

Premium for Heightened Uncertainty: Solving the FOMC Puzzle

Grace Xing Hu, Jun Pan, Jiang Wang, and Haoxiang Zhu*

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Abstract

Lucca and Moench (2015) document that prior to the announcement from FOMC meetings, the stock market yields substantial returns without major increase in conventional measures of risk. This presents a “puzzle” to the simple risk-return connection in most (static) asset pricing models. We hypothesize that the arrival of macroeconomic news, with FOMC announcements at the top of the list, brings heightened uncertainty to the market, as investors cautiously await and assess the outcome. While this heightened uncertainty may not be accurately captured by conventional risk measures, its dissolution occurs during a short time window, mostly prior to the announcement, bringing a significant price appreciation. This hypothesis leads to two testable implications: First, we should see similar return patterns for other pre-scheduled macroeconomic announcements. Second, to the extent that we can find other proxies for heightened uncertainty, we should also observe abnormal returns accompanying its dissolution. Indeed, we find large pre-announcement returns prior to the releases of Nonfarm Payroll, GDP and ISM index. Using CBOE VIX index as a primitive gauge for market uncertainty, we find disproportionately large returns on days following large spike-ups in VIX. Akin to the FOMC result, we find that while such heightened-uncertainty days occur on average only eight times per year, they account for more than 30% of the average annual return on the S&P 500 index. Conversely, we find a gradual but significant build-up in VIX prior to FOMC days, providing direct evidence of heightened uncertainty.

*Hu (gracexhu@hku.hk) is from the University of Hong Kong; Pan (junpan@mit.edu) is from MIT Sloan School of Management, Shanghai Advanced Institute of Finance at Shanghai Jiao Tong University, CAFR and NBER; Wang (wangj@mit.edu) is from MIT Sloan School of Management, CAFR, and NBER; Zhu (zhuh@mit.edu) is from MIT Sloan School of Management and NBER. We thank Meiling Chen and Zhe Geng for research assistance.

1. Introduction

The recent FOMC puzzle documented by Lucca and Moench (2015) provides an interesting and seemingly unique challenge to our understanding of risk and return tradeoff. Using data from September 1994 to March 2011, they find that over the 24-hour window before the scheduled announcements by the Federal Open Market Committee (FOMC), the return on the S&P 500 index is on average 49 basis points per day. Compared with the average return of 4 basis point per day on the same index, the magnitude of the FOMC pre-announcement return is more than 10 times the normal level. More intriguing is the fact that the 24-hour window before the announcement do not appear to be unusually risky. In every conventional measure of risk — return volatility, skewness, kurtosis, the CBOE VIX, etc, it appears just like a normal day. If anything, markets appear to be eerily calm with relatively low volatility and low trading volume during this 24-hour window. This disproportionately large return in the absence of any unusual risk is puzzling: Why don't investors take advantage of this seemingly attractive opportunity?

In solving this FOMC puzzle, we hypothesize that the disproportionately large pre-FOMC return is a premium for heightened uncertainty in the market.¹ In particular, we argue that FOMC days are days of heightened uncertainty by the sheer fact that market-moving information is to be released on these days. Indeed, anecdotes of investors anxiously awaiting the FOMC outcome are abundant.² The pre-scheduled nature of the FOMC announcements allows investors to trade well in advance to spread the price impact over a relatively long window, masking the real impact of the heightened uncertainty. In such situations, risk measures using market trading data are not the most reliable measure of the underlying uncertainty. Moreover, the heightened uncertainty starts to get resolved over a short time window as the announcement approaches and the corresponding premium is realized. Unlike the prolonged window over which heightened uncertainty is developed, the condensed nature of the narrow window allows for a better measurement of the risk premium, giving rise to the large pre-FOMC price drift documented in Lucca and Moench (2015). Moreover, the tighter the pre-FOMC window, the better the measure of the risk premium. This is also why, as reported by Lucca and Moench (2015), the pre-FOMC drift is significantly weaker between 1980 and 1993, when the timing of the announcement is not as precise as that after September 1994.

¹Due to lack of a better terminology, our use of “uncertainty” here is only in an intuitive and loose sense. It merely reflects the fact that the uncertainty or risk here is not accurately captured by conventional risk measures. It does not necessarily imply that we are using it in the sense of Savage (1954).

²Expressions such as “Fed Watch” and “Countdown to FOMC” have been a constant presence in the press since the Greenspan era and especially after 1994.

One immediate implication of our hypothesis is that FOMC is not unique. As a premium for heightened uncertainty, this pattern of disproportionately large return can occur whenever there is heightened uncertainty. This includes pre-scheduled announcements of other macroeconomic news perceived by investors to be of high impact. Indeed, going through a list of widely followed releases of macroeconomic indicators, we find statistically significant pre-announcement returns for the releases of Nonfarm Payroll, GDP, and ISM. Compared with the FOMC result, which averages to 27.1 basis points per day according to our measurement, the magnitudes of pre-announcement returns are smaller but economically significant: 10.1 basis points for Non-farm Payroll, 9.6 basis points for GDP (advance and final releases) and 9.14 basis points for ISM.³ The smaller magnitudes could be contributed by the fact that these news releases are not as impactful as that of FOMC and the associated heightened uncertainty is not as severe.⁴

Heightened uncertainty can also be triggered by unexpectedly adverse market conditions. As an “out-of-sample” test of our hypothesis, we investigate whether there is a premium for such heightened uncertainty. For this, we select days on which the CBOE VIX index suddenly spikes up. To match the FOMC frequency, we choose a constant cutoff value in the daily increase of VIX so that there are on average eight days of heightened VIX per calendar year. By construction, these heightened VIX days are marked with adverse market conditions, depressed aggregate stock prices and heightened uncertainty, as investors anxiously await the next trading day. Akin to the FOMC result, we find disproportionately large returns on the S&P 500 index after sudden spikes in VIX. Using data from January 1986 to May 2018, we find that the next-day return is on average 48 basis points per day with a t-stat of 2.71.⁵ Translating this number to annual frequency, returns realized over eight days per calendar year are on average 3.71% per year, accounting for more than one-third of the annual returns on the S&P 500 index. These numbers are comparable to or larger than the average annualized return of 2.24% associated with pre-FOMC drift, and 1.35% associated

³For all announcements, we measure the pre-announcement return from the market close (4 pm) on the day before to 5 minutes before the scheduled news release. While the 2-hour window from 2 pm to 4 pm (on the day before FOMC) does contribute to the positive pre-FOMC drift (9.29 basis point with a t-stat of 1.58), we believe that the market close serves as a more natural starting point for the pre-announcement window. This definition of pre-announcement window also provides a unified framework for us to examine the pre-announcement returns for other macroeconomic news releases.

⁴FOMC is unique in that its normal release time is 2:15 pm. Most other major news releases occur either after-hours or near the market open at 9:30 am or 10 am. We believe that this fact also contributes to the larger and more precise result for FOMC.

⁵The average VIX is around 20% on FOMC days as well as on normal days. By contrast, the average VIX is 33% on days after heightened VIX. One might be tempted to explain the next-day average return of 48 basis points as larger return for higher risk. In practice, however, the contemporaneous correlation between VIX and return is known to be strongly negative, making our finding even more striking.

with the pre-NFP drift. Moreover, during the years when the heightened VIX return is high, so are the pre-FOMC drift and the pre-NFP drift, with time-series correlations of 79% and 55%, respectively.

Overall, these results provide compelling evidence that the FOMC days are not unique in yielding the disproportionately large returns. When viewed from the perspective of heightened uncertainty, the FOMC puzzle is not really a puzzle, but a manifestation of a risk and return trade-off. Not all trading days are created equal and some are inherently riskier than others. As long as we focus our attention on such high-impact days, either pre-scheduled or stochastically triggered, we will be confronted with this pattern of seemingly large abnormal returns, which are in fact the premium for heightened uncertainty.

While the result of high average return after VIX spike-up is important in its own right, it also help shed light on the mechanism over which the FOMC risk premium arises. In the case of VIX hike, the substantial build-up in VIX helps us to identify the days of heightened uncertainty. Inspired by this observation, we examine the VIX build-up for a relatively long window prior to the FOMC day, and indeed find a sizable build-up in VIX that is statistically significant. This build-up, although much subtler compared to the case of VIX spike-up, provides importance evidence that, associated the announcement of such market-moving news, there is indeed heightened uncertainty. Learning from the case of VIX spike-up, we see that the build-up in VIX is followed by significant reduction in VIX on the day after. More importantly, it is this dissolution of heightened uncertainty that gives rise to the disproportionately large return. For the case of FOMC, significant reduction in VIX does occur on the day of FOMC, which is to be expected. Interestingly, we find that half of the reduction in VIX actually happens before the announcement. Along with this reduction of heightened uncertainty, arises the disproportionately large pre-FOMC drift.

After the FOMC announcement, there is further reduction in VIX, but the average post-announcement return is close to zero, indicating that the heightened uncertainty is on average resolved before the announcement itself. But not all FOMC days are the same, and the severity of heightened uncertainty, as well as the its timing, varies from one FOMC meeting to another. Sorting the FOMC days by their pre-FOMC drift into three groups, we find distinctively different patterns of heightened uncertainty. The high-drift group serves as a turbo version of the average FOMC results and paints a sharper picture of our narrative. Leading up to such FOMC days, there is a significant build-up in VIX, coupled with a significant downward price drift. For this group, the resolution of uncertainty occurs before the scheduled news release and the average impact of the announcement itself is muted. By contrast, for the low-drift group, the heightened uncertainty occurs on the day of the FOMC announcement and the resolution of uncertainty happens after the announcement.

It is important to note that even though we use VIX as a gauge of uncertainty in the market, it is by no means an accurate measure. At best, it partially reacts to the underlying uncertainty when it heightens. Our results suggest that the underlying uncertainty is time varying, its dynamics can be quite rich, driven by both deterministic and stochastic news arrivals, and its relationship with risk premium can be quite complex. In addition, we have no good empirical measure for it, at least yet. Nonetheless, our analysis shows that a richer model for risk and return may be needed to explain observed return patterns than a simple return-risk relationship using conventional measures of risk.

Our paper is most closely related to two strands of literature. The first strand includes empirical studies on the pre-announcement behavior of asset prices around scheduled FOMC announcements and other macroeconomic data releases. Lucca and Moench (2015) first document a significantly positive equity premium during the 24 hours before FOMC announcements, a pattern we also find in our sample.⁶ Different from Lucca and Moench (2015), we find that the other macroeconomic data releases such as Nonfarm Payroll and GDP are also associated with significantly positive pre-announcement drift in equity prices before announcement, albeit with smaller magnitude.⁷ The pre-announcement behavior has also been studied in the markets for bonds, currencies, and volatilities.⁸

Several other papers have examined “announcement day” asset returns, where returns include those realized *after* the announcements. Relevant papers include Savor and Wilson (2013), Savor and Wilson (2014), Brusa, Savor, and Wilson (2018), and Kroencke, Schmeling, and Schrimpf (2018), among others. Ai and Bansal (2018) and Wachter and Zhu (2018) propose theories that explain such patterns. Cieslak, Morse, and Vissing-Jorgensen (2018) find that all equity returns in the US and worldwide since 1994 are earned in weeks 0, 2, 4, and 6 of the FOMC cycle.

