertainty. From column (1) of Table 8, the coefficient for γ_1 is positive and significant at the 1% level across different time intervals and markets. Over the 300-minute window, the estimate of γ_1 is 0.07 (t-stat=2.02) for equity, 0.09 (t-stat=2.39) for calls, and 0.08 (t-stat=2.18) for puts. We note that these results contradict weakly significant changes reported in Section 4. This is because from Equation (2) we are interested in the difference in option trading between the pre- and post-announcement periods. Equation (6), however, runs on the observations following news releases. In other words, option trades in the post-announcement period on event days are higher than those on non-event days, but remain unchanged relative to those prior to news releases.

When volatility and uncertainty shocks are added in column (4), the coefficient for γ_1 becomes insignificant for equity, but positive and significant for option markets in two cases with call volume regression. In our example, the coefficient for γ_1 in Table 8 is 0.00 (t-stat=0.22) for equity, 0.05 (t-stat=1.49) for calls, and 0.04 (t-stat=1.27) for puts. Regarding the coefficients for γ_2 and γ_3, we find a positive (negative) relation between volatility (uncertainty) and volume. The coefficients are similar to those in Table 7 both in terms of magnitude and statistical significance at 1%. For the the longest window (300-minute window), the estimate of γ_2 in the volume regression is 0.65 (t-stat=42.69) for equity, 0.36 (t-stat=24.37) for calls, and 0.36 (t-stat=23.83) for puts; and γ_3 has coefficient values of -0.26 (t-stat=-19.95), -0.09 (t-stat=-6.34) and -0.12 (t-stat=-7.78) across these respective markets. The adjusted R^2 improves substantially, e.g. from 0.06% to 64.51% for equity, 0.09% to 16.84% for calls, and 0.07% to 18.38% for puts in the same example. Lastly, the interaction terms of volatility and uncertainty are largely insignificant across time windows and markets as reported in column (5) (with the exception that it is positive and significant at the 5% level in two cases for the put volume regression). Over the 300-minute window, the coefficients for γ_4 and γ_5 in Table 8 are at most 0.06 in magnitude and insignificant for equity and option markets, but become 0.1 and statistically significant at the 5% level for puts. Similar to the pre-regression results, the risk effect is overestimated by 9-13% in FOMC and 10-23% in non-FOMC regressions in the absence of uncertainty control.

Overall, we document that trading increases with volatility or risk but decreases with uncertainty, supporting the theoretical explanation on volume-volatility and market participation-uncertainty relations. Without controlling for uncertainty, the volume-risk relation is overestimated on average by 7% to 27% in the regressions of both FOMC and non-FOMC news. In addition, the surge in option trades prior to non-FOMC announcements is not completely captured by controls for risk and uncertainty in the equity market, reinforcing the informed trading hypothesis.

6 Macro news effects on stock returns

Lucca and Moench (2015) report that stock market returns drift upward only prior to FOMC meetings and focus on a risk-based explanation for this phenomenon. Given that risk and uncertainty behave differently around FOMC releases as shown above, we are interested in how stock market returns are related to changes in risk as well as uncertainty. We first confirm the pre-announcement drift in our sample period and then examine the relation of stock returns with changes in risk and uncertainty.

We present the pre- and post-FOMC returns calculated over the same time intervals used to measure risk and uncertainty in the last panel of Table 2. For the longest time interval (300-minute window), the mean differentials γ_1 and γ_3 are 0.21 (t-stat=2.67) and -0.33 (t-stat=-1.83), significant at the 1% and 10% levels, respectively. This implies that the pre-FOMC returns are higher by 21 basis points (bps) on event days than those for non-event days. However, post-FOMC stock returns are lower than the pre-announcement value by 33 bps. The coefficients maintain their sign, but their magnitude and statistical significance become weaker as the time interval shrinks to 225 or 150 minutes.[20] For example, over the 225-minute window, the estimates of γ_1 and γ_3 are 0.1 (t-stat=2.15) and -0.18 (t-stat=-1.13), respectively; and over the 150-minute interval, the corresponding values are 0.07 (t-stat=1.62) and -0.06 (t-stat=-0.47). With respect to non-FOMC macro news, the mean returns differentials before and after the announcement are insignificantly different from zero regardless of the time window. For instance, the coefficient estimates γ_1 and γ_3 are -0.04 (t-stat=-1.42) and 0.05 (t-stat=1.15) over the 300-minute window, respectively. The longer the time interval, the higher pre-FOMC market returns, but the lower the post-FOMC market returns. In addition, pre-FOMC market returns are higher than those prior to non-FOMC releases as shown by the γ_5 coefficient of 0.25 (t-stat=3) over the 300-minute window. Similar to the coefficient es-

[20]The weaker results over the short pre-FOMC window are consistent with Figure 1 in Lucca and Moench (2015).

timates of γ_1 under "FOMC releases", the magnitude and statistical significance of γ_5 become weaker as the time interval shrinks to 225 or 150 minutes. Overall, our evidence is consistent with Lucca and Moench (2015) who document a pre-FOMC positive price drift in the stock market.

6.1 Pre-FOMC positive price drift

We report that the positive price drift in the equity market is associated with low risk and trading activity but high uncertainty prior to the FOMC announcements. After the FOMC releases, both risk and trading activity increase dramatically, but uncertainty falls significantly. The contemporaneous relation between returns and volatility (or risk) is well studied in the literature; see Campbell and Hentschel (1992) among others. To evaluate the role of risk and uncertainty on returns before the FOMC meetings, we run a regression of pre-FOMC returns on a dummy variable $event_t$ (equal to 1 in on FOMC days), risk $Rvar_t$, uncertainty $U2_t$, and their interactions with dummy $event_t$. The data sample includes observations calculated over the pre-announcement period on (non-) event days. The regression is presented as follows:

$$\begin{aligned} ret_t =& \gamma_0 + \gamma_1 event_t + \gamma_2 Rvar_t + \gamma_3 U2_t + \\ &+ \gamma_4 Rvar_t event_t + \gamma_5 U2_t event_t + \epsilon_t. \end{aligned} \tag{7}$$

The variables $Rvar_t$ and $U2_t$ are also interpreted as shocks to risk and uncertainty as in Equation (7). We are not only interested in the relation between risk, uncertainty and returns on non-event days but also at times of FOMC release as shown by the interaction terms. We also run a benchmark regression with only the event dummy to see how its coefficient and adjusted R^2 change as we add explanatory variables. We normalize all variables by dividing them by their sample standard deviation for ease of interpretation. Table 9 presents regression estimates for Equation (7), where the first column lists different time windows. The second column presents the Adj-R^2 (%) and the regressors associated with coefficients γ_0 to γ_5, and the next columns report the coefficient estimates and t-stats of Equation (7).

Insert Table 9 here

The results for pre-FOMC returns are presented in Table 9. When only $event_t$ is included in the regression, its coefficient γ_1 is positive and significant at the 1 to 5% levels over longer time intervals. For the longest time interval (300-minute window),

the estimate of γ_1 is 0.25 (t-stat=2.67) and significant at the 1% level; the coefficient becomes 0.14 (t-stat=1.62) for the shortest window (150-minute window). These results imply that the pre-FOMC returns are on average 12-20 bps ($\gamma_0 + \gamma_1$). With the addition of volatility and uncertainty shocks in column (2), the coefficient magnitude of γ_1 falls significantly. Following our example above, γ_1 is estimated at 0.04 (t-stat=0.39) and 0.08 (t-stat=0.87) over the 300- and 150-minute windows, respectively.

The coefficients of volatility and uncertainty shocks are negative and positive, respectively, and their statistical significance varies over different time intervals. The estimates of γ_2 and γ_3 are -0.05 (t-stat=-1.25) and 0.22 (t-stat=4.82), respectively, over the 300-minute window. These coefficient values become -0.11 (t-stat=-3.01) and 0.02 (t-stat=0.43) over the 150-minute window. Hence, a one sigma decrease in volatility (increase in uncertainty) shocks is associated with a 11-16% (7-22%) increase in return volatility across different time intervals. Finally, the adjusted R^2 shows some improvement, e.g. from 0.14% to 6.22% over the 300-minute window. In addition, the positive sign of the uncertainty coefficient supports Cao et al. (2005) who decompose equity premia into risk and uncertainty components. They propose that at times of high uncertainty, not all investors participate in the market because uncertainty-averse agents choose not to enter. The investors who remain in the market are more willing to accept a lower uncertainty premium. However, the risk premium could be high to attract investors to hold stocks as they are the only ones bearing risk. This may explain why equity premia under limited participation can be lower than for the full participation case (i.e. with the presence of ambiguity-averse investors).

We turn to the relation between returns and risk and uncertainty on FOMC days. The coefficients of γ_2 and γ_3 in column (3) are similar to those in column (2), and the statistical significance of interactions with volatility and uncertainty vary across time intervals of different length. For example, the coefficient for γ_4 is -0.26 (t-stat=-1.88) and -0.09 (t-stat=-0.8) over the 300- and 150-minute intervals, respectively. More interestingly, the uncertainty-return relation turns negative, and its statistical significance is strongest over the 300-minute window. That is, the estimate of γ_5 is -0.48 (t-stat=-2.57) or -0.37 (t-stat=-2.02) with uncertainty measured from 10 30-minute intervals or 20 15-minute intervals, respectively. On average, a one sigma increase in uncertainty shocks is associated with a decrease of 22% to 25% ($\gamma_3 + \gamma_5$) in returns. The adjusted R^2 shows a marginal increase from 6.22% to 6.63% and from 6.21% to 6.48% in the two 300-minute examples above, and this is due to only 72 FOMC meetings in our sample period.

In conclusion, the pre-FOMC returns could be explained by volatility and uncertainty shocks given the improved adjusted R^2 and insignificant mean return differential

on FOMC days. Ui (2011) argues that the equity premium increases (current prices fall) when the difference in uncertainty between limited and full participation is higher than some threshold. The high uncertainty and low trading just prior to FOMC announcements illustrate that investors are aware of excessive ambiguity. If ambiguity is high enough, investors can demand high uncertainty or equity premium to hold stocks, especially when the risk premium is small, as evidenced by low pre-FOMC volatility (risk).

7 Conclusion

We stress the distinct roles of risk and uncertainty in trading activity around macro news releases. We use the uncertainty measure outlined in Izhakian (2017), while risk is measured by the more traditional realized volatility. We find a high degree of uncertainty coupled with low risk and trading activity prior to FOMC announcements; this pattern reverses after the FOMC meetings. This uncertainty resolution leads to a sustained increase in post-FOMC trading volume. This is consistent with the text-based FOMC clarifying information on target rate decisions, and hence encourages investors to trade more after the announcement. For non-FOMC macro news, we find that uncertainty remains stable, but risk and trading activity increase moderately following the announcements. In addition, we observe a rise in option trading level before non-FOMC news releases, consistent with the presence of informed trading. Consistent with the work of others, we report strong volatility-volume co-movement, and more importantly, a negative uncertainty-trading activity relation (e.g. Cao et al., 2005; Ui, 2011, , among others). Further analysis of stock returns shows that high uncertainty before FOMC announcements potentially contributes to higher market returns, in addition to any effects of risk at this time. We find risk and uncertainty play different roles in trading activity and market returns, and that these differences are consistent with existing theory.

Table 1: **Key macroeconomic announcements**

Index	release time	frequency	start date	# estimates	N announcements	positive surp	negative surp
ISM manufacturing	10:00	monthly	20050103	75	108	57%	40%
Construction spending	10:00	monthly	20050103	48	107	49%	48%
ISM Non-manufacturing	10:00	monthly	20080205	71	71	56%	44%
Factory orders	10:00	monthly	20050104	62	107	51%	46%
Wholesale inventories	10:00	monthly	20050110	32	108	56%	40%
Business inventories	10:00	monthly	20050114	50	108	41%	42%
FED target fund rate	14:15	8 times per year	20050202	82	72	1%	3%
Leading indicator	10:00	monthly	20050120	54	108	41%	35%
Existing home sales	10:00	monthly	20050323	69	106	52%	46%
Consumer sentiment	10:00	monthly	20050204	59	108	59%	39%
New home sales	10:00	monthly	20050131	69	107	45%	52%
Consumer confidence	10:00	monthly	20050125	68	108	51%	49%
Chicago PMI	9:42	monthly	20050131	55	108	60%	39%

This table presents different macro announcement releases during 2005-2013. Release time is the typical announcement time, # estimates is the average number of estimates in the forecast survey per announcement. N announcements is the number of announcements in the sample, and positive (negative) surp is the percentage of positive (negative) surprises, where a surprise is the difference between the released and forecast values.

Table 2: **Risk, uncertainty, trading activity, and stock returns around U.S. macroeconomic news announcements: FOMC and non-FOMC news**

variable		FOMC releases				non-FOMC releases				FOMC vs. non-FOMC releases			
	range (min.)	γ_1	tstat γ_1	γ_3	tstat γ_3	γ_1	tstat γ_1	γ_3	tstat γ_3	γ_5	tstat γ_5	γ_7	tstat γ_7
20-day adjusted	150	-0.35***	-3.64	1.33***	10.19	0.04	1.41	0.07*	1.94	-0.39***	-3.9	1.25***	9.25
ln(Rvar)	200	-0.4***	-4.49	1.24***	10.45	0.03	0.99	0.06	1.53	-0.42***	-4.58	1.18***	9.47
	225	-0.35***	-3.65	1.33***	10.19	0.04	1.31	0.08**	2.01	-0.38***	-3.87	1.25***	9.23
	300	-0.4***	-4.50	1.24***	10.44	0.03	0.99	0.06	1.54	-0.42***	-4.58	1.18***	9.47
20-day adjusted	10 15 min. int	0.68***	6.14	-1.35***	-9.14	-0.02	-0.38	0	-0.03	0.7***	5.91	-1.35***	-8.62
ln(U2)	10 20 min. int	0.68***	6.64	-1.11***	-7.76	0.01	0.14	-0.02	-0.39	0.67***	6.15	-1.09***	-7.19
	15 15 min. int	0.68***	6.15	-1.34***	-9.02	-0.04	-0.91	0.02	0.39	0.72***	6.08	-1.36***	-8.64
	15 20 min. int	0.68***	6.65	-1.12***	-7.74	-0.01	-0.19	-0.01	-0.13	0.68***	6.27	-1.11***	-7.25
	10 30 min. int	0.71***	6.87	-0.86***	-5.82	-0.01	-0.15	0	-0.09	0.72***	6.53	-0.85***	-5.47
20-day adjusted	150	-0.2***	-5.03	0.75***	13.95	0.01	0.64	0.04**	2.55	-0.21***	-4.98	0.7***	12.48
ln(trade)	200	-0.2***	-5.12	0.66***	12.81	0.01	0.45	0.03**	2.00	-0.20***	-5.01	0.63***	11.52
	225	-0.19***	-5.01	0.63***	12.53	0	0.39	0.03**	2.00	-0.19***	-4.88	0.59***	11.21
	300	-0.17***	-4.83	0.56***	12.11	0	0.21	0.03	1.64	-0.17***	-4.63	0.54***	10.84
20-day adjusted	150	-0.21***	-5.04	0.8***	13.69	0	0.13	0.04**	2.35	-0.21***	-4.83	0.75***	12.3
ln(volume)	200	-0.22***	-5.31	0.72***	12.74	0	-0.15	0.04**	1.99	-0.22***	-5.01	0.68***	11.49
	225	-0.21***	-5.22	0.68***	12.47	0	-0.20	0.04**	1.99	-0.21***	-4.91	0.64***	11.19
	300	-0.19***	-5.25	0.61***	12.35	0	-0.32	0.03	1.65	-0.18***	-4.84	0.58***	11.06
20-day adjusted	150	-0.11**	-2.33	0.65***	9.11	0.05***	3.23	0.02	0.82	-0.17***	-3.24	0.63***	8.4
ln(trade)	200	-0.12***	-2.69	0.56***	8.30	0.06***	3.65	0	0.02	-0.18***	-3.76	0.56***	7.86
calls	225	-0.12***	-2.60	0.54***	8.14	0.06***	3.53	0	0.17	-0.17***	-3.63	0.53***	7.64
	300	-0.11**	-2.39	0.5***	7.97	0.05***	3.23	0	0.15	-0.16***	-3.33	0.49***	7.45
20-day adjusted	150	-0.02	-0.34	0.59***	7.03	0.06***	3.19	0	0.01	-0.09	-1.32	0.59***	6.67
ln(volume)	200	-0.05	-0.89	0.52***	6.27	0.06***	3.19	-0.01	-0.35	-0.12*	-1.82	0.53***	6.07
calls	225	-0.03	-0.58	0.48***	6.01	0.06***	3.07	-0.01	-0.25	-0.09	-1.51	0.48***	5.77
	300	0	-0.07	0.4***	5.72	0.05***	2.78	-0.01	-0.29	-0.05	-1.02	0.41***	5.47
20-day adjusted	150	-0.13**	-2.56	0.67***	9.40	0.06***	3.51	0.03	1.12	-0.18***	-3.52	0.65***	8.61
ln(trade)	200	-0.15***	-3.27	0.6***	8.81	0.06***	3.76	0.01	0.54	-0.21***	-4.31	0.59***	8.19
puts	225	-0.16***	-3.38	0.58***	8.80	0.06***	3.59	0.01	0.67	-0.21***	-4.36	0.57***	8.12
	300	-0.15***	-3.35	0.55***	8.78	0.05***	3.44	0.01	0.44	-0.2***	-4.29	0.54***	8.14
20-day adjusted	150	-0.08	-1.10	0.58***	6.10	0.02	1.24	0.03	1.23	-0.1	-1.4	0.54***	5.51
ln(volume)	200	-0.13**	-1.98	0.53***	6.13	0.03	1.50	0.02	0.84	-0.16**	-2.33	0.51***	5.61
puts	225	-0.13**	-2.06	0.53***	6.17	0.03	1.40	0.02	0.76	-0.15**	-2.37	0.51***	5.67
	300	-0.16***	-2.94	0.55***	7.22	0.02	1.24	0.02	0.69	-0.18***	-3.18	0.53***	6.63
returns (%)	150	0.07	1.62	-0.06	-0.47	-0.01	-0.37	0.01	0.22	0.08	1.56	-0.07	-0.5
(x100)	200	0.07	1.31	-0.1	-0.66	-0.01	-0.25	0	0.12	0.08	1.27	-0.1	-0.67
	225	0.1**	2.15	-0.18	-1.13	-0.01	-0.23	0	0.12	0.1**	1.96	-0.18	-1.13
	300	0.21***	2.67	-0.33*	-1.83	-0.04	-1.42	0.05	1.15	0.25***	3	-0.37**	-2.03
overnight returns (%) (x100)		0.17**	2.09	-0.23*	-1.74	0.01	0.34	0.01	0.2	0.16*	1.83	-0.24*	-1.72
overnight squared returns (x10000)		-0.03	-0.21	0.24	0.98	0.04	0.4	-0.05	-0.41	-0.07	-0.39	0.30	1.05
overnight |returns| (x100)		-0.03	-0.38	0.16	1.57	0.03	1.26	-0.02	-0.45	-0.06	-0.78	0.17	1.63

