Do investors differentiate between uncertainty and risk: Evidence from trading around U.S. macroeconomic news

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Abstract

We provide new evidence on the impact of changes in risk and uncertainty on market participation (trading activity) by investigating these effects simultaneously. We document that a sustained increase in trading activity is coupled with a rise in risk and dramatic drop in uncertainty after the Federal Open Market Committee (FOMC) meetings. Following the non-FOMC news releases, trading activity increases modestly with an increase in risk, but unchanged uncertainty. The evidence suggests that uncertainty affects investors decision to participate to market more than risk does. Limited participation due to higher uncertainty before the FOMC news releases may induce premium to uncertainty in addition to risk that explains the well-documented pre-FOMC announcement drift (Lucca and Moench, Journal of Finance, 2015).

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1 Introduction

Risk and uncertainty are expected to have separate effects on market participation, see Cao et al. (2005b) and Ui (2011) among others. Practitioners and news media have also noted differences about uncertainty and risk measures.[1] We illustrate these crucial distinctions at times of macroeconomic news releases and investigate how investors' participation in equity market vary with changes in risk and uncertainty. Previous literature has examined the effects of risk and uncertainty on financial markets separately, and this raises a concern of what ultimately drives the results. In this paper we examine risk and uncertainty simultaneously to understand better their impact on market participation.

Macro news releases have been reportedly associated with changes in risk (volatility) and uncertainty following the announcement time, see Balduzzi et al. (2001), Beber and Brandt (2009), Savor and Wilson (2013), and Bollerslev et al. (2018). Hence, investigating trading activity around macro news provide an ideal framework in drawing inference about market participation. Most of previous studies do not distinguish different types of macro news and investigate the aggregate effects. Meanwhile, recent works focus on the Federal Open Market Committee (FOMC) meetings.[2]

The FOMC statements stand out among macroeconomic news because their text-based nature clarifies the rationale behind policy action, while other (non-FOMC) macroeconomic news report numerical values to the market.[3] Indeed, the Wall Street Journal (WSJ) dedicates a column named "Parsing the FED" to outline changes in the wording from meeting to meeting.[4] 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)." Meanwhile, other macro news, e.g. nonfarm payroll (that is closely followed by financial press and often referred to as "king" of

[1] See `https://blog.pimco.com/en/2017/06/Dont%20Confuse%20Uncertainty%20With%20Volatility` on the difference between VIX and uncertainty, and `https://www.huffingtonpost.com/entry/dont-confuse-uncertainty-with-risk_us_58d43639e4b06c3d3d3e6be6`.

[2] For example, Lucca and Moench (2015) document the equity price drift prior to FOMC news releases, and Bollerslev et al. (2018) explain the positive relation between trading volume and volatility by the difference-in-opinion theory.

[3] At the announcement time of target rate decision, the FOMC meetings also explain the rationale of policy action and convey the outlook for future policy stance. The FOMC minutes that come out three weeks after provide more detailed information on committee members' views.

[4] See `https://blogs.wsj.com/economics/tag/parsing-the-fed/`. first in press for the FOMC statement on 4 May 2004. The articles have quickly been available after the meeting, i.e. 40 minutes on 30 April 2008 reduced to 3 minutes on 18 December 2013 following news timestamps in Factiva.

announcements, see Andersen and Bollerslev (1998)), release only descriptive statistics and do not bring any insight on the numbers. 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 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."

The difference between FOMC and other macro news is also supported by recent research. Rosa (2013) documents the greater sensitivity of bond and stock market volatilities to FOMC statements relative to nonfarm payroll and other news, and Lucca and Moench (2015) report a positive drift in the stock market prices only prior to FOMC meetings in both U.S. and global markets. This is explained by volatility and liquidity shocks before news releases. Tang (2017) confirms that information released by FOMC meetings determine the types of macro news that influence financial markets. Gilbert et al. (2015) explain heterogeneous asset price responses to non-FOMC macro announcements, e.g. Balduzzi et al. (2001), with the evidence that the magnitude and relevance of revision noise act as determinants of news surprise impact for bond prices. Taken together, this suggests that the FOMC meetings convey more information that may resolve uncertainty to market participants, supporting Lucca and Moench (2015) 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." Hence, we separate FOMC meetings from other macro news to better identify the impact of uncertainty changes on market participation (trading activity) in addition to risk during the announcement days.

We study FOMC meetings and other 12 macro news items released during the trading hours of S&P500 Exchange Traded Fund (SPY) and its options for the period January 2005 to December 2013.[5] We use the uncertainty measure outlined in Izhakian (2017) as the average of expected returns probabilitities weighted by their variances.[6] Meanwhile, risk is measured by realized returns volatility. We gauge market participation from trading activity by volume and number of trades. We focus on how risk and uncertainty explain trading activity and market returns around macro announcement news. Our use of intraday data allows for better isolation of the financial markets' response to new information. More importantly, it allows for analysis of changes in risk and uncertainty induced by news.

[5]See Table 2 for the list of macro news items.

[6]Izhakian and Yermack (2017) and Brenner and Izhakian (2018) follow the uncertainty measure in Izhakian (2017) and document supportive evidence on the difference between risk and uncertainty.

We find that exclusive to FOMC releases, a high degree of uncertainty is coupled with low risk prior to the announcements, but this reverses once the FOMC news become public.[7] Trading activity remains low before the FOMC announcement time but shows a sustained increase afterwards. This aligns with Ui (2011) that limited participation increases on occasion of low returns variance (risk) or high uncertainty. Similar to Lucca and Moench (2015), stock market returns are significantly positive before the FOMC meetings but turn negative and insignificant following the news. Bootstrap computations suggest that these findings are not a result of small sample issues. In contrast, we only observe modest surges in trading activity and risk, but unchanged uncertainty following non-FOMC announcements. In the comparison between the two types of macro news, the pre-announcement uncertainty for FOMC meetings is higher than that for non-FOMC news, but post-announcement uncertainty in the former greatly reduces relative to that in the latter. The patterns in risk and trading activity however contradicts that in uncertainty; that is, their pre- (post-) announcement levels is lower (higher) for FOMC statements than non-FOMC news. Taken together, the strong dynamics of uncertainty and trading activity around FOMC news suggest that uncertainty may play a more important role relative to risk in determining market participation. The pre-FOMC high uncertainty also implies that in addition to risk, the uncertainty premium potentially contributes to the positive market returns documented above.

We have documented that low equity market participation is associated with high uncertainty but low risk over the pre-FOMC window. We are interested in the effect of high uncertainty in option markets. We argue that if uncertainty perceived by market participants is high prior to the announcement, we expect less trading activity from all option participants; hedgers and speculators, regardless of whether they are informed. High ambiguity makes traders unable to identify optimal hedging ratios or appropriate returns distribution to shape expectations, so they are reluctant to trade. That is, uncertainty and information advantage play the first- (i.e., if any trade) and second-order (i.e., if informed trades) effects, respectively, on decision to trade. Once the monetary policy news is made public and uncertainty is resolved, it should also encourage option trading. In the absence of high uncertainty, traders who are informed about forthcoming news may prefer trading in option markets, a potential venue of informed trading (see Back (1992) and Biais and Hillion (1994)). Our empirical evidence supports this argument. For the first-order effect of uncertainty, we document the pre-FOMC high uncertainty, but low trading activity prior to FOMC news relative to those of non-FOMC news. In

[7]The FOMC statements are released at the moment of the target rate decision, and the minutes come out three weeks after the FOMC meetings. See Rosa (2013) for a study on the effects of FOMC minutes.

other words, traders may prefer to trade before non-FOMC news releases as uncertainty is not high. For the second-order effect of information advantage, our results illustrate an abnormal surge in option trading only prior to non-FOMC announcements.

We investigate if such pre-announcement high option trading intensity originates from informed traders for non-FOMC news releases. Following Roll et al. (2010), we first confirm that options are traded more aggressively than equity prior to non-FOMC news. Roll et al. (2010) argue that if informed trading occurs in option markets before the event, the pre-announcement option-to-equity trade ratio should explain the magnitude of post-announcement returns. In addition, the larger the size of pre-announcement returns, the lower is the explanatory power of the pre-announcement option-to-equity trade ratio. This is because profit-taking by informed traders could induce large price movements before the announcement time and hence noisier returns thereafter. Our findings are consistent with this view which gives further support to recent literature on informed trading prior to macro news, e.g. Bernile et al. (2016) and Kurov et al. (2018).

We study the explanatory power of risk and uncertainty on market participation in regression analysis given their separate dynamics around macro news documented above. We report that trading and volatility (risk) are positively related, but a rise in uncertainty reduces trading and vice versa. Bollerslev et al. (2018) (and references therein) provide different explanations for the strong contemporaneous volume-volatility relation, ranging from mixture-of-distribution hypothesis to equilibrium-based economic models. Recent theoretical works, see Cao et al. (2005b), Easley and O'Hara (2010a, b) and Ui (2011), demonstrate the negative impact of uncertainty on market participation or trading activity. In our regression of trading on risk and uncertainty, the pre-FOMC low trading intensity becomes insignificant, and the post-announcement elevated trading falls in size for all macro announcements.

Given the high uncertainty but low risk and trading volume prior to FOMC announcements, we study their roles in determining the pre-release market returns. We document similar results in Lucca and Moench (2015) that volatility decreases with returns (volatility feedback in Campbell and Hentschel (1992)), and the liquidity-return relation is also negative. We find a positive relation between returns and uncertainty in non-announcement days. The results are consistent with the theory in Cao et al. (2005b) who assume that equity premia consist of both risk and uncertainty components. At times of high ambiguity (but not as high as pre-FOMC uncertainty), that prompts limited participation, investors that remain in the market readily accept a low uncertainty premium. However, risk premia could be high to attract these remaining investors to bear all risk. Consequently, high contemporaneous returns potentially result from the

dominant and low uncertainty premium when ambiguity-averse investors are relatively absent.

Over the pre-FOMC window in announcement days, uncertainty and returns become negatively related, supporting the theoretical work of Ui (2011). He shows that the equity premium increases (current price falls) when the difference in uncertainty between limited and full participation is higher than some threshold. The high uncertainty and low trading intensity just prior to FOMC announcements suggest that investors are aware of excessive ambiguity compared to that under full participation. If uncertainty is sufficiently high, investors who stay in the market can demand large uncertainty or equity premium to hold stocks, especially when risk premium associated with low volatility is small before FOMC releases. When market returns are regressed on risk, uncertainty and trading volume, the positive equity price drift in FOMC days becomes insignificant, justifying the explanatory power of these variables.

We extend the analysis of market returns determinants to the post-FOMC announcement period. We find that liquidity and market returns are negatively related, but uncertainty moves in accordance with market returns. The latter contrasts the negative ambiguity-returns relation prior to FOMC announcements. The post-FOMC window is associated with high risk, but low uncertainty and insignificantly negative returns. This suggests a high risk premium (and high equity premia) to compensate for excessive risk since the uncertainty premium induced by low ambiguity is attenuated. In other words, risk and contemporaneous returns are still negatively related.

Our evidence is consistent with several streams of literature. It is important to separate measures of risk and uncertainty to study their impact on financial markets (see also Izhakian and Yermack (2017) and Brenner and Izhakian (2018)). By focusing on macro announcements, we provide evidence to support theoretical predictions about the market participation-uncertainty relation. We find that uncertainty is resolved following FOMC meetings, which encourage investors to participate in markets. We also enlarge informed trading literature with evidence on option market prior to macro news, and enrich recent findings on the outstanding role of FOMC announcement on investors' behaviors (e.g. Rosa (2013), Lucca and Moench (2015) and Tang (2017)). The paper is organized as follows. Section 2 discusses literature review, and Section 3 presents the data, variable construction and a numerical example on the uncertainty-risk difference. The empirical results in Section 4 discuss risk and uncertainty changes surrounding the macro news releases, the informed trading hypothesis in option market, and the explanatory power of risk and uncertainty on trading activity and returns. Section 5 then concludes.

2 Background

In this section we first present empirical works on market reaction to macro announcements. The scheduled FOMC meetings do not only release target rate, i.e. a numerical value, but also explain how this rate is detemined from committee members' point of view. This helps market participants understand the rationale behind policy action and future outlook of monetary policy stance, e.g. Rosa (2013), which may reduce uncertainty. Hence we discuss the latest evidence that supports the separation of FOMC releases from other macro news. Our aim is to examine how uncertainty influences investors' market participation differently from risk. We also present theoretical works on the expected relation between uncertainty and market participation, with trading activity used as proxy of market participation. In the related literature below, trading volume is typically low prior to the macro news releases, but increase following announcements (of FOMC and non-FOMC news), see Balduzzi et al. (2001), Lucca and Moench (2015) among others. If the market participation-uncertainty relation holds in theory, the uncertainty effects are expected to manifest strongly surrounding these events. This is because macro news have been reportedly associated with changes in trading volume, risk and uncertainty, e.g. Beber and Brandt (2009) and Bollerslev et al. (2018). Therefore, macro announcements can help us achieve the goal of studying risk and uncertainty simultaneously. We note that the positive trading volume-risk relation is widely studied in previous literature, see Bollerslev et al. (2018) and references therein. We demonstrate a surge in option trading prior to non-FOMC releases, so we conclude this section with a review of abnormal trading and its implications in the context of news announcements.

2.1 The effects of FOMC news on financial markets

Among the macro news announcements (e.g., Chordia et al. (2017) and Bollerslev et al. (2018) for those released in trading hours of stock market), the FOMC meetings have been recently the focus of a series of research papers. The initial attention of this research was on what explains market reaction to FOMC news. For example, Bernanke and Kuttner (2005) find that the positive effects of unanticipated Federal funds rate (FFR) changes on stock market mainly originate from changes on expected future dividends, not expected real interest rates. Fleming and Piazzesi (2005) emphasize the role of Treasury yield curve slope in explaining the decreasing effects of monetary policy surprises on long-term yields.

FOMC news are also associated with price drifts in financial markets prior to their announcements. Lucca and Moench (2015) focus on the asset returns patterns uncondi-

tional on macro news surprises and report 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 show sustained increases once the FOMC announcements are made. This is consistent with Rosa (2013) who reports the greater sensitivity of bond and stock market volatilities to FOMC statements relative to nonfarm payroll and other news. Bollerslev et al. (2018) recently document a positive relation between risk (volatility) and trading volume around the macro news releases, including FOMC meetings. The literature so far mainly focuses on the effects or risk (volatility) on financial markets,and it is unclear on what among risk and uncertainty ultimately drives the results. Our paper examines the role of risk and uncertainty simultaneously to tackle this issue. We find that uncertainty plays a more important role in detemining market participation, and the pre-FOMC high uncertainy has additional contribution to the positive drift in market returns besides the risk and liquidity effects documented in Lucca and Moench (2015).

Mueller et al. (2017) study the currency markets and document the large excess returns around the FOMC meetings. More specifically, the trading strategy that shorts U.S. dollar and longs other currencies yields both positive pre- and post-announcement returns components. Such positive announcement returns are stronger for currencies with higher interest rate differentials vis-a-vis the U.S. Brooks et al. (2017) document the post-FOMC announcement drift after changes in target rate but no evidence on the initial underreaction in U.S. bond markets.

Current research investigates the impact of FOMC informativeness on financial markets. The text-based nature of FOMC statements help market participants understand better the rationale behind policy action; whereas, non-FOMC macro news only release statistic values. Once the FOMC news are made public, the WSJ dedicates a column "Parsing the FED" to report differences between the currently released and previous news. In Section 1, we illustrate the FOMC release on 30 January 2008 where not all committee members voted for FFR cut. Another example demonstrates a situation in which all members agreed with each other. The scheduled FOMC meeting on 29 April 2009 was analyzed by the WSJ as follows: "this is new: some signs that slowdown is easing"; "as is this: households looking healthier, though same negatives still weight"; "identical analysis of business as last month, except for addition of staffing. Interesting edit, as job losses started a while back"; "Fed again notes that economy appears less dire, though overall picture is still weak"; "Fed, in new free-markets nod, notes that market forces will also help revive economic growth"; "inflation view unchanged from lastmonth: too-low inflation a risk"; "moves announced last month remain on track";

and "Fed may adjust game plan as events warrant." In contrast, the non-FOMC announcements provide only descriptive statistics. For instance, the unemployment news on 3 April 2009 stated that "nonfarm payroll employment continued to decline sharply in March (-663,000), and the unemployment rate rose from 8.1 to 8.5 percent" and on 8 May 2009 that "nonfarm payroll employment continued to decline in April (-539,000), and the unemployment rate rose from 8.5 to 8.9 percent." The informativeness of FOMC statements is also stressed in Rosa (2013) who concludes that the increasing of FOMC statements' transparency has reduced the response of asset prices to FOMC minutes released three weeks later.[8]

Empirical works recently focus on the FOMC informativeness implied from their statement context. Gilbert et al. (2015) study what explains heterogeneous asset price responses to non-FOMC macro releases by the intrinsic value of the news, defined as its ability to nowcast GDP, inflation and FFR. Tang (2017) lately finds that information released by FOMC meetings determine the types of macro news which financial markets pay attention to. In particular, the labor topic intensity measured from FOMC statements and minutes are related to the magnitude of interest rates' response to labor-related news relative to other news. Smales and Apergis (2017) document that bond trading volume increases with linguistic complexity and length of the FOMC statements. In summary, the results support Lucca and Moench (2015) 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." Given that market participation is influenced by ambiguity in theory, uncertainty can help explain the low trading volume and potentially the positive market returns prior to FOMC meetings.