Our paper is also related to the interaction between VIX and expected stock returns. Previous literature has shown that equity returns are predicted, over monthly to annual

⁶Guo, Jia, and Sun (2018) find that the Chinese stock market also has a positive drift ahead of the PBOC’s (People’s Bank of China) announcements of monetary aggregates. Gilbert, Kurov, and Wolfe (2018) find that the pre-FOMC announcement drift is not statistically significant in the more recent and shorter sample of 2011–2017.

⁷Specifically, our calculation of equity returns ahead of other macroeconomic data releases is from 4 pm the previous day to 5 minutes before the scheduled announcement. In Lucca and Moench (2015), the calculation of equity returns before other macroeconomic data releases is based on the previous trading day, which by construction does not include overnight returns.

⁸Examples for bond markets include Fleming and Piazzesi (2005), Balduzzi and Moneta (2017), and Faust and Wright (2018). Examples for currency markets include Mueller, Tahbaz-Salehi, and Vedolin (2017). The high-frequency behavior of VIX is studied by Bailey, Zheng, and Zhou (2014) and Fernandez-Perez, Frijns, and Tourani-Rad (2017). Bernile, Hu, and Tang (2016) and Kurov, Sancetta, Strasser, and Wolfe (2017) find weak evidence of informed trading shortly before these announcements.

horizon, by the variance risk premium (Bollerslev, Tauchen, and Zhou (2009) and Zhou (2018)) and simple variance swap (Martin (2017)). We find that a sufficiently large spike-up in daily VIX is already a strong predictor of positive equity returns on the next day.

The rest of the paper is organized as follows. Section 2 describes in detail the data we use. Section 3 presents our main results and related discussions. Section 4 concludes.

2. Data

We use several data sources. We obtain transaction-level data on E-mini S&P500 index futures from the Chicago Mercantile Exchange (CME). Prior to September 1997, when E-mini was not available, we use transaction-level data on the standard (“big”) S&P500 index futures from the CME. We obtain the transaction-level VIX data from the Chicago Board Options Exchange (CBOE). For daily returns on the S&P 500 index, we use data from the Center for Research in Security Prices (CRSP). For daily closing of VIX, we use the time-series published on the CBOE’s website. The FOMC announcement times are based on the time-stamp of Bloomberg and/or Dow Jones newswires. We follow the same methods as in Lucca and Moench (2015) and Fleming and Piazzesi (2005), and extend the sample period to May 2018. The announcement times for CSI are based on the time-stamp of Bloomberg.

We focus most of our analysis on the sample period from September 1994 to May 2018. During this period, there are in total 190 scheduled releases of FOMC statements. From September 1994 to March 2011, 131 releases are consistently made within a few minutes around 2:15 pm, with only one exception, March 26, 1996, on which the release time was pre-announced to be in the morning because of the Chairman’s other duties. From April 2011 to January 2013, seven releases are around 2:15 pm and eight releases are around 12:30 pm, one and forty five minutes earlier to accommodate the Chairman’s press briefings at 2:15 pm. From February 2013 to May 2018, all of the 43 FOMC releases are around 2:00 pm. For the period before 1994, there is no official announcement and market participants need to infer policy decisions through Fed’s open market operations, usually on the day after the FOMC meeting, with one exception in our sample period.⁹

We calculate market returns based on the transaction level S&P 500 index futures data. For a given time horizon $[t_1, t_2]$, we first pick the most active futures contract as the one with the highest trading volume on the trading day of t_2 , and then calculate the return as the percentage change of the last transaction price of this futures contract before time t_2 ,

⁹As discussed in Lucca and Moench (2015), market participants could have correctly inferred a change in the Fed’s targets on the day of the FOMC meeting on a few occasions before 1994. There is only one day, December 18, 1990, that falls within our sample period. We follow Lucca and Moench (2015) and exclude this day in our analysis.

Table 1: **Summary Statistics**

	FOMC					Non-FOMC				
	Mean	Std	Min	Max	N	Mean	Std	Min	Max	N
Sep 1994 - May 2018										
Return	28.8	115	-313	503	190	2.37	118	-938	1163	5782
VIX	19.7	8.1	9.6	70	190	19.8	8.2	9.1	81	5780
Vol	16.9	11	4.0	83	189	15.1	10	2.4	166	5778
Δ VIX	-0.58	1.6	-13	4.5	190	0.02	1.6	-17	20	5780
Δ Vol	2.90	6.0	-25	29	189	-0.09	7.4	-89	97	5778
Skew	0.27	1.8	-6.9	5.8	189	0.17	1.9	-7.3	8.1	5778
Kurt	7.51	8.8	-0.3	56	189	7.14	11	-1.2	69	5778
Volume	0.30	1.1	-2.2	4.4	164	0.10	1.3	-9.3	13	4962
Jan 1986 - May 2018										
Return	25.4	114	-313	503	259	2.55	120	-2925	1912	7905
VIX	19.8	8.0	9.6	70	259	19.8	8.3	9.1	150	7901
Vol	16.1	11	4.0	83	258	14.8	12	2.4	434	7898
Δ VIX	-0.43	1.5	-13	4.5	259	0.01	2.2	-66	114	7900
Δ Vol	2.25	6.6	-25	33	258	-0.07	9.5	-321	256	7898
Skew	0.24	1.7	-6.9	5.8	258	0.12	1.8	-7.3	8.1	7898
Kurt	6.68	8.5	-0.6	56	258	6.42	10	-1.2	69	7898

This table reports summary statistics of key market variables on FOMC and Non-FOMC days. Return is the percentage daily (4pm - 4pm) return based on the prices of S&P 500 index futures, and is reported in basis points. The realized volatility (Vol), the skewness (Skew), and the excess kurtosis (Kurt) are calculated using the log futures return sampled at 5-minute frequency, during the regular trading hours from 9:30 am to 4:00 pm. Volatility is annualized and reported in percentage points. Δ VIX is the daily changes of the CBOE VIX index; and Δ Vol is the daily changes of the realized volatility. Volume is the total trading volume of all outstanding E-mini S&P 500 futures, and is normalized by its mean and standard deviation during a rolling 1-month window before the announcement day. Non-FOMC refers to all trading days that are not FOMC announcement days.

relative to the last transaction price of the same contract before time t_1 .¹⁰ For the period after September 9, 1997, when trading data for E-mini S&P 500 futures are available, we use the E-mini S&P 500 index futures contracts. Before that, we use the standard S&P 500 futures contracts. From January 1986 and May 2018, we have missing futures trading data on eight trading days. One of these eight trading days, January 29, 2014, is a scheduled FOMC release day. For these eight trading days, we rely on the transaction level S&P 500 index data obtained from TAQ.

Using the log futures returns sampled at 5-minute frequencies, we calculate the realized volatility (Vol), the skewness (Skew), and the excess kurtosis (Kurt). For these risk measures based on intra-day returns, we focus only on the regular trading hours from 9:30 am to 4:00 pm to avoid noises introduced by tradings in the after-hours. Vol is annualized and is reported in percentage points. Volume is the total trading volume of all outstanding E-mini S&P 500 futures, and is normalized by its mean and standard deviation during a rolling 1-month window before the announcement day. Since the standard S&P 500 futures data that we obtained from the CME group doesn't include trading volume, the volume numbers are only available after September 9, 1997 when the E-mini S&P 500 futures started trading.

Table 1 summarizes our key market variables. Clearly, the average daily return (4 pm - 4 pm) on FOMC days is much larger than the average on Non-FOMC days. From September 1994 to May 2018, the average daily return on FOMC release days is 28.8 basis points, more than ten times larger than the average daily return on Non-FOMC days. The pattern is robust for the sample period extended back to January 1986. Despite the larger returns, FOMC release days are not substantially riskier than non-FOMC days in a wide range of risk metrics. Including the time period with large price movements after the releases of FOMC statements, the average realized volatility (16.9%), skewness (0.27), and excess kurtosis (7.51) on FOMC announcement days are still only slightly higher than those on Non-FOMC days.

3. Empirical Results

3.1. *Pre-Announcement Drift for FOMC Announcements*

Following Lucca and Moench (2015), we focus on the performance of the S&P 500 index before the scheduled FOMC announcement. We define the pre-announcement window, (4pm - ann), as from the previous market close at 4 pm to five minutes before the exact announcement time. By stopping at 5 minutes before the news release, this pre-announcement window captures the market movement in anticipation of the FOMC announcements and

¹⁰We choose the most active futures contract as the one with the highest volume, which is usually the nearest-term contract and occasionally the next contract during rolling forward weeks.

avoids any contamination by the outcome of the news release itself. We start the window at the previous market close because it is one of the most important and reliable prices of the day. These considerations become important as we extend our analysis to examine the pre-announcement drift for other macroeconomic news releases. Given that most of the releases occur after hours, the 24-hour window adopted by Lucca and Moench (2015) would involve measuring returns using two illiquid prices. Moreover, the market close on the day before the announcement also serves as a natural break as investors start their preparation to receive the incoming news.

As shown in Table 2, the pre-announcement drift for FOMC is on average 27.1 basis points with a strongly significant t-value of 5.95. The size of the drift is important economically. The average return over the same time window on non-FOMC days is a mere 1.1 basis points. The large pre-announcement drift is also robust to potential outliers. Excluding the top 1% highest returns and the bottom 1% lowest returns, the average drift reduces only slightly to 25.1 bps, and remains strongly significant with a t-value of 6.35.

Compared with the pre-FOMC drift of 49 basis points reported by Lucca and Moench (2015), our number is weaker for two reasons. First, it is because we start the pre-announcement window from the previous market close at 4pm, while Lucca and Moench (2015) start the window at 2pm. While most of the pre-announcement drift is realized on the day of the FOMC announcement, there is a sizable drift occurring near the market close on the day before. As shown in Table 3, the average close-to-close return on Day -1 is 15.1 bps, but is statistically insignificant.

The second reason for the weaker number is because we extend the sample period to May 2018. As shown in Table 2, from April 2011 to May 2018, the pre-announcement drift is on average 8.9 basis points with an insignificant t-value of 1.47. We believe that the relative calm market environment is the main cause of the weaker result. As we will report later, during the same time period, the pre-announcement drift for other macro-economic releases as well as the premium for heightened uncertainty are also insignificant. For this reason, we do not believe that the weaker pre-FOMC drift in the more recent period is a result of this “anomaly” being arbitrated away.¹¹

Also reported in Table 2 are risk measures such as standard deviation, skewness and kurtosis, calculated using pre-announcement returns. Across all FOMC days from September 1994 through May 2018, the standard deviation of the pre-announcement returns is 63 basis points and the distribution is positively skewed and the excess kurtosis is 5.2. On non-FOMC days, the returns are slightly negatively skewed and the excess kurtosis is similar to that on

¹¹The weaker FOMC drift during the recent period is also documented in Gilbert, Kurov, and Wolfe (2018). Detailed results for the sample period after 2011 are available upon request.