This table presents changes in risk, uncertainty, trading activity, and stock returns around U.S. macroeconomic news announcements over the period 2005-2013. The main coefficients are the mean differential between event and non-event days (γ_1), between pre- and post-announcements during event days (γ_3), and between FOMC and non-FOMC news (γ_5, γ_7), respectively. The risk, uncertainty, trading activity, and stock returns are calculated over the 150, 200, 225, and 300 minutes before and after (column range) the news announcement time. The last row presents the results on the original, squared, and absolute value of overnight returns before and after news releases. The risk Rvar, uncertainty U2, and trading activity are adjusted by the moving average over the last 20 non-event days. The natural logarithm is taken before adjustment to avoid extreme values. Under column "FOMC release" and "non-FOMC releases", the coefficients γ_1 and γ_3 of the regression $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 after_t + \gamma_3 event_t after_t + \epsilon_t$ are presented. Under column "FOMC vs. non-FOMC releases", the coefficients γ_5 and γ_7 of the regression $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 after_t + \gamma_3 type_t + \gamma_4 event_t after_t + \gamma_5 event_t type_t + \gamma_6 after_t type_t + \gamma_7 event_t after_t type_t + \epsilon_t$ are presented. $event_t$ is the dummy for event days, $after_t$ is the dummy for the post-announcement period, and $type_t$ is the dummy for FOMC releases. The standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Table 3: **Pre-announcement option-to-equity trade ratio on event days**

		FOMC releases		Non-FOMC releases	
range	ratio	est	t-stat	est	t-stat
		Number of trades			
150 minutes	calls/equity	0.08*	1.76	0.04***	3.51
	puts/equity	0.06	1.40	0.05***	4.02
	(calls+puts)/equity	0.07	1.62	0.05***	3.95
200 minutes	calls/equity	0.07*	1.77	0.05***	4.31
	puts/equity	0.04	1.01	0.05***	4.64
	(calls+puts)/equity	0.05	1.37	0.05***	4.65
225 minutes	calls/equity	0.07*	1.77	0.05***	4.18
	puts/equity	0.03	0.81	0.05***	4.44
	(calls+puts)/equity	0.05	1.24	0.05***	4.46
300 minutes	calls/equity	0.06	1.63	0.05***	3.89
	puts/equity	0.02	0.49	0.05***	4.34
	(calls+puts)/equity	0.03	1.00	0.05***	4.26
		Volume			
150 minute	calls/equity	0.19***	3.10	0.06***	3.71
	puts/equity	0.13*	1.74	0.02	1.40
	(calls+puts)/equity	0.15**	2.39	0.04***	2.61
200 minutes	calls/equity	0.16***	2.75	0.06***	3.99
	puts/equity	0.09	1.43	0.03**	2.00
	(calls+puts)/equity	0.12**	2.14	0.04***	3.04
225 minutes	calls/equity	0.18***	3.11	0.06***	3.85
	puts/equity	0.08	1.33	0.03*	1.91
	(calls+puts)/equity	0.12**	2.21	0.04***	2.96
300 minutes	calls/equity	0.18***	3.71	0.05***	3.58
	puts/equity	0.03	0.63	0.03*	1.82
	(calls+puts)/equity	0.08*	1.81	0.04***	2.85

This table presents the coefficient γ_1 in the regression of pre-announcement option-to-equity trade ratio $y_t = \gamma_0 + \gamma_1 event_t + \epsilon_t$, where $event_t$ is the dummy for event days over the period 2005-2013, and the option-to-equity trade ratio is calculated from the number of trades or volume in options and equity over the time window before the coming announcement under column "range". The ratio is further divided by the ratio of 20-day moving-average option trades over those in equity trades. The natural logarithm is taken for option-equity ratio to avoid extreme values. The standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Table 4: **Regression of post-announcement returns on pre-announcement option-to-equity trade ratio**

range	variable	call	t-stat	put	t-stat	all options	t-stat
			FOMC releases				
			Number of trades				
150 minutes	ln(O/E)	-0.008**	-2.39	-0.009***	-3.20	-0.009***	-2.84
	ln(O/E)*pre-ret	1.842	1.17	1.516	1.18	1.834	1.17
200 minutes	ln(O/E)	-0.006	-1.25	-0.006	-1.61	-0.007	-1.48
	ln(O/E)*pre-ret	0.894	0.68	0.360	0.47	0.680	0.62
225 minutes	ln(O/E)	-0.007	-1.53	-0.009**	-2.04	-0.008*	-1.84
	ln(O/E)*pre-ret	1.810	1.42	1.566**	2.21	1.768*	1.80
300 minutes	ln(O/E)	-0.012*	-1.87	-0.008	-1.12	-0.013*	-1.84
	ln(O/E)*pre-ret	2.963***	2.74	1.041	1.16	2.789**	2.30
			Volume				
150 minutes	ln(O/E)	-0.003	-1.23	-0.003*	-1.91	-0.004**	-2.29
	ln(O/E)*pre-ret	1.238	1.41	1.443	1.29	2.001*	1.88
200 minutes	ln(O/E)	-0.003	-0.99	-0.003	-0.89	-0.005**	-2.01
	ln(O/E)*pre-ret	1.285	1.18	1.321	0.69	2.729*	1.89
225 minutes	ln(O/E)	-0.003	-0.86	-0.005*	-1.79	-0.006*	-1.86
	ln(O/E)*pre-ret	1.890	1.33	2.278	1.63	3.001**	2.01
300 minutes	ln(O/E)	-0.006	-1.28	0.004	0.67	-0.003	-0.88
	ln(O/E)*pre-ret	2.376**	2.23	-0.772	-0.47	1.484	1.51
			Non-FOMC releases				
			Number of trades				
150 minutes	ln(O/E)	0.002***	4.50	0.002***	4.23	0.002***	4.33
	ln(O/E)*pre-ret	-0.303***	-5.82	-0.262***	-6.46	-0.285***	-6.29
200 minutes	ln(O/E)	0.002***	4.05	0.002***	4.15	0.002***	4.10
	ln(O/E)*pre-ret	-0.219***	-6.53	-0.205***	-6.27	-0.214***	-6.63
225 minutes	ln(O/E)	0.002***	3.97	0.002***	4.32	0.002***	4.18
	ln(O/E)*pre-ret	-0.183***	-3.80	-0.178***	-4.05	-0.183***	-4.04
300 minutes	ln(O/E)	0.001	1.52	0.002**	2.14	0.001*	1.89
	ln(O/E)*pre-ret	-0.065	-0.91	-0.089	-1.28	-0.079	-1.13
			Volume				
150 minutes	ln(O/E)	0.001*	1.84	0.001***	3.47	0.001***	3.02
	ln(O/E)*pre-ret	-0.193	-1.60	-0.182***	-10.79	-0.222***	-5.48
200 minutes	ln(O/E)	0.001***	2.91	0.001***	3.04	0.001***	2.96
	ln(O/E)*pre-ret	-0.191***	-2.71	-0.143***	-8.50	-0.169***	-5.74
225 minutes	ln(O/E)	0.001***	3.12	0.001***	2.63	0.001***	2.73
	ln(O/E)*pre-ret	-0.165**	-2.25	-0.133***	-3.08	-0.151***	-2.89
300 minutes	ln(O/E)	0.000	0.58	0.000	-0.04	0.000	0.01
	ln(O/E)*pre-ret	-0.005	-0.05	0.032	0.32	0.028	0.27

This table presents the regression $|ret|_{post,t} = \gamma_0 + \gamma_1 ln(O/E)_{pre,t} + \gamma_2 ln(O/E)_{pre,t}|ret|_{pre,t} + \epsilon_t$ of post-announcement returns on pre-announcement option-to-equity trade ratio and its interaction with pre-announcement returns for macro news releases over the period 2005-2013. Column "range" indicates the time window before and after announcement over which returns and the number of trades/volume in options and equity are calculated. The ratio is further divided by the ratio of the 20-day moving-average option trades over those in equity trades. The natural logarithm is taken for option-to-equity ratio to avoid extreme values. The standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Table 5: **Pre-announcement volume regression for FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat
equity	Adj-R^2(%)	10	0.85		55.24		28.86		57.89		57.94		15	1.09		55.15		34.74		60.19		60.18	
	event	of 15-min	-0.54***	-5.04	-0.2**	-2.31	-0.13	-1.37	-0.1	-1.23	-0.21*	-1.74	of 15-min	-0.6***	-5.22	-0.26***	-3.1	-0.16*	-1.66	-0.13*	-1.71	-0.15	-1.61
	Rvar				0.74***	32.63			0.64***	24.08	0.64***	23.73				0.74***	31.99			0.6***	24.14	0.6***	23.35
	Rvar*event										-0.17	-1.42										-0.08	-0.9
	U2						-0.53***	-24.23	-0.19***	-8.84	-0.19***	-8.4						-0.59***	-26.73	-0.27***	-12.94	-0.26***	-12.24
	U2*event										-0.04	-0.43										-0.08	-1.14
	Adj-R^2(%)	10	1.10		58.46		31.90		61.53		61.51		15	1.10		58.23		35.96		63.01		63.01	
	event	of 20-min	-0.61***	-5.31	-0.18**	-2.31	-0.18*	-1.7	-0.08	-1.12	-0.12	-1.12	of 20-min	-0.61***	-5.25	-0.18**	-2.17	-0.15	-1.52	-0.06	-0.78	-0.1	-0.89
	Rvar				0.76***	34.84			0.65***	25.53	0.65***	24.93				0.76***	33.7			0.62***	25.94	0.62***	25.25
	Rvar*event										-0.04	-0.37										-0.09	-0.85
	U2						-0.56***	-26.07	-0.21***	-9.71	-0.21***	-9.43						-0.6***	-27.41	-0.26***	-13	-0.26***	-12.44
	U2*event										0.01	0.12										-0.07	-0.82
	Adj-R^2(%)	10	1.10		63.27		40.20		67.18		67.16												
	event	of 30-min	-0.61***	-5.25	-0.16**	-2.39	-0.09	-0.97	-0.04	-0.68	-0.06	-0.73											
	Rvar				0.79***	40.94			0.65***	27.88	0.65***	27.11											
	Rvar*event										-0.02	-0.22											
	U2						-0.63***	-30.66	-0.25***	-12.54	-0.25***	-12.18											
	U2*event										0	0											
call	Adj-R^2(%)	10	-0.04		11.64		6.15		12.25		12.33		15	-0.03		12.31		7.49		13.36		13.34	
	event	of 15-min	-0.03	-0.34	0.12	1.13	0.15	1.47	0.17	1.61	0.01	0.04	of 15-min	-0.06	-0.58	0.1	0.9	0.14	1.32	0.16	1.51	0.06	0.53
	Rvar				0.34***	15.91			0.29***	11.89	0.3***	12.14				0.35***	16.49			0.29***	12.21	0.29***	12.15
	Rvar*event										-0.2	-1.54										-0.11	-0.97
	U2						-0.25***	-11.15	-0.1***	-4.03	-0.09***	-3.93						-0.28***	-12.18	-0.12***	-5.33	-0.12***	-5.2
	U2*event										0.03	0.31										0.04	0.43
	Adj-R^2(%)	10	-0.02		13.56		6.77		14.08		14.08		15	-0.04		13.23		8.37		14.46		14.46	
	event	of 20-min	-0.1	-0.89	0.1	0.96	0.1	0.94	0.15	1.35	0.02	0.15	of 20-min	-0.01	-0.07	0.19*	1.91	0.22**	2.2	0.26***	2.62	0.16	1.32
	Rvar				0.37***	17.55			0.32***	13.36	0.33***	13.4				0.37***	16.9			0.29***	12.07	0.3***	12.17
	Rvar*event										-0.14	-1.08										-0.16	-1.27
	U2						-0.26***	-11.74	-0.09***	-3.84	-0.09***	-3.75						-0.29***	-12.94	-0.13***	-5.65	-0.13***	-5.36
	U2*event										0.03	0.3										-0.08	-0.77
	Adj-R^2(%)	10	-0.04		14.24		9.12		15.18		15.20												
	event	of 30-min	-0.01	-0.07	0.2**	2.02	0.24**	2.51	0.26***	2.7	0.17	1.58											
	Rvar				0.38***	18.25			0.31***	12.31	0.31***	12.4											
	Rvar*event										-0.2	-1.53											
	U2						-0.31***	-14.1	-0.12***	-5.14	-0.12***	-4.81											
	U2*event										-0.13	-1.26											
put	Adj-R^2(%)	10	0.00		13.15		8.37		14.43		14.42		15	0.12		13.49		10.32		15.66		15.60	
	event	of 15-min	-0.12	-1.1	0.04	0.34	0.09	0.81	0.11	0.98	0	0.02	of 15-min	-0.23**	-2.06	-0.07	-0.64	0	0.04	0.02	0.18	-0.02	-0.22
	Rvar				0.36***	17.68			0.29***	12.96	0.3***	12.76				0.37***	17.4			0.27***	11.83	0.28***	11.53
	Rvar*event										-0.11	-1.09										-0.06	-0.71
	U2						-0.29***	-13.1	-0.14***	-5.93	-0.14***	-5.83						-0.32***	-14.25	-0.18***	-7.31	-0.18***	-7.03
	U2*event										0.06	0.6										-0.01	-0.14
	Adj-R^2(%)	10	0.11		14.82		8.90		15.95		15.88		15	0.27		16.27		10.83		17.96		17.90	
	event	of 20-min	-0.22**	-1.98	-0.01	-0.12	0.01	0.05	0.05	0.45	0	-0.03	of 20-min	-0.32***	-2.94	-0.1	-0.98	-0.07	-0.66	-0.03	-0.27	-0.08	-0.67
	Rvar				0.39***	18.45			0.32***	13.25	0.32***	12.98				0.4***	18.81			0.32***	12.93	0.32***	12.67
	Rvar*event										-0.04	-0.37										-0.06	-0.5
	U2						-0.3***	-13.31	-0.13***	-5.38	-0.13***	-5.29						-0.33***	-14.73	-0.16***	-6.43	-0.16***	-6.26
	U2*event										0.04	0.36										0.02	0.16
	Adj-R^2(%)	10	0.27		16.48		12.15		18.21		18.16												
	event	of 30-min	-0.32***	-2.94	-0.1	-1.03	-0.04	-0.38	-0.02	-0.2	-0.02	-0.23											
	Rvar				0.4***	19.57			0.31***	12.07	0.3***	11.67											
	Rvar*event										0.06	0.56											
	U2						-0.35***	-16.17	-0.17***	-6.57	-0.17***	-6.57											
	U2*event										0.11	0.97											

