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ABSTRACT

The substantial stock market return prior to FOMC announcements without major increase in conventional measures of risk, as documented by Lucca and Moench (2015), presents a "puzzle" to the simple notion of risk-return trade off. We hypothesize that the arrival of macroeconomic news, with FOMC announcements leading the list, brings heightened uncertainty to the market as an additional source of risk. While this heightened uncertainty may not be accurately captured by common risk measures, its dissolution occurs mostly during a short time window prior to the announcement and brings a significant price appreciation, reflecting the risk premium associated with it. 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 proxies for heightened uncertainty in the market can be found, 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 gauge for market uncertainty, we find disproportionately large returns on days following large spike-ups in VIX. Akin to the FOMC result, such heightened-uncertainty days occur on average only eight times per year, but account for more than 30% of the average annual return on the S&P 500 index. We further find that there is a gradual but significant build-up in VIX over a window of up to six business days prior to the FOMC announcements.

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1. Introduction

The FOMC puzzle recently documented by Lucca and Moench (2015) provides an interesting and seemingly unique challenge to our understanding of risk and return relationship in asset returns. 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, more than ten times the average return of 4 basis point per day on the same index. More intriguing is the fact that, during the 24-hour window before the announcement, markets do not appear to be unusually risky. In every conventional measure of risk—return volatility, skewness, kurtosis, etc.—the pre-FOMC window looks just like a normal day. If anything, markets seem 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?

We hypothesize that the pre-FOMC drift is in fact a result of heightened uncertainty prior to the announcement and its resolution. In particular, market-moving news carries two different risks: one is associated with the news realization itself, and the other is associated with the uncertainty on how the news may impact the market.[1] Each risk carries its own risk premium, yielding a positive price shift when it is resolved. If the uncertainty about the potential market impact of the news is resolved before the actual announcement, a positive return will be realized, separate from the news realization itself. Because this uncertainty is not directly tied to the actual news realization, conventional risk measures do not accurately capture the magnitude of this uncertainty. Thus, we will observe a price shift without unusual risk during this period using conventional measures.

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 overall price impact of the heightened uncertainty. Approaching the announcement, this heightened uncertainty gets resolved in a relatively short period, and the corresponding risk premium is realized. While typical risk measures using market price data do not reliably reflect this uncertainty, the condensed nature of

[1]For the lack of a better terminology, our use of "uncertainty" here is only in an intuitive sense. It merely reflects the fact that the uncertainty or risk here is not well characterized by conventional risk measures. It does not necessarily imply that we are using it in the sense of Knight (1921) or Savage (1954).

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

the narrow window 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.

One immediate implication of our hypothesis is that the FOMC result is not unique. The pattern of disproportionately large return can occur whenever there is heightened uncertainty, including pre-scheduled announcements of other macroeconomic news perceived by investors to be of potentially 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 around macroeconomic data releases 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 unexpectedly by adverse market conditions. As an "out-of-sample" test of our hypothesis, we investigate whether there is a premium for such unexpected 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, such as depressed aggregate stock prices, 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

[3]For 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.

[4]FOMC 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.

[5]The 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

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 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 intertemporal risk and return relationship with multiple sources of risks resolving over different time windows. Not all trading days are created equal and some have inherently higher exposure to risks than others. As long as we focus our attention on such high-impact days, either pre-scheduled (e.g., FOMC and NFP releases) or stochastically triggered (e.g., heightened VIX), we will be confronted with this pattern of seemingly large abnormal returns, which are in fact the premium for heightened uncertainty on these days.

Our result on heightened VIX and the associated premium, important in its own right, also helps to shed light on the mechanism over which the FOMC risk premium arises. Specifically, by using VIX as a proxy for uncertainty, we are able to identify days of heightened uncertainty triggered unexpectedly by adverse market conditions. For pre-scheduled announcements such as that of FOMC, the reaction of heightened uncertainty might be more diffused since investors can plan ahead. Nevertheless, the undercurrent of heightened uncertainty is still there. Inspired by this observation, we examine the behavior of VIX over a relatively long window prior to the FOMC days. Indeed, we find a gradual but significant build-up in VIX over a window of up to six business days prior to the FOMC announcements. This build-up, although much subtler compared to the case of heightened VIX, provides a direct evidence of heightened uncertainty in anticipation of the announcements of such market-moving news.