Table 2: Summary Statistics on Pre-announcement Returns

	All Observations										Exclude Top/Bottom 1%					
	Mean	TStat	Std	Skew	Kurt	Min	Max	N	Mean	TStat	Std	Skew	Kurt	Min	Max	N
FOMC	27.10	5.95	63	1.3	5.2	-164	336	190	25.10	6.35	54	0.8	2.1	-145	261	187
FOMC (post 86)	24.10	5.06	77	0.1	4.2	-295	336	258	24.00	6.02	63	0.1	1.9	-200	261	252
FOMC (post 11)	8.90	1.47	46	1.1	1.5	-68	154	57	10.30	1.71	45	1.2	1.6	-64	154	56
NFP	10.10	3.63	43	-0.2	3.0	-165	177	243	9.80	4.00	38	-0.2	1.4	-118	129	238
GDP	9.60	2.06	57	1.3	11	-201	356	151	8.70	2.26	47	0.4	4.4	-160	242	149
ISM	9.10	2.10	73	-1.1	7.0	-461	213	277	10.30	2.69	63	-0.3	1.6	-213	196	273
IP	5.20	1.19	68	-0.7	4.8	-339	291	240	5.10	1.34	58	-0.7	2.2	-227	154	235
PI	3.50	0.94	58	-1.0	3.8	-248	191	244	5.00	1.55	50	-0.7	1.8	-166	162	239
HST	2.50	0.69	54	-0.2	4.2	-177	279	230	1.60	0.52	47	-0.9	1.8	-167	105	225
INC	1.60	0.95	54	-0.1	5.4	-259	356	1073	1.70	1.25	45	-0.4	1.4	-172	130	1052
PPI	-0.60	-0.17	52	-2.4	14	-392	129	241	1.40	0.55	40	-0.8	1.6	-182	81	235
CPI	-2.10	-0.69	47	-0.8	2.8	-208	130	232	-1.60	-0.56	43	-0.6	1.6	-167	110	228
CSI	-4.00	-0.88	69	0.9	8.1	-232	439	226	-4.40	-1.15	56	-0.2	0.8	-160	150	221
Non-FOMC	1.10	0.89	94	-0.4	5.2	-718	565	5782	1.50	1.46	79	-0.2	0.9	-263	251	5666
Non-Macro (8:25 am)	1.80	2.09	58	-0.3	9.6	-596	430	4418	1.90	2.73	47	-0.4	1.4	-174	157	4330
Non-Macro (9:55 am)	0.70	0.82	64	-0.3	7.8	-574	439	5070	1.00	1.34	52	-0.2	1.1	-189	161	4968

This table reports summary statistics for the pre-announcement returns (in basis points) on FOMC and other macroeconomic index announcement days. The pre-announcement window is from 4 pm on the previous trading day to five minutes before indexes' releases. The macroeconomic announcements include: total nonfarm payroll employment (NFP), the advance and final releases of GDP (GDP), the Institute for Supply Management's manufacturing index (ISM), industrial production (IP), personal income (PI), housing starts (HST), initial claims for unemployment insurance (INC), producer price index (PPI), consumer price index (CPI), and the preliminary release of the Consumer Sentiment Index (CSI). The sample period is from January 1986 to May 2018 for FOMC (post 1986); and from April 2011 to May 2018 for FOMC (post 2011). For all others, the sample period is from September 1994 to May 2018. Announcement days that coincide with FOMC days are excluded for all other macroeconomic announcements. Non-FOMC refers to all trading days that are not FOMC announcement days. Non-Macro refers to all trading days that are not FOMC, NFP, GDP, and ISM announcement days. Non-Macro (8:25am) reports the cumulative return from 4 pm (on the day before) to 8:25 am; Non-Macro (9:55 am) reports the cumulative return from 4 pm (on the day before) to 9:55 am.

FOMC days.¹² Interestingly, the standard deviation is markedly lower when measured on FOMC days than across Non-FOMC days. Overall, however, the stock returns do not appear to be more risky over the pre-announcement window on FOMC days.

3.2. Pre-Announcement Drift for Other Macroeconomic Announcements

One immediate implication of our hypothesis is that the pre-announcement drift is not unique to FOMC announcements and should also exist for other macroeconomic announcements with high market impact. For this reason, we focus on the performance of the S&P 500 index before the release of other major widely-tracked U.S. macroeconomic indicators. These economic indicators are: total nonfarm payroll employment (NFP), the advance and final releases of GDP (GDP), the Institute for Supply Management's manufacturing index (ISM), industrial production (IP), personal income (PI), housing starts (HST), initial claims for unemployment insurance (INC), producer price index (PPI), consumer price index (CPI), and the preliminary release of the Consumer Sentiment Index (CSI). Except for ISM and CSI, all other economic indicators are public indexes released by government agencies at either 8:30 am or 9:15 am (only for IP). ISM and CSI are economic indicators released by private institutions. ISM is released at 10:00 am, while CSI's release time varies from 9:35 am to 10:00 am during our sample period. We exclude macroeconomic announcement days that coincide with FOMC announcement days to avoid potential confounding effect.

Most of these macroeconomic indicators are released in the morning, often not within the regular trading hours of US equity markets (9:30 am - 4 pm). We therefore rely on the S&P 500 index futures, which are traded almost around the clock, to obtain the returns from the market close to five minutes prior to the exact time of these macroeconomic announcements.¹³ Using the market close as a natural starting point, our construction of the pre-announcement window is consistent with the one for FOMC and allows for a unified comparison of the pre-announcement drift across different releases.

The results are summarized in Tables 2 and 3. We find that there are indeed economically significant pre-announcement returns for nonfarm payrolls (NFP), advance and final releases of GDP (GDP), and ISM. The average pre-announcement drift is 10.1 basis points for NFP with a t-value of 3.63; 9.6 basis points for GDP with a t-value of 2.06; 9.1 basis points for ISM with a t-value of 2.10. These drift are robust to potential outliers. After removing

¹²To be consistent, the returns on non-FOMC days are measured over the same time window as the FOMC days.

¹³Due to data limit, prices of standard S&P 500 futures contracts are not available at non-regular trading hours. Therefore, the pre-announcement returns for macro-announcements that are released before market opens are only available after September 9, 1997, when E-mini S&P 500 index futures started trading.

the top 1% highest returns and the bottom 1% lowest returns, the average drift is 9.8 basis points for NFP, 8.7 basis points for GDP, and 10.3 basis points for ISM. All drift remains statistically significant at the 5% level.

Compared with the average 27.1 basis points pre-announcement drift on FOMC days, the magnitudes are indeed smaller for macroeconomic announcements. Though with smaller magnitudes, these drift are quite large economically. Relative to the returns on normal days, on average less than 2 basis points during the same pre-announcement window, these drift are four to five times larger.¹⁴ Significant drift only exists for the pre-announcement window. The average market returns after news releases are not significant for all macroeconomic announcements, similar to FOMC announcements.

To the best of our knowledge, the significant pre-announcement market returns for non-FOMC macroeconomic announcements have not been documented before. Lucca and Moench (2015) do not find significant pre-announcement drift for non-FOMC macroeconomic announcements. This is because they use the close-to-close daily returns on the day before the release day to proxy for the pre-announcement returns and miss the most important window over which the pre-announcement drift takes place. This decision of their might be due to the limit of their intra-day tick data on the S&P 500 index. We use the data from the futures market, which offers better liquidity and almost around-the-clock trading hours, allowing us to focus on a more precise time window before the releases.

To draw a direct comparison of our results with those in Lucca and Moench (2015), we also report the close-to-close return on the day before the release day (Day -1) for all macroeconomic announcements in Table 3. Out of the ten macroeconomic indicators, the average return on Day -1 is 17 basis points with a t-value of 2.40 for HST (Housing Starts), and 19 basis points with a t-value of 2.68 for CSI (Consumer Sentiment Index) releases. These magnitudes are large economically, compared with an approximately 3 basis points daily return on normal days. The magnitudes for HST releases also match the results in Lucca and Moench (2015), in which they find that HST days have 13 basis points excess returns on Day -1 , the largest among their list of macroeconomic indexes.¹⁵

Ai and Bansal (2018) also investigated the market returns before the release of five announcements: FOMC, nonfarm payrolls (NFP), GDP, ISM, and PPI. They, however, combine the four non-FOMC announcements together, and report the average results for

¹⁴The non-macroeconomic announcement days include all trading days that are not FOMC, NFP, GDP, and ISM announcement days. The pre-announcement window is 4 pm to 8:25 am for NFP and GDP announcements, and 4 pm to 9:55 am for ISM announcements.

¹⁵Lucca and Moench (2015) did not include the consumer sentiment index in their analysis. They test nine macroeconomic releases: total nonfarm payroll employment, the advance GDP, the Institute for Supply Management's manufacturing index, industrial production, personal income, housing starts, initial claims for unemployment insurance, producer price index, and consumer price index.

five trading hours, hour by hour, before announcements. Several factors may attribute to the insignificant results documented in Ai and Bansal (2018). First, as the pre-announcement window for NFP, GDP, ISM, and PPI, all fall in the non-regular trading hours, the drift is more difficult to observe on the hourly frequency. In our tests, we therefore consider the pre-announcement return during a much longer horizon, from 4 pm on the previous trading day up to 5 minutes before the actual release time. Secondly, combining the four non-FOMC macroeconomic indicators together also weaken the results. Since the pre-announcement drift is strong only for NFP, GDP, and ISM, we choose to report the drift for each of the index separately. Lastly, Ai and Bansal (2018) uses the high-frequency data for the S&P 500 SPDR from the TAQ database. The low liquidity of the SPDR during the after hours, especially for announcements in their early sample period, might also contribute to the weaker results.¹⁶

Overall, the evidence suggest that there is smaller but still significant pre-announcement drift for other major macroeconomic announcements. The smaller magnitudes could be contributed by the fact that these news releases are not as impactful as that of FOMC and the associated heightened uncertainty is not as severe. Moreover, as many macroeconomic announcements are released at either after-hours or near market opens, noises in market prices may also contribute to the less precise results.

3.3. Premium for Heightened Uncertainty

3.3.1. Capturing Heightened Uncertainty using Heightened VIX

Heightened uncertainty can be triggered by severe, adverse market conditions, including sudden drops in market price or sudden increases in market volatility. While both indicators will be investigated later in the section, the main measure to be used in our investigation is the CBOE VIX index. Computed from the prices of S&P 500 index options, VIX has been widely monitored as the “fear gauge” of the overall financial markets. Unlike market volatility, measured directly from the cash market, the information contained in VIX is considered to have a risk aversion component and is also believed to be forward looking.¹⁷ For these reasons, this index, among all market indicators, offers the best opportunity for us to identify days of heightened uncertainty.