This table presents the regression $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 Rvar_t + \gamma_3 U2_t + \gamma_4 Rvar_t event_t + \gamma_5 U2_t event_t + \epsilon_t$ of pre-announcement volume on risk and uncertainty for FOMC releases over the period 2005-2013, where $event_t$ is the dummy for event days. The volume, risk, and uncertainty are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken for volume, risk, and uncertainty before adjustment to avoid extreme values. The range column indicates the time range over which each variable in the regression is calculated before the next FOMC announcement time. The variables are standardized by their sample standard deviation, and the standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Table 6: **Pre-announcement volume regression for non-FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat
equity	Adj-R^2(%)	10	-0.02		49.03		23.39		54.71		54.73		15	-0.02		50.72		27.73		59.26		59.28	
	event	of 15-min	0	0.13	-0.03	-1.25	-0.01	-0.24	-0.03	-1.41	-0.01	-0.23	of 15-min	-0.01	-0.2	-0.04	-1.63	-0.03	-0.81	-0.05**	-2.02	-0.02	-0.6
	Rvar				0.7***	35.65			0.59***	33.21	0.58***	29.29				0.71***	40.33			0.6***	37.16	0.59***	33.19
	Rvar*event										0.05	1.18										0.05	1.24
	U2						-0.47***	-25.39	-0.25***	-18.86	-0.26***	-16.38						-0.52***	-28.49	-0.31***	-23.1	-0.32***	-20.4
	U2*event										0.02	0.72										0.02	0.74
	Adj-R^2(%)	10	-0.02		48.81		19.58		53.40		53.47		15	-0.02		50.31		25.91		58.79		58.86	
	event	of 20-min	-0.01	-0.15	-0.03	-1.24	0	-0.11	-0.03	-1.12	0.01	0.38	of 20-min	-0.01	-0.32	-0.04	-1.48	-0.02	-0.48	-0.04	-1.53	0.01	0.24
	Rvar				0.7***	36.32			0.61***	30.91	0.6***	26.68				0.71***	40.73			0.61***	37.32	0.59***	33.1
	Rvar*event										0.08*	1.75										0.08*	1.85
	U2						-0.44***	-23.63	-0.24***	-14.91	-0.24***	-13.22						-0.51***	-27.62	-0.31***	-22.52	-0.32***	-20.33
	U2*event										0.04	1.29										0.05	1.64
	Adj-R^2(%)	10	-0.02		53.86		21.37		58.47		58.59												
	event	of 30-min	-0.01	-0.32	-0.03	-1.37	-0.01	-0.44	-0.03	-1.37	0.02	0.55											
	Rvar				0.73***	43.74			0.65***	38.11	0.64***	34.02											
	Rvar*event										0.1**	2.17											
	U2						-0.46***	-26.02	-0.23***	-16.48	-0.24***	-15.29											
	U2*event										0.06**	2.01											
call	Adj-R^2(%)	10	0.17		15.38		5.23		15.41		15.41		15	0.16		15.26		7.11		16.93		16.95	
	event	of 15-min	0.11***	3.19	0.09***	2.89	0.11***	3.14	0.09***	2.92	0.12***	2.97	of 15-min	0.11***	3.07	0.09***	2.81	0.1***	2.92	0.09***	2.76	0.13***	3.1
	Rvar				0.39***	24.8			0.34***	21.67	0.33***	19.25				0.39***	25.32			0.33***	20.4	0.32***	17.74
	Rvar*event										0.05	1.09										0.06	1.42
	U2						-0.22***	-14.01	-0.1***	-6.93	-0.1***	-6.47						-0.26***	-15.38	-0.14***	-8.52	-0.15***	-7.83
	U2*event										0.03	0.87										0.05	1.29
	Adj-R^2(%)	10	0.17		14.80		4.47		15.10		15.16		15	0.13		15.78		6.20		17.28		17.29	
	event	of 20-min	0.11***	3.19	0.1***	3.09	0.11***	3.23	0.1***	3.09	0.15***	3.59	of 20-min	0.1***	2.78	0.08***	2.62	0.1***	2.8	0.09***	2.65	0.12***	2.93
	Rvar				0.38***	23.98			0.35***	20.55	0.33***	17.77				0.4***	26.83			0.35***	23.18	0.34***	20.58
	Rvar*event										0.08*	1.82										0.05	1.34
	U2						-0.21***	-12.71	-0.09***	-6.02	-0.1***	-5.93						-0.25***	-15.2	-0.13***	-8.99	-0.14***	-8.46
	U2*event										0.06*	1.75										0.04	1.21
	Adj-R^2(%)	10	0.13		17.00		5.08		17.65		17.69												
	event	of 30-min	0.1***	2.78	0.09***	2.71	0.1***	2.8	0.09***	2.73	0.13***	3.23											
	Rvar				0.41***	28.18			0.38***	24.77	0.37***	22.08											
	Rvar*event										0.07*	1.68											
	U2						-0.22***	-13.86	-0.09***	-6.18	-0.1***	-6.16											
	U2*event										0.05	1.57											
put	Adj-R^2(%)	10	0.01		16.46		4.10		15.95		16.03		15	0.02		18.12		6.80		19.38		19.45	
	event	of 15-min	0.04	1.24	0.02	0.73	0.04	1.11	0.02	0.72	0.07*	1.67	of 15-min	0.05	1.4	0.03	0.94	0.04	1.23	0.03	0.93	0.08*	1.83
	Rvar				0.41***	23.86			0.37***	21.4	0.35***	18.85				0.43***	26.37			0.38***	22.46	0.36***	19.71
	Rvar*event										0.09*	1.81										0.08*	1.81
	U2						-0.2***	-11.92	-0.07***	-4.41	-0.08***	-4.6						-0.26***	-14.41	-0.13***	-7.67	-0.14***	-7.28
	U2*event										0.06	1.57										0.06	1.48
	Adj-R^2(%)	10	0.02		16.19		3.62		16.08		16.23		15	0.01		17.81		5.94		19.02		19.13	
	event	of 20-min	0.05	1.5	0.04	1.22	0.05	1.5	0.04	1.22	0.1**	2.34	of 20-min	0.04	1.24	0.03	0.92	0.04	1.22	0.03	0.94	0.08**	2.03
	Rvar				0.4***	23.21			0.37***	20.15	0.35***	17.25				0.42***	27.45			0.38***	24.07	0.37***	21.17
	Rvar*event										0.11**	2.35										0.1**	2.26
	U2						-0.19***	-10.94	-0.07***	-3.95	-0.08***	-4.19						-0.24***	-14.01	-0.12***	-7.71	-0.13***	-7.53
	U2*event										0.07*	1.87										0.06	1.5
	Adj-R^2(%)	10	0.01		18.28		4.89		18.81		18.93												
	event	of 30-min	0.04	1.24	0.03	1.01	0.04	1.23	0.03	1.02	0.09**	2.14											
	Rvar				0.43***	28.07			0.4***	24.54	0.38***	21.77											
	Rvar*event										0.11**	2.31											
	U2						-0.22***	-13.05	-0.08***	-5.18	-0.09***	-5.4											
	U2*event										0.07*	1.79											

This table presents the regression $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 Rvar_t + \gamma_3 U2_t + \gamma_4 Rvar_t event_t + \gamma_5 U2_t event_t + \epsilon_t$ of pre-announcement volume on risk and uncertainty for non-FOMC releases over the period 2005-2013, where $event_t$ is the dummy for event days. The volume, risk, and uncertainty are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken for volume, risk, and uncertainty before adjustment to avoid extreme values. The range column indicates the time range over which each variable in the regression is calculated before the next other announcement time. The variables are standardized by their sample standard deviation, and the standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Table 7: **Post-announcement volume regression for FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat
equity	Adj-R^2(%)	10	7.85		53.24		26.60		58.46		58.52		15	6.13		48.64		24.18		54.31		54.31	
	event	of 15-min	1.59***	14.52	0.7***	8.25	1.31***	11.73	0.65***	7.73	0.81***	6.23	of 15-min	1.41***	12.94	0.54***	6.16	1.15***	10.64	0.49***	5.79	0.6***	4.85
	Rvar				0.69***	23.79			0.61***	22.56	0.61***	21.9				0.67***	22.35			0.59***	21.09	0.59***	20.45
	Rvar*event										0.06	0.61										0.04	0.46
	U2						-0.44***	-15.17	-0.24***	-13.73	-0.25***	-13.75						-0.43***	-15.31	-0.25***	-12.04	-0.25***	-11.98
	U2*event										0.23***	2.72										0.15*	1.7
	Adj-R^2(%)	10	6.54		54.77		26.20		59.97		60.03		15	5.44		51.17		25.25		56.84		56.86	
	event	of 20-min	1.46***	13.18	0.62***	7.4	1.26***	11.22	0.61***	7.3	0.69***	6.59	of 20-min	1.33***	12.37	0.51***	6.14	1.13***	10.59	0.5***	6.16	0.56***	5.58
	Rvar				0.71***	25.25			0.63***	23.87	0.63***	23.24				0.69***	24.51			0.61***	23.19	0.61***	22.54
	Rvar*event										0.08	0.85										0.06	0.81
	U2						-0.44***	-15.22	-0.24***	-13.06	-0.25***	-13.08						-0.45***	-15.46	-0.25***	-12.86	-0.26***	-12.8
	U2*event										0.2***	3.57										0.15**	2.46
	Adj-R^2(%)	10	5.44		59.48		30.79		64.43		64.55												
	event	of 30-min	1.33***	12.37	0.54***	6.85	1.25***	11.13	0.61***	7.48	0.65***	7.44											
	Rvar				0.75***	27.86			0.65***	24.21	0.64***	23.57											
	Rvar*event										0.08	0.89											
	U2						-0.5***	-18.49	-0.24***	-12.41	-0.25***	-12.54											
	U2*event										0.23***	3.46											
call	Adj-R^2(%)	10	3.00		15.08		7.43		16.15		16.17		15	2.29		13.88		6.35		14.93		14.94	
	event	of 15-min	1***	9.96	0.53***	5.6	0.86***	8.31	0.51***	5.28	0.63***	3.32	of 15-min	0.87***	8.26	0.42***	4.12	0.75***	6.92	0.39***	3.86	0.49***	2.71
	Rvar				0.36***	15.27			0.32***	13.72	0.32***	13.23				0.35***	14.5			0.32***	13.09	0.31***	12.64
	Rvar*event										0.08	0.9										0.1	1.03
	U2						-0.21***	-8.96	-0.11***	-5.67	-0.12***	-5.82						-0.2***	-8.52	-0.11***	-5.11	-0.11***	-5.24
	U2*event										0.22*	1.95										0.21*	1.89
	Adj-R^2(%)	10	2.35		15.12		6.87		16.13		16.18		15	2.03		14.53		6.40		15.51		15.53	
	event	of 20-min	0.88***	8.52	0.45***	4.62	0.79***	7.4	0.44***	4.51	0.5***	3.33	of 20-min	0.82***	8.06	0.39***	4.12	0.73***	7.03	0.39***	4.02	0.43***	3
	Rvar				0.37***	15.69			0.33***	14.26	0.33***	13.78				0.36***	15.64			0.33***	14.11	0.32***	13.65
	Rvar*event										0.12	1.19										0.12	1.1
	U2						-0.21***	-8.93	-0.11***	-5.48	-0.11***	-5.67						-0.21***	-8.53	-0.11***	-5.28	-0.11***	-5.43
	U2*event										0.22***	2.99										0.19**	2.35
	Adj-R^2(%)	10	2.03		16.81		8.33		17.86		17.84												
	event	of 30-min	0.82***	8.06	0.4***	4.26	0.78***	7.51	0.44***	4.53	0.44***	3.22											
	Rvar				0.39***	17.17			0.34***	14.37	0.34***	13.92											
	Rvar*event										0.08	0.72											
	U2						-0.25***	-10.12	-0.11***	-5.43	-0.12***	-5.54											
	U2*event										0.14*	1.68											
put	Adj-R^2(%)	10	2.38		14.58		6.13		15.29		15.27		15	1.90		13.42		5.45		14.21		14.17	
	event	of 15-min	0.89***	7.87	0.42***	3.89	0.76***	6.59	0.4***	3.68	0.44*	1.94	of 15-min	0.8***	6.89	0.34***	3.07	0.68***	5.81	0.32***	2.89	0.32	1.52
	Rvar				0.36***	13.98			0.33***	12.58	0.32***	12.11				0.35***	13.91			0.32***	12.6	0.32***	12.13
	Rvar*event										0.1	0.97										0.1	1.12
	U2						-0.2***	-7.72	-0.09***	-4.37	-0.1***	-4.47						-0.19***	-7.77	-0.1***	-4.36	-0.1***	-4.41
	U2*event										0.14	1.04										0.1	0.79
	Adj-R^2(%)	10	1.90		15.52		6.15		16.32		16.34		15	2.00		15.42		6.14		16.20		16.19	
	event	of 20-min	0.8***	6.9	0.35***	3.16	0.71***	5.98	0.34***	3.1	0.4**	2.32	of 20-min	0.82***	7.28	0.37***	3.5	0.73***	6.41	0.37***	3.45	0.37**	2.34
	Rvar				0.38***	15.39			0.35***	13.86	0.34***	13.41				0.37***	15.76			0.34***	14.3	0.34***	13.85
	Rvar*event										0.11	0.95										0.11	1.1
	U2						-0.21***	-8.24	-0.1***	-4.63	-0.1***	-4.78						-0.2***	-8.17	-0.1***	-4.52	-0.1***	-4.61
	U2*event										0.19**	2.25										0.13	1.47
	Adj-R^2(%)	10	2.00		18.34		8.43		19.26		19.27												
	event	of 30-min	0.82***	7.28	0.38***	3.61	0.77***	6.76	0.41***	3.86	0.4**	2.52											
	Rvar				0.41***	17.66			0.37***	14.99	0.36***	14.52											
	Rvar*event										0.11	0.98											
	U2						-0.25***	-10.24	-0.11***	-4.96	-0.11***	-5.13											
	U2*event										0.15	1.51											