2.2 Market reaction to macroeconomic news

We start with empirical studies on the impact of risk and uncertainty in financial markets. Beber and Brandt (2009) focus on the relation between pre-announcement macroeconomic uncertainty and resolution of financial market uncertainty around macro news. The authors proxy macroeconomic uncertainty by the implied volatility of economic derivatives (calls, puts, and digital options), and financial market uncertainty by implied volatility of stock and bond markets. In particular, Goldman Sachs and Deutsche Bank launched a market for economic derivatives before a scheduled macro news announce-

[8] According to Rosa (2013), "the FOMC minutes provide more detailed information on the committee members' view on the appropriate policy stance, on the U.S. economic outlook, and on the near-term monetary policy inclination."

ment, whose underlying is the initial release of forthcoming macroeconomic statistic. 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 after the macro news are released. This supports Beber and Brandt (2009) hypothesis that options are important as instruments to hedge or speculate on macroeconomic news at times of high uncertainty given their benefits increasing with uncertainty.

Savor and Wilson (2013) document high daily stock market returns, but marginal risk (realized volatility) change, and low risk-free returns in macro announcement days (relative to those in non-announcement days). The sample covers the releases of inflation, unemployment and FOMC news over an extended period 1958-2009. Under the assumption of positive correlation between stock returns and state variables, stocks perform poorly at times of negative news on economy state, so they are riskier than what their volatilities suggest. Savor and Wilson (2013) argue that the state variable risk is deterministically higher when scheduled economic 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 returns on risk-free asset.

Additionally, a large body of literature has documented responses of financial markets to macroeconomic news, see initial works in Jones et al. (1998), Boyd et al. (1998) and Fleming and Remolona (1999) that focus on a few macro news releases and more recent works in Balduzzi et al. (2001), Andersen et al. (2003), Chordia et al. (2017) based on a large set of macro news. 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 in less than a minute. Additionally, the bid-ask spreads of Treasury bonds initially widen at announcement time and then quickly revert to normal levels in 5 to 15 minutes. Andersen et al. (2003) analyze the asymmetric effect of news on foreign exchange market reaction, where bad news have greater impact than 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 comovement between trading intensity and spot volatility in stock markets for a comprehensive set of macro news.

We note that no previous studies evaluate the effects of risk and uncertainty on

financial markets around macro news releases. Beber and Brandt (2009) study the impact of pre-announcement macro uncertainty on implied volatility 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 in macro announcement days. Given that Beber and Brandt (2009) work closely on uncertainty, our work differs from theirs in three aspects. We cover a longer sample period over 2005-2013 vs. 2002-2006 given the short-lived economic derivatives data. We focus on a large (more than four) number of macroeconomic news. More importantly, we study different patterns in risk and uncertainty and their relation to market participation before and after the news releases. Meanwhile, Beber and Brandt (2009) evaluate the effects of pre-announcement macro uncertainty on financial markets.

2.3 Uncertainty and limited participation

Theoretical models predict that uncertainty may reduce market participation. Cao et al. (2005b) 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 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 case, i.e. with the presence of ambiguity-averse investors.

Ui (2011) further identifies when the equity premium increases under limited market participation by incorporating asymmetric information, or private signals received by investors, in the model framework. He first shows that limited market participation is driven by either high uncertainty or low stock returns variance. When uncertainty is the main driver, equity premium increases when the difference in ambiguity of participating investors between limited and full participation is higher than some threshold; or such 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 causes limited market participation. They separate market 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 case of return distribution, they can opt not to participate into the markets, leading to limited market participation.

Easley and O'Hara (2010b) recognize that there is no trades in some financial products at times of high uncertainty, e.g. mortgage-backed securities during the Global Financial Crisis. If some investors face high uncertainty on the payoff distribution in crisis times, they are inclined to leave the market by selling their position, but market rather exhibits zero trading. To explain this, Easley and O'Hara (2010b) employ the approach of Bewley (2000); the 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 his preferences. When an agent can't rank order some portfolios because of facing extreme uncertainty, this leads to neither buy nor sell decision.

2.4 Market participation and trading activity

Market participation and trading activity are closely related. Equity trading activity has increased over the past few years. For example, for all stocks traded by NYSE Group,[9] trades have risen from 728,094 thousands trades for the year of 2004 to 1,441,792 thousand trades in 2017. Over the same time trading turnover has increased from 14,402 billion dollars to 15,778 billion dollars. Barber and Odean (2000) argue that retail investors are participating to a great extent because of enhanced access to online trading, lower trading costs arising from technological improvements, and decreases in tick size. Bogan (2008) documents that since Internet trading began, a general upward trend in stock market volume and values of shares traded has been observed. In addition, she finds a substantial increase in stock market participation of households with Internet usage, even after controlling for the bull market of the 1990s and the growth of tax-deferred retirement savings vehicles. Chordia et al. (2011) illustrate that both secular decreases in trading costs and greater information-based trading (i.e. stocks with large institutional holdings) influence the sharply increasing turnover trend. Naes et al. (2011) use both the U.S. and Norwegian data over 1947-2008 and 1980-2008, respectively, to confirm that spread worsens (high trading cost) when the number of participants in the market falls. Taken together, the findings support that lower trading cost and easier access to trading encourage more market participants, which explains the increasing

[9] See `http://www.nyxdata.com/nysedata/asp/factbook/viewer_edition.asp?mode=tables&key=332&category=3`.

trend in stock market volume. Therefore, we proxy market participation by trading activity, i.e. number of trades and trading volume.

2.5 Option trading around news announcements

Option markets are often a venue for informed trading and thus enhance information efficiency. Informed traders prefer to trade options rather than stocks given the implicit leverage to maximize profitability, see Back (1992) and Biais and Hillion (1994). Easley et al. (1998) and Pan and Poteshman (2006) find that option order flows contain information about the future direction of the underlying stock price. Ni et al. (2008) show the forecastability of option order flow on stock volatility as option markets attract traders informed about future volatility. Option trading also allows for stock prices to adjust quickly before, rather than after earnings announcement by means of insider trading, see Mendenhall and Fehrs (1999). Cao et al. (2005a) focus on merger activity to document options volume predicts returns around takeover announcements. Later empirical works have illustrated informed trading in option markets around corporate events, such as earning announcements in Jin et al. (2012) and Atilgan (2014), analyst recommendation in Hayunga and Lung (2014) and Lin and Lu (2015), mergers and acquisitions in Lin and Lu (2015), and stock split announcements in Gharghori et al. (2017).

The frequency of option trades relative to those in underlying asset also suggests informed trading. Initial work by Roll et al. (2010) looks at the ratio of option to equity trades to analyze its time series properties and determinants. They also investigate whether traders act on option market to exploit their information advantage around earnings announcements. They find supportive evidence that the option-to-equity trade ratio increases a few days prior to announcement and is able to predict the magnitude of post-announcement returns. Given different patterns in option and asset trading around the macro news documented below, we study their implications on informed trading hypothesis by following the approach in Roll et al. (2010).

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 a sample of macroeconomic series studied in Balduzzi et al. (2001) and Chordia et al. (2017) over January

2005 to December 2013, because option data on S&P500 Exchange Traded Fund (SPY) is available from 2005. Equity and options start to trade at 9:30 to 16:00 and to 16:15, respectively, so we focus on the announcements during this time period and present the relevant macro news in Table 2. The typical announcement time of FOMC releases and 12 non-FOMC macro news 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 participants are on average interviewed for their forecasts, which is 82 for FOMC announcements or ranges from 32 (wholesale inventories) to 75 (ISM manufacturing) among the non-FOMC news. In addition, the percentages of positive and negative surprises[10] are approximately equal to each other. The FOMC statements have text-based nature, which is different from descriptive statistics in the non-FOMC news.

We are interested in relations between trading activity, market-wide returns, risk and uncertainty. Hence we focus on the largest and most heavily traded ETF SPY; this is also studied in Brenner and Izhakian (2018), Chordia et al. (2017), and Bollerslev et al. (2018). High frequency data for SPY is obtained from the Trade and Quote (TAQ) database. Following Bollerslev et al. (2016), any entry is first removed if satisfying 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. We further obtain the trade data of options on SPY at intraday level from CBOE.[11] We first retain the observations that satisfy the trade conditions similar to those in equity,[12] and only keep the options whose maturities between 10 and 100 days with an absolute delta between 0.02 and 0.98. This sampling procedure helps us avoid thinly traded options in our analysis.

3.2 Variable construction

We first discuss the risk and uncertainty in theoretical work of Izhakian (2017). Brenner and Izhakian (2018) and Izhakian and Yermack (2017) introduce an empirical measure of uncertainty in Izhakian (2017) and find supportive evidence on the difference between

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

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

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

risk and uncertainty. Given T time intervals of M numbers of returns observations each,[13] they are calculated as follows:

$$\begin{aligned} Risk &= \Sigma_{t=1}^{T\times M} r_t^2, \\ Uncertainty &= \frac{1}{\omega(1-\omega)}\big\{E\big[\Phi(r_0;\mu_\tau,\sigma_\tau)\big]Var\big[\Phi(r_0;\mu_\tau,\sigma_\tau)\big] \\ &\quad + \Sigma_{i=1}^{N} E\big[\Phi(r_i;\mu_\tau,\sigma_\tau)-\Phi(r_{i-1};\mu_\tau,\sigma_\tau)\big]Var\big[\Phi(r_i;\mu_\tau,\sigma_\tau)-\Phi(r_{i-1};\mu_\tau,\sigma_\tau)\big] \\ &\quad + E\big[1-\Phi(r_N;\mu_\tau,\sigma_\tau)\big]Var\big[1-\Phi(r_N;\mu_\tau,\sigma_\tau)\big]\big\}, \end{aligned} \tag{1}$$

where $r_i, i = 0, ..., N$ are the fixed points chosen to cover a broad range of returns scenarios, $\Phi(.;\mu_\tau,\sigma_\tau)$ is the normal cumulative distribution function with mean μ_τ and variance σ_τ^2,$\tau = 1, ..., T$, and $\omega = r_i - r_{i-1}$. The cumulative returns probability $\Phi(r_i;\mu_\tau,\sigma_\tau), i = 0, ..., N$, is computed for each time interval τ, where μ_τ and σ_τ are the average and standard deviation of M returns observations in the corresponding time interval. In other words, risk is simply equal realized variance over the time period of $T \times M$ observations, and uncertainty is the average of expected returns probabilitities weighted by their variances.

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 150 minutes before and after the announcement time, equivalent to 10 intervals of 15 observations of 1-minute returns. This is because we need a sufficient amount of returns sample of $T \times M$ observations in Equation (1) in uncertainty calculation around macro news releases. As a robustness check, we also consider 200, 225 and 300 minutes, equivalent to 10 or 15 intervals of 15 (20, 30) minutes. Each 15 (20, 30)-minute interval must have at least 10 (13, 20) available one-minute returns. Risk is equal to the sum of one-minute squared returns. For our uncertainty measure we first divide the returns range from $r_0 = -1\%$ to $r_N = 1\%$ into bins of width $\omega = 0.002\%$. From the empirical distribution of one-minute returns, 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 broad range of returns possibilities. For each 15-minute interval, we calculate the returns probability in each

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

bin as well as probabilities of returns less than -1% or higher than 1%. Using these probabilities, we compute the mean and variance of probabilities for each bin over 150 trading minutes before/after the news release, and hence degree of uncertainty from Equation (1). We take the natural logarithm (log) of original risk and uncertainty measures to avoid extreme values.

To measure trading activity, we follow Chordia et al. (2001) to employ total trading volume and number of trades aggregated over the same time intervals used for construction of risk and uncertainty measures, and we further take natural logarithm on those variables to mitigate the outlier effects. We note that Hasbrouck and Seppi (2001), Cao and Wei (2010), and Lucca and Moench (2015) also use trading volume as liquidity measures in equity and option markets. Figures 1 and 2 illustrate the intraday pattern of squared returns, trading volume and number of trades at the 1-minute frequency over the trading day. These show a well-documented U-shape with high volatility and trading activity at the start and end of the trading day. Because these intraday patterns may confound our results,[14] we deal with this in two ways. To adjust for the log level of trading activity, risk and uncertainty, we follow Bernile et al. (2016) and Bollerslev et al. (2018) and subtract the log of moving average over the last 20 non-announcement days from the current values for the same time window in a given day. For example, the pre-announcement trading volume in FOMC day is adjusted by its moving average of pre-release values in the last 20 non-FOMC days. Trading volume in (non-)FOMC days is computed over a certain time window before the announcement time of the coming event. This adjustment is similar to a first difference to obtain time series stationarity, see Naes et al. (2011). These adjusted variables can be considered as abnormal movements in trading activity, risk and uncertainty. We alternatively adjust the option-to-equity trade ratio by dividing it by the ratio of moving-average trades in option over equity markets in the last 20 non-announcement days, and log transform the adjusted ratio to attenuate the influence of outliers.

3.3 A numerical example

The uncertainty measure in Izhakian (2017) is constructed from individual expected returns probabilities weighted by their own variances. This implies that the returns distribution shape plays an important role in determining uncertainty by inflating both

[14] For example, Lucca and Moench (2015) document a sustained increase in trading volume and volatility after the announcement time, e.g. 14:15, of FOMC meetings. In contrast, we observe the high intraday levels of these variables trading after 14:15 in an average day of the sample. This raises a concern that the increase in trading volume and volatility is simply due to the intraday effect.

expected value and variance of any returns event. It is not clear, however, how the risk and uncertainty measured in Equation (1) move under changes in the shape of the underlying distribution, e.g. from a shift in mean and/or variance of returns. To answer this, we undertake a simulation exercise and analyze the patterns of risk and uncertainty from different data generating processes. In particular, we generate 20 returns for each of 15 time intervals, equivalent to 300 observations of 1-minute returns.[15] The returns in each time interval are sampled from a specific normal distribution, whose parameter set $(\hat{\mu}, \hat{\sigma})$ is randomly chosen from four different pairs of values. This aligns with the assumption in measuring uncertainty. Also, this ensures that the simulated returns are not independent and identically distributed, and possess negative skewness and fat tails that are typically reported for asset returns. From this simulation exercise, we sample three random returns series of 300 observations each, calculate their risk and uncertainty as outlined in Section 3.2, and repeat this process 1,000 times.

The mean vectors of μ_1, μ_2, μ_3 and standard deviation of $\sigma_1, \sigma_2, \sigma_3$ from normal distribution are presented as follows:

$$\mu_1 = \begin{bmatrix} -2 & 0 & 0 & 0 \end{bmatrix}, \mu_2 = \begin{bmatrix} -2 & 0 & 0.25 & 0.5 \end{bmatrix}, \mu_3 = \begin{bmatrix} -2 & 0 & 0.5 & 1 \end{bmatrix},$$
$$\sigma_1 = \begin{bmatrix} 2 & 1 & 1 & 1 \end{bmatrix}, \sigma_2 = \begin{bmatrix} 3 & 1.5 & 1.5 & 1.5 \end{bmatrix}, \sigma_3 = \begin{bmatrix} 4 & 2 & 2 & 2 \end{bmatrix},$$

where μ_{ji} (σ_{ji}) is the element i^{th} of vector μ_j (σ_j), $j = 1, 2, 3$, $i = 1, 2, 3, 4$. Given the fixed value of j in a scenario, the parameter set $(\hat{\mu}, \hat{\sigma})$ of each time interval is randomly chosen from four different pairs (μ_{ji}, σ_{ji}) with probability 10%, 40%, 25%, and 25% for $i = 1, 2, 3$ and 4, respectively. We simulate three returns series under the following scenarios. They correspond to a shift in either variance (Scenario 1) or mean (Scenario 2), both mean and variance in the same direction (Scenario 3), and both mean and variance in opposite direction (Scenario 4). That is,

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Series 1	(μ_2, σ_1)	(μ_1, σ_2)	(μ_1, σ_1)	(μ_3, σ_1)
Series 2	(μ_2, σ_2)	(μ_2, σ_2)	(μ_2, σ_2)	(μ_2, σ_2)
Series 3	(μ_2, σ_3)	(μ_3, σ_2)	(μ_3, σ_3)	(μ_1, σ_3)

Insert Table 1 here

Table 1 presents the statistical values of average, $1^{st}, 2.5^{th}, 97.5^{th}, 99^{th}$ percentiles

[15] The simulation results remain unchanged when we sample 15 (20) returns for each of 10 (15) time intervals, equivalent to 150 (200, 225, 300) observations of 1-minute returns.

of mean returns, risk, and uncertainty computed from 1,000 replications. In regard to mean returns, this table demonstrates expected patterns across three series under each scenario assumption. That is, the statistical values increase (decrease) monotonically under scenario 2 and 3 (4) with a positive (negative) shift in underlying mean. For example, the average statistics rises from -0.2 in series 1 to -0.01 in series 2, and to 0.18 in series 3 under scenario 2 and 3; but decreases from 0.18 in series 1 to -0.01 in series 2, and to -0.2 in series 3 under scenario 4. Under scenario 1 of a fixed underlying mean, the statistical values are identical across different returns series, e.g. the average valued at -0.01 for all series.

Moving to the risk measure, its patterns in statistical values also align with the scenario assumptions, i.e. a monotonic increase under scenario 1, 3 and 4 with a positive shift in underlying variance. For instance, the average statistics rises from 6.23 in series 1 to 6.89 in series 2, and to 7.41 in series 3 under scenario 1, equivalent to a change of 11% (8%) from series 1 to 2 (series 2 to 3). The percentage changes in average statistics from series 1 to 2 (series 2 to 3) under scenario 3 and 4 are 12% (8%) and 8% (7%), respectively. Meanwhile, the statistical values of risk in a series are very close to those in the others under scenario 2 of fixed underlying variance, i.e. the average valued at 6.87 to 6.96 for all series.