Our sample starts from January 1986 to May 2018. For the early period from 1986 through 1989, when VIX was not available, we use the old VIX index (VXO). The sample

¹⁶We re-produced Ai and Bansal (2018) using the same data source and the same sample period. The average return during the pre-announcement window (4pm -ann) is 11 basis points for the four non-FOMC macroeconomic indicators(NFP, GDP, ISM, and PPI), with a significant t-value of 3.81.

¹⁷See, for example, Pan (2002) and references therein.

Table 3: Returns around FOMC and Other Macroeconomic Releases

	FOMC	NFP	GDP	ISM	IP	PI	HST	INC	PPI	CPI	CSI	Non-FOMC
Day 0	27.14	10.10	9.62	9.14	5.23	3.50	2.46	1.51	-0.58	-2.14	-4.03	1.10
4pm-ann	[5.95]	[3.63]	[2.06]	[2.10]	[1.19]	[0.94]	[0.69]	[0.92]	[-0.17]	[-0.69]	[-0.88]	[0.89]
Day 0	1.68	1.51	-4.89	11.39	5.23	2.26	1.31	0.99	4.72	-2.31	-1.57	1.22
ann-4pm	[0.23]	[0.21]	[-0.59]	[1.85]	[1.19]	[0.35]	[0.20]	[0.30]	[0.64]	[-0.32]	[-0.30]	[1.52]
Day 0	30.48	12.91	7.19	20.44	9.58	4.96	4.84	2.70	4.17	0.02	-2.97	2.72
close - close	[3.70]	[1.80]	[0.84]	[2.54]	[1.43]	[0.69]	[0.70]	[0.81]	[0.59]	[0.00]	[-0.47]	[1.78]
Day -1	15.11	-2.28	10.16	-4.45	7.14	5.79	16.95	2.47	-2.60	2.84	19.13	3.21
close - close	[1.53]	[-0.33]	[1.35]	[-0.67]	[0.99]	[0.89]	[2.40]	[0.78]	[-0.41]	[0.38]	[2.68]	[2.11]

This table reports the returns (in basis points) around FOMC and other macroeconomic releases. The pre-announcement window is from 4 pm on the previous trading day to 5 minutes before index release (4pm - ann), and the post-announcement time window is from 5 minutes before index release to 4 pm on the announcement day (ann - 4pm). For the pre-announcement and post-announcement windows, the returns are percentage returns based on futures prices. For the announcement day (Day 0) and the day prior to the announcement day (Day -1), we report the daily close-to-close percentage returns on the S&P 500 index. The macroeconomic announcements include: total nonfarm payroll employment (NFP), the advance and final releases of GDP (GDP), the Institute for Supply Management's manufacturing index (ISM), industrial production (IP), personal income (PI), housing starts (HST), initial claims for unemployment insurance (INC), producer price index (PPI), consumer price index (CPI), and the preliminary release of the Consumer Sentiment Index (CSI). Announcement days that coincide with FOMC days are excluded for all macroeconomic releases. Non-FOMC refers to all trading days that are not FOMC announcement days. The sample period is from September 1994 to May 2018.

average of VIX is 19.84%. The main variable in this section is the time-series of daily changes in VIX,

$$\Delta VIX_t = VIX_t - VIX_{t-1}.$$

It has a sample mean that is slightly negative but close to zero, and its full-sample standard deviation is 2.16%. The events surrounding the 1987 stock market crash significantly affect its distribution, resulting in extreme values in its skewness and kurtosis. Taking out October 1987, the sample standard deviation is 1.51%, skewness is close to 1 (with a t-stat of 2.77), and kurtosis is 24 (with a t-stat of 6.09). Overall, this is a distribution marked by large movements in the tails, with sudden spikes in VIX being more frequent and larger in magnitude than sudden reductions in VIX. Our objective in this section is to use the tail events associated the sudden spikes in VIX to capture heightened uncertainty in financial markets and measure the premium for heightened uncertainty.

We define day t as of heightend VIX (HVIX) if ΔVIX_t is larger than a pre-determined constant cutoff value. As shown in Table 4, we experiment with different cutoff values, ranging from 2% to 4%. With higher cutoff values, fewer days are selected, making the events rarer. To smooth out the potential noise in daily changes in VIX, we also compare the level of VIX relative to a moving average of its recent past. More specifically, day t is defined as a heightened VIX day if

$$VIX_t - \mu_{t-1} \geq \text{cutoff},$$

where

$$\mu_{t-1} = \lambda \mu_{t-2} + (1 - \lambda) VIX_{t-1},$$

with λ serving as the decay factor. When $\lambda = 0$, the simple version of daily change in VIX, $VIX_t - VIX_{t-1}$, is used. As shown in our results, this simple daily change in VIX does a pretty good job in capturing heightened uncertainty, especially after 1990s. For the early sample that includes the late 1980s, it helps to smooth the past VIX with a fast decay factor such as $\lambda = 0.3$.

Our results are summarized in Table 4, which reports the average daily returns on the S&P 500 index on the days after heightened VIX. Also reported are their t-stat's. Overall, these returns are significant both economically and statistically and are quite stable over different specifications. In the upper middle panel, with $\lambda = 0.3$ and cutoff value of 3%, the average occurrence of heightened VIX is 7.6 days per calendar year, matching the FOMC

Table 4: Average Daily S&P 500 Index Returns After Heightened VIX

Cutoff (%)	N Days (/year)	Ret (bps)	T-stat	Cutoff (%)	N Days (/year)	Ret (bps)	T-stat	Cutoff (%)	N Days (/year)	Ret (bps)	T-stat
1986-2018											
$\lambda = 0$											
4.0	3.6	36	1.19	4.0	4.0	53	1.74	4.0	4.7	53	1.97
3.8	4.2	24	0.90	3.8	4.5	52	1.90	3.8	5.0	53	2.10
3.6	4.7	22	0.90	3.6	5.1	46	1.87	3.6	5.9	45	2.04
3.4	5.1	25	1.11	3.4	5.7	47	2.13	3.4	6.6	43	2.14
3.2	5.7	27	1.31	3.2	6.4	43	2.16	3.2	7.4	42	2.35
3.0	6.9	31	1.73	3.0	7.6	48	2.71	3.0	8.4	43	2.65
2.8	7.8	34	2.15	2.8	8.5	43	2.68	2.8	9.4	37	2.48
2.6	9.3	31	2.26	2.6	9.9	33	2.31	2.6	10.8	26	1.92
2.4	10.4	29	2.33	2.4	11.1	27	2.12	2.4	12.3	22	1.82
2.2	12.3	22	2.02	2.2	12.9	24	2.14	2.2	14.5	20	1.89
2.0	14.3	17	1.78	2.0	14.9	22	2.16	2.0	16.7	17	1.83
1994-2018											
$\lambda = 0$											
4.0	3.9	59	2.07	4.0	4.5	66	2.29	4.0	5.3	63	2.38
3.8	4.6	43	1.63	3.8	5.0	67	2.55	3.8	5.8	62	2.54
3.6	5.1	38	1.57	3.6	5.7	59	2.48	3.6	6.8	51	2.41
3.4	5.5	40	1.78	3.4	6.3	61	2.83	3.4	7.5	51	2.55
3.2	6.3	42	2.07	3.2	7.3	55	2.80	3.2	8.3	49	2.71
3.0	7.7	43	2.46	3.0	8.5	57	3.24	3.0	9.4	49	2.97
2.8	8.7	44	2.83	2.8	9.5	51	3.15	2.8	10.5	46	3.03
2.6	10.5	39	2.89	2.6	10.9	39	2.68	2.6	12.0	34	2.45
2.4	11.6	38	3.03	2.4	12.5	31	2.41	2.4	13.8	28	2.27
2.2	13.7	29	2.65	2.2	14.3	29	2.48	2.2	16.0	26	2.41
2.0	15.9	24	2.45	2.0	16.4	28	2.70	2.0	18.3	21	2.21
1986-2018											
$\lambda = 0.5$											
4.0	3.6	36	1.19	4.0	4.0	53	1.74	4.0	4.7	53	1.97
3.8	4.2	24	0.90	3.8	4.5	52	1.90	3.8	5.0	53	2.10
3.6	4.7	22	0.90	3.6	5.1	46	1.87	3.6	5.9	45	2.04
3.4	5.1	25	1.11	3.4	5.7	47	2.13	3.4	6.6	43	2.14
3.2	5.7	27	1.31	3.2	6.4	43	2.16	3.2	7.4	42	2.35
3.0	6.9	31	1.73	3.0	7.6	48	2.71	3.0	8.4	43	2.65
2.8	7.8	34	2.15	2.8	8.5	43	2.68	2.8	9.4	37	2.48
2.6	9.3	31	2.26	2.6	9.9	33	2.31	2.6	10.8	26	1.92
2.4	10.4	29	2.33	2.4	11.1	27	2.12	2.4	12.3	22	1.82
2.2	12.3	22	2.02	2.2	12.9	24	2.14	2.2	14.5	20	1.89
2.0	14.3	17	1.78	2.0	14.9	22	2.16	2.0	16.7	17	1.83
1994-2018											
$\lambda = 0.5$											
4.0	3.9	59	2.07	4.0	4.5	66	2.29	4.0	5.3	63	2.38
3.8	4.6	43	1.63	3.8	5.0	67	2.55	3.8	5.8	62	2.54
3.6	5.1	38	1.57	3.6	5.7	59	2.48	3.6	6.8	51	2.41
3.4	5.5	40	1.78	3.4	6.3	61	2.83	3.4	7.5	51	2.55
3.2	6.3	42	2.07	3.2	7.3	55	2.80	3.2	8.3	49	2.71
3.0	7.7	43	2.46	3.0	8.5	57	3.24	3.0	9.4	49	2.97
2.8	8.7	44	2.83	2.8	9.5	51	3.15	2.8	10.5	46	3.03
2.6	10.5	39	2.89	2.6	10.9	39	2.68	2.6	12.0	34	2.45
2.4	11.6	38	3.03	2.4	12.5	31	2.41	2.4	13.8	28	2.27
2.2	13.7	29	2.65	2.2	14.3	29	2.48	2.2	16.0	26	2.41
2.0	15.9	24	2.45	2.0	16.4	28	2.70	2.0	18.3	21	2.21

Day t is defined as a “Heightened VIX” day if $VIX_t - \mu_{t-1} \geq \text{Cutoff}$, where $\mu_{t-1} = \lambda \mu_{t-2} + (1 - \lambda) VIX_{t-1}$, with λ serving as the decay factor. “N Days” measures the average number of such “Heightened VIX” days per year. The sample period extends from January 1986 through May 2018. The sample standard deviation of daily changes in VIX is 2.16% for the full sample and 1.59% for the second sample starting from September 1994 to May 2018.

frequency. The average return associated with this heightened uncertainty is 48 basis points with a t-stat of 2.71. Akin to the FOMC result, these disproportionately large returns are realized on only a few days in a year. More importantly, these returns occur after heightened uncertainty, when the “fear gauge” spikes up and the market price drops precipitously. We therefore argue that these returns are the premium for the heightened uncertainty.