This table presents the regression $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 Rvar_t + \gamma_3 U2_t + \gamma_4 Rvar_t event_t + \gamma_5 U2_t event_t + \epsilon_t$ of post-announcement volume on risk and uncertainty for FOMC releases over the period 2005-2013, where $event_t$ is the dummy for event days. The volume, risk, and uncertainty are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken for volume, risk, and uncertainty before adjustment to avoid extreme values. The range column indicates the time range over which each variable in the regression is calculated after the next FOMC announcement time. The variables are standardized by their sample standard deviation, and the standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Table 8: **Post-announcement volume regression for non-FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat
equity	Adj-R^2(%)	10	0.25		62.75		38.07		64.14		64.14		15	0.13		60.23		38.57		62.16		62.17	
	event	of 15-min	0.13***	3.63	0	-0.17	0.12***	4.2	0.01	0.53	0	0.01	of 15-min	0.1***	2.65	-0.04	-1.58	0.09***	2.99	-0.02	-0.83	-0.03	-1.15
	Rvar				0.79***	62.52			0.69***	37.4	0.69***	35.38				0.78***	60.94			0.65***	37.09	0.66***	34.77
	Rvar*event										-0.02	-0.44										-0.01	-0.29
	U2						-0.62***	-49.1	-0.16***	-10.27	-0.15***	-9.16						-0.62***	-50.19	-0.19***	-12.37	-0.18***	-10.86
	U2*event										-0.03	-0.75										-0.05	-1.18
	Adj-R^2(%)	10	0.14		61.29		38.89		64.55		64.55		15	0.06		54.22		35.21		57.41		57.41	
	event	of 20-min	0.1***	2.74	0	0.01	0.09***	3.12	0.02	0.67	0.03	0.94	of 20-min	0.07**	2.02	-0.02	-0.86	0.07**	2.15	-0.01	-0.29	0.01	0.31
	Rvar				0.78***	56.81			0.64***	36.36	0.64***	32.84				0.74***	51.48			0.6***	33.42	0.59***	29.75
	Rvar*event										0.04	0.75										0.03	0.75
	U2						-0.62***	-47.56	-0.23***	-15.36	-0.23***	-14.35						-0.59***	-43.25	-0.23***	-14.47	-0.23***	-13.55
	U2*event										0.03	0.7										0.04	1.01
	Adj-R^2(%)	10	0.06		59.23		30.51		64.51		64.54												
	event	of 30-min	0.07**	2.02	0	-0.19	0.07**	2.18	0	0.22	0.03	1.06											
	Rvar				0.77***	52.34			0.65***	42.69	0.64***	37.8											
	Rvar*event										0.06	1.49											
	U2						-0.55***	-31.26	-0.26***	-19.95	-0.27***	-18.44											
	U2*event										0.05	1.52											
call	Adj-R^2(%)	10	0.20		13.14		8.03		13.41		13.39		15	0.13		13.85		8.82		14.25		14.22	
	event	of 15-min	0.12***	3.37	0.06*	1.76	0.12***	3.34	0.07**	1.97	0.07*	1.75	of 15-min	0.1***	2.82	0.04	1.11	0.1***	2.77	0.05	1.36	0.04	1.19
	Rvar				0.36***	26.11			0.31***	17.26	0.31***	15.58				0.37***	26.64			0.31***	17.34	0.31***	15.56
	Rvar*event										0.02	0.32										0.02	0.33
	U2						-0.28***	-19.87	-0.07***	-4.14	-0.07***	-3.69						-0.3***	-20.88	-0.09***	-4.93	-0.08***	-4.37
	U2*event										-0.01	-0.19										-0.01	-0.25
	Adj-R^2(%)	10	0.14		13.83		8.63		14.48		14.46		15	0.09		13.95		8.71		14.62		14.59	
	event	of 20-min	0.1***	2.84	0.05	1.63	0.1***	2.84	0.06*	1.83	0.06	1.53	of 20-min	0.09**	2.39	0.04	1.13	0.08**	2.35	0.04	1.33	0.04	1.09
	Rvar				0.37***	26.84			0.31***	18.62	0.31***	16.7				0.37***	26.55			0.31***	18.34	0.31***	16.47
	Rvar*event										0.01	0.17										0	-0.08
	U2						-0.29***	-20.41	-0.1***	-6.39	-0.1***	-5.52						-0.29***	-20.26	-0.1***	-6.33	-0.1***	-5.53
	U2*event										-0.02	-0.55										-0.01	-0.31
	Adj-R^2(%)	10	0.09		16.17		6.57		16.84		16.87												
	event	of 30-min	0.09**	2.39	0.05	1.39	0.08**	2.36	0.05	1.49	0.08**	2.13											
	Rvar				0.4***	29.38			0.36***	24.37	0.35***	21.2											
	Rvar*event										0.06	1.61											
	U2						-0.25***	-15.52	-0.09***	-6.34	-0.1***	-6.25											
	U2*event										0.05	1.59											
put	Adj-R^2(%)	10	0.16		14.83		9.69		15.33		15.32		15	0.10		15.99		10.70		16.63		16.60	
	event	of 15-min	0.11***	3	0.04	1.26	0.1***	2.95	0.05	1.53	0.07*	1.79	of 15-min	0.09**	2.48	0.02	0.59	0.08**	2.41	0.03	0.91	0.04	1.13
	Rvar				0.38***	28.64			0.32***	17.44	0.31***	15.35				0.4***	29.16			0.33***	17.76	0.32***	15.77
	Rvar*event										0.05	1										0.03	0.71
	U2						-0.31***	-23.1	-0.1***	-5.57	-0.1***	-5.4						-0.33***	-23.85	-0.11***	-6.14	-0.11***	-5.81
	U2*event										0.03	0.77										0.02	0.55
	Adj-R^2(%)	10	0.12		15.30		10.54		16.41		16.46		15	0.07		15.43		11.29		16.85		16.88	
	event	of 20-min	0.1***	2.74	0.05	1.46	0.09***	2.71	0.06*	1.72	0.09**	2.55	of 20-min	0.08**	2.18	0.03	0.84	0.07**	2.12	0.04	1.13	0.07*	1.84
	Rvar				0.39***	28.15			0.31***	17.76	0.29***	15.26				0.39***	27.34			0.3***	17.03	0.29***	14.78
	Rvar*event										0.08*	1.79										0.06	1.44
	U2						-0.32***	-23.06	-0.13***	-7.9	-0.15***	-7.92						-0.34***	-23.45	-0.15***	-8.79	-0.17***	-8.62
	U2*event										0.08**	1.98										0.07*	1.68
	Adj-R^2(%)	10	0.07		17.25		8.03		18.38		18.51												
	event	of 30-min	0.08**	2.18	0.04	1.14	0.08**	2.15	0.04	1.27	0.09**	2.43											
	Rvar				0.41***	30.14			0.36***	23.83	0.34***	20.34											
	Rvar*event										0.1**	2.55											
	U2						-0.28***	-16.7	-0.12***	-7.78	-0.14***	-7.86											
	U2*event										0.09**	2.55											

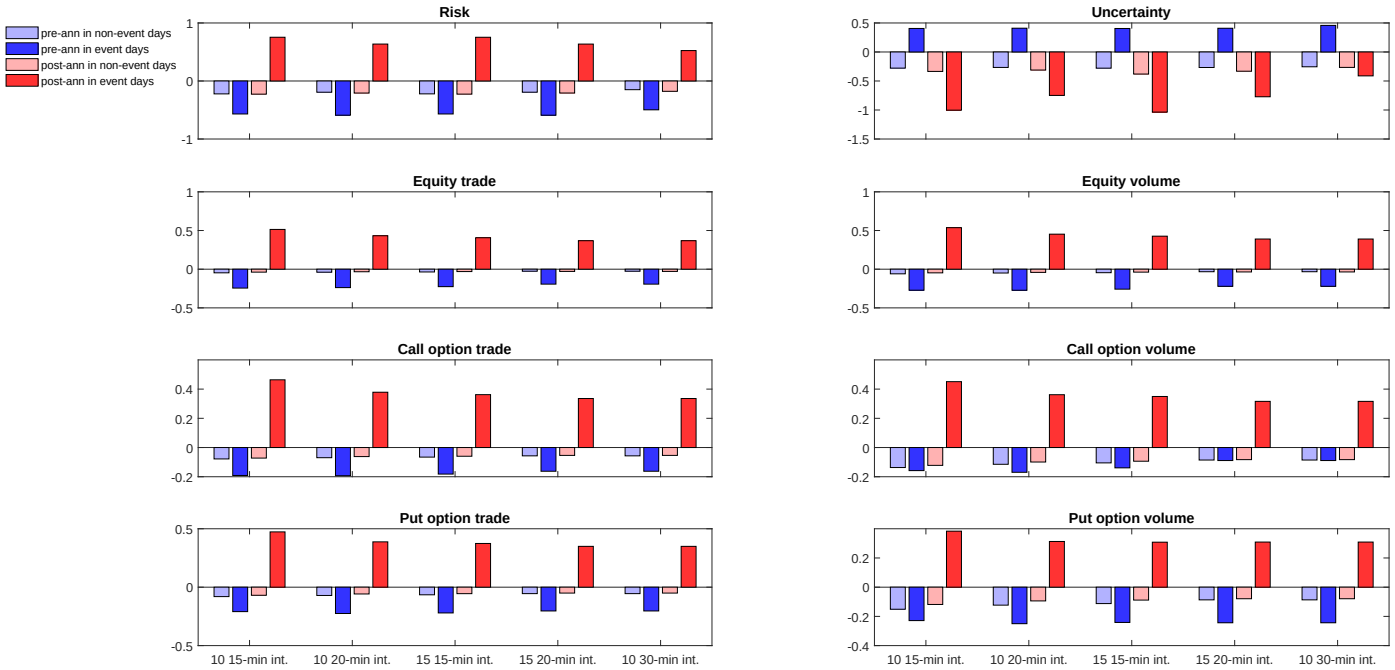
This table presents the regression $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 Rvar_t + \gamma_3 U2_t + \gamma_4 Rvar_t event_t + \gamma_5 U2_t event_t + \epsilon_t$ of post-announcement volume on risk and uncertainty for non-FOMC releases over the period 2005-2013, where $event_t$ is the dummy for event days. The volume, risk, and uncertainty are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken for volume, risk, and uncertainty before adjustment to avoid extreme values. The range column indicates the time range over which each variable in the regression is calculated before the next other announcement time. The variables are standardized by their sample standard deviation, and the standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Table 9: **Regression for pre-FOMC returns**

range	variable	(1)	t-stat	(2)	t-stat	(3)	t-stat
10 intervals	Adj-R^2(%)	0.02		1.35		1.31	
	Intercept	-0.02	-0.85	-0.04	-1.50	-0.04	-1.36
of 15 minutes	event	0.14	1.62	0.08	0.87	0.06	0.43
	Rvar			-0.11***	-3.01	-0.1***	-2.75
	Rvar*event					-0.09	-0.80
	U2			0.02	0.43	0.02	0.54
	U2*event					-0.12	-0.90
10 intervals	Adj-R^2(%)	0.00		2.67		4.91	
	Intercept	-0.03	-1.34	-0.04	-1.38	-0.05*	-1.73
of 20 minutes	event	0.12	1.31	0	0.03	0.02	0.18
	Rvar			-0.12***	-3.21	-0.16***	-4.34
	Rvar*event					-0.05	-0.52
	U2			0.07*	1.72	0.1**	2.45
	U2*event					-0.10	-0.92
15 intervals	Adj-R^2(%)	0.03		4.96		2.73	
	Intercept	-0.03	-1.60	-0.05*	-1.84	-0.03	-1.19
of 15 minutes	event	0.16**	2.15	0.01	0.17	-0.06	-0.38
	Rvar			-0.16***	-4.62	-0.11***	-2.89
	Rvar*event					-0.19	-1.22
	U2			0.09**	2.44	0.08*	1.86
	U2*event					-0.20	-1.08
15 intervals	Adj-R^2(%)	0.14		6.21		6.48	
	Intercept	-0.05**	-2.26	-0.05	-1.59	-0.04	-1.38
of 20 minutes	event	0.25***	2.67	0.06	0.59	0.14	1.14
	Rvar			-0.15***	-3.86	-0.15***	-3.58
	Rvar*event					-0.10	-0.87
	U2			0.13***	2.88	0.15***	3.09
	U2*event					-0.37**	-2.02
10 intervals	Adj-R^2(%)	0.14		6.22		6.63	
	Intercept	-0.05**	-2.26	0	0.10	0.01	0.35
of 30 minutes	event	0.25***	2.67	0.04	0.39	0.07	0.60
	Rvar			-0.05	-1.25	-0.04	-0.96
	Rvar*event					-0.26**	-1.88
	U2			0.22***	4.82	0.23***	5.09
	U2*event					-0.48**	-2.57

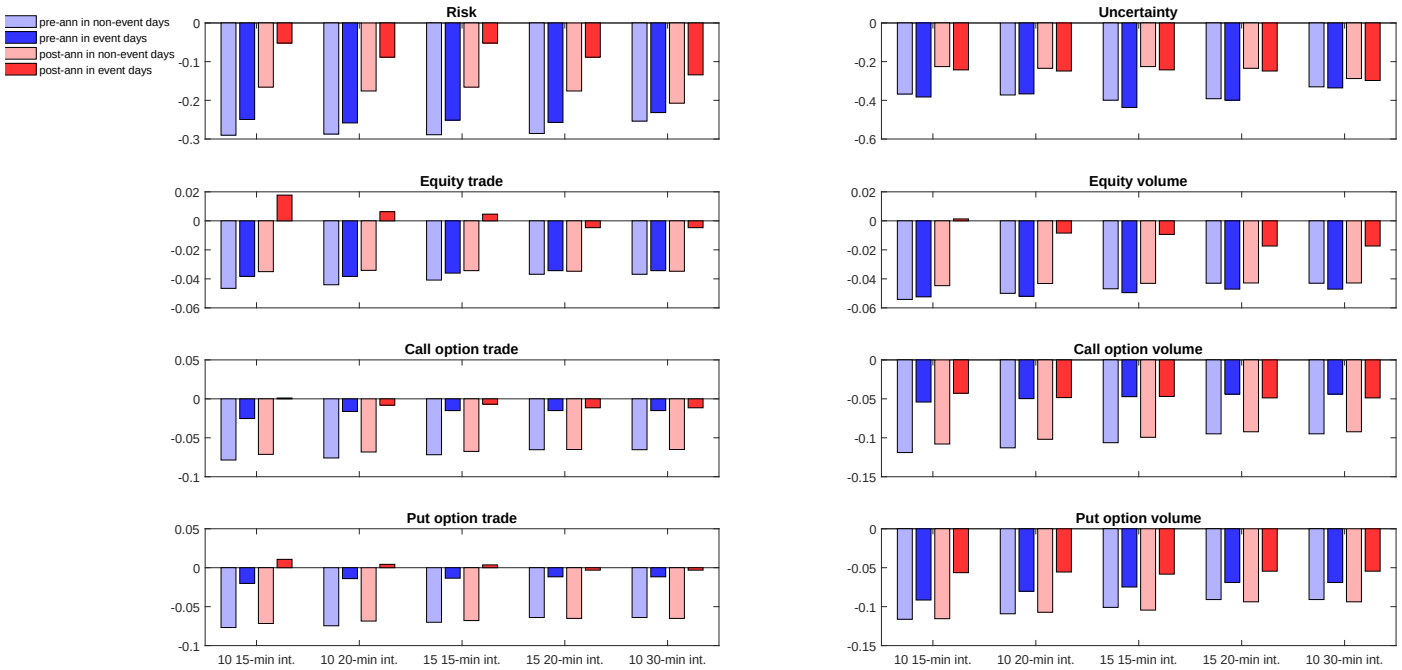
This table presents the regression of pre-announcement returns on risk and uncertainty $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 Rvar_t + \gamma_3 U2_t + \gamma_4 Rvar_t event_t + \gamma_5 U2_t event_t + \epsilon_t$ for FOMC releases over the period 2005-2013, where $event_t$ is the dummy of FOMC days. The risk and uncertainty are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken for risk and uncertainty before adjustment to avoid extreme values. The range column indicates the time range over which each variable in the regression is calculated before the next FOMC announcement time. The variables are standardized by their sample standard deviation, and the standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Figure 1: **Adjusted risk, uncertainty, and trading activity around FOMC releases**



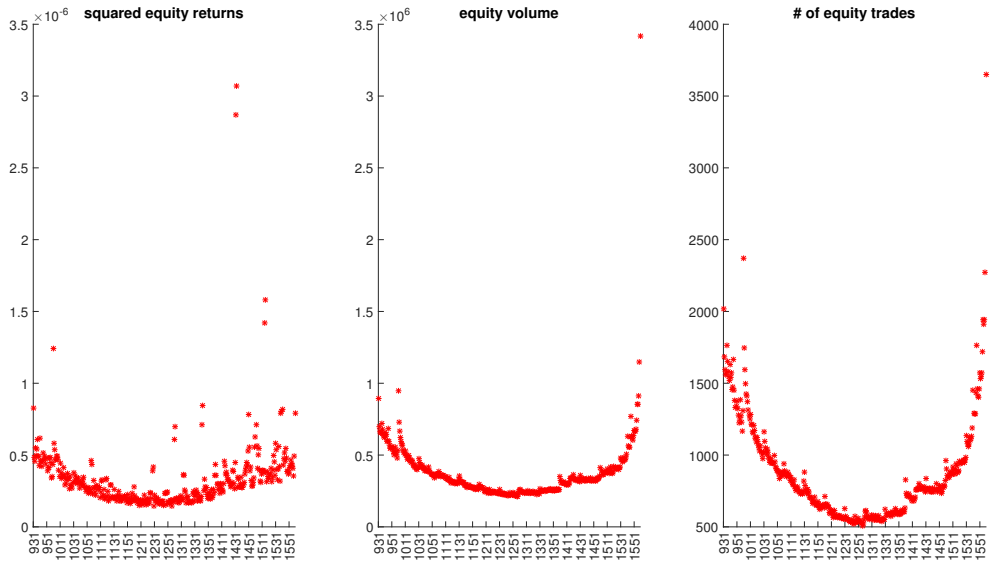
This figure presents the average adjusted risk, uncertainty, and trading activity around FOMC releases over the period 2005-2013. The risk, uncertainty and trading activity are calculated over the 150, 200, 225, and 300 minutes before and after the news announcement time. The natural logarithm is taken to avoid extreme values. The risk, uncertainty, and trading activity are adjusted by the moving average over the last 20 non-event trading days.