With respect to uncertainty measure, intuitively, it should remain the same between different series when their distribution shape is not altered. Indeed, the statistical values are indistinguishable across three returns series under scenario 2 of a fixed underlying variance, e.g. the average between -12.03 and -11.7 for all series. This is because a shift in underlying mean only moves the returns distribution and does not change its shape. However, a shift in underlying variance is associated with decreasing uncertainty, whose declining rate depends on the magnitude of variance change. We first discuss the results with a shift of 50% in underlying standard deviation from σ_1 (series 1) to σ_2 (series 2). When only underlying variance changes (scenario 1), uncertainty decreases by 9%, while risk increases by 11%. To study the net effect on uncertainty with a shift in both underlying mean and variance, we investigate two cases: they move in the same (scenario 3) or opposite (scenario 4) directions. Under scenario 3, it only prompts less reduction in uncertainty by 7% since risk still rises by 12%. Under scenario 4, uncertainty reduces by 13%, while risk only increases by 8%. The conclusions remain unchanged with a shift by 33.3% from σ_2 (series 2) to σ_3 (series 3), except that the percentage change lessens by a half in uncertainty. Under scenario 1 of a fixed underlying mean, uncertainty reduces by 4%. The declining rate in uncertainy is also modest when underlying mean changes under scenario 3 and 4, with values of 3% and 5%, respectively. In contrast, risk rises

by 7 to 8%, whose magnitude is similar to that under the shift from σ_1 to σ_2.

In summary, the simulation exercise illustrates two important patterns of risk and uncertainty. First, an increase in either or both underlying mean and variance of returns is not always associated with a rise in uncertainty. Second, the degree of uncertainty is mainly driven by changes in underlying variance. A shift in underlying mean only affects uncertainty in the presence of underlying variance change.

4 Results

4.1 Pre- and post-announcement windows

This section presents the magnitude of risk, uncertainty, trading activity, and stock market return before and after the releasing time during macro announcement days. These measures are considered as dependent variables y_t in a regression on a dummy variable $event_t$ (equal 1 on announcement days), another dummy variable $after_t$ (equal 1 after the announcement time of the coming event), and their interaction. We study different time window before (after) the announcement time, namely, 150-, 200-, 225- and 300-minute time intervals. That is,

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

We are primarily interested in the coefficients for γ_1 and γ_3 or the mean differentials on pre- and post-announcement windows in announcement days, respectively. The coefficients γ_0 and γ_2 measure the average returns on pre-announcement window and the mean differential on post-announcement window in non-announcement days, respectively. We further separate FOMC releases from the others given their distinguished effects on stock market from literature. Equation (2) is similar to difference-in-difference approach because we are interested in the difference between pre- (post-) releasing value in event days and that in non-announcement (announcement) days via coefficient γ_1 (γ_3).

For comparison of the variables' magnitude between FOMC and non-FOMC releases, we add in Equation (2) with a dummy variable $type_t$ (equal 1 for FOMC releases) 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 coefficients γ_5 and γ_7 represent the mean difference between FOMC and non-FOMC

releases on pre- and post-announcement windows in announcement days, respectively, and Equation (3) is similar to difference-in-difference-in-difference approach.

Insert Table 3 here

Table 3 contains estimates based on the regression specified in Equation (2) and (3). Its first column lists the dependent variable, namely risk, uncertainty, stock market returns, the natural logarithm number of trades and volume in equity and option markets. We adjust the variables (except returns) by subtracting their expected component proxied by moving average in the previous 20 non-announcement days from them.[16] 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, so that we can observe if the variables' patterns are short- or long-lived. Different time windows also serve as a robustness check on the uncertainty results computed from 10- (15-) time intervals of 15 (20, 30) observations of 1-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". The last two columns present the estimates and t-stat of γ_5 and γ_7 of Equation (3). Table 14 and 15 in Appendix present the summary statistics on pre- and post-releasing time window of (non-)FOMC announcement days and non-announcement days for the main variables used in our analysis. We refer interested readers to the table.

4.1.1 Risk and uncertainty

We first discuss the results on risk and uncertainty for FOMC releases in the first two panels of Table 3. 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), and the results are significant at the 1% level. When the time window shrinks to 225, 200 and 150 minutes, the coefficients are still significant with t-stats greater than 3 in magnitude. This implies that on average pre-FOMC risk is lower by 35-40% (relative to pre-releasing time in non-FOMC days), but risk rises by 124-133% after the FOMC releases (relative to pre-announcement time in FOMC days). For sake of brevity, we interpret the value of coefficient γ_1 (γ_3) relative to the pre-releasing time in non-event days (event days) in the following. The uncertainty regression however provides 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), which

[16] This helps to eliminate the intraday effects and similar to a first difference to obtain time series stationarity.

are significant at the 1% level. The results are robust to different shorter time intervals as the coefficients remain their sign and statistical significance with t-stats above 3 in magnitude. Taken together, this shows that uncertainty is greater by 68-71% prior to FOMC meetings but dramatically lower by 86-135% following announcement time.

When we estimate Equation (2) for non-FOMC announcement days, there appears to be no drastic change in risk and uncertainty before and after the announcements. When risk is measured over a 300-minute window, the estimates of γ_1 and γ_3 are 0.03 (t-stat=0.99) and 0.06 (t-stat=1.54), respectively, and they are insignificant at the 10% level. These results are maintained similar when the time window reduces 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), which are weakly significant at the 10% level. In general, the volatility increase in the post-announcement window is consistent with previous literature on market reactions to macro news, e.g. Bollerslev et al. (2018). With respect to uncertainty, the coefficients for γ_1 and γ_3 are essentially zero across different time windows. With a 300-minute interval, their corresponding values are -0.01 (t-stat=-0.15) and 0.00 (t-stat=-0.09), which are insignificant at the 10% level.

In the comparison between FOMC and non-FOMC releases, 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 equal -0.42 (t-stat=-4.58) and 1.18 (t-stat=9.47) with risk as dependent variable. For the uncertainty variable, its cofficient 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. For uncertainty, the pre-FOMC level is higher by 67-72% than that prior to non-FOMC releases, but lower by 85-136% after news.

In summary, we document lower risk and higher uncertainty prior to FOMC meetings, but greater risk and moderate uncertainty following the FOMC news. These patterns are unique to FOMC announcements given that only risk weakly increases after non-FOMC macro releases. Over the pre-announcement period, risk is lower, but uncertainty is higher for FOMC meetings relative non-FOMC releases. This however reverses over the post-announcement period.

4.1.2 Stock and option market trading

The distinguished effects of FOMC releases manifest in trading activity. Regarding number of trades measured over the 300-minute window in panel 3 of Table 3, the coefficient estimates of γ_1 and γ_3 are -0.17 (t-stat=-4.83) and 0.56 (t-stat=12.11), and they are significant at the 1% level. In general, different time intervals and an alternative proxy for trading activity, volume, do not change the results, and the t-stats are all greater than 3 in magnitude. For instance, given trading volume over a 300-minute interval in panel 4 of Table 3, the coefficients for γ_1 and γ_3 are -0.19 (t-stat=-5.25) and 0.61 (t-stat=12.35), respectively. This implies that on average, the number of trades (trading volume) in equity market are 17-20% (19-21%) lower prior to FOMC meetings. Following the FOMC releases, the number of trades (trading volume) rise by 56-75% (61-80%). When we shift the focus to non-FOMC announcements, equity trading only exhibits a weaker increase during the post-release period. With the 300-minute window, the coefficient estimates of γ_1 and γ_3 are 0.00 (t-stat=0.21) and 0.03 (t-stat=1.64) for number of trades; 0.00 (t-stat=-0.32) and 0.03 (t-stat=1.65) for volume. As the time interval shortens, only the coefficient for γ_3 becomes significant at the 5% level. For instance, with the shortest 150-minute window, the coefficient values of γ_1 and γ_3 are 0.04 (t-stat=0.64) and 0.04 (t-stat=2.55) for number of trades; 0.00 (t-stat=0.13) and 0.04 (t-stat=2.35) for volume. Taken together, the evidence suggests that market participants refrain from trade before the FOMC announcement but trade aggressively once the FOMC news is made public. In addition, the post-FOMC trade intensity is much greater than that over the post-announcement period of non-FOMC macro releases.

The pattern in option trading around FOMC meetings follows that documented in equity, see panel 5 to 8 of Table 3. For number of trades over a 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; -0.15 (t-stat=-3.35) and 0.55 (t-stat=8.78) for puts, which are significant at the 5% level. The 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 a 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; -0.16 (t-stat=-2.94) and 0.55 (t-stat=7.22) for puts. Therefore, prior to FOMC releases, the number of trades (volume) in option markets are lower by 11-12% (3-9%) lower for calls and 13-16% (13-16%) for puts. Following the FOMC statements, the number of trades (volume) increase by 50-65% (40-59%) for calls and 55-67% (55-58%) for puts.

With respect to non-FOMC announcements, option trading demonstrates a distinct pattern from equity. With number of trades over a 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; 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 volume in puts has coefficient γ_1 insignificant. For instance, the trading volume measured over a 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; 0.02 (t-stat=1.24) and 0.02 (t-stat=0.69) for puts. The results imply that prior to non-FOMC announcements, there is a surge in option trading by 5-6% for both number of trades and volume of calls and puts. Meanwhile, equity market does not exhibit any abnormal trading activity.

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

4.1.3 Stock returns

Lucca and Moench (2015) report that stock market price drifts upward only prior to FOMC meetings. Given that risk and uncertainty behave differently around FOMC releases as shown above, we are interested in their explanatory power on stock market returns and supportive theories. We present the pre- and post-FOMC returns calculated over the same time intervals of risk and uncertainty measures in panel 9 of Table 3. With the longest 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), and they are significant at the 1% and 10% level, respectively. This implies that the pre-FOMC returns is higher by 21 basis points (bps), but the post-FOMC returns is lower 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.[17] For example, over a 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 a 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 γ_1 and γ_3 are insignificantly different from zero regardless of the time window. For instance, the coefficient estimates are -0.04 (t-stat=-1.42) and 0.05 (t-stat=1.15) over a 300-minute window, respectively. Therefore, our results on stock market returns are consistent with Lucca and Moench (2015). The longer is time interval, the higher are pre-FOMC market returns, but the lower are market returns after FOMC announcements. In addition, the pre-FOMC market returns is higher than that prior to non-FOMC releases as shown by the coefficient γ_5 of 0.25 (t-stat=3) over the 300-minute window. Similar to the coefficient estimates of γ_3 under "FOMC releases", the magnitude and statistical significance of γ_5 become weaker as the time interval shrinks to 225 or 150 minutes.

In summary, our evidence is consistent with Lucca and Moench (2015) who document a pre-FOMC positive drift in stock market price, and a sustained increase in post-FOMC volatility and trading volume. We further report a dramatic drop in uncertainty following FOMC releases, and similar option trading activity as in equity markets around the FOMC announcement time. The results align with Ui (2011) that limited participation increases (trading decreases) on occasions of low returns variance or high uncertainty. The dynamics of uncertainty and trading activity around FOMC meetings are stronger than those reported in non-FOMC releases. Over the pre-announcement period, uncertainty is higher, but risk and trading activity is lower for FOMC relative to non-FOMC news. This however reverses over the post-announcement period. In the analysis of non-FOMC news, both risk and trading activity modestly increase following the announcement time. Taken together, this suggests that uncertainty may play an important role in determining market participation (trading activity) more than risk does. The option trading activity, however, exhibits a surge prior to non-FOMC news, so this raises a concern of informed option trading. We formally test this hypothesis in Section 4.2.

4.2 Abnormal trading in option market

Section 4.1 reports an increase in option trading associated with no significant change in equity trading before non-FOMC macro news. We argue that if uncertainty perceived by option market participants, informed or not, is high prior to the news release, they

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

wouldn't trade due to concerns of unidentified hedging ratios (for hedgers) or returns distribution (for speculators). Our empirical evidence documents that the high uncertainty is coupled with low option trading activity only before the FOMC meetings relative to non-FOMC news, so this confirms the first-order effect of uncertainty. In the absence of high uncertainty, traders who are informed about forthcoming news may prefer trading in option markets, e.g. Back (1992) and Biais and Hillion (1994). Indeed, we report an increase in option trading only prior to non-FOMC announcements, so it confirms the second-order effect of information advantage. We formally test if this represents abnormal option trading using the option-to-equity trade ratio. This is defined as the ratio between number of trades (volume) in option and equity markets over the time window prior to news releases, namely number-of-trades (volume) ratio. This option-to-equity trade ratio serves as dependent variable in a regression on a dummy variable $event_t$ (equal 1 on announcement days):

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

The coefficient γ_1 present the mean differential in announcement days, and the constant γ_0 is interpreted as the average of log option-to-equity trade ratio in non-announcement days. Table 4 contains regression estimates in Equation (4). Its first column presents the time window before announcement time over which 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. The next (last) two columns present the coefficient estimates and t-stats of γ_1 for (non-) FOMC releases. We present the results for number of trades followed by volume.

Insert Table 4 here

We first discuss the results for FOMC meetings. For number-of-trades ratio over a 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, and estimates of γ_1 are 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, with the 300- vs. 150-minute window, 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 support no abnormal option trading relative to asset before the FOMC releases.

Moving to non-FOMC news, the coefficient for γ_1 is positive and statistically significant. For number-of-trades ratio over a 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. The significant results are robust to different time intervals, option type, and volume as another proxy of trading activity. For example, with volume ratio over a 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, option is traded more frequently than asset prior to non-FOMC announcements.

We evaluate whether the increase in option-to-equity trade ratio prior to macro news comes from informed investors. Roll et al. (2010) argue that if the pre-announcement option-to-equity trade ratio is due to informed trading, it should predict the post-announcement returns, and this relation depends on the size of pre-announcement returns. That is, profit-taking by informed traders could induce larger absolute returns prior to news releases and hence noisier returns after news. This would imply that post-announcement returns are less sensitive to pre-announcement option-to-equity trade ratio. We follow Roll et al. (2010) and run a regression on the sample restricted to observations in announcement 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 predicted to be positive and negative, respectively. Table 5 contains regression estimates in Equation (5). Its first and second columns list the time window prior to news release and the explanatory variables associated with γ_1 and γ_2. The next columns present the estimates and t-stats of coefficients in the regression of option-to-equity trade ratio for calls, puts, and all options.

Insert Table 5 here

In regard to FOMC meetings, the results do not support the informed trading hypothesis. For the number-of-trades ratio over a 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 informed trading hypothesis. The coefficient signs remain robust across different time intervals, option types, and volume as another proxy of trading activity. Taken together, this evidence supports that option volume is higher than equity volume prior to FOMC

releases, but option volume is significantly lower than that in non-FOMC days. In addition, the observed option-to-equity-trade ratio does not suggest informed trading.

However, we find strong evidence of informed trade in option markets before non-FOMC announcements. For the number-of-trades ratio over a 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 of the 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, given the number of trades 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. In short, the higher pre-release option-to-equity trade ratio, the greater post-announcement returns size. This relation becomes weaker in the presence of large absolute price movements prior to news releases.

Our evidence on informed trading prior to non-FOMC news aligns with recent empirical works. 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 in Kurov et al. (2018), we further report their details. The "correct" pre-release price movement direction is significant prior to 4 news releases but insignificant with "correct" sign for another 4 macro announcements among our 12 non-FOMC news items. Our sample of non-FOMC macro news also matter in financial markets. For example, in Kurov et al. (2018), stock and bond market prices react to news surprises in 8 out of our 12 non-FOMC news releases over the time window of 30 minutes before and 5 minutes after announcement time. Similarly, the surprise components in 10 out of our 12 non-monetary policy news impact stock market returns over 5 minutes before and after news releases over 2008-2014 as in Chordia et al. (2017). Taken together, our findings are consistent with literature on pre-announcement informed trading, but we focus on option trading over a longer time window (between 150 to 300 minutes before news release).

4.3 Trading activity

In this section we investigate how risk and uncertainty can contribute to changes in trading activity. The literature has documented the positive relation between volatility and volume, e.g. Bollerslev et al. (2018) and references therein, and recent theoretical works, see Easley and O'Hara (2010a,b) and Ui (2011), demonstrate how uncertainty can limit market participation. This suggests that uncertainty is negatively related to trading activity. We empirically confirm this by estimating the following regression of trading activity $trade_t$ on a dummy variable $event_t$ (equal 1 on announcement days), risk $rvar_t$, uncertainty $u2_t$ and their interactions with $event_t$. The data sample includes observations calculated over the pre-release period in (non-) announcement days, separately for FOMC meetings and non-FOMC macro news. We then repeat this for the post-announcement observations. This resulting regression is:

$$trade_t = \gamma_0 + \gamma_1 event_t + \gamma_2 rvar_t + \gamma_3 u2_t + \gamma_4 rvar_t event_t + \gamma_5 u2_t event_t + \epsilon_t. \quad (6)$$

The variables $rvar_t$ and $u2_t$ are interepreted as the shocks to risk and uncertainty since they are adjusted by the 20-day moving average presented in section 3.2.[18] 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. To preserve space, we present the analysis with number of trades and leave the results for trading volume to the Appendix.[19] We also present the benchmark regression with only announcement-day dummy to see how its coefficient and the adjusted R^2 change as we add risk and uncertainty to the regression. Tables 6 through 9 contains regression estimates in Equation (6). Their 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).

[18] Lucca and Moench (2015) raise the importance to decompose the volatility and liquidity into innovation and expected component and report the statistical significance only for innovation terms. They use the VIX innovation as a measure of risk, although VIX also commonly proxies for uncertainty, see Bloom (2009).

[19] The results for trading volume as proxies are presented in Tables 16, 17, 18 and 19 in Appendix and similar to those reported here in that the positive (negative) relation between volatility (uncertainty) and trading still remains.

4.3.1 Pre-announcement

We present the results of trading activity prior to FOMC and non-FOMC news releases in Tables 6 and 7, respectively.