3.3.2. Heightened VIX as a Trading Strategy

One might question whether this premium can be captured in practice given that the closing time for CBOE’s S&P 500 index options is 4:15 pm, that is, after the close of the U.S. stock markets at 4 pm.¹⁸ For this, we use the intraday tick data on CBOE VIX, which is available after January 1992. As reported in Table 5, the results based on intraday VIX measured at 3:30 pm or 3:45 pm are similar to those using the VIX Close. For example, for the cutoff value of 2.8%, there are on average 7.4 heightened VIX days per year using daily changes in VIX measured at 3:45pm, and 8.0 days per year using daily changes in VIX Close. In both cases, the average daily return is 44 basis points.

Our result indicates that using information as early as 3:45 pm, we can identify whether heightened uncertainty has been triggered, and it leaves plenty time to buy S&P 500 index futures or other cash products on the index at 4 pm to capture the average next-day return of 44 basis points. This, however, is not money on the table, but premium for heightened uncertainty. On the day of heightened VIX, the market price is severely depressed, reflecting investors’ reluctance to hold market risk. Only on the next day, when the heightened uncertainty is resolved, does market price start to recover, yielding the 44 basis points average return. Indeed, the change in VIX on the next day is on average -1.15% and statistically significant. Extending this analysis to FOMC days, the same mechanism of heightened uncertainty takes place. Prior to the announcement, investors are unwilling to jump in because of heightened uncertainty. Only when this uncertainty is slowly resolved does market price start to recover, yielding the 27 basis points pre-FOMC return.

3.3.3. Can Heightened Uncertainty be Captured by Extreme Movements in Price and Volatility?

Given the close connection between market price and VIX, it is natural to question whether heightened uncertainty can be captured by sudden drops in price. Table 6 examines this possibility. After large price drops, the stock market does on average yield positive returns on

¹⁸Using the tick data on the CBOE VIX, we find that the pre-2003, the VIX Close is timed at 4pm, and post-2003, the VIX Close is timed at 4:15pm.

Table 5: Average Daily S&P 500 Index Returns After Heightened VIX, Using Intraday VIX

Cutoff (%)	3:30 pm			3:45 pm			4 pm			Close		
	N Days (/year)	Ret (bps)	T-stat	N Days (/year)	Ret (bps)	T-stat	N Days (/year)	Ret (bps)	T-stat	N Days (/year)	Ret (bps)	T-stat
4.0	3.2	48	1.63	3.5	70	2.66	3.8	62	2.34	3.6	59	2.09
3.8	3.6	43	1.58	4.0	67	2.81	4.2	59	2.43	4.2	43	1.64
3.6	4.0	38	1.53	4.6	58	2.70	4.7	58	2.58	4.6	38	1.58
3.4	4.8	41	1.80	5.2	64	3.26	5.1	61	2.88	5.1	41	1.86
3.2	5.8	49	2.54	5.9	58	3.13	5.8	53	2.78	5.7	43	2.14
3.0	6.7	41	2.32	6.5	47	2.65	7.1	49	2.83	7.0	43	2.53
2.8	7.6	35	2.09	7.4	44	2.71	8.1	41	2.71	8.0	44	2.89
2.6	8.6	32	2.13	9.1	33	2.36	9.4	38	2.84	9.7	39	2.97
2.4	9.7	28	1.96	10.5	28	2.25	10.7	36	2.95	10.7	39	3.15
2.2	11.6	25	2.08	12.5	28	2.54	12.5	30	2.70	12.7	30	2.76
2.0	14.1	21	2.09	14.5	24	2.41	14.7	28	2.87	14.9	24	2.51

Daily changes in VIX are used to measure sudden changes in VIX, using Intraday VIX measured at 3:30 pm, 3:45 pm, 4:00 pm, and the CBOE close, respectively. Reported in “Ret” are the average daily returns after days of heightened VIX, defined as a day when the daily change in VIX is above the “Cutoff” value. Also reported are the T-stat’s for the average returns. “N Days” measures the average number of such Heightened VIX days per year. The sample period extends from 1992 through May 2018. The sample standard deviation of daily changes in VIX (close-to-close) is 1.54%.

Table 6: **Days After Large Changes in Returns and Intraday Volatility**

Cutoff (%)	N Days (/year)	Ret (bps)	T-stat	Cutoff (%)	N Days (/year)	Ret (bps)	T-stat
Daily Returns				Intraday Volatility			
-2.4	5.3	28.0	1.26	16	4.4	-26.2	-1.04
-2.3	6.0	16.9	0.85	15	5.2	-18.3	-0.85
-2.2	7.0	14.7	0.84	14	5.8	-19.2	-0.96
-2.1	7.7	12.1	0.74	13	6.9	-17.0	-1.00
-2.0	8.6	12.7	0.86	12	8.3	-18.1	-1.24
-1.9	9.5	19.2	1.40	11	9.6	-17.4	-1.32
-1.8	11.1	15.4	1.27	10	11.2	-13.3	-1.14
-1.7	12.6	17.8	1.65	9	13.5	-6.8	-0.68
-1.6	14.2	14.2	1.45	8	16.6	-3.7	-0.44
-1.5	16.3	15.5	1.77	7	20.5	0.8	0.11

Daily returns on the S&P 500 index are used. Intraday volatility is measured using 5-minute S&P 500 index returns and converted to annual volatility. The heightened uncertainty days are picked if daily returns fall below the “Cutoff” values or daily changes in volatility increase above the “Cutoff” values. “N Days” measures the average number of such extreme days per year. The sample is from 1986 to May 2018. The sample standard deviations are 1.13% and 9.42%, respectively, for daily returns and daily changes in volatility.

the next day, but the statistical significance of the results is weak. For the sample after 1990s, the performance of this signal does improve. Overall, both signals, large price drop and large VIX increase, capture the same information of heightened uncertainty. Indeed, the premium of heightened uncertainty is realized out of the initial large price drop that accompanies the heightened VIX. In terms of serving as a signal, however, VIX has more of an advantage, partly because it is not as noisy as stock market returns. Moreover, although the correlation between daily returns and daily changes in VIX is close to -70%, the information contained is not entirely identical. Our result shows that VIX does perform better in capturing the heightened uncertainty.

Another natural comparison is between VIX and volatility. Unlike VIX, which can be measured daily or even intraday using S&P 500 index option prices, market volatility needs to be calculated using time-series of stock market returns. To obtain daily measures of volatility, we use intraday 5-minute returns on S&P 500 index futures. Table 6 shows that, after large increase in volatility, the next-day returns are on average negative but statistically insignificant. In other words, although the daily correlation between VIX and volatility is as

high as 77%, they contain very different information for the purpose of capturing heightened uncertainty. In particular, the volatility component in VIX is not helpful in identifying heightened uncertainty.

Compared with VIX, the volatility measure using the intraday returns is noisier. But the result in Table 6 cannot simply be explained by noise, as the sign of the average returns is opposite to the results using increase in VIX or decrease in price. In fact, if we reverse the sign of the signal by focusing on the extreme days when volatility suddenly drops, we find next-day returns are on average positive. Moreover, extreme days captured this way have very little overlap, less than 10%, with the extreme days captured by heightened VIX. Overall, the contrast of the informational content in these two measures shows that it is the fear or risk aversion component in VIX that is important in driving our result. It also raises the question as to whether volatility is a reliable risk measure.¹⁹

3.4. FOMC vs. Heightened VIX

3.4.1. Comparison in Magnitude: Premium for Heightened Risk

To make a more direct comparison between FOMC and heightened VIX, we calculate their respective yearly returns by adding up the event returns within each calendar year. As shown in Table 7, the pre-FOMC and pre-NFP returns are on average 2.24% and 1.35% per year, respectively, while the heightened VIX returns are on average 3.71% per year. For the sample time period over which the pre-FOMC returns are observed, the heightened VIX returns are on average 5.17% per year, accounting for more than half the annual return of the S&P 500 index.

Throughout the paper, the heightened VIX days are selected using a cutoff value of 3.0% and $\lambda = 0.3$. For ease of replication, we use the CBOE VIX Close published on the CBOE website. As a robustness check, we also examine the risk premium measure using simple daily changes in VIX, measured by 3:30 pm, 3:45 pm, and 4 pm. As shown in Table 5, using a cutoff value of 2.8%, the heightened VIX days occur on average 7.6, 7.4, and 8.1 days per year. For these specifications of heightened VIX, the annual returns from 1995 through 2017 are 2.75%, 3.68%, and 3.91%, respectively for 3:30 pm, 3:45 pm, and 4 pm. The associated t-stat's are 2.45, 2.90, and 2.88, respectively. Not surprisingly, given the timing of the signals, these annual returns are lower in magnitude than the HVIX return, and offer an more conservative estimate for the risk premium measure. As we can see from

¹⁹Indeed, prior to important news announcements such as the FOMC days, markets are usually quiet with low trading volume and low volatility, documented in the literature as “quiet-before-the-storm” by Bomfim (2003) and Jones, Lamont, and Lumsdaine (1998).