Figure 2: **Adjusted risk, uncertainty, and trading activity around non-FOMC releases**



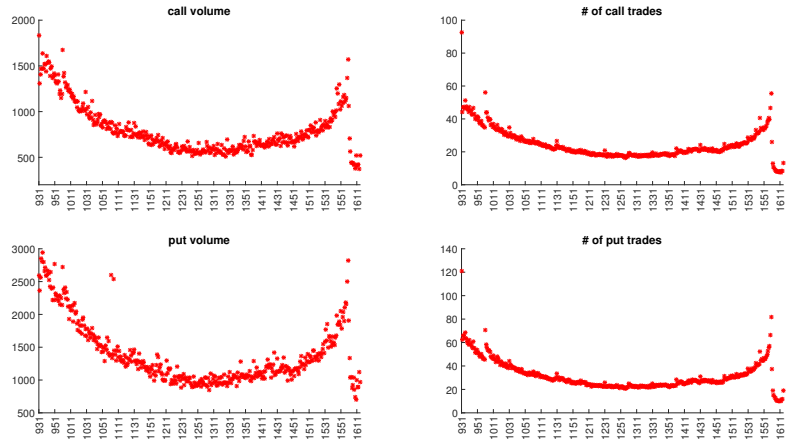
This figure presents the average adjusted risk, uncertainty, and trading activity around non-FOMC releases over the period 2005-2013. The risk, uncertainty and trading activity are calculated over the 150, 200, 225, and 300 minutes before and after the news announcement time. The natural logarithm is taken to avoid extreme values. The risk, uncertainty, and trading activity are adjusted by the moving average over the last 20 non-event trading days.

Figure 3: **Intraday patterns for equity during 2005-2013**



This figure presents the average intra day patterns of one-minute squared returns, total volume, and number of trades during trading time 9:30 to 16:00 for equity in 2005-2013. The number of trades and volume is aggregated over one-minute intervals, and all variables are averaged over trading days in the sample.

Figure 4: **Intraday patterns for call and put options during 2005-2013**



This figure presents the average intra day patterns of total volume and number of trades during trading time 9:30 to 16:15 in 2005-2013. The number of trades and volume is aggregated over one-minute intervals, and all variables are averaged over trading days in the sample.

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Appendix

Inference

We rely on asymptotic normality to obtain the statistical significance of coefficients in Table 2. Given the relatively small number of FOMC news or 72 announcements over the period 2005-2013, it is possible that the asymptotic distribution poorly approximates the small-sample distribution of coefficient estimates. We address this issue by bootstrap procedure in two ways[21] and show that the statistical significance based on asymptotic inference does not result from small-sample concerns.

In Approach 1, we calculate the bootstrapped confidence intervals (CIs) for the point estimates of γ_1 and γ_3 from Equation (2). For the pre-announcement observations, we draw with replacement from the empirical distribution of the data sample on (non-) event days a series of length equal to the actual number of (non-) event days. We repeat

[21]Lucca and Moench (2015) and Mueller et al. (2017) also use bootstrap approaches to overcome small-sample issues.

the sampling for the post-announcement observations, and we re-estimate the Equation (2) to obtain the coefficients with the random sample at hand. We also perform this bootstrap exercise for non-FOMC macro news for comparison (although the number of non-FOMC announcements of 1,052 is far greater than the 72 pre-scheduled FOMC meetings).

In Approach 2, we assess how likely it is to observe the mean differentials as large as those reported in Table 2, in a sample drawn from the distribution on non-event days. To do this, we draw with replacement from the empirical distribution of pre-announcement observations on non-event days a time series of length equal to the actual number of event days, and similarly for post-announcement observations. For both approaches, we implement bootstrapping 500 times. Table 12 presents the bootstrapped results for FOMC meetings. The first column lists the dependent variable of Equation (2) studied in Section 4. The second column presents the time window before (after) the announcement time over which the dependent variable is calculated, e.g. 150, 200, 225, and 300 minutes. The next (last) four columns exhibit original coefficient estimates in Table 2, the 99% and 95% bootstrapped CIs under approach 1, and the p-value of bootstrapped coefficients under approach 2 for γ_1 (γ_3).

Insert Table 12 here

We first discuss the results from Approach 1. The coefficient estimates that are significant at the 1% (5%) level in Table 2 have bootstrapped CIs that are always different from zero at 1% (5%) cutoff, and vice versa for insignificant coefficients. We demonstrate this with an example for uncertainty measured over a 300-minute window around the announcement time. For FOMC meetings, the coefficients γ_1 and γ_3 are significant at the 1% level and associated with 99% CIs of [0.43, 0.99] and [-1.14,-0.56], respectively.

With respect to Approach 2, we document that the coefficients significant at the 1% (5%) level in Table 2 have p-values very close to 0.01 (0.05). By continuing the example above, the uncertainty coefficients γ_1 and γ_3 have the p-values of 0 for FOMC meetings. Hence, it is unlikely to observe such large differentials from the distribution of observations on non-event days for coefficients that are significant in Table 2.

Table 10: **Summary statistics with variables calculated over 150- and 200-minute windows**

	FOMC releases								non-FOMC releases							
	pre-announcement				post-announcement				pre-announcement				post-announcement			
variable	mean	stdev.	max	min	mean	stdev.	max	min	mean	stdev.	max	min	mean	stdev.	max	min
150-minute window																
non-event days																
ln Rvar	-0.222	0.746	3.267	-2.806	-0.227	0.738	4.593	-3.840	-0.290	0.809	4.761	-4.755	-0.166	0.644	3.295	-2.953
ln U2 (10 15-min int.)	-0.278	0.898	4.283	-3.625	-0.335	1.043	6.199	-5.805	-0.367	1.058	5.833	-5.416	-0.226	0.843	2.998	-4.525
ln trade	-0.047	0.355	1.426	-1.531	-0.038	0.328	1.536	-2.812	-0.047	0.373	1.650	-3.622	-0.035	0.315	1.371	-1.684
ln trade (calls)	-0.078	0.480	1.746	-1.809	-0.072	0.458	2.040	-2.980	-0.079	0.468	1.924	-3.509	-0.071	0.447	2.610	-1.597
ln trade (puts)	-0.081	0.482	1.717	-1.680	-0.069	0.450	2.131	-2.965	-0.077	0.465	1.717	-3.500	-0.072	0.444	2.338	-1.722
ln volume	-0.060	0.394	1.488	-1.513	-0.047	0.352	1.721	-2.922	-0.054	0.391	1.569	-3.813	-0.045	0.338	1.380	-1.618
ln volume (calls)	-0.137	0.612	2.456	-2.727	-0.122	0.570	2.508	-3.121	-0.119	0.568	2.465	-3.612	-0.108	0.532	2.134	-2.726
ln volume (puts)	-0.151	0.624	2.800	-2.895	-0.118	0.559	2.831	-3.624	-0.116	0.561	2.276	-4.064	-0.115	0.542	2.799	-2.315
returns (%)	-0.009	0.480	3.626	-4.923	0.018	0.782	8.047	-0.067	0.009	0.734	8.042	-7.683	0.001	0.572	3.197	-0.039
event days																
ln Rvar	-0.569	0.800	1.996	-2.215	0.754	0.748	2.879	-0.899	-0.249	0.798	4.088	-2.413	-0.052	0.679	2.913	-2.136
ln U2 (10 15-min int.)	0.406	0.937	2.140	-2.028	-1.003	0.810	0.840	-3.213	-0.383	1.121	4.636	-5.674	-0.243	0.884	2.400	-3.472
ln trade	-0.244	0.329	0.879	-1.098	0.514	0.308	1.644	0.031	-0.038	0.356	1.384	-1.903	0.018	0.323	1.176	-1.057
ln trade (calls)	-0.191	0.403	0.778	-1.721	0.464	0.435	1.513	-0.523	-0.025	0.451	2.172	-1.694	0.001	0.456	1.464	-1.510
ln trade (puts)	-0.209	0.416	0.764	-1.742	0.473	0.423	1.399	-0.558	-0.020	0.440	2.317	-1.624	0.011	0.451	1.364	-1.306
ln volume	-0.272	0.351	0.850	-0.977	0.537	0.338	1.664	-0.066	-0.052	0.383	1.894	-1.985	0.001	0.352	1.262	-1.124
ln volume (calls)	-0.158	0.514	1.143	-1.244	0.451	0.477	1.453	-0.523	-0.054	0.557	2.596	-2.311	-0.043	0.533	1.525	-1.817
ln volume (puts)	-0.229	0.587	1.481	-1.461	0.384	0.531	1.425	-1.414	-0.091	0.547	2.891	-1.888	-0.056	0.543	1.870	-2.126
returns (%)	0.058	0.340	1.262	-1.032	0.019	1.132	3.032	-0.035	-0.001	0.785	8.193	-4.349	-0.002	0.589	3.023	-0.031
200-minute window																
non-event days																
ln Rvar	-0.194	0.705	2.847	-2.783	-0.208	0.701	4.278	-3.571	-0.287	0.809	4.484	-4.359	-0.176	0.664	3.172	-2.944
ln U2 (10 20-min int.)	-0.266	0.872	4.149	-4.081	-0.312	0.997	5.804	-5.837	-0.372	1.044	6.444	-6.310	-0.234	0.877	3.468	-4.159
ln trade	-0.039	0.333	1.298	-1.460	-0.033	0.306	1.493	-2.422	-0.044	0.362	1.600	-3.340	-0.034	0.315	1.348	-1.671
ln trade (calls)	-0.070	0.460	2.064	-1.564	-0.062	0.429	2.115	-2.448	-0.076	0.465	1.781	-3.550	-0.068	0.443	2.428	-1.658
ln trade (puts)	-0.071	0.462	1.869	-1.567	-0.058	0.419	1.970	-2.477	-0.075	0.462	1.740	-3.580	-0.069	0.439	2.165	-1.783
ln volume	-0.050	0.365	1.340	-1.433	-0.041	0.328	1.649	-2.476	-0.050	0.372	1.538	-3.481	-0.043	0.336	1.408	-1.625
ln volume (calls)	-0.115	0.566	2.148	-2.711	-0.099	0.519	2.162	-2.892	-0.113	0.559	2.329	-3.401	-0.102	0.520	1.919	-2.751
ln volume (puts)	-0.123	0.571	2.473	-2.390	-0.094	0.507	2.593	-2.709	-0.109	0.546	2.134	-4.004	-0.107	0.524	2.572	-2.527
returns (%)	-0.016	0.573	2.804	-5.505	0.015	0.880	8.716	-0.088	0.009	0.778	8.998	-8.924	0.003	0.627	4.618	-0.040
event days																
ln Rvar	-0.590	0.742	1.847	-1.893	0.637	0.668	2.575	-0.866	-0.258	0.799	3.927	-2.648	-0.088	0.692	2.720	-2.335
ln U2 (10 20-min int.)	0.410	0.856	1.786	-1.833	-0.749	0.844	1.086	-3.950	-0.367	1.078	4.023	-5.307	-0.248	0.903	1.996	-3.146
ln trade	-0.238	0.327	0.668	-1.068	0.432	0.288	1.359	-0.056	-0.038	0.350	1.334	-1.694	0.006	0.324	1.126	-1.042
ln trade (calls)	-0.193	0.380	0.804	-1.645	0.379	0.419	1.319	-0.613	-0.016	0.447	2.163	-1.833	-0.008	0.446	1.407	-1.578
ln trade (puts)	-0.225	0.391	0.802	-1.688	0.388	0.411	1.324	-0.630	-0.014	0.439	2.276	-1.758	0.004	0.443	1.274	-1.308
ln volume	-0.272	0.352	0.615	-0.987	0.453	0.315	1.391	-0.094	-0.052	0.372	1.855	-1.621	-0.008	0.353	1.187	-1.058
ln volume (calls)	-0.170	0.515	1.182	-1.493	0.362	0.449	1.317	-0.701	-0.050	0.542	2.457	-2.473	-0.048	0.519	1.547	-1.888
ln volume (puts)	-0.250	0.534	0.938	-1.662	0.313	0.492	1.397	-1.407	-0.080	0.528	2.835	-2.020	-0.056	0.518	1.698	-1.804
returns (%)	0.054	0.448	2.003	-1.548	-0.015	1.205	3.491	-0.038	0.002	0.829	10.686	-4.692	0.000	0.624	2.990	-0.036

This table presents the summary statistics over the period 2005-2013. The risk, uncertainty, trading activity, and stock returns are calculated over the 150 and 200 minutes before and after (column range) the news announcement time. The risk Rvar, uncertainty U2, and trading activity are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken before adjustment to avoid extreme values.

Table 11: **Summary statistics with variables calculated over 225- and 300-minute windows**

	FOMC releases								non-FOMC releases							
	pre-announcement				post-announcement				pre-announcement				post-announcement			
variable	mean	stdev.	max	min	mean	stdev.	max	min	mean	stdev.	max	min	mean	stdev.	max	min
225-minute window																
non-event days																
ln Rvar	-0.222	0.745	3.267	-2.808	-0.226	0.738	4.593	-3.633	-0.289	0.805	4.761	-3.854	-0.166	0.644	3.295	-2.953
ln U2 (15 15-min int.)	-0.279	0.899	4.283	-3.625	-0.380	1.083	6.199	-5.805	-0.399	1.100	5.833	-5.416	-0.226	0.843	2.998	-4.525
ln trade	-0.036	0.322	1.246	-1.444	-0.031	0.298	1.479	-2.309	-0.041	0.346	1.560	-2.739	-0.034	0.316	1.322	-1.664
ln trade (calls)	-0.066	0.449	2.144	-1.590	-0.060	0.422	2.177	-2.281	-0.072	0.452	1.722	-3.136	-0.067	0.441	2.320	-1.703
ln trade (puts)	-0.065	0.448	1.936	-1.556	-0.055	0.413	1.921	-2.381	-0.070	0.447	1.724	-3.145	-0.068	0.437	2.080	-1.794
ln volume	-0.045	0.351	1.288	-1.412	-0.038	0.320	1.608	-2.351	-0.047	0.357	1.502	-2.732	-0.043	0.336	1.383	-1.615
ln volume (calls)	-0.105	0.546	2.049	-2.435	-0.094	0.505	2.084	-2.804	-0.106	0.540	2.312	-3.038	-0.099	0.514	1.870	-2.463
ln volume (puts)	-0.112	0.551	2.365	-2.367	-0.088	0.494	2.555	-2.483	-0.101	0.523	2.118	-3.707	-0.104	0.517	2.498	-2.602
returns (%)	-0.021	0.626	3.763	-3.831	0.012	0.905	9.736	-0.073	0.011	0.781	8.747	-8.296	0.003	0.654	4.728	-0.041
event days																
ln Rvar	-0.569	0.800	1.996	-2.215	0.754	0.748	2.879	-0.899	-0.251	0.796	4.088	-2.413	-0.052	0.679	2.913	-2.136
ln U2 (15 15-min int.)	0.405	0.936	2.140	-2.028	-1.036	0.818	0.840	-3.213	-0.437	1.149	4.144	-5.674	-0.243	0.884	2.400	-3.472
ln trade	-0.226	0.318	0.690	-1.037	0.407	0.274	1.159	-0.051	-0.036	0.342	1.282	-1.376	0.005	0.326	1.124	-1.034
ln trade (calls)	-0.182	0.371	0.841	-1.626	0.362	0.405	1.266	-0.620	-0.015	0.440	2.113	-1.558	-0.007	0.443	1.463	-1.548
ln trade (puts)	-0.220	0.381	0.823	-1.693	0.374	0.401	1.267	-0.676	-0.013	0.431	2.222	-1.495	0.004	0.440	1.267	-1.263
ln volume	-0.258	0.343	0.589	-0.981	0.427	0.301	1.201	-0.089	-0.050	0.365	1.790	-1.347	-0.009	0.355	1.177	-1.060
ln volume (calls)	-0.139	0.487	1.278	-1.547	0.350	0.446	1.294	-0.735	-0.047	0.528	2.384	-2.108	-0.047	0.512	1.535	-1.807
ln volume (puts)	-0.241	0.523	0.973	-1.852	0.308	0.480	1.384	-1.167	-0.075	0.513	2.706	-1.788	-0.058	0.511	1.671	-1.915
returns (%)	0.077	0.373	1.251	-1.147	-0.067	1.272	3.185	-0.046	0.004	0.809	9.016	-4.408	0.001	0.655	3.075	-0.037
300-minute window																
non-event days																
ln Rvar	-0.193	0.704	2.847	-2.785	-0.207	0.701	4.278	-3.435	-0.286	0.803	4.484	-3.586	-0.176	0.664	3.172	-2.944
ln U2 (15 20-min int.)	-0.267	0.874	4.149	-4.081	-0.332	1.010	5.804	-5.837	-0.392	1.069	6.444	-6.310	-0.234	0.877	3.468	-4.159
ln U2 (10 30-min int.)	-0.255	0.866	3.472	-3.780	-0.266	0.913	5.419	-4.921	-0.330	0.982	5.439	-5.733	-0.287	0.945	5.156	-5.503
ln trade	-0.026	0.289	1.155	-1.632	-0.029	0.291	1.400	-2.159	-0.037	0.331	1.429	-2.317	-0.035	0.321	1.203	-1.710
ln trade (calls)	-0.057	0.425	2.091	-1.537	-0.054	0.409	2.291	-2.149	-0.065	0.436	1.653	-2.057	-0.065	0.436	1.970	-1.593
ln trade (puts)	-0.055	0.422	1.853	-1.601	-0.051	0.401	2.044	-2.175	-0.064	0.431	1.621	-2.296	-0.065	0.432	1.752	-1.630
ln volume	-0.033	0.310	1.188	-1.641	-0.036	0.312	1.498	-2.196	-0.043	0.345	1.386	-2.318	-0.043	0.339	1.293	-1.667
ln volume (calls)	-0.086	0.494	1.739	-2.075	-0.083	0.482	1.979	-2.612	-0.095	0.514	2.135	-2.448	-0.092	0.501	2.095	-2.157
ln volume (puts)	-0.087	0.492	2.162	-2.029	-0.079	0.472	2.410	-2.277	-0.091	0.495	1.963	-2.865	-0.094	0.495	2.270	-2.454
returns (%)	-0.041	0.845	6.221	-5.725	0.013	0.947	8.682	-0.061	0.021	0.875	10.068	-6.771	0.009	0.762	4.293	-0.058
event days																
ln Rvar	-0.590	0.742	1.847	-1.893	0.636	0.667	2.575	-0.867	-0.257	0.793	3.927	-2.252	-0.088	0.692	2.720	-2.335
ln U2 (15 20-min int.)	0.409	0.855	1.786	-1.833	-0.772	0.855	1.086	-3.950	-0.399	1.082	3.752	-5.307	-0.248	0.903	1.996	-3.146
ln U2 (10 30-min int.)	0.458	0.873	2.016	-1.482	-0.412	0.882	1.135	-3.588	-0.336	1.010	3.674	-4.866	-0.297	1.006	3.321	-5.112
ln trade	-0.193	0.291	0.732	-0.885	0.368	0.261	1.074	-0.087	-0.034	0.331	1.232	-1.234	-0.005	0.325	1.177	-1.109
ln trade (calls)	-0.163	0.366	0.823	-1.516	0.336	0.364	1.199	-0.659	-0.015	0.426	2.010	-1.432	-0.012	0.436	1.735	-1.618
ln trade (puts)	-0.203	0.367	0.812	-1.615	0.349	0.367	1.207	-0.733	-0.012	0.415	2.113	-1.136	-0.003	0.436	1.673	-1.301
ln volume	-0.221	0.301	0.656	-0.839	0.390	0.288	1.059	-0.098	-0.047	0.354	1.714	-1.198	-0.017	0.351	1.337	-1.221
ln volume (calls)	-0.089	0.415	0.965	-1.231	0.316	0.411	1.283	-0.830	-0.044	0.505	2.303	-1.829	-0.049	0.503	1.990	-2.114
ln volume (puts)	-0.244	0.444	0.594	-1.381	0.309	0.444	1.148	-1.112	-0.069	0.485	2.590	-1.732	-0.055	0.497	2.104	-2.038
returns (%)	0.166	0.642	3.457	-1.216	-0.111	1.378	3.738	-0.045	-0.020	0.843	7.281	-4.467	0.013	0.772	3.842	-0.044