Insert Table 6

When only $event_t$ is included in regression of pre-FOMC trades, see column (1) in Table 6, its coefficient γ_1 is negative across different time intervals and markets, and significant at the 1 to 5% levels. For example, over a 300-minute window or 10 intervals of 30 minutes, the coefficient estimate of γ_1 is -0.58 (t-stat=-4.83) for equity, -0.25 (t-stat=-2.39) for calls, and -0.35 (t-stat=-3.35) for puts. On average, pre-FOMC trading activity is lower by 55 to 60% in equity market, 24 to 27% in calls, and 27 to 35% in puts.

With the addition of volatility shocks in column (2), the dummy coefficient γ_1 reduces in magnitude and statistical significance. We continue to demonstrate this with 300-minute interval. In column (2), the coefficient for γ_1 is -0.13 (t-stat=-2.06) for equity, 0 (t-stat=-0.02) for calls, and -0.08 (t-stat=-0.96) for puts. In general, γ_1 reduces to -13 or -24% for equity, about -6% for calls and -13% for puts. The volatility coefficient γ_2 is positive and significant at the 1% level. The estimate of γ_2 is 0.79 (t-stat=39.44) for equity, 0.46 (t-stat=21.5) for calls, and 0.49 (t-stat=23.82) for puts over a 300-minute window; and the adjusted R^2 rises from 0.98% to 63.31% for equity, 0.15% to 20.66% for calls, and 0.34% to 24.39% for puts. This implies that a one sigma in volatility shock increases the trade sigma by 74 to 79% in equity and 44 to 49% in options. The adjusted R^2 also dramatically improves from less than 1% to 57% in equity and 19 to 25% in options.

Uncertainty shocks also help to reduce statistical significance of coefficient γ_1 across different time intervals shown in column (3). Over the 300-minute window, the coefficient for γ_1 becomes 0.01 (t-stat=0.15) for equity, 0.08 (t-stat=0.89) for calls, and 0.01 (t-stat=0.06) for puts; and the adjusted R^2 increases by 2 to 6% in column (2). This supports the uncertainty role by explaining the magnitude of γ_1, and the adjusted R^2 continues to increase by 4 to 6% in equity and 1 to 2% in option markets overall. The inclusion of uncertainty shocks does not affect the positive relation between volatility and trade. With a 300-minute window, γ_2 reduces from 0.79 to 0.62 (t-stat=26.77) for equity, from 0.46 to 0.36 (t-stat=14.21) for calls, and from 0.49 to 0.38 (t-stat=16.11) for puts. The marginal decrease in magnitude of γ_2 is similar over different time intervals, and its statistical significance is achieved at the 1% level. More importantly, the coefficient for γ_3 carries a negative sign (absolute t-stats above 3), with the sign aligned

with theoretical works on the relation between market participation and uncertainty. Following the example above, the estimate of γ_3 is -0.29 (t-stat=-14.81) for equity, -0.17 (t-stat=-6.97) for calls, and -0.19 (t-stat=-8.02). On average, a one sigma increase in uncertainty shocks suppresses the trade sigma by 24 to 31% for equity, 13 to 17% for calls, and 15 to 19% for puts. When we consider the interaction terms in column (4), their coefficients are close to zero and insignificant, so this implies the robust negative (positive) relations between trading and uncertainty (volatility) in FOMC days. In the example of 300-minute interval, the coefficients for γ_4 and γ_5 are at most 0.18 in magnitude, and their statistical significance is greater than 10% for equity and option markets.

Insert Table 7

We analyze the results on trades prior to non-FOMC news in Table 7. Section 4.1 documents a surge in option trades prior to non-FOMC news, which may originate from informed trading as shown in section 4.2. We are interested in the explanatory power of volatility and uncertainty measured in equity market on the intensity of option trades. In column (1) with stand-alone $event_t$ in regression, the coefficient for γ_1 is not significant for equity, but positive and significant at the 1% level for options. With a 300-minute window, the estimate of γ_1 is 0.01 (t-stat=0.21) for equity, 0.12 (t-stat=3.23) for calls, and 0.12 (t-stat=3.44) for puts. When volatility and uncertainty shocks are added, the coefficient for γ_1 remains insignificant for equity as expected, but it is positive and significant at the 1% level across different time intervals for options. In the example above, its estimate is -0.01 (t-stat=-0.56) for equity, 0.1 (t-stat=3.39) for calls, and 0.11 (t-stat=3.68) for puts in column (3). The other coefficient signs of γ_2 and γ_3 of volatility and uncertainty shocks yield similar results reported for pre-FOMC trade regression, which are significant at the 1% level. With a 300-minute window, the estimate of γ_2 is 0.63 (t-stat=36.8) for equity, 0.46 (t-stat=29.1) for calls, and 0.48 (t-stat=30.94); and the corresponding values of γ_3 across markets are -0.28 (t-stat=-16.73), -0.15 (t-stat=-9.06) and -0.13 (t-stat=-9.37). The adjusted R^2 also improves, e.g. from -0.02% to 60.32% for equity, from 0.18% to 27.5% for calls, and from 0.2% to 29.58% for puts in the same example. The interaction terms in column (4) are also insignificant as in the case of pre-FOMC trade. Therefore, either a positive volatility shock or negative uncertainty innovation is associated with an increase in option trade. They, however, are not able to fully explain the surge in option trades prior to non-FOMC announcements, since on average it increases by 13%, even with volatility and uncertainty controls.

4.3.2 Post-announcement

In regard to the post-announcement period, we present the results in Equation (6) for FOMC and non-FOMC news in Tables 8 and 9, respectively.

Insert Table 8

Shifting the focus to post-FOMC trading presented in Table 8, the general relation between trading and volatility or uncertainty still exists. In column (1), the coefficient for γ_1 is 1.33 (t-stat=12.75) for equity, 0.94 (t-stat=8.9) for calls, and 0.98 (t-stat=9.07) for puts over a 300-minute window or 15 20-minute intervals. The results hold in other time windows and are significant at the 1% level, which implies that trading is higher by 133 to 166% in equity and 94 to 118% in options after FOMC news. The addition of volatility shocks in column (2) of Table 8 halves the value of γ_1 and improves the adjusted R^2. With a 300-minute window, the estimate of γ_1 becomes 0.53 (t-stat=7.41) for equity, 0.47 (t-stat=4.52) for calls, and 0.45 (t-stat=4.63) for puts; and the adjusted R^2 increases from 5.44% to 60.1% for equity, from 2.69% to 23.8% for calls, and 2.93% to 26.79% for puts. On average, the dummy coefficient γ_1 reduces to between 53 and 75% in equity and between 43 and 57% in options, which are all significant at the 1% level. The goodness-of-fit improves from about 8% to between 50 and 60% for equity and 4% to between 17 and 24% 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 6. For example, the estimate of γ_2 is 0.75 (t-stat=27.74) for equity, 0.47 (t-stat=20.53) for calls, and 0.5 (t-stat=21.03) for puts over the 300-minute interval.

In column (3) with uncertainty shocks, both the coefficients for γ_1 and γ_2 marginally change their magnitude and statistical significance. The estimate of γ_1 is 0.61 (t-stat=8.54) for equity, 0.48 (t-stat=5.03) for calls, and 0.49 (t-stat=5.06) for puts; and the corresponding γ_2 across markets are 0.64 (t-stat=24.11), 0.41 (t-stat=17.48), and 0.44 (t-stat=18.24) over a 300-minute window. The uncertainty coefficient γ_3 is negative, significant at the 1% level, and very close to that in column (3) of Table 6. The adjusted R^2 also increases on average by 6% for equity and 2% for options in column (2). In the example above, the estimate of γ_3 is -0.27 (t-stat=-14.54) for equity, -0.14 (t-stat=-6.88) for calls, and -0.14 (t-stat=-7.07) for puts; and the adjusted R^2 rises to 66.28%, 25.43%, and 28.49%, respectively.

To assess the volatility and uncertainty coefficients on announcement days, we add their interaction terms with dummy $event_t$ in column (4). In regard to equity market,

the coefficients for γ_1 to γ_3 carry the same values as in column (3). The interaction term of uncertainty, however, turns positive and significant at the 5% level in 3 cases and marginally significant (t-stat above 1.49) in the other two. For example, the estimate of γ_5 is 0.16 (t-stat=3.08) over a 300-minute window, but 0.14 (t-stat=1.49) over a 150-minute time interval. Meanwhile, γ_4 is insignificant at conventional levels, and it is 0.08 (t-stat=1.08) over a 300-minute window. Taken together, a one sigma decrease in uncertainty shocks intensifies trading by 7-15% ($\gamma_3 + \gamma_5$); whereas a one sigma increase of volatility shocks increases trading by 59-64%. With respect to option market, the coefficient for γ_5 has similar magnitude to γ_3, although it is mostly inisignificant over different time windows. For example, the estimate of γ_5 is 0.15 (t-stat=1.83) for calls and 0.09 (t-stat=1.13) for puts over a 300-minute interval. The coefficient γ_4 is also insignificant as in equity market, e.g. 0.08 (t-stat=0.65) for calls and 0.05 (t-stat=0.4) for puts in the example above.

Insert Table 9

We study the results on trades following non-FOMC news in Table 9. Section 4.1 documents a weak increase in post-announcement equity trade for non-FOMC news. We continue to explain this by risk and uncertainty. From column (1), 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 0.09 (t-stat=2.55) for equity, 0.12 (t-stat=3.39) for calls, and 0.14 (t-stat=3.92) for puts. We note that these results contradict weakly significant changes reported in Section 4.1. This is because by Equation (2) we are interested in option trading intensity before and after the news releases. Equation (6), however, runs on the post-announcement observations. Option trades in the post-release period in announcement days are higher than those in non-announcement days, but remain unchanged relative to pre-release period in announcement days.

When volatility and uncertainty shocks are added in column (3), the coefficient for γ_1 becomes insignificant for equity, but positive and significant in option markets. In our example, the coefficient for γ_1 is 0.01 (t-stat=0.64) for equity, 0.07 (t-stat=2.33) for calls, and 0.09 (t-stat=2.91) for puts. Regarding the coefficients for γ_2 and γ_3, we find a positive (negative) relation between volatility (uncertainty) and trades. The coefficients are similar to those under Table 8 both in terms of magnitude and statistical significance of 1%. With the longest 300-minute window, the estimate of γ_2 is 0.63 (t-stat=41.04) for equity, 0.42 (t-stat=28.91) for calls, and 0.44 (t-stat=30.84) for puts; and γ_3 has coefficient values of -0.3 (t-stat=-23.36), -0.15 (t-stat=-9.93) and -0.16 (t-stat=-11.03) across markets, respectively. The adjusted R^2 improves substantially, e.g. from 0.11%

to 65.82% for equity, 0.2% to 25.32% for calls, and 0.28% to 28.6% in the same example. Lastly, the interaction terms of volatility and uncertainty are insignificant across time windows and markets in column (4). Over the 300-minute window, the coefficients for γ_4 and γ_5 at most 0.06 in magnitude, and their statistical significance is greater than 10% level for equity and option markets.

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. In addition, the surge in option trades prior to non-FOMC announcements is not completely captured by controls of risk and uncertainty in equity market, reinforcing the informed trading hypothesis.

4.4 Pre-FOMC returns

We report that the positive drift in stock prices is associated with low risk and trading 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) and liquidity are well studied in literature, see Campbell and Hentschel (1992), Hameed et al. (2010) and Naes et al. (2011) among others. To evaluate the role of trading activity, risk and uncertainty on returns before the FOMC meetings, we run a regression of pre-FOMC returns on a dummy variable $event_t$ (equal 1 on announcement days), risk $rvar_t$, uncertainty $u2_t$ and liquidity $volume_t$,[20] and their interactions with dummy $event_t$. The data sample includes observations calculated over the pre-release period in (non-) announcement days. We then repeat this for post-annoucement observations. The regression is presented as follows:

$$\begin{aligned} ret_t =& \gamma_0 + \gamma_1 event_t + \gamma_2 rvar_t + \gamma_3 u2_t + \gamma_4 volume \\ &+ \gamma_5 rvar_t event_t + \gamma_6 u2_t event_t + \gamma_7 volume_t event_t + \epsilon_t. \end{aligned} \tag{7}$$

The variables $rvar_t$, $u2_t$, and $volume_t$ are also interepreted as the shocks to risk, uncertainty and liquidity as in Equation (7). We are not only interested in the relation between liquidity, risk, uncertainty and returns in non-announcement days but also at times of FOMC release as shown by the interaction terms. We also run a benchmark

[20] Hasbrouck and Seppi (2001), Cao and Wei (2010), and Lucca and Moench (2015) among others proxy liquidity by trading volume. Lou and Shu (2017) illustrate that the return premium associated with the widely used Amihud (2002) illiquidity measure, which is negatively correlated with trading volume, is only attributable to trading volume component, not its construction of the return-to-volume ratio to capture price impact.

regression only with the event dummy to see how its coefficient and adjusted R^2 change when we add more explanatory variables. We normalize all variables by dividing them by their sample standard deviation for ease of interpretation. Table 10 contains regression estimates in Equation (7). Its first column lists different time windows, and the second column presents the Adj-R^2 (%) and the regressors associated with coefficients γ_0 to γ_7. The next columns report the coefficient estimates and t-stats of Equation (7).

Insert Table 10 here

The results for pre-FOMC returns are presented in Table 10. When only $event_t$ is included in regression, its coefficient γ_1 is positive and significant at the 1 to 5% levels over longer time intervals. With the longest 300-minute window, the estimate of γ_1 is 0.25 (t-stat=2.67) and significant at the 1% level; meanwhile, it becomes 0.14 (t-stat=1.62) with the shortest 150-minute window. The results imply that the pre-FOMC returns is on average 12-20 bps ($\gamma_0 + \gamma_1$). With the addition of volatility and liquidity shocks in column (2), the coefficient magnitude of γ_1 reduces by a half and is insignificant. In the example above, γ_1 is estimated at 0.13 (t-stat=1.45) and 0.07 (t-stat=0.84) over a 300- and 150-minute windows, respectively. The coefficients of volatility and liquidity shocks are negative, and their statistical significance varies over different time intervals. The estimates of γ_2 and γ_4 are -0.11 (t-stat=-2.6) and -0.09 (t-stat=-2.58), respectively, over a 300-minute window. These coefficient values become -0.07 (t-stat=-1.98) and -0.07 (t-stat=-2.32) over a 150-minute window, and both cases are significant at the 1 to 5% levels. Hence, a one sigma decrease in liquidity (volatility) shocks is associated with a 7 to 12% (6 to 21%) increase in returns sigma across different time intervals. Finally, the adjusted R^2 shows some improvement, e.g. from 0.14% to 3.5% over a 300-minute window. The explanatory power of liquidity and volatility shocks are consistent with Lucca and Moench (2015).

In the presence of uncertainty shocks in column (3), the coeffient γ_1 remains insignificant, e.g. 0.04 (t-stat=0.39) over a 300-minute window. The coefficients of volatility and liquidity shocks, however, have their statistical significance varied over different time intervals. With a 300-minute window, the estimates of γ_2 and γ_4 are -0.05 (t-stat=-1.15) and 0 (t-stat=0.15), respectively; meanwhile, their corresponding values are -0.06 (t-stat=-1.63) and -0.07 (t-stat=-2.4) over the 150-minute interval. The coefficient of uncertainty shocks γ_3, is positive and significant only over a longer time window. That is, estimates of γ_3 are 0.22 (t-stat=4.73) and 0.01 (t-stat=0.12), over the 300- and 150-minute windows, respectively. The adjusted R^2 also increases from 3.5% in column

(2) to 6.17% in column (3) over a 300-minute interval. Therefore, a one sigma increase in uncertainty shocks is associated with 9 to 22% increase in returns sigma. Liquidity shocks play a dominant role in short time intervals, while volatility shocks still carry negative effects on returns over longer time windows. The positive sign of uncertainty coefficient also supports Cao et al. (2005b) 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 rinvestors who remain in the market are more willing to accept a lower uncertainty premium. Risk premium however could be high to attract them to hold stocks as only they bear the risk. This may explain why equity premia under limited participation can be lower than that under full case, i.e. the presence of ambiguity-averse investors.

We turn to the relation between returns and risk, liquidity and uncertainty in FOMC days. The coefficients of γ_1 to γ_4 in column (4) are similar to those in column (3), and the interactions of volatility and uncertainty shocks are insignificant. For example, the coefficients for γ_5 and γ_7 are -0.24 (t-stat=-1.56) and -0.03 (t-stat=-0.25) over the 300-minute interval. More interestingly, the uncertainty-returns relation turns negative, and its statistical significance is strongest over the 300-minute window. That is, the estimate of γ_6 is -0.49 (t-stat=-2.55) or -0.44 (t-stat=-2.3) 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 by 25 to 28% ($\gamma_3 + \gamma_6$) in returns sigma. The adjusted R^2 shows a marginal increase from 6.17% to 6.55% and from 6.27% to 6.53% in the two 300-minute examples above, and it is due to only 72 FOMC meetings in our sample period.

In conclusion, the pre-FOMC returns could be accounted for liquidity, volatility and uncertainty shocks given the improved adjusted R^2 and insignificant mean return differential in announcement days. Ui (2011) argues that equity premium increases (current price falls) 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 it is high enough, investors can demand high uncertainty or equity premium to hold stocks, especially when risk premium associated with low volatility is small before the FOMC releases.