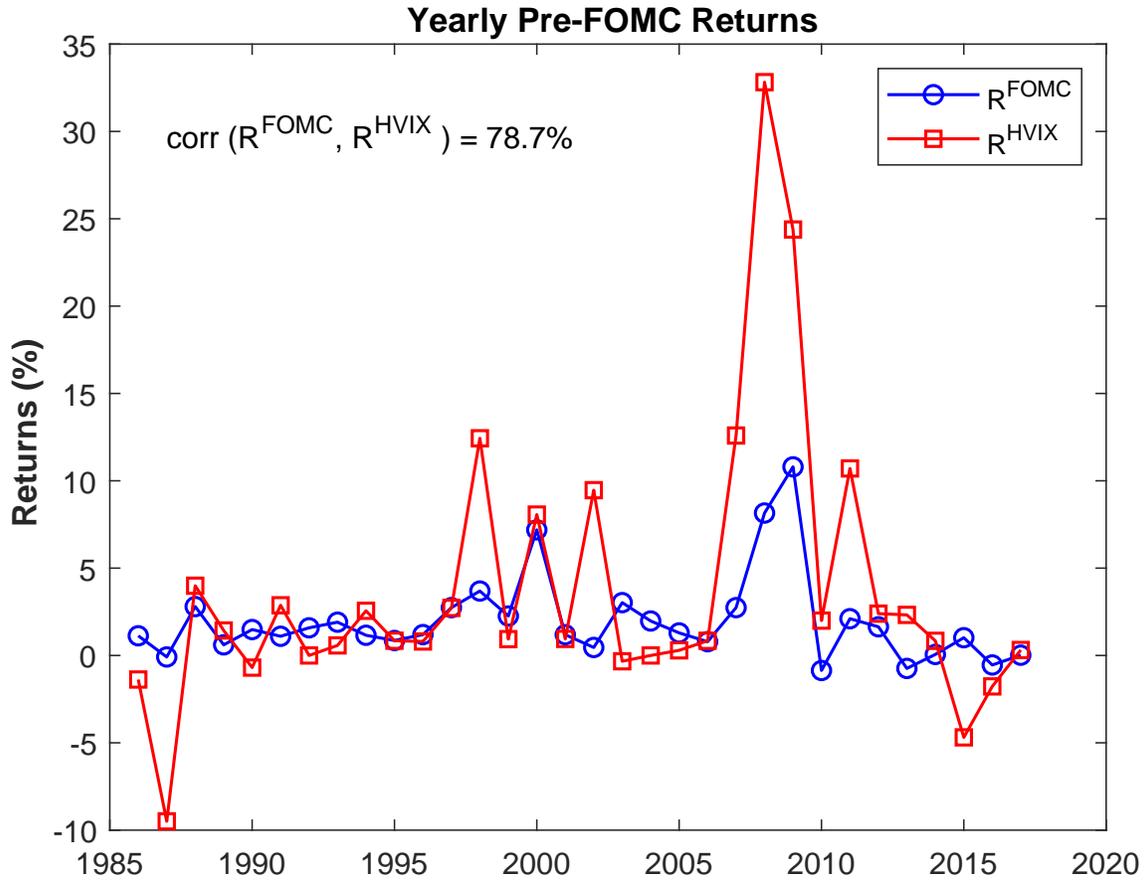


Figure 1: Time-series of yearly S&P 500 index returns realized on event days. For FOMC and NFP (Nonfarm Payroll), the pre-announcement returns realized within each calendar year are used to calculate the respective yearly returns. For HVIX (heightened VIX), the next-day returns after sudden spikes in VIX are used.

Table 7: Yearly Pre-announcement Returns Realized on Event Days

	Event Days						All Days
	FOMC	NFP	GDP	ISM	HVIX	HVIX	SPX
	95-17	98-17	98-17	95-17	95-17	86-17	95-17
Avg Return (%)	2.24 [3.68]	1.35 [4.47]	0.78 [3.47]	1.23 [1.82]	5.17 [2.83]	3.71 [2.62]	9.61 [2.55]
Avg VIX (%)	19.83	19.92	19.67	20.20	32.91	33.84	19.82
N Days/Year	8	12	7	12	9	8	252
N Days	184	235	145	268	196	240	5791
N Years	23	20	20	23	23	32	23
Correlations	FOMC	NFP	GDP	ISM	HVIX	VIX	SPX
FOMC	1.00	0.69	0.19	-0.26	0.79	0.69	-0.23
NFP	0.69	1.00	0.04	0.08	0.55	0.35	0.05
GDP	0.19	0.04	1.00	-0.33	0.38	0.43	-0.34
ISM	-0.26	0.08	-0.33	1.00	-0.39	-0.28	0.44
HVIX	0.79	0.55	0.38	-0.39	1.00	0.73	-0.43
Regressions	Dependent Variable: Yearly Event Returns (%)						
	FOMC	FOMC	NFP	NFP	GDP	ISM	HVIX
Intercept	-4.62 [-2.59]	-1.71 [-1.06]	-0.73 [-0.68]	0.73 [0.68]	-0.08 [-0.09]	0.12 [0.04]	-13.09 [-2.64]
SPX Ret (%)	0.01 [0.48]	0.03 [1.27]	0.02 [1.05]	0.03 [1.65]	-0.01 [-0.84]	0.06 [1.68]	-0.07 [-0.87]
VIX (%)	0.34 [4.21]	0.13 [1.49]	0.10 [1.99]	-0.01 [-0.12]	0.04 [0.89]	0.06 [0.39]	0.95 [4.26]
HVIX Ret (%)		0.22 [3.68]		0.10 [2.63]	0.01 [0.34]	-0.12 [-1.16]	
R-Squared (%)	47.5	67.5	17.4	39.5	22.1	24.8	55.3
N Obs	23	23	20	20	20	23	23

Pre-announcement returns on the S&P 500 index within each year are used to calculate the yearly returns. FOMC days are excluded from NFP, GDP, and ISM days. Correlations and regressions are at annual frequency. The sample period extends from 1995 through 2017, except for GDP and NFP, which uses after-hours prices and starts from 1998.

these numbers, even for the most conservative measure, the premium for heightened VIX remains important in its economic and statistical significance.

Figure 1 plots the yearly heightened VIX returns along with the yearly pre-FOMC returns, and there is substantive co-movements between the yearly returns. It should be noted, however, these returns are realized mostly on different days within each calendar year. Out of the 190 FOMC days, only 7 are identified as days after heightened VIX, and out of the 243 NFP days, only 13 are identified as days after heightened VIX. Also, unlike the FOMC or NFP days, which are evenly distributed over the year, heightened VIX days are clustered together. From 1986 through 2018, the top three years with the highest number of heightend VIX days are: 27 days in 2008, 21 days in 2011, 19 days in 1998. By contrast, the top three years with the highest annual average of VIX are: 32.7% in 2008, 31.5% in 2009, and 29.3% in 1987. In other words, in identifying days of heightened uncertainty, the information contained in changes in VIX is more useful than the level of VIX.

As reported in Lucca and Moench (2015), the pre-FOMC drift is stronger when VIX is higher. Indeed, regressing the yearly pre-announcement returns of FOMC and NFP on the yearly averages of VIX, Table 7 shows that the R-squared's of the regressions are 47.5% and 17.4%, respectively. Regressing heightened VIX returns on VIX yields an R-squared of 55.3%. Indeed, the time variation in VIX is important in explanation the time variation in these returns. But once the heightened VIX returns are included in explaining the FOMC and NFP returns, the level of VIX loses its explanatory power. As shown in Table 7, adding the heightened VIX returns as an explanatory variable further improves the R-squared's to 67.5% and 39.5%, respectively. More importantly, in the bi-variate regressions, the regression coefficients on VIX are smaller in magnitude and no longer statistically significant.

3.4.2. Comparison in Mechanism: Build-up and Release of Heightend Uncertainty

While the result of heightened VIX is important in its own right, it also helps shed light on the mechanism over which the FOMC risk premium arises. The upper panels in Figure 2 plot the pattern in VIX for both FOMC and heightened VIX. As companion plots, the lower panels in Figure 2 plot the pattern in cumulative return on the S&P 500 index.

For ease of comparison, we label the day after the heightened VIX as Day 0, and the FOMC day is also labeled as Day 0. In the case of heightened VIX, the substantial increase in VIX on Day -1 helps us identify the days of heightened uncertainty. Inspired by this observation, we examine the VIX build-up prior to the FOMC day. Indeed, as shown in the upper right panel of Figure 2, there is a mild but significant build-up in VIX prior to Day 0.

Table 8 evaluates the magnitude of the build-up by regressing cumulative changes in VIX on the event day dummies. Focusing on the window from Day -6 through Day -1, the

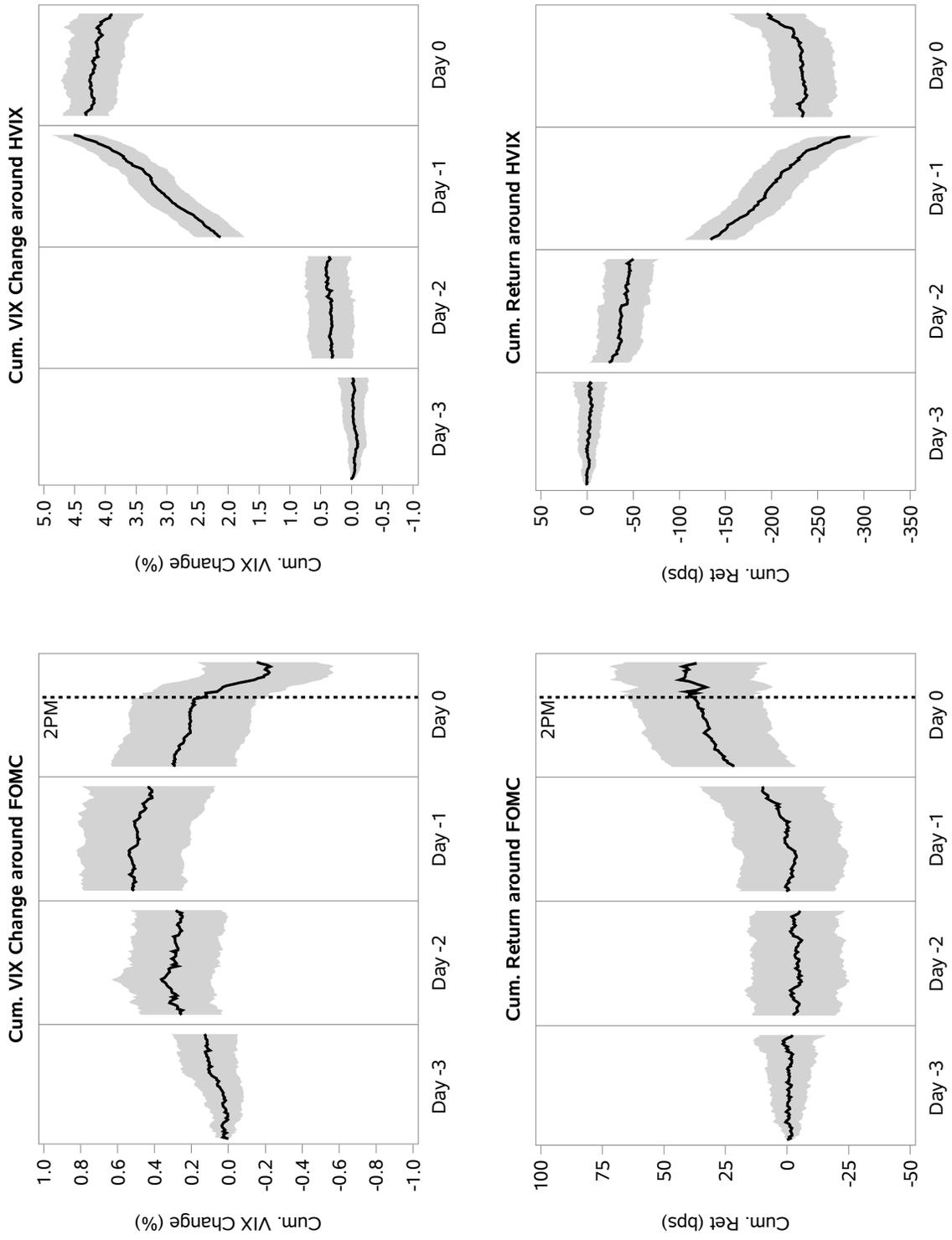


Figure 2: Cumulative VIX Change and Return around FOMC and HVIX Days.