This table presents the summary statistics over the period 2005-2013. The risk, uncertainty, trading activity, and stock returns are calculated over the 225 and 300 minutes before and after (column range) the news announcement time. The risk Rvar, uncertainty U2, and trading activity are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken before adjustment to avoid extreme values.

Table 12: **Bootstrap statistics for returns, uncertainty, risk, and trading activity around FOMC releases**

			γ_1				γ_3		
			Approach 1		Approach 2		Approach 1		Approach 2
variable	range (min.)	estimate	99% CI	95% CI	p-value (%)	estimate	99% CI	95% CI	p-value (%)
20-day adjusted	150	-0.35***	[-0.58, -0.11]	[-0.52, -0.17]	0	1.33***	[1.07, 1.6]	[1.13, 1.51]	0
ln Rvar	200	-0.4***	[-0.61, -0.18]	[-0.57, -0.23]	0	1.24***	[1, 1.5]	[1.08, 1.42]	0
	225	-0.35***	[-0.58, -0.11]	[-0.52, -0.17]	0	1.33***	[1.08, 1.6]	[1.13, 1.51]	0
	300	-0.4***	[-0.61, -0.18]	[-0.57, -0.23]	0	1.24***	[1, 1.5]	[1.08, 1.42]	0
20-day adjusted	10 15-min int.	0.68***	[0.37, 0.99]	[0.45, 0.93]	0	-1.35***	[-1.67, -1.04]	[-1.59, -1.1]	0
ln U2	10 20-min int.	0.68***	[0.41, 0.94]	[0.47, 0.87]	0	-1.11***	[-1.4, -0.84]	[-1.32, -0.89]	0
	15 15-min int.	0.68***	[0.37, 0.99]	[0.45, 0.93]	0	-1.34***	[-1.67, -1.02]	[-1.58, -1.08]	0
	15 20-min int.	0.68***	[0.41, 0.94]	[0.47, 0.87]	0	-1.12***	[-1.4, -0.84]	[-1.33, -0.89]	0
	10 30-min int.	0.71***	[0.43, 0.99]	[0.5, 0.94]	0	-0.86***	[-1.14, -0.56]	[-1.06, -0.65]	0
20-day adjusted	150	-0.2***	[-0.29, -0.1]	[-0.26, -0.12]	0	0.75***	[0.63, 0.86]	[0.66, 0.83]	0
ln trade	200	-0.2***	[-0.29, -0.1]	[-0.27, -0.13]	0	0.66***	[0.55, 0.78]	[0.58, 0.75]	0
	225	-0.19***	[-0.28, -0.09]	[-0.26, -0.12]	0	0.63***	[0.52, 0.73]	[0.55, 0.7]	0
	300	-0.17***	[-0.25, -0.08]	[-0.23, -0.1]	0	0.56***	[0.46, 0.67]	[0.49, 0.64]	0
20-day adjusted	150	-0.21***	[-0.33, -0.12]	[-0.29, -0.14]	0	0.8***	[0.65, 0.93]	[0.69, 0.9]	0
ln volume	200	-0.22***	[-0.33, -0.12]	[-0.3, -0.15]	0	0.72***	[0.59, 0.84]	[0.61, 0.82]	0
	225	-0.21***	[-0.31, -0.12]	[-0.29, -0.14]	0	0.68***	[0.55, 0.81]	[0.58, 0.77]	0
	300	-0.19***	[-0.27, -0.1]	[-0.26, -0.12]	0	0.61***	[0.5, 0.73]	[0.52, 0.7]	0
20-day adjusted	150	-0.11**	[-0.24, 0]	[-0.21, -0.03]	2.6	0.65***	[0.52, 0.79]	[0.54, 0.76]	0
ln trade	200	-0.12***	[-0.25, -0.02]	[-0.22, -0.04]	1.6	0.56***	[0.44, 0.71]	[0.46, 0.67]	0
(calls)	225	-0.12***	[-0.24, -0.02]	[-0.21, -0.04]	1.8	0.54***	[0.42, 0.68]	[0.44, 0.64]	0
	300	-0.11**	[-0.23, 0.01]	[-0.19, -0.02]	1.2	0.5***	[0.37, 0.63]	[0.41, 0.59]	0
20-day adjusted	150	-0.02	[-0.16, 0.16]	[-0.14, 0.09]	38.2	0.59***	[0.43, 0.77]	[0.46, 0.72]	0
ln volume	200	-0.05	[-0.23, 0.11]	[-0.18, 0.06]	18.2	0.52***	[0.36, 0.67]	[0.38, 0.64]	0
(calls)	225	-0.03	[-0.17, 0.11]	[-0.14, 0.07]	27.2	0.48***	[0.32, 0.64]	[0.35, 0.6]	0
	300	0	[-0.12, 0.11]	[-0.1, 0.08]	45.4	0.4***	[0.25, 0.53]	[0.29, 0.51]	0
20-day adjusted	150	-0.13**	[-0.26, -0.01]	[-0.24, -0.04]	1.8	0.67***	[0.53, 0.82]	[0.56, 0.78]	0
ln trade	200	-0.15***	[-0.28, -0.03]	[-0.26, -0.07]	0.2	0.6***	[0.46, 0.73]	[0.49, 0.71]	0
(puts)	225	-0.16***	[-0.28, -0.04]	[-0.25, -0.07]	0	0.58***	[0.46, 0.71]	[0.48, 0.69]	0
	300	-0.15***	[-0.27, -0.03]	[-0.23, -0.06]	0	0.55***	[0.42, 0.67]	[0.46, 0.63]	0
20-day adjusted	150	-0.08	[-0.24, 0.09]	[-0.22, 0.06]	14.2	0.58***	[0.38, 0.78]	[0.42, 0.73]	0
ln volume	200	-0.13**	[-0.3, 0.02]	[-0.25, 0]	4.6	0.53***	[0.34, 0.73]	[0.39, 0.67]	0
(puts)	225	-0.13**	[-0.29, 0.02]	[-0.26, -0.01]	3	0.53***	[0.34, 0.71]	[0.39, 0.66]	0
	300	-0.16***	[-0.28, -0.02]	[-0.26, -0.05]	0.8	0.55***	[0.39, 0.69]	[0.42, 0.67]	0
returns (%)	150	0.07	[-0.03, 0.19]	[-0.01, 0.14]	11.6	-0.06	[-0.52, 0.29]	[-0.4, 0.22]	27.6
(x100)	200	0.07	[-0.06, 0.21]	[-0.03, 0.17]	13.8	-0.1	[-0.65, 0.31]	[-0.48, 0.2]	18.6
	225	0.1**	[-0.03, 0.2]	[0.02, 0.19]	8.2	-0.18	[-0.69, 0.22]	[-0.56, 0.12]	5.2
	300	0.21***	[0.02, 0.4]	[0.07, 0.37]	0.8	-0.33*	[-0.97, 0.07]	[-0.79, 0.01]	0.6

This table presents the bootstrap statistics of coefficients γ_1 and γ_3 in the regression $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 after_t + \gamma_3 event_t after_t + \epsilon_t$ over the period 2005-2013, where $event_t$ is the dummy for event days and $after_t$ is the dummy for the post-announcement period. The risk, uncertainty, stock returns, number of trades and total volumes are calculated over the 150, 200, 225, and 300 minutes before and after (column range) the news announcement time. The risk Rvar, uncertainty U2, and trading activity are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken before adjustment to avoid extreme values. In "Approach 1", for each variable we draw with replacement from the empirical distribution of pre(post)-announcement observations on event days a time series of length equal to the number of event days, and similarly from the empirical distribution on non-event days with a time series of length equal to the number of non-event days, and rerun the regression. Columns "99% CI'" and "95% CI" report confidence intervals from the bootstrap distribution of estimated coefficients across 500 replications. In "Approach 2", for each variable we draw with replacement a times series of length equal to the number of event days from the empirical distribution of pre(post)-announcement observations on non-event days and rerun the regression. Column "p-value" presents the p-value of coefficient values under column "estimate" in Table 2 from the bootstrap distribution of estimated coefficients across 500 replications.

Table 13: **Risk, uncertainty, trading activity, and stock returns around FOMC news without press conferences and release of a Summary of Economic Projections.**

				γ_1						γ_3			
		Eq.(2)			Approach 1		Approach 2	Eq.(2)			Approach 1		Approach 2
variable	range (min.)	est.	tstat	99% CI	95% CI	90% CI	p-value (%)	est.	tstat	99% CI	95% CI	90% CI	p-value (%)
20-day adjusted	150	-0.36***	-3.31	[-0.62, -0.07]	[-0.55, -0.12]	[-0.54, -0.17]	0	1.32***	9.36	[1.01, 1.58]	[1.08, 1.51]	[1.15, 1.48]	0
ln Rvar	200	-0.42***	-4.11	[-0.66, -0.17]	[-0.61, -0.19]	[-0.58, -0.24]	0	1.25***	9.55	[0.99, 1.49]	[1.04, 1.43]	[1.09, 1.4]	0
	225	-0.36***	-3.31	[-0.62, -0.07]	[-0.55, -0.12]	[-0.54, -0.17]	0	1.32***	9.35	[1.01, 1.58]	[1.08, 1.51]	[1.15, 1.48]	0
	300	-0.42***	-4.11	[-0.66, -0.17]	[-0.61, -0.19]	[-0.58, -0.24]	0	1.25***	9.54	[0.98, 1.49]	[1.04, 1.43]	[1.09, 1.4]	0
20-day adjusted	10 15 min. int	0.73***	5.64	[0.42, 1.04]	[0.47, 0.98]	[0.5, 0.93]	0	-1.4***	-8.39	[-1.73, -1.05]	[-1.64, -1.13]	[-1.62, -1.19]	0
ln (U2)	10 20 min. int	0.7***	5.92	[0.38, 0.98]	[0.45, 0.91]	[0.48, 0.89]	0	-1.08***	-6.58	[-1.39, -0.75]	[-1.3, -0.83]	[-1.27, -0.88]	0
	15 15 min. int	0.73***	5.64	[0.42, 1.04]	[0.47, 0.98]	[0.5, 0.93]	0	-1.38***	-8.35	[-1.69, -1]	[-1.61, -1.11]	[-1.59, -1.17]	0
	15 20 min. int	0.7***	5.93	[0.38, 0.98]	[0.45, 0.91]	[0.48, 0.89]	0	-1.08***	-6.60	[-1.39, -0.76]	[-1.31, -0.84]	[-1.26, -0.89]	0
	10 30 min. int	0.78***	6.53	[0.46, 1.08]	[0.53, 1.02]	[0.58, 0.97]	0	-0.85***	-5.09	[-1.23, -0.52]	[-1.1, -0.6]	[-1.05, -0.63]	0
20-day adjusted	150	-0.23***	-5.85	[-0.33, -0.13]	[-0.3, -0.15]	[-0.29, -0.17]	0	0.75***	14.69	[0.65, 0.86]	[0.68, 0.83]	[0.69, 0.82]	0
ln(trade)	200	-0.23***	-5.46	[-0.33, -0.12]	[-0.31, -0.15]	[-0.29, -0.16]	0	0.67***	12.70	[0.56, 0.77]	[0.58, 0.76]	[0.6, 0.74]	0
	225	-0.21***	-5.14	[-0.32, -0.11]	[-0.29, -0.13]	[-0.28, -0.14]	0	0.64***	12.16	[0.54, 0.73]	[0.55, 0.72]	[0.57, 0.71]	0
	300	-0.18***	-4.54	[-0.28, -0.08]	[-0.25, -0.1]	[-0.24, -0.11]	0	0.57***	11.26	[0.47, 0.68]	[0.49, 0.64]	[0.5, 0.63]	0
20-day adjusted	150	-0.24***	-5.71	[-0.36, -0.13]	[-0.32, -0.16]	[-0.31, -0.18]	0	0.81***	14.32	[0.68, 0.97]	[0.71, 0.92]	[0.72, 0.89]	0
ln(volume)	200	-0.26***	-5.68	[-0.37, -0.12]	[-0.35, -0.16]	[-0.33, -0.19]	0	0.74***	12.83	[0.61, 0.87]	[0.63, 0.84]	[0.65, 0.82]	0
	225	-0.24***	-5.38	[-0.36, -0.12]	[-0.33, -0.15]	[-0.32, -0.17]	0	0.7***	12.31	[0.58, 0.84]	[0.6, 0.81]	[0.62, 0.79]	0
	300	-0.21***	-4.98	[-0.32, -0.1]	[-0.29, -0.13]	[-0.27, -0.14]	0	0.63***	11.69	[0.51, 0.76]	[0.53, 0.73]	[0.55, 0.71]	0
20-day adjusted	150	-0.13**	-2.34	[-0.25, 0.01]	[-0.23, -0.02]	[-0.21, -0.04]	2.4	0.64***	8.47	[0.51, 0.78]	[0.54, 0.74]	[0.55, 0.73]	0
ln(trade)	200	-0.13***	-2.60	[-0.25, -0.02]	[-0.23, -0.04]	[-0.21, -0.06]	1.6	0.55***	7.54	[0.42, 0.69]	[0.45, 0.66]	[0.47, 0.64]	0
calls	225	-0.12**	-2.39	[-0.25, 0]	[-0.21, -0.03]	[-0.2, -0.05]	2.2	0.52***	7.29	[0.4, 0.66]	[0.42, 0.62]	[0.44, 0.61]	0
	300	-0.11**	-2.12	[-0.22, 0.01]	[-0.21, -0.01]	[-0.19, -0.03]	2.2	0.49***	7.05	[0.37, 0.63]	[0.39, 0.59]	[0.41, 0.57]	0
20-day adjusted	150	-0.06	-0.92	[-0.24, 0.11]	[-0.21, 0.07]	[-0.19, 0.04]	24.2	0.63***	6.93	[0.43, 0.81]	[0.48, 0.77]	[0.51, 0.75]	0
ln(volume)	200	-0.09	-1.21	[-0.27, 0.09]	[-0.24, 0.05]	[-0.21, 0.02]	11.6	0.54***	6.01	[0.37, 0.73]	[0.4, 0.68]	[0.43, 0.66]	0
calls	225	-0.06	-0.85	[-0.24, 0.1]	[-0.2, 0.07]	[-0.17, 0.05]	21.8	0.5***	5.72	[0.32, 0.7]	[0.36, 0.64]	[0.38, 0.61]	0
	300	-0.02	-0.41	[-0.16, 0.12]	[-0.15, 0.09]	[-0.12, 0.07]	37	0.41***	5.36	[0.26, 0.59]	[0.29, 0.53]	[0.3, 0.51]	0
20-day adjusted	150	-0.13**	-2.31	[-0.27, 0]	[-0.25, -0.03]	[-0.22, -0.04]	2.2	0.65***	8.45	[0.51, 0.81]	[0.55, 0.77]	[0.57, 0.75]	0
ln(trade)	200	-0.16***	-2.97	[-0.3, -0.02]	[-0.26, -0.06]	[-0.24, -0.07]	0	0.59***	7.83	[0.45, 0.72]	[0.49, 0.7]	[0.51, 0.68]	0
puts	225	-0.16***	-2.99	[-0.28, -0.02]	[-0.26, -0.06]	[-0.25, -0.08]	0	0.57***	7.77	[0.44, 0.71]	[0.48, 0.69]	[0.49, 0.66]	0
	300	-0.15***	-2.92	[-0.27, -0.01]	[-0.25, -0.06]	[-0.24, -0.07]	0	0.55***	7.73	[0.44, 0.7]	[0.46, 0.66]	[0.47, 0.64]	0
20-day adjusted	150	-0.06	-0.71	[-0.26, 0.13]	[-0.22, 0.11]	[-0.2, 0.09]	25.4	0.55***	5.21	[0.32, 0.79]	[0.37, 0.74]	[0.41, 0.72]	0
ln(volume)	200	-0.12	-1.64	[-0.29, 0.05]	[-0.27, 0.02]	[-0.25, 0]	4.2	0.53***	5.37	[0.32, 0.73]	[0.37, 0.7]	[0.4, 0.68]	0
puts	225	-0.13*	-1.73	[-0.3, 0.05]	[-0.27, 0.01]	[-0.26, -0.01]	2.8	0.52***	5.44	[0.33, 0.72]	[0.37, 0.7]	[0.4, 0.67]	0
	300	-0.16**	-2.57	[-0.33, 0.01]	[-0.29, -0.04]	[-0.27, -0.06]	0.6	0.56***	6.55	[0.37, 0.76]	[0.42, 0.71]	[0.44, 0.68]	0
returns (%)	150	0.07	1.51	[-0.06, 0.2]	[-0.02, 0.16]	[-0.01, 0.14]	11.8	-0.13	-0.84	[-0.65, 0.27]	[-0.51, 0.22]	[-0.44, 0.17]	13.4
(x100)	200	0.09	1.41	[-0.07, 0.24]	[-0.03, 0.21]	[-0.01, 0.18]	10.6	-0.17	-1.02	[-0.73, 0.25]	[-0.59, 0.19]	[-0.54, 0.13]	8.6
	225	0.12**	2.32	[-0.02, 0.24]	[0.03, 0.21]	[0.04, 0.2]	6.4	-0.25	-1.43	[-0.78, 0.2]	[-0.65, 0.09]	[-0.57, 0.04]	2.2
	300	0.25***	2.77	[0.04, 0.46]	[0.07, 0.43]	[0.1, 0.41]	0.8	-0.42**	-2.10	[-1.07, 0.12]	[-0.9, -0.02]	[-0.79, -0.07]	0.2