4.5 Post-FOMC returns

We present the results on post-announcement data in Table 10. The column (1) with stand-alone $event_t$, its coefficient γ_1 is negative and not statistically different from zero, e.g. -0.13 (t-stat=-0.76) over a 300-minute window. The insiginificant γ_1 also holds in other columns (2) to (4). By adding volatility and liquidity shocks in column (2), we document that the negative returns-liquidity relation is significant at longer time intervals. In the example of 300-minute window, the coefficient for γ_4 is -0.1 (t-stat=-3.08) and significant at the 1% level, and the adjusted R^2 increases from 0.01% to 1.55%. On average, a one sigma increase in liquidity shocks is associated with a decrease of 10 to 16% returns sigma. When uncertainty shocks are added in column (3), the negative coefficient of liquidity shocks on returns remains, and the coefficient for γ_3 of uncertainty is positive but insignificant. The only exception is with uncertainty measured over 10 30-minute intervals, where γ_3 is significant at the 1% level, and γ_4 becomes weakly significant. That is, the estimates of γ_3 and γ_4 are 0.13 (t-stat=2.56) and -0.03 (t-stat=-1.01), respectively.

Following the FOMC meetings on announcement days, the coefficients of volatility shocks are only significant at the 10% level over short time intervals. For example, with a 150-minute window, the estimates of γ_2 and γ_5 are -0.05 (t-stat=-1.76) and 0.46 (t-stat=1.68). Equivalently, a one sigma increase in volatility shocks weakly increases returns by 41% ($\gamma_2 + \gamma_5$). With respect to liquidity shocks, the results continue to hold over longer time windows. That is, the coefficients for γ_4 and γ_7 are -0.16 (t-stat=-5.04) and 0.06 (t-stat=0.26) with uncertainty measured from 15 20-minute intervals. On average, a sigma increase in liquidity is associated with a decrease by 13 to 16% ($\gamma_4 + \gamma_7$) in returns sigma. More importantly, the uncertainty-return relation is positive and significant across different time intervals. Over the 300-and 150-minute windows, the estimate of γ_6 is 0.42 (t-stat=1.93) and 0.55 (t-stat=2.15), respectively. The results imply that a one sigma decrease in uncertainty shocks reduces returns by 51 to 57% of its sigma ($\gamma_3 + \gamma_6$). The adjusted R^2 shows some improvements, e.g. from 2.72% in column (3) to 3.2% in column (4) over a 300-minute interval.

In general, we find a negative coefficient for liquidity shocks on stock returns, but it turns positive for uncertainty shocks in announcement days. The latter contrasts the negative sign documented for pre-FOMC returns regression. Although we are unable to document the volatility-returns relation, we find that negative uncertainty shocks are coupled with low contemporaneous returns or high equity premium. This implies that high risk premium (and high equity premia) compensates for high volatility since the

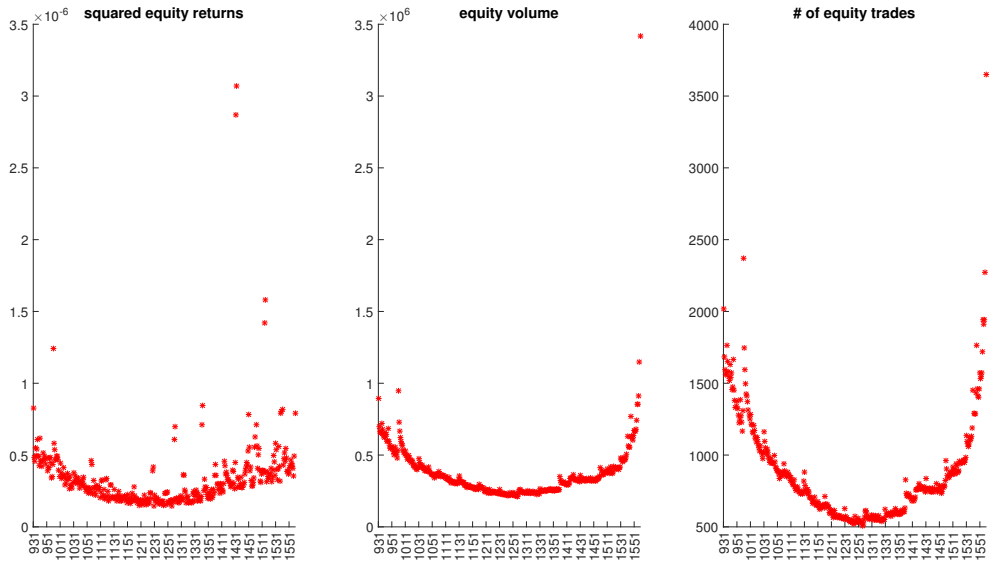
uncertainty premium induced by low ambiguity is attenuated.

5 Conclusion

In this paper we stress the separate consequences of risk and uncertainty for stock returns during macro news releases. We use the uncertainty measure outlined in Izhakian (2017); while risk is measured by realized returns volatility. We find a high degree of uncertainty coupled with low risk and trading activity prior to the FOMC announcements. This however reverses after the FOMC meetings. The uncertainty resolution leads to a sustained increase in post-FOMC trading volume since the FOMC text-based nature clarifies information on target rate decision and hence encourages investors to participate in the market to a greater extent. We also find supportive evidence on the important role of uncertainty in determining market participation relative to risk.

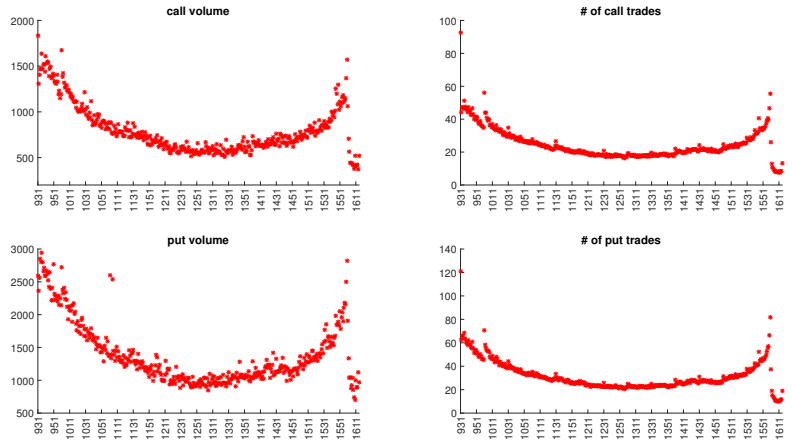
For non-FOMC macro news, we document a high option trading intensity before announcement time and provide an explanation from informed trading. Similar to previous findings, e.g. Bollerslev et al. (2018), we report the positive volatility-volume comovement, and more importantly, the negative uncertainty-trading activity relation, as predicted by theories in Cao et al. (2005b) and Ui (2011) among others. Further analysis on stock returns shows that the pre-FOMC high uncertainty potentially contributes to the positive market returns in addition to risk. Therefore, risk and uncertainty play different roles in trading activity and market returns as suggested by theory.

Figure 1: **Intraday patterns for equity over in 2005-2013**



This figure presents the average intra day patterns of 1-minute squared returns, total volume, and number of trades during trading time 9:30 to 16:00 for equity and 9:30 to 16:15 for options in 2005-2013. The number of trades and volume is aggregated over 1-minute interval, and all variables are averaged over trading days in the sample.

Figure 2: **Intraday patterns for call and put options in 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 1-minute interval, and all variables are averaged over trading days in the sample.

Table 1: **Simulation results**

		Scenario 1: fixed μ (μ_2)			Scenario 2: fixed σ (σ_2)		
		low σ_1	medium σ_2	high σ_3	low μ_1	medium μ_2	high μ_3
Mean	1^{st} pct	-0.50	-0.54	-0.63	-0.71	-0.53	-0.44
	2.5^{th} pct	-0.43	-0.48	-0.51	-0.61	-0.43	-0.34
	average	-0.01	-0.01	-0.01	-0.20	-0.01	0.18
	97.5^{th} pct	0.30	0.33	0.38	0.11	0.32	0.58
	99^{th} pct	0.33	0.35	0.41	0.16	0.36	0.67
Risk	1^{st} pct	5.64	6.40	6.96	6.36	6.42	6.48
	2.5^{th} pct	5.68	6.45	7.00	6.41	6.44	6.54
	average	6.23	6.89	7.41	6.87	6.89	6.96
	97.5^{th} pct	6.84	7.40	7.90	7.41	7.41	7.45
	99^{th} pct	6.92	7.47	7.97	7.50	7.48	7.55
Uncertainty	1^{st} pct	-11.91	-12.89	-13.48	-13.01	-12.92	-12.51
	2.5^{th} pct	-11.78	-12.72	-13.34	-12.87	-12.68	-12.36
	average	-10.91	-11.92	-12.45	-12.03	-11.92	-11.70
	97.5^{th} pct	-10.35	-11.33	-11.38	-11.41	-11.32	-11.21
	99^{th} pct	-10.30	-11.24	-11.13	-11.31	-11.23	-11.13
		Scenario 3: high μ-high σ			Scenario 4: high μ-low σ		
		(μ_1, σ_1)	(μ_2, σ_2)	(μ_3, σ_3)	(μ_3, σ_1)	(μ_2, σ_2)	(μ_1, σ_3)
Mean	1^{st} pct	-0.67	-0.58	-0.44	-0.37	-0.58	-0.69
	2.5^{th} pct	-0.58	-0.47	-0.33	-0.29	-0.46	-0.61
	average	-0.20	-0.01	0.18	0.18	-0.01	-0.20
	97.5^{th} pct	0.08	0.32	0.61	0.58	0.34	0.16
	99^{th} pct	0.10	0.37	0.65	0.62	0.39	0.23
Risk	1^{st} pct	5.56	6.41	7.02	5.80	6.40	6.94
	2.5^{th} pct	5.60	6.45	7.06	5.84	6.45	6.99
	average	6.17	6.90	7.45	6.36	6.89	7.39
	97.5^{th} pct	6.82	7.46	7.91	6.91	7.41	7.86
	99^{th} pct	6.90	7.52	8.01	6.99	7.48	7.92
Uncertainty	1^{st} pct	-12.25	-12.90	-13.32	-11.49	-12.83	-13.62
	2.5^{th} pct	-12.04	-12.73	-13.18	-11.23	-12.66	-13.48
	average	-11.10	-11.93	-12.33	-10.59	-11.92	-12.54
	97.5^{th} pct	-10.43	-11.33	-11.37	-10.15	-11.31	-11.48
	99^{th} pct	-10.36	-11.25	-11.20	-10.10	-11.24	-11.19

This table presents the summary statistsics of mean returns, risk, and uncertainty from simulation exercise. Under each scenario, we sample three random return series of 300 observations each, equivalent to 20 returns for each of 15 time intervals. The returns in each time interval are sampled from a specific normal distribution, whose parameter set is randomly chosen from four different pairs of (μ_{ji}, σ_{ji}), $i = 1, 2, 3, 4$ with probabilitiy 10%, 40%, 25% and 25%, respectively, and $j = 1, 2, 3$. The mean vectors are $\mu_1 = [-2, 0, 0, 0], \mu_2 = [-2, 0, 0.25, 0.5], \mu_3 = [-2, 0, 0.5, 1]$, and the standard deviation vectors are $\sigma_1 = [2, 1, 1, 1], \sigma_2 = [3, 1.5, 1.5, 1.5], \sigma_3 = [4, 2, 2, 2]$. The mean returns, risk, and uncertainty are calculated from the simulated returns series. The simulation is implemented 1,000 times to provide the mean, the $1^{st}, 2.5^{th}, 97.5^{th}, 99^{th}$ percentiles of each variable.

Table 2: **Key macroeconomic announcements**

Index	release time	frequency	start date	# participants	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 in 2005-2013. Release time is the typical announcement time, # participants is the average number of participants interviewed for their forecasts. N announcements is the number of announcements in the sample, and positive (negative) surp is the percentage of positive (negative) surprises, where surprise is the difference between the released and forecast values.

Table 3: **Patterns in event days**

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
	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
ln trade	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

This table presents the patterns in event days over the period 2005-2013,. 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. Given the intraday patterns of squared returns and trading at 1-minute frequency, the risk Rvar, uncertainty U2 and trading activity are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window before and after announcement time of the coming event. 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 announcement 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 4: **Pre-announcement option-to-equity trade ratio in event days**

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

This table presents the coefficient γ_1 in 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 underlying 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 20-day moving average underlying trades computed from the same time window. This adjustment takes into account intraday pattern in trading of option and underlying. 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 5: **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 announcement releases over 2005-2013. Column "range" indicates the time window before and after announcement over which returns and the number of trades/volume in options and underlying are calculated. The ratio of option-equity ratio is further divided by the ratio of 20-day moving-average option trades over 20-day moving average underlying trades computed from the same time window. This adjustment takes into account intraday pattern in trading of option and underlying. The natural logarithm is taken for option-underlying ratio to avoid extreme values. The standard errors are heteroskedasticity adjusted. ***, **, and * denote statistical significance at 10%, 5%, and 1% level.