Table 8: Changes in VIX Surrounding FOMC Announcements

	Cum Days [-6 -1]		Cum Days [-3 -1]		Day 0		Day 0, Before Ann				
Intercept	0.00 [0.02]	-0.02 [-0.23]	-0.26 [-3.87]	0.00 [0.02]	-0.01 [-0.32]	-0.23 [-5.74]	0.00 [0.01]	0.02 [1.10]	0.10 [4.53]	0.04 [2.90]	0.05 [3.38]
FOMC Days	0.60 [2.60]	0.60 [2.85]	0.59 [2.85]	0.48 [2.52]	0.47 [2.94]	0.60 [2.94]	-0.60 [-5.02]	-0.60 [-5.02]	-0.62 [-5.35]	-0.27 [-3.81]	-0.27 [-3.81]
Matched		0.11 [0.60]	0.11 [0.60]	0.28 [1.82]	0.28 [1.82]	0.28 [1.82]	0.28 [1.82]	0.28 [1.82]	-0.30 [-3.04]	-0.30 [-3.04]	-0.30 [-3.04]
NFP		0.10 [0.69]	0.10 [0.69]	-0.11 [-0.83]	-0.11 [-0.83]	-0.11 [-0.83]	-0.11 [-0.83]	-0.11 [-0.83]	-0.42 [-4.28]	-0.42 [-4.28]	-0.42 [-4.28]
GDP		0.00 [0.01]	0.00 [0.01]	0.00 [0.01]	0.00 [0.01]	0.00 [0.01]	0.00 [0.01]	0.00 [0.01]	-0.21 [-1.93]	-0.21 [-1.93]	-0.21 [-1.93]
ISM		0.22 [1.22]	0.22 [1.22]	0.20 [1.55]	0.20 [1.55]	0.20 [1.55]	0.20 [1.55]	0.20 [1.55]	-0.03 [-0.23]	-0.03 [-0.23]	-0.03 [-0.23]
HVIX		6.50 [12.57]	6.50 [12.57]	6.04 [18.49]	6.04 [18.49]	6.04 [18.49]	6.04 [18.49]	6.04 [18.49]	-1.15 [-4.61]	-1.15 [-4.61]	-1.15 [-4.61]
Adj R-Sqr (%)	0.00	0.09	13.64	0.00	0.1	19.11	0.00	0.42	2.45	0.00	0.11
N Obs	5970	5970	5970	5970	5970	5970	5970	5970	5970	5896	5896
N FOMC	190	190	190	190	190	190	190	190	190	188	188

Changes in VIX (in percent) are regressed on event dummies: 'FOMC Days' is one for FOMC announcements. 'Matched' is a matched sample of non-FOMC days to match the FOMC close-to-close returns. The reported t-stat's use Newey-West standard errors, adjusting for serial correlations. The sample period is from September 1994 through May 2018.

average build-up in VIX is 0.60% with a t-stat of 2.60 in leading up to FOMC. By contrast, the average build-up is close to zero for non-FOMC days. This 0.60% build-up in VIX is much subtler compared the 6.50% build-up to the case of heightened VIX when investors are caught off guard by adverse market conditions. Nevertheless, this is the first result in the literature that differentiates the FOMC days from the non-FOMC days in terms of risk measures. It provides importance evidence that, associated the announcement of such market-moving news, there is indeed heightened uncertainty.

Learning from the case of heightened VIX, we see that the build-up in VIX is followed by significant reduction in VIX on Day 0. More importantly, it is this resolution of heightened uncertainty that gives rise to the disproportionately large return on Day 0. For the case of FOMC, a significant reduction in VIX does occur on Day 0, which is to be expected. But as shown in the upper left panel of Figure 2, a significant portion of the reduction in VIX actually happens before the announcement. As reported in Table 8, the overall change in VIX on Day 0 is -0.60%, on par with the long build-up before Day 0. But the change in VIX on Day 0 before the announcement is -0.27%, which accounts for half of the Day 0 reduction in VIX. It is coupled with this release of heightened uncertainty, arises the disproportionately large pre-FOMC drift.

Another ways to summarize our risk premium result is by investigating return predictability. In Table 10, daily returns on the S&P 500 index are regressed on lagged VIX and lagged cumulative changes in VIX:

$$R_t = a + bVIX_{t-1} + c(VIX_{t-1} - VIX_{t-7}) + \epsilon_t,$$

where both of the independent variables are demeaned so that the intercept can be read as the event day returns. For the full sample, we find that the cumulative change in VIX is a significant predictor of future returns, while the lagged VIX is not. Using the cumulative change in VIX as a predictor, the regression coefficient is 2.95 with a t-stat of 3.59. Given that the sample standard deviation for the cumulative change in VIX is 3.19%, this result indicates that one standard deviation increase in the change in VIX results in 9.14 basis points increase in daily returns.

As we move away from the full sample to focusing on the event days, the lagged VIX becomes a significant predictor while change in VIX is no longer important. This is consistent with the result of Lucca and Moench (2015), which reports that lagged VIX can predict the pre-FOMC drift. As shown in Table 10, the same is true for the case of heightened VIX. These results indicate that in identifying the days of heightened uncertainty, the changes in VIX is more informative than the level of VIX. But once the event days are identified, then it is the level of VIX that is important.

Table 9: SPX Returns Surrounding FOMC Announcements

	Cum Days [-6 -2]		Day -1		Day 0		Day 0, Before Ann					
Intercept	17.58 [3.12]	17.99 [3.18]	22.80 [4.12]	3.59 [2.65]	3.21 [2.32]	13.11 [9.02]	3.61 [2.66]	2.72 [1.95]	-1.61 [-1.00]	1.92 [1.67]	1.10 [0.92]	
FOMC Days	-12.92 [-0.74]	-10.89 [-0.62]		11.89 [1.19]	12.51 [1.40]	27.76 [3.29]	28.79 [3.45]	26.04 [5.47]				
Matched	-6.80 [-0.40]			-0.77 [-0.10]			25.30 [3.43]					
NFP	19.09			-1.80			10.64					
GDP	[1.56]			[-0.30]			[1.44]					
	-19.50			1.42			7.64					
ISM	[-1.29]			[0.20]			[0.93]					
	1.64			-7.58			18.09					
	[0.12]			[-1.28]			[2.21]					
HVIX	-148 [-4.03]			-281 [-23.04]			56.10 [3.54]					
Adj R-Sqr (%)	0.00	-0.01	1.22	0.00	0.02	18.98	0.00	0.16	1.10	0.00	0.23	
N Obs	5972	5972	5972	5972	5972	5972	5972	5972	5972	5972	5972	
N FOMC	190	190	190	190	190	190	190	190	190	190	190	

SPX returns (in basis points) are regressed on event dummies: 'FOMC Days' is one for FOMC announcement days; 'FOMC Regular' is one for FOMC days scheduled between 2:00 and 2:30pm. The VIX buildup is also examined for three placebos containing non-FOMC days: 'Wed Before' and 'Wed After' are two Wednesdays before and after the FOMC day, and 'Matched' matches the FOMC close-to-close returns. The reported t-stat's use Newey-West standard errors, adjusting for serial correlations. The sample period is from 1994 through May 2018.

Table 10: **Daily S&P 500 Index Returns on Lagged VIX and Changes in VIX**

	FOMC			HVIX			All		
Intercept	30.48 [3.84]	30.48 [3.31]	30.48 [3.71]	57.22 [4.32]	57.22 [3.82]	57.22 [4.18]	3.60 [2.62]	3.60 [2.48]	3.60 [2.47]
VIX -1	3.12 [2.07]		2.65 [1.39]	4.13 [3.05]		3.51 [2.72]	0.49 [1.47]		0.27 [0.81]
Δ VIX $[-6 - 1]$		6.19 [1.04]	4.31 [0.67]		7.03 [1.76]	4.34 [1.11]		2.95 [3.59]	2.81 [3.48]
Adj R-Sqr (%)	4.82	2.70	5.77	4.78	2.34	5.27	0.10	0.64	0.65
N Obs	190	190	190	202	202	202	5972	5972	5972

Daily S&P 500 index returns are regressed on lagged VIX and changes in VIX, with both expressed in percentage. The regressands are demeaned so that the intercept reflects the average event day returns. The sample period is from Septemeber 1994 to May 2018. The reported t-stat's use Newey-West standard errors, adjusting for serial correlations.

3.4.3. *Not All FOMC Days are the Same*

The severity of heightened uncertainty, as well as the timing of its resolution, varies from one FOMC meeting to another. Correspondingly, the implication for the pre-FOMC drift also differs. In Table 11, we sort the FOMC days by their pre-FOMC drift into three groups, and examine the patterns of heightened uncertainty surrounding the events. Figure 3 shows the VIX and Return pattern for the high-drift and low-drift groups separately. For comparison, we repeat the same analysis using two control groups. One is a matched sample of non-FOMC days, with the objective to match the distribution of the FOMC close-to-close returns. Another is a sample of non-FOMC Wednesdays three weeks after each FOMC day, with the objective to capture and control the day-of-the-week effect.

The high-drift group, with an average pre-FOMC return of 92 basis points, serves as a turbo version of the average FOMC results and paints a sharper picture of our narrative. First, the build-up of heightened uncertainty is stronger. The six-day VIX build-up is 1.74% for the high group, compared with 0.59% for the full FOMC sample. More interestingly, the corresponding cumulative six-day return is -83 basis points with a t-stat of -2.40. Indeed, this pattern resembles that of heightened VIX, where the impact of heightened uncertainty is reflected not only by the large increase in VIX, but also by the large decrease in price. For the full FOMC sample, however, we are unable to detect this downward drift in price. As shown in Table 9, over the five days before FOMC, the cumulative returns are -12.92% lower than the full-sample average, but it is statistically insignificant.