This table presents changes in risk, uncertainty, trading activity, and stock returns around FOMC news without press conferences and release of a Summary of Economic Projections over the period 2005-2013. The main coefficients are the mean differential between event and non-event days (γ_1), and between pre- and post-announcements during event days (γ_3), respectively. The risk, uncertainty, trading activity, and stock returns are calculated over the 150, 200, 225, and 300 minutes before and after (column range) the news announcement time. The risk Rvar, uncertainty U2 and trading activity are adjusted by the moving average over the last 20 non-event days. The natural logarithm is taken before adjustment to avoid extreme values. The coefficients γ_1 and γ_3 are from Eq.(2) $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 after_t + \gamma_3 event_t after_t + \epsilon_t$ are presented. $event_t$ is the dummy for event days, and $after_t$ is the dummy for the post-announcement period. The standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level. In "Approach 1", for each variable we draw with replacement from the empirical distribution of pre(post)-announcement observations on event days a time series of length equal to the number of event days, and similarly from the empirical distribution on non-event days with a time series of length equal to the number of non-event days, and rerun the regression. Columns "99% CI'" and "95% CI" report confidence intervals from the bootstrap distribution of estimated coefficients across 500 replications. In "Approach 2", for each variable we draw with replacement a times series of length equal to the number of event days from the empirical distribution of pre(post)-announcement observations on non-event days and rerun the regression. Column "p-value" presents the p-value of coefficient values under column "est." from the bootstrap distribution of estimated coefficients across 500 replications.

Table 14: **Pre-announcement number-of-trades regression for FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat
equity	Adj-R^2(%)	10	0.91		56.80		33.36		60.96		60.95		15	1.02		55.30		38.16		61.97		61.96	
	event	of 15-min	-0.55***	-5.03	-0.21***	-2.69	-0.12	-1.28	-0.08	-1.24	-0.12	-1.11	of 15-min	-0.59***	-5.01	-0.24***	-3.14	-0.12	-1.31	-0.09	-1.37	-0.06	-0.7
	Rvar				0.75***	31.29			0.62***	22.43	0.63***	21.79				0.74***	30.81			0.58***	22.66	0.58***	21.75
	Rvar*event										-0.09	-0.83										-0.01	-0.13
	U2						-0.57***	-26.27	-0.24***	-10.7	-0.24***	-10.1						-0.61***	-28.05	-0.31***	-14.35	-0.3***	-13.56
	U2*event										-0.06	-0.98										-0.09	-1.51
	Adj-R^2(%)	10	1.06		59.49		35.66		63.91		63.88		15	0.98		58.01		39.12		64.33		64.31	
	event	of 20-min	-0.6***	-5.12	-0.17**	-2.32	-0.14	-1.35	-0.05	-0.71	-0.04	-0.36	of 20-min	-0.58***	-4.83	-0.15*	-1.87	-0.1	-0.99	-0.01	-0.14	0.01	0.09
	Rvar				0.77***	33.45			0.63***	24.29	0.63***	23.56				0.76***	32.76			0.6***	25.12	0.6***	24.36
	Rvar*event										0.03	0.29										-0.01	-0.15
	U2						-0.59***	-27.37	-0.25***	-11.33	-0.25***	-11.04						-0.62***	-28.57	-0.3***	-14.83	-0.3***	-14.27
	U2*event										0.03	0.39										-0.07	-0.83
	Adj-R^2(%)	10	0.98		63.31		43.76		68.72		68.70												
	event	of 30-min	-0.58***	-4.83	-0.13**	-2.06	-0.04	-0.39	0.01	0.15	0.04	0.54											
	Rvar				0.79***	39.44			0.62***	26.77	0.62***	25.93											
	Rvar*event										0.06	0.76											
	U2						-0.66***	-32.16	-0.29***	-14.81	-0.29***	-14.48											
	U2*event										0.04	0.47											
call	Adj-R^2(%)	10	0.13		20.76		11.40		22.00		22.11		15	0.16		19.49		12.66		21.49		21.45	
	event	of 15-min	-0.24**	-2.33	-0.03	-0.32	0.01	0.14	0.03	0.34	-0.14	-1.03	of 15-min	-0.26***	-2.6	-0.06	-0.66	0	0.04	0.02	0.26	-0.05	-0.45
	Rvar				0.46***	20.46			0.39***	15.27	0.39***	15.42				0.44***	20.01			0.35***	14.65	0.36***	14.44
	Rvar*event										-0.21	-1.62										-0.09	-0.76
	U2						-0.34***	-14.95	-0.13***	-5.65	-0.13***	-5.47						-0.36***	-15.71	-0.17***	-7.35	-0.17***	-7.13
	U2*event										0.04	0.38										0.03	0.27
	Adj-R^2(%)	10	0.18		21.45		11.75		22.63		22.62		15	0.15		19.39		12.80		21.40		21.35	
	event	of 20-min	-0.27***	-2.69	-0.02	-0.18	-0.01	-0.08	0.04	0.48	-0.06	-0.5	of 20-min	-0.25**	-2.39	-0.01	-0.09	0.02	0.24	0.07	0.77	0.03	0.27
	Rvar				0.46***	21.11			0.39***	15.71	0.4***	15.61				0.44***	19.96			0.35***	14.25	0.35***	14.12
	Rvar*event										-0.11	-0.77										-0.08	-0.59
	U2						-0.34***	-15.34	-0.13***	-5.66	-0.13***	-5.58						-0.36***	-16.04	-0.17***	-7.34	-0.17***	-7.08
	U2*event										0.06	0.5										-0.05	-0.48
	Adj-R^2(%)	10	0.15		20.66		14.24		22.42		22.36												
	event	of 30-min	-0.25**	-2.39	0	-0.02	0.06	0.58	0.08	0.89	0.06	0.55											
	Rvar				0.46***	21.5			0.36***	14.21	0.36***	13.97											
	Rvar*event										-0.03	-0.24											
	U2						-0.38***	-17.7	-0.17***	-6.97	-0.17***	-6.79											
	U2*event										-0.01	-0.1											
put	Adj-R^2(%)	10	0.18		24.03		13.28		25.49		25.59		15	0.33		22.52		14.96		24.96		24.93	
	event	of 15-min	-0.27**	-2.56	-0.05	-0.47	0	0.03	0.02	0.24	-0.14	-1.12	of 15-min	-0.35***	-3.38	-0.13	-1.43	-0.06	-0.61	-0.04	-0.44	-0.12	-1.03
	Rvar				0.49***	22.49			0.41***	17.08	0.42***	17.13				0.47***	21.59			0.37***	15.99	0.38***	15.76
	Rvar*event										-0.18	-1.37										-0.08	-0.69
	U2						-0.37***	-16.52	-0.15***	-6.48	-0.15***	-6.43						-0.39***	-17.21	-0.19***	-8.34	-0.19***	-8.17
	U2*event										0.1	0.85										0.05	0.43
	Adj-R^2(%)	10	0.30		24.51		13.75		25.97		25.98		15	0.34		23.54		15.33		25.85		25.81	
	event	of 20-min	-0.34***	-3.27	-0.07	-0.7	-0.05	-0.51	0	0.02	-0.12	-0.91	of 20-min	-0.35***	-3.35	-0.09	-0.93	-0.06	-0.56	0	-0.03	-0.06	-0.48
	Rvar				0.49***	22.86			0.42***	17.17	0.42***	17.08				0.48***	22.28			0.39***	16.29	0.39***	16.2
	Rvar*event										-0.09	-0.66										-0.08	-0.61
	U2						-0.37***	-16.77	-0.15***	-6.53	-0.15***	-6.54						-0.39***	-17.57	-0.18***	-8.09	-0.18***	-7.88
	U2*event										0.11	0.93										-0.02	-0.16
	Adj-R^2(%)	10	0.34		24.39		17.08		26.56		26.50												
	event	of 30-min	-0.35***	-3.35	-0.08	-0.96	-0.02	-0.21	0.01	0.06	-0.01	-0.09											
	Rvar				0.49***	23.82			0.38***	16.11	0.38***	15.83											
	Rvar*event										0.01	0.11											
	U2						-0.41***	-19.35	-0.19***	-8.02	-0.19***	-7.95											
	U2*event										0.06	0.48											

This table presents the regression $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 Rvar_t + \gamma_3 U2_t + \gamma_4 Rvar_t event_t + \gamma_5 U2_t event_t + \epsilon_t$ of pre-announcement number-of-trades on risk and uncertainty for FOMC releases over the period 2005-2013, where $event_t$ is the dummy for event days. The number of trades, risk, and uncertainty are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken for number of trades, risk, and uncertainty before adjustment to avoid extreme values. The range column indicates the time range over which each variable in the regression is calculated before the next FOMC announcement time. The variables are standardized by their sample standard deviation, and the standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Table 15: **Pre-announcement number-of-trades regression for non-FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat
equity	Adj-R^2(%)	10	-0.01		49.87		27.36		57.77		57.76		15	-0.02		50.13		32.47		61.72		61.72	
	event	of 15-min	0.02	0.64	-0.01	-0.55	0.01	0.33	-0.01	-0.68	0	-0.05	of 15-min	0.01	0.39	-0.02	-0.79	0	-0.16	-0.02	-1.16	-0.01	-0.19
	Rvar				0.71***	35.43			0.58***	32.14	0.57***	28.19				0.71***	38.88			0.58***	34.49	0.57***	30.21
	Rvar*event										0.03	0.65										0.03	0.77
	U2						-0.51***	-27.4	-0.29***	-21.86	-0.3***	-18.69						-0.57***	-30.01	-0.36***	-23.99	-0.37***	-20.59
	U2*event										0.01	0.39										0.02	0.73
	Adj-R^2(%)	10	-0.02		47.86		23.11		54.57		54.60		15	-0.02		49.58		30.24		60.90		60.93	
	event	of 20-min	0.02	0.45	-0.01	-0.36	0.02	0.59	0	-0.16	0.03	0.73	of 20-min	0.01	0.21	-0.02	-0.72	0	0.12	-0.02	-0.73	0.02	0.51
	Rvar				0.69***	34.58			0.59***	28.64	0.58***	24.43				0.7***	39.56			0.59***	35.49	0.58***	30.93
	Rvar*event										0.06	1.43										0.06	1.46
	U2						-0.48***	-25.26	-0.28***	-16.73	-0.29***	-14.42						-0.55***	-29.8	-0.36***	-24.92	-0.36***	-21.84
	U2*event										0.03	0.85										0.04	1.31
	Adj-R^2(%)	10	-0.02		53.58		25.35		60.32		60.39												
	event	of 30-min	0.01	0.21	-0.01	-0.58	0	0.15	-0.01	-0.56	0.03	0.84											
	Rvar				0.73***	42.49			0.63***	36.8	0.62***	32.35											
	Rvar*event										0.08*	1.82											
	U2						-0.5***	-28.51	-0.28***	-19.71	-0.29***	-17.75											
	U2*event										0.05*	1.72											
call	Adj-R^2(%)	10	0.17		24.57		9.51		25.53		25.52		15	0.21		24.00		12.57		27.50		27.50	
	event	of 15-min	0.11***	3.23	0.09***	2.94	0.11***	3.2	0.09***	2.99	0.11***	2.94	of 15-min	0.13***	3.53	0.1***	3.35	0.11***	3.45	0.1***	3.36	0.13***	3.26
	Rvar				0.49***	30.13			0.43***	25.77	0.42***	22.8				0.49***	30.53			0.41***	24.35	0.41***	21.39
	Rvar*event										0.04	0.94										0.04	0.99
	U2						-0.3***	-17.77	-0.15***	-10.21	-0.15***	-9.19						-0.35***	-19.33	-0.2***	-12.03	-0.21***	-10.73
	U2*event										0.03	0.91										0.04	1.09
	Adj-R^2(%)	10	0.23		23.79		8.69		25.26		25.28		15	0.18		24.10		11.40		27.47		27.46	
	event	of 20-min	0.13***	3.65	0.11***	3.71	0.13***	3.87	0.11***	3.84	0.15***	3.7	of 20-min	0.12***	3.23	0.1***	3.19	0.11***	3.36	0.1***	3.29	0.12***	3.13
	Rvar				0.49***	28.63			0.43***	23.9	0.42***	20.76				0.49***	32.66			0.42***	27.33	0.42***	24.36
	Rvar*event										0.06	1.45										0.04	1
	U2						-0.29***	-16.48	-0.15***	-9.06	-0.15***	-8.11						-0.34***	-19.67	-0.19***	-13.33	-0.2***	-11.95
	U2*event										0.03	0.9										0.02	0.68
	Adj-R^2(%)	10	0.18		25.81		9.33		27.50		27.52												
	event	of 30-min	0.12***	3.23	0.1***	3.33	0.11***	3.34	0.1***	3.39	0.13***	3.46											
	Rvar				0.51***	34.26			0.46***	29.1	0.45***	26											
	Rvar*event										0.06	1.46											
	U2						-0.3***	-18.13	-0.14***	-9.79	-0.15***	-8.98											
	U2*event										0.03	0.94											
put	Adj-R^2(%)	10	0.20		26.06		9.33		26.72		26.72		15	0.22		26.43		13.22		29.94		29.95	
	event	of 15-min	0.12***	3.51	0.1***	3.28	0.11***	3.47	0.1***	3.31	0.12***	3.18	of 15-min	0.13***	3.59	0.1***	3.45	0.12***	3.51	0.1***	3.46	0.13***	3.35
	Rvar				0.51***	30.26			0.44***	26.66	0.44***	23.73				0.51***	31.63			0.44***	26.18	0.43***	23.1
	Rvar*event										0.04	1.01										0.04	1.03
	U2						-0.3***	-17.5	-0.13***	-9.52	-0.14***	-8.66						-0.36***	-19.81	-0.2***	-12.51	-0.21***	-11.22
	U2*event										0.03	0.96										0.04	1.12
	Adj-R^2(%)	10	0.24		25.15		8.44		26.27		26.30		15	0.20		26.48		11.85		29.79		29.80	
	event	of 20-min	0.13***	3.76	0.11***	3.87	0.13***	3.97	0.12***	3.99	0.15***	3.84	of 20-min	0.12***	3.44	0.1***	3.47	0.12***	3.59	0.1***	3.58	0.13***	3.5
	Rvar				0.5***	28.84			0.45***	24.44	0.43***	21.16				0.51***	34.1			0.45***	29.58	0.44***	26.37
	Rvar*event										0.07	1.53										0.05	1.14
	U2						-0.28***	-16.26	-0.14***	-8.4	-0.14***	-7.55						-0.34***	-19.97	-0.19***	-13.59	-0.2***	-12.3
	U2*event										0.03	0.93										0.03	0.86
	Adj-R^2(%)	10	0.20		28.05		9.45		29.58		29.60												
	event	of 30-min	0.12***	3.44	0.11***	3.63	0.12***	3.56	0.11***	3.68	0.14***	3.76											
	Rvar				0.53***	35.59			0.48***	30.94	0.47***	27.67											
	Rvar*event										0.06	1.53											
	U2						-0.3***	-18.1	-0.13***	-9.37	-0.14***	-8.69											
	U2*event										0.04	1.08											