Table 6: **Pre-announcement trades regression for FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat
equity	Adj-R^2(%)	10	0.91		56.80		60.96		60.95		15	1.02		55.30		61.97		61.96	
	event	of 15-min	-0.55***	-5.03	-0.21***	-2.69	-0.08	-1.24	-0.12	-1.11	of 15-min	-0.59***	-5.01	-0.24***	-3.14	-0.09	-1.37	-0.06	-0.70
	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						-0.24***	-10.70	-0.24***	-10.10						-0.31***	-14.35	-0.30***	-13.56
	u2*event								-0.06	-0.98								-0.09	-1.51
	Adj-R^2(%)	10	1.06		59.49		63.91		63.88		15	0.98		58.01		64.33		64.31	
	event	of 20-min	-0.60***	-5.12	-0.17**	-2.32	-0.05	-0.71	-0.04	-0.36	of 20-min	-0.58***	-4.83	-0.15*	-1.87	-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	0.60***	25.12	0.60***	24.36
	rvar*event								0.03	0.29								-0.01	-0.15
	u2						-0.25***	-11.33	-0.25***	-11.04						-0.30***	-14.83	-0.30***	-14.27
	u2*event								0.03	0.39								-0.07	-0.83
	Adj-R^2(%)	10	0.98		63.31		68.72		68.70										
	event	of 30-min	-0.58***	-4.83	-0.13**	-2.06	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						-0.29***	-14.81	-0.29***	-14.48									
	u2*event								0.04	0.47									
call	Adj-R^2(%)	10	0.13		20.76		22.00		22.11		15	0.16		19.49		21.49		21.45	
	event	of 15-min	-0.24**	-2.33	-0.03	-0.32	0.03	0.34	-0.14	-1.03	of 15-min	-0.26***	-2.60	-0.06	-0.66	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						-0.13***	-5.65	-0.13***	-5.47						-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		22.63		22.62		15	0.15		19.39		21.40		21.35	
	event	of 20-min	-0.27***	-2.69	-0.02	-0.18	0.04	0.48	-0.06	-0.50	of 20-min	-0.25**	-2.39	-0.01	-0.09	0.07	0.77	0.03	0.27
	rvar				0.46***	21.11	0.39***	15.71	0.40***	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						-0.13***	-5.66	-0.13***	-5.58						-0.17***	-7.34	-0.17***	-7.08
	u2*event								0.06	0.50								-0.05	-0.48
	Adj-R^2(%)	10	0.15		20.66		22.42		22.36										
	event	of 30-min	-0.25**	-2.39	0.00	-0.02	0.08	0.89	0.06	0.55									
	rvar				0.46***	21.50	0.36***	14.21	0.36***	13.97									
	rvar*event								-0.03	-0.24									
	u2						-0.17***	-6.97	-0.17***	-6.79									
	u2*event								-0.01	-0.10									
put	Adj-R^2(%)	10	0.18		24.03		25.49		25.59		15	0.33		22.52		24.96		24.93	
	event	of 15-min	-0.27**	-2.56	-0.05	-0.47	0.02	0.24	-0.14	-1.12	of 15-min	-0.35***	-3.38	-0.13	-1.43	-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						-0.15***	-6.48	-0.15***	-6.43						-0.19***	-8.34	-0.19***	-8.17
	u2*event								0.10	0.85								0.05	0.43
	Adj-R^2(%)	10	0.30		24.51		25.97		25.98		15	0.34		23.54		25.85		25.81	
	event	of 20-min	-0.34***	-3.27	-0.07	-0.70	0.00	0.02	-0.12	-0.91	of 20-min	-0.35***	-3.35	-0.09	-0.93	0.00	-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***	16.20
	rvar*event								-0.09	-0.66								-0.08	-0.61
	u2						-0.15***	-6.53	-0.15***	-6.54						-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		26.56		26.50										
	event	of 30-min	-0.35***	-3.35	-0.08	-0.96	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						-0.19***	-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 trades on risk and uncertainty for FOMC releases over the period 2005-2013, where event variable is a dummy of announcement days. Given the intraday patterns of 1-minute returns squared and trading, the trade, risk and uncertainty are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window before announcement time of the coming event. The natural logarithm is taken for trade, 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 7: **Pre-announcement trades regression for non-FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat
equity	Adj-R^2(%)	10	-0.01		49.87		57.77		57.76		15	-0.02		50.13		61.72		61.72	
	event	of 15-min	0.02	0.64	-0.01	-0.55	-0.01	-0.68	0.00	-0.05	of 15-min	0.01	0.39	-0.02	-0.79	-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						-0.29***	-21.86	-0.30***	-18.69						-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		54.57		54.60		15	-0.02		49.58		60.90		60.93	
	event	of 20-min	0.02	0.45	-0.01	-0.36	0.00	-0.16	0.03	0.73	of 20-min	0.01	0.21	-0.02	-0.72	-0.02	-0.73	0.02	0.51
	rvar				0.69***	34.58	0.59***	28.64	0.58***	24.43				0.70***	39.56	0.59***	35.49	0.58***	30.93
	rvar*event								0.06	1.43								0.06	1.46
	u2						-0.28***	-16.73	-0.29***	-14.42						-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		60.32		60.39										
	event	of 30-min	0.01	0.21	-0.01	-0.58	-0.01	-0.56	0.03	0.84									
	rvar				0.73***	42.49	0.63***	36.80	0.62***	32.35									
	rvar*event								0.08*	1.82									
	u2						-0.28***	-19.71	-0.29***	-17.75									
	u2*event								0.05*	1.72									
call	Adj-R^2(%)	10	0.17		24.57		25.53		25.52		15	0.21		24.00		27.50		27.50	
	event	of 15-min	0.11***	3.23	0.09***	2.94	0.09***	2.99	0.11***	2.94	of 15-min	0.13***	3.53	0.10***	3.35	0.10***	3.36	0.13***	3.26
	rvar				0.49***	30.13	0.43***	25.77	0.42***	22.80				0.49***	30.53	0.41***	24.35	0.41***	21.39
	rvar*event								0.04	0.94								0.04	0.99
	u2						-0.15***	-10.21	-0.15***	-9.19						-0.20***	-12.03	-0.21***	-10.73
	u2*event								0.03	0.91								0.04	1.09
	Adj-R^2(%)	10	0.23		23.79		25.26		25.28		15	0.18		24.10		27.47		27.46	
	event	of 20-min	0.13***	3.65	0.11***	3.71	0.11***	3.84	0.15***	3.70	of 20-min	0.12***	3.23	0.10***	3.19	0.10***	3.29	0.12***	3.13
	rvar				0.49***	28.63	0.43***	23.90	0.42***	20.76				0.49***	32.66	0.42***	27.33	0.42***	24.36
	rvar*event								0.06	1.45								0.04	1.00
	u2						-0.15***	-9.06	-0.15***	-8.11						-0.19***	-13.33	-0.20***	-11.95
	u2*event								0.03	0.90								0.02	0.68
	Adj-R^2(%)	10	0.18		25.81		27.50		27.52										
	event	of 30-min	0.12***	3.23	0.10***	3.33	0.10***	3.39	0.13***	3.46									
	rvar				0.51***	34.26	0.46***	29.10	0.45***	26.00									
	rvar*event								0.06	1.46									
	u2						-0.14***	-9.79	-0.15***	-8.98									
	u2*event								0.03	0.94									
put	Adj-R^2(%)	10	0.20		26.06		26.72		26.72		15	0.22		26.43		29.94		29.95	
	event	of 15-min	0.12***	3.51	0.10***	3.28	0.10***	3.31	0.12***	3.18	of 15-min	0.13***	3.59	0.10***	3.45	0.10***	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***	23.10
	rvar*event								0.04	1.01								0.04	1.03
	u2						-0.13***	-9.52	-0.14***	-8.66						-0.20***	-12.51	-0.21***	-11.22
	u2*event								0.03	0.96								0.04	1.12
	Adj-R^2(%)	10	0.24		25.15		26.27		26.30		15	0.20		26.48		29.79		29.80	
	event	of 20-min	0.13***	3.76	0.11***	3.87	0.12***	3.99	0.15***	3.84	of 20-min	0.12***	3.44	0.10***	3.47	0.10***	3.58	0.13***	3.50
	rvar				0.50***	28.84	0.45***	24.44	0.43***	21.16				0.51***	34.10	0.45***	29.58	0.44***	26.37
	rvar*event								0.07	1.53								0.05	1.14
	u2						-0.14***	-8.40	-0.14***	-7.55						-0.19***	-13.59	-0.20***	-12.30
	u2*event								0.03	0.93								0.03	0.86
	Adj-R^2(%)	10	0.20		28.05		29.58		29.60										
	event	of 30-min	0.12***	3.44	0.11***	3.63	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						-0.13***	-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 trades on risk and uncertainty for non-FOMC releases over the period 2005-2013, where event variable is a dummy of announcement days. Given the intraday patterns of 1-minute returns squared and trading, the trade, risk and uncertainty are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window before announcement time of the coming event. The natural logarithm is taken for trade, 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 8: **Post-announcement trades regression for FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat
equity	Adj-R^2(%)	10	8.09		54.20		61.01		61.06		15	6.25		49.52		56.72		56.71	
	event	of 15-min	1.62***	15.03	0.72***	8.78	0.66***	8.26	0.79***	6.05	of 15-min	1.42***	13.36	0.55***	6.49	0.49***	6.13	0.58***	4.25
	rvar				0.70***	23.03	0.61***	21.19	0.60***	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						-0.28***	-14.92	-0.28***	-14.85						-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		62.30		62.31		15	5.44		51.77		59.03		59.02	
	event	of 20-min	1.47***	13.56	0.63***	7.93	0.62***	8.12	0.63***	6.31	of 20-min	1.33***	12.75	0.51***	6.59	0.50***	6.91	0.49***	5.31
	rvar				0.71***	24.21	0.62***	22.21	0.62***	21.54				0.70***	24.54	0.60***	23.24	0.60***	22.52
	rvar*event								0.10	1.02								0.08	1.11
	u2						-0.28***	-14.27	-0.28***	-14.10						-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		66.28		66.33										
	event	of 30-min	1.33***	12.75	0.53***	7.41	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						-0.27***	-14.54	-0.28***	-14.42									
	u2*event								0.16***	3.08									
call	Adj-R^2(%)	10	4.01		23.11		25.10		25.07		15	2.94		20.24		21.95		21.93	
	event	of 15-min	1.15***	10.27	0.56***	5.51	0.53***	5.18	0.59***	2.94	of 15-min	0.99***	8.68	0.43***	4.08	0.40***	3.80	0.45**	2.48
	rvar				0.45***	18.39	0.40***	16.37	0.40***	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						-0.15***	-7.55	-0.15***	-7.58						-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		24.49		24.49		15	2.69		21.01		22.62		22.60	
	event	of 20-min	1.01***	8.78	0.47***	4.52	0.47***	4.45	0.48***	2.87	of 20-min	0.94***	8.90	0.42***	4.43	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								0.10	0.89
	u2						-0.14***	-6.77	-0.14***	-6.83						-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		25.43		25.43										
	event	of 30-min	0.94***	8.90	0.44***	4.66	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						-0.14***	-6.88	-0.15***	-6.95									
	u2*event								0.15*	1.83									
put	Adj-R^2(%)	10	4.25		24.91		26.89		26.84		15	3.18		21.64		23.39		23.34	
	event	of 15-min	1.18***	10.68	0.57***	5.65	0.54***	5.35	0.59***	3.12	of 15-min	1.02***	8.93	0.45***	4.16	0.42***	3.90	0.48***	2.72
	rvar				0.47***	18.39	0.42***	16.67	0.42***	16.22				0.44***	17.16	0.40***	15.69	0.40***	15.29
	rvar*event								0.05	0.42								0.04	0.38
	u2						-0.15***	-7.66	-0.15***	-7.65						-0.14***	-6.64	-0.14***	-6.65
	u2*event								0.10	0.88								0.11	0.97
	Adj-R^2(%)	10	3.32		25.26		26.92		26.91		15	2.93		22.92		24.53		24.49	
	event	of 20-min	1.05***	9.07	0.48***	4.54	0.47***	4.48	0.51***	3.13	of 20-min	0.98***	9.07	0.44***	4.40	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	0.50
	u2						-0.14***	-7.08	-0.14***	-7.15						-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		28.49		28.46										
	event	of 30-min	0.98***	9.07	0.45***	4.63	0.49***	5.06	0.50***	3.55									
	rvar				0.50***	21.03	0.44***	18.24	0.44***	17.79									
	rvar*event								0.05	0.40									
	u2						-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 trades on risk and uncertainty for FOMC releases over the period 2005-2013, where event variable is a dummy of announcement days. Given the intraday patterns of 1-minute returns squared and trading, the trade, risk and uncertainty are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window after announcement time of the coming event. The natural logarithm is taken for trade, 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 9: **Post-announcement trades regression for non-FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat
equity	Adj-R^2(%)	10	0.39		63.97		66.34		66.34		15	0.20		61.14		64.14		64.14	
	event	of 15-min	0.17***	4.53	0.03	1.19	0.05**	2.18	0.03	1.17	of 15-min	0.12***	3.32	-0.01	-0.64	0.01	0.37	-0.01	-0.20
	rvar				0.80***	60.21	0.66***	35.66	0.67***	33.73				0.78***	58.70	0.63***	35.28	0.63***	32.95
	rvar*event								-0.04	-0.72								-0.03	-0.63
	u2						-0.21***	-13.48	-0.20***	-12.12						-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		66.47		66.46		15	0.11		54.84		59.47		59.47	
	event	of 20-min	0.13***	3.46	0.02	1.10	0.04**	1.99	0.05*	1.68	of 20-min	0.09**	2.55	0.00	-0.14	0.01	0.61	0.03	0.87
	rvar				0.79***	53.89	0.62***	34.34	0.62***	30.88				0.74***	49.30	0.57***	31.40	0.57***	27.78
	rvar*event								0.01	0.31								0.02	0.39
	u2						-0.27***	-18.17	-0.28***	-16.61						-0.27***	-17.51	-0.28***	-16.00
	u2*event								0.02	0.50								0.03	0.89
	Adj-R^2(%)	10	0.11		58.67		65.82		65.84										
	event	of 30-min	0.09**	2.55	0.01	0.64	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						-0.30***	-23.36	-0.31***	-21.07									
	u2*event								0.04	1.48									
call	Adj-R^2(%)	10	0.36		21.21		21.93		21.91		15	0.26		21.35		22.28		22.25	
	event	of 15-min	0.16***	4.39	0.08**	2.47	0.09***	2.81	0.09**	2.57	of 15-min	0.14***	3.77	0.06*	1.76	0.07**	2.15	0.07*	1.93
	rvar				0.46***	33.60	0.38***	21.01	0.38***	19.22				0.46***	33.01	0.37***	20.30	0.37***	18.26
	rvar*event								-0.01	-0.13								0.00	-0.10
	u2						-0.11***	-6.43	-0.12***	-5.96						-0.13***	-7.31	-0.13***	-6.61
	u2*event								0.01	0.22								0.00	0.08
	Adj-R^2(%)	10	0.25		21.63		23.10		23.08		15	0.20		20.90		22.31		22.30	
	event	of 20-min	0.14***	3.72	0.08**	2.32	0.08***	2.63	0.09**	2.53	of 20-min	0.12***	3.39	0.06*	1.95	0.07**	2.26	0.08**	2.26
	rvar				0.46***	33.32	0.37***	22.33	0.37***	20.20				0.46***	31.91	0.36***	21.30	0.36***	19.12
	rvar*event								0.00	0.01								0.00	-0.07
	u2						-0.15***	-9.65	-0.16***	-9.02						-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		25.32		25.36										
	event	of 30-min	0.12***	3.39	0.07**	2.33	0.08**	2.50	0.11***	3.06									
	rvar				0.48***	35.75	0.42***	28.91	0.41***	25.48									
	rvar*event								0.04	1.06									
	u2						-0.15***	-9.93	-0.16***	-9.73									
	u2*event								0.07*	1.84									
put	Adj-R^2(%)	10	0.48		24.49		25.32		25.30		15	0.37		24.59		25.62		25.59	
	event	of 15-min	0.18***	5.04	0.10***	3.08	0.11***	3.45	0.11***	3.22	of 15-min	0.16***	4.48	0.08**	2.42	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	0.40***	22.46	0.40***	20.35
	rvar*event								-0.01	-0.12								-0.01	-0.14
	u2						-0.12***	-7.03	-0.13***	-6.61						-0.14***	-7.87	-0.14***	-7.21
	u2*event								0.02	0.42								0.01	0.20
	Adj-R^2(%)	10	0.38		24.72		26.31		26.29		15	0.28		23.55		25.11		25.10	
	event	of 20-min	0.17***	4.53	0.10***	3.17	0.11***	3.51	0.12***	3.33	of 20-min	0.14***	3.92	0.08**	2.48	0.09***	2.81	0.10***	2.73
	rvar				0.49***	35.69	0.40***	24.35	0.40***	22.04				0.48***	34.01	0.39***	23.18	0.39***	20.89
	rvar*event								0.00	-0.08								-0.01	-0.17
	u2						-0.16***	-10.10	-0.16***	-9.39						-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		28.60		28.62										
	event	of 30-min	0.14***	3.92	0.09***	2.91	0.10***	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						-0.16***	-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 trades on risk and uncertainty for non-FOMC releases over the period 2005-2013, where event variable is a dummy of announcement days. Given the intraday patterns of 1-minute returns squared and trading, the trade, risk and uncertainty are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window before announcement time of the coming event. The natural logarithm is taken for trade, 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 10: **Returns regression for FOMC releases**

		Before announcement								After announcement							
range	variable	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat
10 intervals	Adj-R^2(%)	0.02		1.55		1.51		1.43		-0.04		0.07		0.03		0.89	
	Intercept	-0.02	-0.85	-0.05*	-1.90	-0.05	-1.55	-0.04	-1.40	0.02	1.06	0.01	0.47	0.01	0.49	0.00	0.13
of 15 minutes	event	0.14	1.62	0.07	0.84	0.07	0.79	0.04	0.30	0.00	0.01	0.06	0.37	0.06	0.37	0.13	0.41
	rvar			-0.07**	-1.98	-0.06	-1.63	-0.06	-1.41			-0.04	-1.31	-0.04	-1.30	-0.05*	-1.76
	rvar*event							-0.10	-0.78							0.46*	1.68
	u2					0.01	0.12	0.01	0.25					0.01	0.11	-0.01	-0.18
	u2*event							-0.13	-0.95							0.55**	2.15
	volume			-0.07**	-2.32	-0.07**	-2.40	-0.07**	-2.36			-0.01	-0.21	0.00	-0.13	-0.01	-0.36
	volume*event							-0.01	-0.11							0.01	0.05
10 intervals	Adj-R^2(%)	0.00		2.92		3.04		3.06		-0.04		0.50		0.69		1.50	
	Intercept	-0.03	-1.34	-0.06***	-2.58	-0.04	-1.45	-0.04	-1.26	0.02	0.81	0.00	0.07	0.02	0.80	0.01	0.46
of 20 minutes	event	0.12	1.31	0.01	0.16	-0.01	-0.06	-0.07	-0.42	-0.03	-0.21	0.08	0.49	0.07	0.41	0.12	0.42
	rvar			-0.06*	-1.73	-0.05	-1.20	-0.04	-0.94			-0.04	-1.33	-0.04	-1.36	-0.05*	-1.66
	rvar*event							-0.21	-1.32							0.35	1.45
	u2					0.05	1.18	0.06	1.34					0.06	0.96	0.04	0.64
	u2*event							-0.19	-1.02							0.57**	2.40
	volume			-0.12***	-3.68	-0.10***	-3.27	-0.11***	-3.22			-0.05	-1.57	-0.02	-0.68	-0.03	-0.97
	volume*event							0.04	0.31							0.06	0.27
15 intervals	Adj-R^2(%)	0.03		4.45		4.93		4.83		-0.02		0.76		0.72		1.32	
	Intercept	-0.03	-1.60	-0.09***	-3.78	-0.05*	-1.84	-0.05*	-1.73	0.01	0.60	0.01	0.46	0.01	0.29	0.00	-0.01
of 15 minutes	event	0.16**	2.15	0.05	0.68	0.01	0.15	0.01	0.12	-0.09	-0.53	0.03	0.19	0.03	0.19	0.08	0.27
	rvar			-0.17***	-5.08	-0.15***	-4.02	-0.15***	-3.77			0.03	1.26	0.03	1.24	0.03	0.93
	rvar*event							-0.03	-0.35							0.27	1.35
	u2					0.09**	2.29	0.10**	2.31					-0.01	-0.13	-0.02	-0.39
	u2*event							-0.11	-0.97							0.53**	1.96
	volume			-0.05	-1.62	-0.01	-0.40	-0.01	-0.38			-0.12***	-3.85	-0.12***	-3.90	-0.13***	-4.13
	volume*event							-0.02	-0.24							0.15	0.68
15 intervals	Adj-R^2(%)	0.14		4.97		6.27		6.53		0.01		1.55		1.52		2.22	
	Intercept	-0.05**	-2.26	-0.11***	-4.43	-0.05	-1.56	-0.04	-1.36	0.01	0.63	0.01	0.38	0.01	0.51	0.00	0.18
of 20 minutes	event	0.25***	2.67	0.12	1.31	0.06	0.62	0.13	1.01	-0.13	-0.76	0.03	0.18	0.03	0.17	0.04	0.12
	rvar			-0.21***	-5.33	-0.18***	-4.16	-0.18***	-3.94			0.04	1.43	0.04	1.42	0.03	1.07
	rvar*event							0.01	0.12							0.36	1.55
	u2					0.15***	3.11	0.16***	3.34					0.01	0.24	0.00	-0.07
	u2*event							-0.44**	-2.30							0.51*	1.89
	volume			-0.01	-0.36	0.05*	1.67	0.06*	1.78			-0.16***	-5.34	-0.15***	-4.84	-0.16***	-5.04
	volume*event							-0.20	-1.54							0.06	0.26
10 intervals	Adj-R^2(%)	0.14		3.50		6.17		6.55		0.01		1.55		2.72		3.20	
	Intercept	-0.05**	-2.26	-0.08***	-3.43	0.00	0.11	0.01	0.36	0.01	0.63	-0.01	-0.31	0.04	1.62	0.03	1.29
of 30 minutes	event	0.25***	2.67	0.13	1.45	0.04	0.39	0.07	0.57	-0.13	-0.76	0.04	0.25	-0.03	-0.16	-0.10	-0.38
	rvar			-0.11***	-2.60	-0.05	-1.15	-0.04	-0.91			-0.04	-1.30	-0.04	-1.13	-0.04	-1.37
	rvar*event							-0.24	-1.56							0.30	1.06
	u2					0.22***	4.73	0.24***	5.00					0.13**	2.56	0.11**	2.17
	u2*event							-0.49**	-2.55							0.42*	1.93
	volume			-0.09***	-2.58	0.00	0.15	0.01	0.17			-0.10***	-3.08	-0.03	-1.01	-0.04	-1.29
	volume*event							-0.03	-0.25							0.04	0.15

This table presents the regression of pre/post-announcement returns on volume, risk and uncertainty $y_t = \gamma_0 + \gamma_1 event_t + \gamma_2 rvar_t + \gamma_3 u2_t + \gamma_4 volume_t + \gamma_5 rvar_t event_t + \gamma_6 u2_t event_t + \gamma_7 volume_t event_t + \epsilon_t$ for FOMC releases over the period 2005-2013, where event variable is a dummy of announcement days. Given the intraday patterns of 1-minute returns squared and trading, the volume, risk and uncertainty are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window before/after announcement time of the coming event. 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/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.