Table 11: Returns and Changes in VIX Leading up to FOMC Announcements

	FOMC			Matched			Wed			Unconditional		
	High	Med	Low	High	Med	Low	High	Med	Low	FOMC	Matched	Wed
Event Day Avg Returns (bps)												
4pm - ann	92	19	-29	47	0.6	-8.8	102	8.4	-73	27	13	12
	[12.53]	[12.83]	[-7.64]	[3.76]	[0.08]	[-0.86]	[10.62]	[4.39]	[-8.01]	[5.95]	[2.12]	[1.80]
ann - 4pm	-11	-12	28	20	3.8	8.4	6.4	2.0	-22	1.7	11	-4.4
	[-0.70]	[-1.16]	[2.57]	[2.96]	[0.57]	[1.20]	[0.77]	[0.36]	[-2.69]	[0.23]	[2.70]	[-1.01]
4pm - 4pm	81	7.4	-1.5	67	4.3	-0.5	109	10	-95	29	24	8.1
	[4.27]	[0.77]	[-0.14]	[4.58]	[0.46]	[-0.05]	[7.89]	[1.83]	[-6.15]	[3.44]	[3.33]	[0.87]
Event Day Changes in VIX (%)												
4pm - ann	-0.96	-0.11	0.40	-0.57	0.11	0.14	-0.97	-0.07	0.71	-0.22	-0.10	-0.12
	[-7.44]	[-1.71]	[4.32]	[-3.13]	[1.22]	[0.91]	[-8.14]	[-1.07]	[5.46]	[-3.18]	[-1.17]	[-1.48]
ann - 4pm	-0.41	-0.06	-0.62	-0.23	-0.04	-0.07	0.03	-0.13	0.24	-0.36	-0.11	0.05
	[-2.16]	[-0.61]	[-5.20]	[-3.02]	[-0.65]	[-1.16]	[0.32]	[-2.01]	[2.41]	[-4.35]	[-2.89]	[0.88]
4pm - 4pm	-1.37	-0.17	-0.22	-0.80	0.07	0.07	-0.94	-0.20	0.95	-0.58	-0.21	-0.07
	[-4.95]	[-1.67]	[-1.57]	[-3.94]	[0.69]	[0.41]	[-6.26]	[-2.04]	[5.15]	[-5.07]	[-2.21]	[-0.71]
VIX Level	23.5	17.1	18.4	23.2	17.1	18.0	19.8	18.2	21.3	19.7	19.4	19.8
Cumulative Changes in VIX (%)												
Cum [-3 -1]	1.20	-0.20	0.41	0.35	-0.21	0.01	-0.06	-0.11	0.14	0.47	0.05	-0.01
	[2.52]	[-0.85]	[1.98]	[1.06]	[-0.91]	[0.05]	[-0.20]	[-0.42]	[0.43]	[2.43]	[0.33]	[-0.04]
Cum [-6 -1]	1.74	-0.40	0.44	0.04	-0.24	-0.24	-0.14	-0.05	-0.05	0.59	-0.14	-0.08
	[3.30]	[-1.21]	[1.44]	[0.11]	[-0.82]	[-0.75]	[-0.33]	[-0.13]	[-0.12]	[2.46]	[-0.76]	[-0.34]
Cumulative Returns (bps)												
Cum [-3 -1]	-55	46	27	-20	36	4.8	6.1	28	4.8	6.4	7.1	13
	[-1.84]	[2.78]	[1.21]	[-0.71]	[1.86]	[0.23]	[0.22]	[1.40]	[0.19]	[0.46]	[0.53]	[0.92]
Cum [-6 -1]	-83	98	42	-8.4	48	44	7.4	50	26	20	28	28
	[-2.40]	[3.07]	[1.57]	[-0.22]	[2.13]	[1.58]	[0.21]	[1.56]	[0.72]	[1.04]	[1.59]	[1.41]
N Days	63	64	63	63	64	63	63	64	63	190	190	190

FOMC days are sorted by pre-FOMC returns into high, med, and low. ‘Matched’ is a matched sample of non-FOMC days to match the FOMC close-to-close returns. ‘Wed’ is a sample of non-FOMC Wednesdays three weeks after each FOMC day. The “Unconditional” tab reports the full sample results for each of the three samples. The sample period is from 1994 to May 2018.

Second, the resolution of heightened uncertainty is also larger in magnitudes. On the announcement day, the pre-FOMC change in VIX is -0.96%, reversing more than half of the six-day build-up, and the pre-FOMC return is on average 92 basis points, reversing the six-day downward price drift. After the announcement, there is a further reduction of -0.41% in VIX, but the post-announcement return is insignificant.²⁰ These results indicate that the heightened uncertainty is resolved on the announcement day before the announcement, just like the average case. The average impact of the announcement itself is somewhat muted.

For the low-drift group, with an average pre-FOMC return of -29 basis points, the announcement itself has a much larger impact. The reversal in VIX actually occurs at the point of the announcement. After the announcement, the change in VIX is -0.62%, reversing the 0.40% build-up in VIX during the pre-FOMC window. With the resolution of heightened uncertainty, the post-FOMC average return is 28 basis points, reversing the downward drift of -29 basis points during the FOMC window. Compared with the high group, whose heightened uncertainty is resolved before the announcement, the low-drift group needs the information at the announcement to help resolve the uncertainty.

For the medium-drift group, with an average pre-FOMC return of 19 basis points, the announcement day itself seems to have very little impact. Over the six-day window before the announcement, the cumulative return is 98 basis points and is statistically significant. Relative to the baseline of provided by the two control groups, however, this 98 basis points is still large, but not significantly so.

4. Conclusions

We hypothesize that the disproportionately large pre-FOMC return is a premium for heightened uncertainty in the market, as investors cautiously await the upcoming announcements. This heightened uncertainty is, however, difficult to capture by conventional risk measures. On the other hand, the resolution of the uncertainty occurs during a short time window, mostly prior to the announcement, accompanied by a significant price appreciation. We support our hypothesis by providing two tests that share very similar heightens uncertainty and can generate comparable risk premium. First, we show that there is significant, albeit with small magnitudes, premium before the announcements of other pre-scheduled macroeconomic news releases, i.e., total nonfarm payrolls, GDP, and the ISM manufacturing index. Second, we show that similar premium exists for days following unexpected large spike-ups in VIX, an indicator for heightened uncertainty. We conclude the paper by showing a significant

²⁰We define announcement as 5 minutes before the scheduled the news release to avoid any contamination on the pre-FOMC returns. By this design, the five minutes before the announcement are included in the post-FOMC window. Taking out this five minutes does not affect our results.

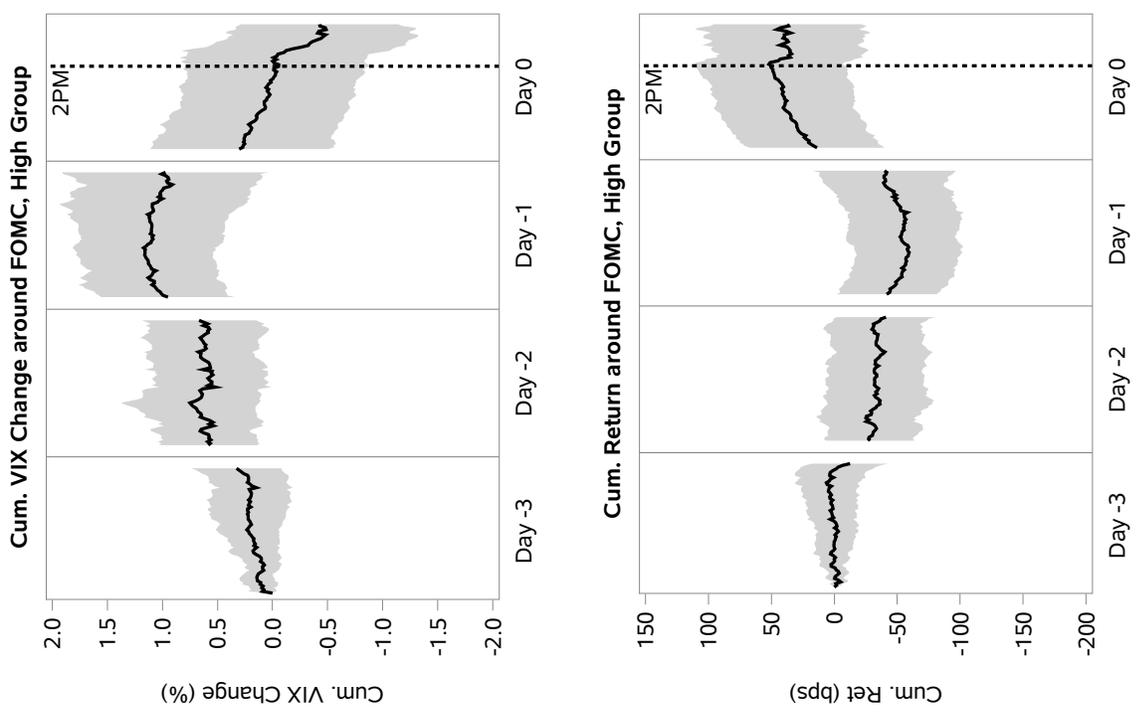
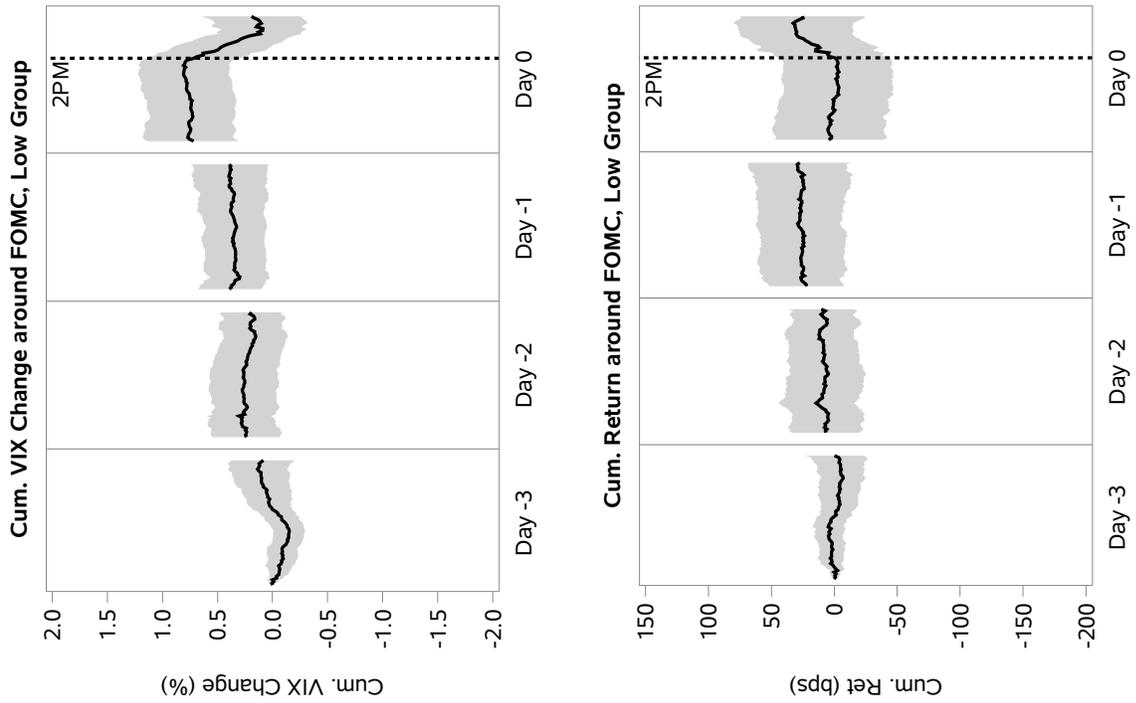


Figure 3: Cumulative VIX Change and Return around High and Low FOMC Days.

build-up and reversal pattern of VIX around FOMC announcements, where the build-up of VIX is a direct evidence of heightened uncertainty in the market, and the subsequent reversal of VIX, accompanying high return, starts prior to FOMC announcements.

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