This table presents the regression $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 Rvar_t + \gamma_3 U2_t + \gamma_4 Rvar_t event_t + \gamma_5 U2_t event_t + \epsilon_t$ of pre-announcement number-of-trades on risk and uncertainty for non-FOMC releases over the period 2005-2013, where $event_t$ is the dummy for event days. The number of trades, risk, and uncertainty are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken for number of trades, risk, and uncertainty before adjustment to avoid extreme values. The range column indicates the time range over which each variable in the regression is calculated before the next other announcement time. The variables are standardized by their sample standard deviation, and the standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Table 16: **Post-announcement number-of-trades regression for FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat
equity	Adj-R^2(%)	10	8.09		54.20		29.76		61.01		61.06		15	6.25		49.52		26.97		56.72		56.71	
	event	of 15-min	1.62***	15.03	0.72***	8.78	1.32***	12.12	0.66***	8.26	0.79***	6.05	of 15-min	1.42***	13.36	0.55***	6.49	1.15***	10.98	0.49***	6.13	0.58***	4.25
	Rvar				0.7***	23.03			0.61***	21.19	0.6***	20.54				0.68***	21.98			0.59***	20.46	0.59***	19.82
	Rvar*event										0.07	0.67										0.05	0.57
	U2						-0.47***	-16.06	-0.28***	-14.92	-0.28***	-14.85						-0.46***	-15.92	-0.28***	-13.18	-0.29***	-13.07
	U2*event										0.21**	2.56										0.14	1.49
	Adj-R^2(%)	10	6.69		55.34		29.54		62.30		62.31		15	5.44		51.77		28.12		59.03		59.02	
	event	of 20-min	1.47***	13.56	0.63***	7.93	1.26***	11.85	0.62***	8.12	0.63***	6.31	of 20-min	1.33***	12.75	0.51***	6.59	1.12***	11.26	0.5***	6.91	0.49***	5.31
	Rvar				0.71***	24.21			0.62***	22.21	0.62***	21.54				0.7***	24.54			0.6***	23.24	0.6***	22.52
	Rvar*event										0.1	1.02										0.08	1.11
	U2						-0.48***	-16.11	-0.28***	-14.27	-0.28***	-14.1						-0.48***	-16.3	-0.29***	-15.06	-0.29***	-14.82
	U2*event										0.13**	2.31										0.08	1.54
	Adj-R^2(%)	10	5.44		60.10		33.41		66.28		66.33												
	event	of 30-min	1.33***	12.75	0.53***	7.41	1.24***	11.94	0.61***	8.54	0.62***	8.04											
	Rvar				0.75***	27.74			0.64***	24.11	0.64***	23.38											
	Rvar*event										0.08	1.08											
	U2						-0.53***	-19.27	-0.27***	-14.54	-0.28***	-14.42											
	U2*event										0.16***	3.08											
call	Adj-R^2(%)	10	4.01		23.11		11.54		25.10		25.07		15	2.94		20.24		9.25		21.95		21.93	
	event	of 15-min	1.15***	10.27	0.56***	5.51	0.97***	8.54	0.53***	5.18	0.59***	2.94	of 15-min	0.99***	8.68	0.43***	4.08	0.83***	7.23	0.4***	3.8	0.45**	2.48
	Rvar				0.45***	18.39			0.4***	16.37	0.4***	15.89				0.43***	17.36			0.38***	15.57	0.38***	15.13
	Rvar*event										0.07	0.63										0.08	0.72
	U2						-0.28***	-10.64	-0.15***	-7.55	-0.15***	-7.58						-0.25***	-10.05	-0.14***	-6.38	-0.14***	-6.43
	U2*event										0.13	1.16										0.14	1.29
	Adj-R^2(%)	10	3.10		22.89		10.17		24.49		24.49		15	2.69		21.01		9.41		22.62		22.60	
	event	of 20-min	1.01***	8.78	0.47***	4.52	0.9***	7.66	0.47***	4.45	0.48***	2.87	of 20-min	0.94***	8.9	0.42***	4.43	0.83***	7.76	0.42***	4.36	0.43***	2.87
	Rvar				0.45***	19.23			0.41***	17.36	0.41***	16.89				0.44***	18.87			0.39***	17.11	0.39***	16.65
	Rvar*event										0.11	0.88										0.1	0.89
	U2						-0.27***	-10.35	-0.14***	-6.77	-0.14***	-6.83						-0.26***	-10.28	-0.14***	-6.73	-0.14***	-6.77
	U2*event										0.14*	1.65										0.13*	1.67
	Adj-R^2(%)	10	2.69		23.80		11.97		25.43		25.43												
	event	of 30-min	0.94***	8.9	0.44***	4.66	0.89***	8.25	0.48***	5.03	0.49***	3.57											
	Rvar				0.47***	20.53			0.41***	17.48	0.41***	17.01											
	Rvar*event										0.08	0.65											
	U2						-0.31***	-12.09	-0.14***	-6.88	-0.15***	-6.95											
	U2*event										0.15*	1.83											
put	Adj-R^2(%)	10	4.25		24.91		12.07		26.89		26.84		15	3.18		21.64		9.77		23.39		23.34	
	event	of 15-min	1.18***	10.68	0.57***	5.65	1***	8.94	0.54***	5.35	0.59***	3.12	of 15-min	1.02***	8.93	0.45***	4.16	0.87***	7.5	0.42***	3.9	0.48***	2.72
	Rvar				0.47***	18.39			0.42***	16.67	0.42***	16.22				0.44***	17.16			0.4***	15.69	0.4***	15.29
	Rvar*event										0.05	0.42										0.04	0.38
	U2						-0.28***	-10.86	-0.15***	-7.66	-0.15***	-7.65						-0.26***	-10.35	-0.14***	-6.64	-0.14***	-6.65
	U2*event										0.1	0.88										0.11	0.97
	Adj-R^2(%)	10	3.32		25.26		10.91		26.92		26.91		15	2.93		22.92		10.00		24.53		24.49	
	event	of 20-min	1.05***	9.07	0.48***	4.54	0.93***	7.9	0.47***	4.48	0.51***	3.13	of 20-min	0.98***	9.07	0.44***	4.4	0.87***	7.95	0.44***	4.35	0.47***	3.17
	Rvar				0.48***	19.41			0.43***	17.82	0.43***	17.39				0.46***	18.91			0.41***	17.43	0.41***	17.01
	Rvar*event										0.08	0.65										0.06	0.5
	U2						-0.28***	-10.81	-0.14***	-7.08	-0.14***	-7.15						-0.27***	-10.66	-0.14***	-6.85	-0.14***	-6.86
	U2*event										0.15*	1.83										0.11	1.58
	Adj-R^2(%)	10	2.93		26.79		13.10		28.49		28.46												
	event	of 30-min	0.98***	9.07	0.45***	4.63	0.93***	8.55	0.49***	5.06	0.5***	3.55											
	Rvar				0.5***	21.03			0.44***	18.24	0.44***	17.79											
	Rvar*event										0.05	0.4											
	U2						-0.32***	-12.8	-0.14***	-7.07	-0.15***	-7.06											
	U2*event										0.09	1.13											

This table presents the regression $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 Rvar_t + \gamma_3 U2_t + \gamma_4 Rvar_t event_t + \gamma_5 U2_t event_t + \epsilon_t$ of post-announcement number-of-trades on risk and uncertainty for FOMC releases over the period 2005-2013, where $event_t$ is the dummy for event days. The number of trades, risk, and uncertainty are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken for number of trades, risk, and uncertainty before adjustment to avoid extreme values. The range column indicates the time range over which each variable in the regression is calculated after the next FOMC announcement time. The variables are standardized by their sample standard deviation, and the standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Table 17: **Post-announcement number-of-trades regression for non-FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(5)	t-stat
equity	Adj-R^2(%)	10	0.39		63.97		42.14		66.34		66.34		15	0.20		61.14		42.36		64.14		64.14	
	event	of 15-min	0.17***	4.53	0.03	1.19	0.15***	5.49	0.05**	2.18	0.03	1.17	of 15-min	0.12***	3.32	-0.01	-0.64	0.11***	3.94	0.01	0.37	-0.01	-0.2
	Rvar				0.8***	60.21			0.66***	35.66	0.67***	33.73				0.78***	58.7			0.63***	35.28	0.63***	32.95
	Rvar*event										-0.04	-0.72										-0.03	-0.63
	U2						-0.65***	-53.1	-0.21***	-13.48	-0.2***	-12.12						-0.65***	-53.99	-0.23***	-15.52	-0.22***	-13.75
	U2*event										-0.03	-0.65										-0.04	-0.93
	Adj-R^2(%)	10	0.22		61.87		42.61		66.47		66.46		15	0.11		54.84		39.05		59.47		59.47	
	event	of 20-min	0.13***	3.46	0.02	1.1	0.12***	4.15	0.04**	1.99	0.05*	1.68	of 20-min	0.09**	2.55	0	-0.14	0.08***	2.89	0.01	0.61	0.03	0.87
	Rvar				0.79***	53.89			0.62***	34.34	0.62***	30.88				0.74***	49.3			0.57***	31.4	0.57***	27.78
	Rvar*event										0.01	0.31										0.02	0.39
	U2						-0.65***	-50.94	-0.27***	-18.17	-0.28***	-16.61						-0.62***	-47.07	-0.27***	-17.51	-0.28***	-16
	U2*event										0.02	0.5										0.03	0.89
	Adj-R^2(%)	10	0.11		58.67		34.17		65.82		65.84												
	event	of 30-min	0.09**	2.55	0.01	0.64	0.09***	2.88	0.03	1.22	0.05*	1.67											
	Rvar				0.77***	50.62			0.63***	41.04	0.62***	36.08											
	Rvar*event										0.04	1.17											
	U2						-0.58***	-34.19	-0.3***	-23.36	-0.31***	-21.07											
	U2*event										0.04	1.48											
call	Adj-R^2(%)	10	0.36		21.21		13.90		21.93		21.91		15	0.26		21.35		14.58		22.28		22.25	
	event	of 15-min	0.16***	4.39	0.08**	2.47	0.15***	4.46	0.09***	2.81	0.09**	2.57	of 15-min	0.14***	3.77	0.06*	1.76	0.13***	3.82	0.07**	2.15	0.07*	1.93
	Rvar				0.46***	33.6			0.38***	21.01	0.38***	19.22				0.46***	33.01			0.37***	20.3	0.37***	18.26
	Rvar*event										-0.01	-0.13										0	-0.1
	U2						-0.37***	-26.31	-0.11***	-6.43	-0.12***	-5.96						-0.38***	-27.11	-0.13***	-7.31	-0.13***	-6.61
	U2*event										0.01	0.22										0	0.08
	Adj-R^2(%)	10	0.25		21.63		14.68		23.10		23.08		15	0.20		20.90		14.15		22.31		22.30	
	event	of 20-min	0.14***	3.72	0.08**	2.32	0.13***	3.8	0.08***	2.63	0.09**	2.53	of 20-min	0.12***	3.39	0.06*	1.95	0.12***	3.42	0.07**	2.26	0.08**	2.26
	Rvar				0.46***	33.32			0.37***	22.33	0.37***	20.2				0.46***	31.91			0.36***	21.3	0.36***	19.12
	Rvar*event										0	0.01										0	-0.07
	U2						-0.38***	-26.89	-0.15***	-9.65	-0.16***	-9.02						-0.37***	-25.74	-0.15***	-9.14	-0.16***	-8.58
	U2*event										0.02	0.53										0.03	0.78
	Adj-R^2(%)	10	0.20		23.64		11.38		25.32		25.36												
	event	of 30-min	0.12***	3.39	0.07**	2.33	0.12***	3.43	0.08**	2.5	0.11***	3.06											
	Rvar				0.48***	35.75			0.42***	28.91	0.41***	25.48											
	Rvar*event										0.04	1.06											
	U2						-0.33***	-19.8	-0.15***	-9.93	-0.16***	-9.73											
	U2*event										0.07*	1.84											
put	Adj-R^2(%)	10	0.48		24.49		16.08		25.32		25.30		15	0.37		24.59		16.70		25.62		25.59	
	event	of 15-min	0.18***	5.04	0.1***	3.08	0.18***	5.19	0.11***	3.45	0.11***	3.22	of 15-min	0.16***	4.48	0.08**	2.42	0.15***	4.61	0.09***	2.84	0.09***	2.61
	Rvar				0.49***	36.23			0.41***	22.77	0.41***	20.86				0.49***	35.99			0.4***	22.46	0.4***	20.35
	Rvar*event										-0.01	-0.12										-0.01	-0.14
	U2						-0.4***	-28.24	-0.12***	-7.03	-0.13***	-6.61						-0.4***	-29	-0.14***	-7.87	-0.14***	-7.21
	U2*event										0.02	0.42										0.01	0.2
	Adj-R^2(%)	10	0.38		24.72		16.59		26.31		26.29		15	0.28		23.55		15.88		25.11		25.10	
	event	of 20-min	0.17***	4.53	0.1***	3.17	0.16***	4.71	0.11***	3.51	0.12***	3.33	of 20-min	0.14***	3.92	0.08**	2.48	0.14***	4.02	0.09***	2.81	0.1***	2.73
	Rvar				0.49***	35.69			0.4***	24.35	0.4***	22.04				0.48***	34.01			0.39***	23.18	0.39***	20.89
	Rvar*event										0	-0.08										-0.01	-0.17
	U2						-0.4***	-28.2	-0.16***	-10.1	-0.16***	-9.39						-0.4***	-26.95	-0.16***	-9.69	-0.16***	-8.99
	U2*event										0.02	0.53										0.03	0.64
	Adj-R^2(%)	10	0.28		26.49		13.28		28.60		28.62												
	event	of 30-min	0.14***	3.92	0.09***	2.91	0.14***	4.02	0.1***	3.12	0.12***	3.53											
	Rvar				0.51***	38.01			0.44***	30.84	0.43***	27.36											
	Rvar*event										0.04	1.06											
	U2						-0.36***	-21.12	-0.16***	-11.03	-0.17***	-10.67											
	U2*event										0.06	1.54											

This table presents the regression $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 Rvar_t + \gamma_3 U2_t + \gamma_4 Rvar_t event_t + \gamma_5 U2_t event_t + \epsilon_t$ of post-announcement number-of-trades on risk and uncertainty for non-FOMC releases over the period 2005-2013, where $event_t$ is the dummy for event days. The number of trades, risk, and uncertainty are adjusted by the moving average over the last 20 non-event trading days. The natural logarithm is taken for number of trades, risk, and uncertainty before adjustment to avoid extreme values. The range column indicates the time range over which each variable in the regression is calculated before the next other announcement time. The variables are standardized by their sample standard deviation, and the standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.