Appendix: Inference

We rely on asymptotic normality to obtain the statistical significance of coefficients in Table 3. Given the relatively small number of FOMC release or 72 announcements over 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-release observations, we draw with replacement from the empirical distribution of data sample in (non-) announcement days a series of length equal to the number of (non-) announcements observations. We repeat 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 do 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 3, in a sample drawn from the distribution on non-announcement days. To do this, we draw with replacement from the empirical distribution of pre-release observations in non-announcement days a time series of length equal to the number of announcement days, and similarly for observations following the news release. For both approaches, we implement bootstrapping 500 times. Table 11 and 12 present the bootstrapped results for FOMC and non-FOMC releases, respectively. In each table, the first column lists the dependent variable of Equation (2) studied in Section 4.1. The second column presents the time window before (after) announcement time over which the dependent variable is calculated, e.g. 150, 200, 225, and 300 minutes. The next (last) four columns present original coefficient estimates in Table 3, 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 11 here

Insert Table 12 here

We first discuss the results from Approach 1. The coefficient estimates that are sig-

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

nificant at the 1% (5%) level in Table 3 have their bootstrapped CIs always different from zero at 1% (5%) cutoff, and vice versa for insignificant coefficients. We demonstrate this with an example on uncertainty measured over a 300-minute window around 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. On the other hand, for non-FOMC news releases, these coefficients are insigificant and associated with the 99% CIs of [-0.11, 0.09] and [-0.11, 0.1], respectively.

With respect to Approach 2, we document that the coefficients significant at the 1% (5%) level in Table 3 have their p-value 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; meanwhile, their corresponding p-values are 0.444 and 0.448, respectively, for non-FOMC announcements. Hence, it is unlikely to observe such large differentials from the distribution of observations in non-announcement days for coefficients that are significant in Table 3. The two bootstrap methods also help to validate each other. For instance, some insignificant coefficients, e.g. γ_1 in the regression of risk around non-FOMC releases, have p-value in approach 2 less than 0.1. Their bootstrapped CIs, however, include zero, supporting that they are indifferent from zero at conventional confidence levels in Table 3.

Insert Table 13 here

To test the robustness of FOMC results on equity-to-option trade (volume) ratio to small sample issues, we perform the bootstrap exercise. In Table 13, the first two columns present the time window over which the ratio for calls, puts, and all options are computed. The next (last) four columns present original coefficient estimate of γ_1 in Table 4, the 99% and 95% bootstrapped CIs under Approach 1, and the p-value of bootstrapped coefficients under Approach 2. Regarding number of trades, the 99% and 95% CIs include zero and p-values center around 0.1, regardless of time intervals and option types. For example, with the 300-minute window, the insignificant coefficient γ_1 has the 99% CIs of [-0.03, 0.15] for calls, [-0.07, 0.11] for puts, and [-0.05, 0.12] for all options; and the corresponding p-values under approach 2 are 0.094, 0.346, and 0.196. For trading volume, the statistically significant coefficients in Table 4 are verified by both 99% or 95% CIs and p-values. For example, with the 300-minute window, γ_1 is significant at the 1% level for calls, insignificant for puts, and significant at the 10% level for all options. The 99% CIs of this coefficient is [0.07, 0.3] for calls, [-0.09, 0.15] for puts, and [-0.02, 0.2] for all options; and the corresponding p-values are 0, 0.309, and 0.04. We also validate the statistical significance of γ_1 for non-FOMC macro news

and find consistent results. For coefficients significant at the 1% and 5% levels, the CIs are always different from zero at 1% and 5% cutoff, and p-values are less than 0.05. For instance, the coefficient of number-of-trades ratio with the 300-minute window is significant at the 1% level. The 99% CIs are [0.01, 0.08], and p-values are zero for calls, puts, and all options.

Table 11: **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 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 announcement 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. Given the intraday patterns of squared returns and trading at 1-minute frequency, the risk Rvar, uncertainty U2, and trading activity are adjusted by the moving average over the last 20 non-event trading days, where variables in these days are computed over the same time window before and after announcement time of the coming event. 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 in event days a time series of length equal to the number of event days, and similarly from the empirical distribution in 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 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 in 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 12: **Bootstrap statistics for returns, uncertainty, risk and trading activity around non-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	0.04	[-0.04, 0.13]	[-0.02, 0.1]	4.6	0.07*	[0, 0.15]	[0.02, 0.12]	0
ln Rvar	200	0.03	[-0.06, 0.11]	[-0.03, 0.09]	10.4	0.06	[0, 0.14]	[0.01, 0.11]	0.4
	225	0.04	[-0.05, 0.12]	[-0.02, 0.1]	5.6	0.08**	[0.01, 0.16]	[0.02, 0.13]	0
	300	0.03	[-0.06, 0.11]	[-0.03, 0.08]	11	0.06	[0, 0.14]	[0.01, 0.11]	0.6
20-day adjusted	10 15-min int.	-0.02	[-0.12, 0.1]	[-0.1, 0.06]	31.4	0.00	[-0.13, 0.12]	[-0.09, 0.09]	47.2
ln U2	10 20-min int.	0.01	[-0.09, 0.09]	[-0.07, 0.08]	46.2	-0.02	[-0.13, 0.11]	[-0.1, 0.06]	27
	15 15-min int.	-0.04	[-0.15, 0.06]	[-0.12, 0.04]	12.4	0.02	[-0.09, 0.13]	[-0.07, 0.11]	29.6
	15 20-min int.	-0.01	[-0.13, 0.09]	[-0.09, 0.07]	41.4	-0.01	[-0.12, 0.1]	[-0.08, 0.07]	40.8
	10 30-min int.	-0.01	[-0.11, 0.09]	[-0.08, 0.07]	44.4	0.00	[-0.11, 0.1]	[-0.08, 0.07]	44.8
20-day adjusted	150	0.01	[-0.02, 0.04]	[-0.02, 0.03]	23.6	0.04**	[0.02, 0.07]	[0.02, 0.06]	0
ln trade	200	0.01	[-0.03, 0.04]	[-0.02, 0.03]	30.2	0.03**	[0.01, 0.06]	[0.01, 0.05]	0
	225	0	[-0.03, 0.04]	[-0.02, 0.03]	33.6	0.03**	[0.01, 0.06]	[0.01, 0.05]	0
	300	0	[-0.03, 0.03]	[-0.02, 0.02]	40.8	0.03	[0, 0.05]	[0.01, 0.05]	0
20-day adjusted	150	0	[-0.03, 0.04]	[-0.03, 0.03]	45.6	0.04**	[0.01, 0.07]	[0.02, 0.07]	0
ln volume	200	0	[-0.04, 0.03]	[-0.03, 0.02]	40.8	0.04**	[0.01, 0.06]	[0.02, 0.06]	0
	225	0	[-0.03, 0.03]	[-0.03, 0.02]	39.8	0.04**	[0.01, 0.06]	[0.01, 0.06]	0
	300	0	[-0.03, 0.03]	[-0.03, 0.02]	33.6	0.03*	[0, 0.06]	[0.01, 0.05]	0
20-day adjusted	150	0.05***	[0.01, 0.1]	[0.02, 0.09]	0	0.02	[-0.02, 0.06]	[-0.01, 0.05]	5.6
ln trade	200	0.06***	[0.02, 0.1]	[0.03, 0.09]	0	0.00	[-0.04, 0.03]	[-0.03, 0.03]	45
(calls)	225	0.06***	[0.02, 0.1]	[0.03, 0.09]	0	0.00	[-0.03, 0.04]	[-0.02, 0.03]	34.2
	300	0.05***	[0.01, 0.09]	[0.02, 0.08]	0	0.00	[-0.03, 0.04]	[-0.02, 0.03]	36
20-day adjusted	150	0.06***	[0.02, 0.11]	[0.03, 0.11]	0	0.00	[-0.05, 0.05]	[-0.04, 0.04]	48.8
ln volume	200	0.06***	[0.01, 0.11]	[0.03, 0.1]	0	-0.01	[-0.06, 0.04]	[-0.05, 0.03]	29.8
(calls)	225	0.06***	[0.01, 0.1]	[0.02, 0.1]	0	-0.01	[-0.06, 0.05]	[-0.04, 0.03]	36
	300	0.05***	[0, 0.1]	[0.02, 0.09]	0	-0.01	[-0.05, 0.04]	[-0.04, 0.03]	32.2
20-day adjusted	150	0.06***	[0.01, 0.1]	[0.03, 0.09]	0	0.03	[-0.02, 0.06]	[0, 0.05]	1.8
ln trade	200	0.06***	[0.02, 0.1]	[0.03, 0.09]	0	0.01	[-0.03, 0.05]	[-0.02, 0.04]	16
(puts)	225	0.06***	[0.02, 0.1]	[0.03, 0.09]	0	0.01	[-0.03, 0.05]	[-0.01, 0.04]	9.6
	300	0.05***	[0.01, 0.09]	[0.02, 0.08]	0	0.01	[-0.03, 0.05]	[-0.02, 0.04]	19
20-day adjusted	150	0.02	[-0.04, 0.07]	[-0.02, 0.06]	7.8	0.03	[-0.02, 0.09]	[0, 0.07]	2.6
ln volume	200	0.03	[-0.03, 0.07]	[-0.01, 0.07]	4.6	0.02	[-0.03, 0.08]	[-0.01, 0.06]	9.8
(puts)	225	0.03	[-0.02, 0.07]	[-0.01, 0.06]	6.2	0.02	[-0.03, 0.07]	[-0.01, 0.06]	11.2
	300	0.02	[-0.03, 0.06]	[-0.01, 0.05]	8.2	0.02	[-0.03, 0.07]	[-0.02, 0.05]	12.4
returns (%)	150	-0.01	[-0.08, 0.05]	[-0.06, 0.04]	31.6	0.01	[-0.08, 0.09]	[-0.06, 0.07]	39
(x100)	200	-0.01	[-0.08, 0.07]	[-0.07, 0.05]	36.6	0.00	[-0.08, 0.1]	[-0.06, 0.07]	45.8
	225	-0.01	[-0.09, 0.07]	[-0.06, 0.05]	38.6	0.00	[-0.08, 0.1]	[-0.06, 0.07]	46
	300	-0.04	[-0.13, 0.03]	[-0.1, 0.01]	5.8	0.05	[-0.05, 0.15]	[-0.03, 0.12]	8.6

This table presents the bootstrap statistics of coefficients γ_1 and γ_3 in 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 announcement days and $after_t$ is the dummy for the post-announcement period. The equity returns, risk, uncertainty, 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. Given the intraday patterns of squared returns and trading at 1-minute frequency, the risk Rvar, uncertainty U2, and trading activity are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window before and after announcement time of the coming event. 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 in event days a time series of length equal to the number of event days, and similarly from the empirical distribution in 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 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 in 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: **Bootstrap statistics for option-to-equity trade ratio before macro releases**

		FOMC release				Non-FOMC releases			
			Approach 1		Approach 2		Approach 1		Approach 2
range	ratio	estimate	99% CI	95% CI	p-value (%)	estimate	99% CI	95% CI	p-value (%)
				Number of trades					
150 minutes	calls/underlying	0.08*	[-0.05, 0.18]	[-0.02, 0.16]	4.4	0.04***	[0, 0.08]	[0.02, 0.07]	0
	puts/underlying	0.06	[-0.05, 0.16]	[-0.03, 0.14]	8.8	0.05***	[0.01, 0.08]	[0.02, 0.07]	0
	(calls+puts)/underlying	0.07	[-0.05, 0.16]	[-0.02, 0.15]	5.4	0.05***	[0.01, 0.08]	[0.02, 0.07]	0
200 minutes	calls/underlying	0.07*	[-0.04, 0.16]	[-0.01, 0.15]	6.4	0.05***	[0.02, 0.09]	[0.03, 0.08]	0
	puts/underlying	0.04	[-0.06, 0.13]	[-0.04, 0.12]	17	0.05***	[0.02, 0.08]	[0.03, 0.08]	0
	(calls+puts)/underlying	0.05	[-0.05, 0.14]	[-0.03, 0.13]	11.6	0.05***	[0.02, 0.09]	[0.03, 0.08]	0
225 minutes	calls/underlying	0.07*	[-0.04, 0.15]	[-0.01, 0.14]	5.8	0.05***	[0.02, 0.08]	[0.03, 0.08]	0
	puts/underlying	0.03	[-0.06, 0.12]	[-0.05, 0.1]	22.4	0.05***	[0.02, 0.08]	[0.03, 0.07]	0
	(calls+puts)/underlying	0.05	[-0.05, 0.13]	[-0.03, 0.12]	13.2	0.05***	[0.02, 0.08]	[0.03, 0.07]	0
300 minutes	calls/underlying	0.06	[-0.03, 0.15]	[-0.02, 0.13]	9.4	0.05***	[0.01, 0.08]	[0.02, 0.07]	0
	puts/underlying	0.02	[-0.07, 0.11]	[-0.05, 0.08]	34.6	0.05***	[0.01, 0.08]	[0.03, 0.07]	0
	(calls+puts)/underlying	0.03	[-0.05, 0.12]	[-0.04, 0.1]	19.6	0.05***	[0.01, 0.08]	[0.03, 0.07]	0
				Volume					
150 minutes	calls/underlying	0.19***	[0.04, 0.36]	[0.07, 0.3]	0.2	0.06***	[0.02, 0.1]	[0.03, 0.09]	0
	puts/underlying	0.13*	[-0.04, 0.31]	[-0.01, 0.27]	1.8	0.02	[-0.02, 0.06]	[-0.01, 0.05]	6
	(calls+puts)/underlying	0.15**	[0, 0.31]	[0.03, 0.27]	0.2	0.04***	[0, 0.07]	[0.01, 0.06]	0
200 minutes	calls/underlying	0.18***	[0.02, 0.33]	[0.05, 0.29]	0.4	0.06***	[0.03, 0.1]	[0.03, 0.09]	0
	puts/underlying	0.08	[-0.06, 0.23]	[-0.03, 0.22]	6	0.03*	[-0.01, 0.06]	[0, 0.06]	1.8
	(calls+puts)/underlying	0.12**	[0, 0.25]	[0.02, 0.23]	0.8	0.04***	[0.01, 0.08]	[0.02, 0.07]	0.2
225 minutes	calls/underlying	0.16***	[0.04, 0.33]	[0.06, 0.29]	0	0.06***	[0.02, 0.1]	[0.03, 0.09]	0
	puts/underlying	0.09	[-0.06, 0.23]	[-0.04, 0.21]	6.6	0.03**	[-0.01, 0.06]	[0, 0.06]	2.4
	(calls+puts)/underlying	0.12**	[-0.01, 0.26]	[0.02, 0.22]	0.6	0.04***	[0.01, 0.07]	[0.01, 0.06]	0.2
300 minutes	calls/underlying	0.18***	[0.07, 0.3]	[0.08, 0.27]	0	0.05***	[0.02, 0.09]	[0.03, 0.08]	0
	puts/underlying	0.03	[-0.09, 0.15]	[-0.07, 0.12]	30.8	0.03*	[-0.02, 0.06]	[0, 0.05]	3.2
	(calls+puts)/underlying	0.08*	[-0.02, 0.2]	[-0.01, 0.16]	4	0.04***	[0.01, 0.07]	[0.01, 0.06]	0.4

This table presents the bootstrap statistics of coefficient γ_1 in 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 underlying 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 20-day moving average underlying trades computed from the same time window. This adjustment takes into account intraday pattern in trading of option and underlying. The natural logarithm is taken for option-equity ratio to avoid extreme values. In "Approach 1", for each variable we draw with replacement from the empirical distribution of pre(post)-announcement observations in event days a time series of length equal to the number of event days, and similarly from the empirical distribution in 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 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 in non-event days and rerun the regression. Column "p-value" presents the p-value of coefficient values under column "estimate" in Table 4 from the bootstrap distribution of estimated coefficients across 500 replications.

Table 14: **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 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. Given the intraday patterns of squared returns and trading at 1-minute frequency, the risk Rvar, uncertainty U2 and trading activity are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window before and after announcement time of the coming event. The natural logarithm is taken before adjustment to avoid extreme values.

Table 15: **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 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. Given the intraday patterns of squared returns and trading at 1-minute frequency, the risk Rvar, uncertainty U2 and trading activity are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window before and after announcement time of the coming event. The natural logarithm is taken before adjustment to avoid extreme values.

Table 16: **Pre-announcement volume regression for FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat
equity	Adj-R^2(%)	10	0.85		55.24		57.89		57.94		15	1.09		55.15		60.19		60.18	
	event	of 15-min	-0.54***	-5.04	-0.20**	-2.31	-0.10	-1.23	-0.21*	-1.74	of 15-min	-0.60***	-5.22	-0.26***	-3.10	-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	0.60***	24.14	0.60***	23.35
	rvar*event								-0.17	-1.42								-0.08	-0.90
	u2						-0.19***	-8.84	-0.19***	-8.40						-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		61.53		61.51		15	1.10		58.23		63.01		63.01	
	event	of 20-min	-0.61***	-5.31	-0.18**	-2.31	-0.08	-1.12	-0.12	-1.12	of 20-min	-0.61***	-5.25	-0.18**	-2.17	-0.06	-0.78	-0.10	-0.89
	rvar				0.76***	34.84	0.65***	25.53	0.65***	24.93				0.76***	33.70	0.62***	25.94	0.62***	25.25
	rvar*event								-0.04	-0.37								-0.09	-0.85
	u2						-0.21***	-9.71	-0.21***	-9.43						-0.26***	-13.00	-0.26***	-12.44
	u2*event								0.01	0.12								-0.07	-0.82
	Adj-R^2(%)	10	1.10		63.27		67.18		67.16										
	event	of 30-min	-0.61***	-5.25	-0.16**	-2.39	-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						-0.25***	-12.54	-0.25***	-12.18									
	u2*event								0.00	0.00									
call	Adj-R^2(%)	10	-0.04		11.64		12.25		12.33		15	-0.03		12.31		13.36		13.34	
	event	of 15-min	-0.03	-0.34	0.12	1.13	0.17	1.61	0.01	0.04	of 15-min	-0.06	-0.58	0.10	0.90	0.16	1.51	0.06	0.53
	rvar				0.34***	15.91	0.29***	11.89	0.30***	12.14				0.35***	16.49	0.29***	12.21	0.29***	12.15
	rvar*event								-0.20	-1.54								-0.11	-0.97
	u2						-0.10***	-4.03	-0.09***	-3.93						-0.12***	-5.33	-0.12***	-5.20
	u2*event								0.03	0.31								0.04	0.43
	Adj-R^2(%)	10	-0.02		13.56		14.08		14.08		15	-0.04		13.23		14.46		14.46	
	event	of 20-min	-0.10	-0.89	0.10	0.96	0.15	1.35	0.02	0.15	of 20-min	-0.01	-0.07	0.19*	1.91	0.26***	2.62	0.16	1.32
	rvar				0.37***	17.55	0.32***	13.36	0.33***	13.40				0.37***	16.90	0.29***	12.07	0.30***	12.17
	rvar*event								-0.14	-1.08								-0.16	-1.27
	u2						-0.09***	-3.84	-0.09***	-3.75						-0.13***	-5.65	-0.13***	-5.36
	u2*event								0.03	0.30								-0.08	-0.77
	Adj-R^2(%)	10	-0.04		14.24		15.18		15.20										
	event	of 30-min	-0.01	-0.07	0.20**	2.02	0.26***	2.70	0.17	1.58									
	rvar				0.38***	18.25	0.31***	12.31	0.31***	12.40									
	rvar*event								-0.20	-1.53									
	u2						-0.12***	-5.14	-0.12***	-4.81									
	u2*event								-0.13	-1.26									
put	Adj-R^2(%)	10	0.00		13.15		14.43		14.42		15	0.12		13.49		15.66		15.60	
	event	of 15-min	-0.12	-1.10	0.04	0.34	0.11	0.98	0.00	0.02	of 15-min	-0.23**	-2.06	-0.07	-0.64	0.02	0.18	-0.02	-0.22
	rvar				0.36***	17.68	0.29***	12.96	0.30***	12.76				0.37***	17.40	0.27***	11.83	0.28***	11.53
	rvar*event								-0.11	-1.09								-0.06	-0.71
	u2						-0.14***	-5.93	-0.14***	-5.83						-0.18***	-7.31	-0.18***	-7.03
	u2*event								0.06	0.60								-0.01	-0.14
	Adj-R^2(%)	10	0.11		14.82		15.95		15.88		15	0.27		16.27		17.96		17.90	
	event	of 20-min	-0.22**	-1.98	-0.01	-0.12	0.05	0.45	0.00	-0.03	of 20-min	-0.32***	-2.94	-0.10	-0.98	-0.03	-0.27	-0.08	-0.67
	rvar				0.39***	18.45	0.32***	13.25	0.32***	12.98				0.40***	18.81	0.32***	12.93	0.32***	12.67
	rvar*event								-0.04	-0.37								-0.06	-0.50
	u2						-0.13***	-5.38	-0.13***	-5.29						-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		18.21		18.16										
	event	of 30-min	-0.32***	-2.94	-0.10	-1.03	-0.02	-0.20	-0.02	-0.23									
	rvar				0.40***	19.57	0.31***	12.07	0.30***	11.67									
	rvar*event								0.06	0.56									
	u2						-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 variable is a dummy of announcement days. Given the intraday patterns of 1-minute returns squared and trading, the volume, risk and uncertainty are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window before announcement time of the coming event. 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 17: **Pre-announcement volume regression for non-FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat
equity	Adj-R^2(%)	10	-0.02		49.03		54.71		54.73		15	-0.02		50.72		59.26		59.28	
	event	of 15-min	0.00	0.13	-0.03	-1.25	-0.03	-1.41	-0.01	-0.23	of 15-min	-0.01	-0.20	-0.04	-1.63	-0.05**	-2.02	-0.02	-0.60
	rvar				0.70***	35.65	0.59***	33.21	0.58***	29.29				0.71***	40.33	0.60***	37.16	0.59***	33.19
	rvar*event								0.05	1.18								0.05	1.24
	u2						-0.25***	-18.86	-0.26***	-16.38						-0.31***	-23.10	-0.32***	-20.40
	u2*event								0.02	0.72								0.02	0.74
	Adj-R^2(%)	10	-0.02		48.81		53.40		53.47		15	-0.02		50.31		58.79		58.86	
	event	of 20-min	-0.01	-0.15	-0.03	-1.24	-0.03	-1.12	0.01	0.38	of 20-min	-0.01	-0.32	-0.04	-1.48	-0.04	-1.53	0.01	0.24
	rvar				0.70***	36.32	0.61***	30.91	0.60***	26.68				0.71***	40.73	0.61***	37.32	0.59***	33.10
	rvar*event								0.08*	1.75								0.08*	1.85
	u2						-0.24***	-14.91	-0.24***	-13.22						-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		58.47		58.59										
	event	of 30-min	-0.01	-0.32	-0.03	-1.37	-0.03	-1.37	0.02	0.55									
	rvar				0.73***	43.74	0.65***	38.11	0.64***	34.02									
	rvar*event								0.10**	2.17									
	u2						-0.23***	-16.48	-0.24***	-15.29									
	u2*event								0.06**	2.01									
call	Adj-R^2(%)	10	0.17		15.38		15.41		15.41		15	0.16		15.26		16.93		16.95	
	event	of 15-min	0.11***	3.19	0.09***	2.89	0.09***	2.92	0.12***	2.97	of 15-min	0.11***	3.07	0.09***	2.81	0.09***	2.76	0.13***	3.10
	rvar				0.39***	24.80	0.34***	21.67	0.33***	19.25				0.39***	25.32	0.33***	20.40	0.32***	17.74
	rvar*event								0.05	1.09								0.06	1.42
	u2						-0.10***	-6.93	-0.10***	-6.47						-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		15.10		15.16		15	0.13		15.78		17.28		17.29	
	event	of 20-min	0.11***	3.19	0.10***	3.09	0.10***	3.09	0.15***	3.59	of 20-min	0.10***	2.78	0.08***	2.62	0.09***	2.65	0.12***	2.93
	rvar				0.38***	23.98	0.35***	20.55	0.33***	17.77				0.40***	26.83	0.35***	23.18	0.34***	20.58
	rvar*event								0.08*	1.82								0.05	1.34
	u2						-0.09***	-6.02	-0.10***	-5.93						-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		17.65		17.69										
	event	of 30-min	0.10***	2.78	0.09***	2.71	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						-0.09***	-6.18	-0.10***	-6.16									
	u2*event								0.05	1.57									
put	Adj-R^2(%)	10	0.01		16.46		15.95		16.03		15	0.02		18.12		19.38		19.45	
	event	of 15-min	0.04	1.24	0.02	0.73	0.02	0.72	0.07*	1.67	of 15-min	0.05	1.40	0.03	0.94	0.03	0.93	0.08*	1.83
	rvar				0.41***	23.86	0.37***	21.40	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						-0.07***	-4.41	-0.08***	-4.60						-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		16.08		16.23		15	0.01		17.81		19.02		19.13	
	event	of 20-min	0.05	1.50	0.04	1.22	0.04	1.22	0.10**	2.34	of 20-min	0.04	1.24	0.03	0.92	0.03	0.94	0.08**	2.03
	rvar				0.40***	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								0.10**	2.26
	u2						-0.07***	-3.95	-0.08***	-4.19						-0.12***	-7.71	-0.13***	-7.53
	u2*event								0.07*	1.87								0.06	1.50
	Adj-R^2(%)	10	0.01		18.28		18.81		18.93										
	event	of 30-min	0.04	1.24	0.03	1.01	0.03	1.02	0.09**	2.14									
	rvar				0.43***	28.07	0.40***	24.54	0.38***	21.77									
	rvar*event								0.11**	2.31									
	u2						-0.08***	-5.18	-0.09***	-5.40									
	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 variable is a dummy of announcement days. Given the intraday patterns of 1-minute returns squared and trading, the volume, risk and uncertainty are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window before announcement time of the coming event. 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 18: **Post-announcement volume regression for FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat
equity	Adj-R^2(%)	10	7.85		53.24		58.46		58.52		15	6.13		48.64		54.31		54.31	
	event	of 15-min	1.59***	14.52	0.70***	8.25	0.65***	7.73	0.81***	6.23	of 15-min	1.41***	12.94	0.54***	6.16	0.49***	5.79	0.60***	4.85
	rvar				0.69***	23.79	0.61***	22.56	0.61***	21.90				0.67***	22.35	0.59***	21.09	0.59***	20.45
	rvar*event								0.06	0.61								0.04	0.46
	u2						-0.24***	-13.73	-0.25***	-13.75						-0.25***	-12.04	-0.25***	-11.98
	u2*event								0.23***	2.72								0.15*	1.70
	Adj-R^2(%)	10	6.54		54.77		59.97		60.03		15	5.44		51.17		56.84		56.86	
	event	of 20-min	1.46***	13.18	0.62***	7.40	0.61***	7.30	0.69***	6.59	of 20-min	1.33***	12.37	0.51***	6.14	0.50***	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						-0.24***	-13.06	-0.25***	-13.08						-0.25***	-12.86	-0.26***	-12.80
	u2*event								0.20***	3.57								0.15**	2.46
	Adj-R^2(%)	10	5.44		59.48		64.43		64.55										
	event	of 30-min	1.33***	12.37	0.54***	6.85	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						-0.24***	-12.41	-0.25***	-12.54									
	u2*event								0.23***	3.46									
call	Adj-R^2(%)	10	3.00		15.08		16.15		16.17		15	2.29		13.88		14.93		14.94	
	event	of 15-min	1.00***	9.96	0.53***	5.60	0.51***	5.28	0.63***	3.32	of 15-min	0.87***	8.26	0.42***	4.12	0.39***	3.86	0.49***	2.71
	rvar				0.36***	15.27	0.32***	13.72	0.32***	13.23				0.35***	14.50	0.32***	13.09	0.31***	12.64
	rvar*event								0.08	0.90								0.10	1.03
	u2						-0.11***	-5.67	-0.12***	-5.82						-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		16.13		16.18		15	2.03		14.53		15.51		15.53	
	event	of 20-min	0.88***	8.52	0.45***	4.62	0.44***	4.51	0.50***	3.33	of 20-min	0.82***	8.06	0.39***	4.12	0.39***	4.02	0.43***	3.00
	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	1.10
	u2						-0.11***	-5.48	-0.11***	-5.67						-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		17.86		17.84										
	event	of 30-min	0.82***	8.06	0.40***	4.26	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						-0.11***	-5.43	-0.12***	-5.54									
	u2*event								0.14*	1.68									
put	Adj-R^2(%)	10	2.38		14.58		15.29		15.27		15	1.90		13.42		14.21		14.17	
	event	of 15-min	0.89***	7.87	0.42***	3.89	0.40***	3.68	0.44*	1.94	of 15-min	0.80***	6.89	0.34***	3.07	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***	12.60	0.32***	12.13
	rvar*event								0.10	0.97								0.10	1.12
	u2						-0.09***	-4.37	-0.10***	-4.47						-0.10***	-4.36	-0.10***	-4.41
	u2*event								0.14	1.04								0.10	0.79
	Adj-R^2(%)	10	1.90		15.52		16.32		16.34		15	2.00		15.42		16.20		16.19	
	event	of 20-min	0.80***	6.90	0.35***	3.16	0.34***	3.10	0.40**	2.32	of 20-min	0.82***	7.28	0.37***	3.50	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***	14.30	0.34***	13.85
	rvar*event								0.11	0.95								0.11	1.10
	u2						-0.10***	-4.63	-0.10***	-4.78						-0.10***	-4.52	-0.10***	-4.61
	u2*event								0.19**	2.25								0.13	1.47
	Adj-R^2(%)	10	2.00		18.34		19.26		19.27										
	event	of 30-min	0.82***	7.28	0.38***	3.61	0.41***	3.86	0.40**	2.52									
	rvar				0.41***	17.66	0.37***	14.99	0.36***	14.52									
	rvar*event								0.11	0.98									
	u2						-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 variable is a dummy of announcement days. Given the intraday patterns of 1-minute returns squared and trading, the volume, risk and uncertainty are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window after announcement time of the coming event. 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 19: **Post-announcement volume regression for non-FOMC releases**

type	variable	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat	range	(1)	t-stat	(2)	t-stat	(3)	t-stat	(4)	t-stat
equity	Adj-R^2(%)	10	0.25		62.75		64.14		64.14		15	0.13		60.23		62.16		62.17	
	event	of 15-min	0.13***	3.63	0.00	-0.17	0.01	0.53	0.00	0.01	of 15-min	0.10***	2.65	-0.04	-1.58	-0.02	-0.83	-0.03	-1.15
	rvar				0.79***	62.52	0.69***	37.40	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						-0.16***	-10.27	-0.15***	-9.16						-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		64.55		64.55		15	0.06		54.22		57.41		57.41	
	event	of 20-min	0.10***	2.74	0.00	0.01	0.02	0.67	0.03	0.94	of 20-min	0.07**	2.02	-0.02	-0.86	-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	0.60***	33.42	0.59***	29.75
	rvar*event								0.04	0.75								0.03	0.75
	u2						-0.23***	-15.36	-0.23***	-14.35						-0.23***	-14.47	-0.23***	-13.55
	u2*event								0.03	0.70								0.04	1.01
	Adj-R^2(%)	10	0.06		59.23		64.51		64.54										
	event	of 30-min	0.07**	2.02	0.00	-0.19	0.00	0.22	0.03	1.06									
	rvar				0.77***	52.34	0.65***	42.69	0.64***	37.80									
	rvar*event								0.06	1.49									
	u2						-0.26***	-19.95	-0.27***	-18.44									
	u2*event								0.05	1.52									
call	Adj-R^2(%)	10	0.20		13.14		13.41		13.39		15	0.13		13.85		14.25		14.22	
	event	of 15-min	0.12***	3.37	0.06*	1.76	0.07**	1.97	0.07*	1.75	of 15-min	0.10***	2.82	0.04	1.11	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						-0.07***	-4.14	-0.07***	-3.69						-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		14.48		14.46		15	0.09		13.95		14.62		14.59	
	event	of 20-min	0.10***	2.84	0.05	1.63	0.06*	1.83	0.06	1.53	of 20-min	0.09**	2.39	0.04	1.13	0.04	1.33	0.04	1.09
	rvar				0.37***	26.84	0.31***	18.62	0.31***	16.70				0.37***	26.55	0.31***	18.34	0.31***	16.47
	rvar*event								0.01	0.17								0.00	-0.08
	u2						-0.10***	-6.39	-0.10***	-5.52						-0.10***	-6.33	-0.10***	-5.53
	u2*event								-0.02	-0.55								-0.01	-0.31
	Adj-R^2(%)	10	0.09		16.17		16.84		16.87										
	event	of 30-min	0.09**	2.39	0.05	1.39	0.05	1.49	0.08**	2.13									
	rvar				0.40***	29.38	0.36***	24.37	0.35***	21.20									
	rvar*event								0.06	1.61									
	u2						-0.09***	-6.34	-0.10***	-6.25									
	u2*event								0.05	1.59									
put	Adj-R^2(%)	10	0.16		14.83		15.33		15.32		15	0.10		15.99		16.63		16.60	
	event	of 15-min	0.11***	3.00	0.04	1.26	0.05	1.53	0.07*	1.79	of 15-min	0.09**	2.48	0.02	0.59	0.03	0.91	0.04	1.13
	rvar				0.38***	28.64	0.32***	17.44	0.31***	15.35				0.40***	29.16	0.33***	17.76	0.32***	15.77
	rvar*event								0.05	1.00								0.03	0.71
	u2						-0.10***	-5.57	-0.10***	-5.40						-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		16.41		16.46		15	0.07		15.43		16.85		16.88	
	event	of 20-min	0.10***	2.74	0.05	1.46	0.06*	1.72	0.09**	2.55	of 20-min	0.08**	2.18	0.03	0.84	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	0.30***	17.03	0.29***	14.78
	rvar*event								0.08*	1.79								0.06	1.44
	u2						-0.13***	-7.90	-0.15***	-7.92						-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		18.38		18.51										
	event	of 30-min	0.08**	2.18	0.04	1.14	0.04	1.27	0.09**	2.43									
	rvar				0.41***	30.14	0.36***	23.83	0.34***	20.34									
	rvar*event								0.10**	2.55									
	u2						-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 variable is a dummy of announcement days. Given the intraday patterns of 1-minute returns squared and trading, the volume, risk and uncertainty are adjusted by the moving average over the last 20 non-event trading days, where the variables in these days are computed over the same time window before announcement time of the coming event. 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.

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