Also learning from the case of heightened VIX, we see that the build-up in VIX is followed by significant reduction in VIX on the day after. Along with this dissolution of heightened uncertainty, arises the disproportionately large return. The same pattern can be observed in the case of FOMC. On the day of FOMC, significant reduction in VIX does occur, which is to be expected. Interestingly, we find that half of this reduction in VIX on the FOMC day actually happens before the actual announcement. Along with this reduction of heightened uncertainty before the announcement, arises the disproportionately large pre-FOMC drift, indicating that a significant portion of the heightened uncertainty is resolved before the

of 48 basis points as larger return for higher risk. In the data, however, the contemporaneous correlation between VIX and return is known to be significantly negative, making our finding even more striking.

announcement itself. After the FOMC announcement, there is further reduction in VIX, but the average post-announcement return is close to zero.[6]

In the final part of the empirical analysis, we show that not all FOMC days are the same. 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. On the FOMC day, the resolution of uncertainty occurs largely before the scheduled news release and the average market return after the announcement is close to zero. By contrast, for the low-drift group, the heightened uncertainty actually occurs on the day of the FOMC announcement. The resolution of uncertainty happens after the announcement, and the average market return after the announcement is positive and significant.

It is important to note that we know little about the exact nature of the underlying uncertainty. Because our empirical analysis requires measurement of market dynamics during a short time window and at high frequency, VIX seems a natural proxy for uncertainty, but we by no means claim that VIX is an accurate measure. It is entirely possible that VIX is merely a reaction, a manifestation of some deeper underlying uncertainty when it heightens. Although the exact nature of such uncertainty eludes us, our results show 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. Our empirical analysis suggests that a richer model for risk and return may be needed to explain observed return patterns than a simple static return-risk relationship using conventional risk measures.

To illustrate this point, in the last part of the paper, we construct a simple model in which the uncertainty is about the variability of how market news may impact asset fundamentals. This additional risk, separate from the risk about the news itself, carries its own risk premium. In the model, the fundamental asset value v is realized upon announcement, but the variance of v, which reflects how much the news may impact asset fundamentals, is learned before the announcement. The resolution of uncertainty in our model is taken to mean the observation of the variance of v, which is associated with a positive pre-announcement return. In addition, the corresponding return volatility, as a common measure of risk, can be relatively low. We provide parameter conditions under which the pre-announcement

[6]At the same time, there is a substantial increase in market volatility induced by the announcement. Even if there is further resolution of uncertainty associated with the announcement itself, the associated risk premium is difficult to be measured with precision because of the increased market volatility.

risk premium is higher and the pre-announcement return volatility is lower than the post-announcement counterparts. Hence, the model's predictions about risks and returns around important news events are qualitatively similar to those observed in the data.

Although our proposed explanation of the FOMC puzzle is both theoretically and empirically coherent and supported by several sets of "out-of-sample" tests, open questions remain. For example, our analysis does not reveal the nature of the uncertainty around announcements, what drives its resolution, and how. These questions are important but beyond the scope of this paper, especially with the data we have. We will provide some further discussion in the model section.

The rest of the paper is organized as follows. The remainder of this section provides a brief discussion of the related literature. Section 2 describes in detail the data we use. Section 3 presents our main results and related discussions. Section 4 introduces an illustrative model that can generate the observed risk-return patterns around FOMC and other macroeconomic announcements as well as VIX hikes. Section 5 concludes.

Relation to the Literature

Our paper is most closely related to the empirical literature that studies asset return dynamics 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.[7] Adding to the evidence of 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.[8] Pre-announcement returns have also been studied in the markets for bonds and currencies.[9]

[7]Guo, 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 from 2011 to 2017, but Lucca and Moench (2018) show that the pre-FOMC announcement drift remains in this period and only shows up ahead of FOMC announcements that are followed by a press conference.

[8]Specifically, 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.

[9]Lucca and Moench (2018) find that the returns of Treasury securities are generally small and statistically insignificant 24 hours before FOMC announcements. Balduzzi and Moneta (2017) find that the 10-year and 30-year Treasury futures have statistically significant return of 1-2 bps over the 30 minutes window proceeding the FOMC announcements. Fleming and Piazzesi (2005) and Faust and Wright (2018) provide high-frequency analysis of Treasury yields around, respectively, FOMC announcements and macroeconomic announcements at 8:30 am, while the focus of both papers is not pre-announcement returns. Mueller, Tahbaz-Salehi, and Vedolin (2017) find abnormal returns in interest-rate-sorted currency portfolios before

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.

So far, the predominant explanation for the pre-announcement drift in the literature is some form of information leakage. 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. They suggest that information is leaked from the Federal Reserve and that the Fed's rate decisions have been unexpectedly dovish; hence, the leaked information, which on average is supportive of stock market, tends to leads to a stock market rally pre-announcement. Ai and Bansal (2018) and Wachter and Zhu (2018) provide theoretical explanations for the *announcement-day* return patterns, although their theories imply that there should not be any abnormal pre-announcement return. Therefore, Ai and Bansal (2018) and Wachter and Zhu (2018) also informally invoke and discuss the idea that information is leaked pre-announcement. Recently, Jiang, Pan, and Qiu (2019) formally model informed trading ahead of FOMC and macroeconomic announcements under the standard rational expectation equilibrium (REE) framework. As information is incorporated into prices by trading, a pre-announcement premium is realized. In the data, however, Bernile, Hu, and Tang (2016) and Kurov, Sancetta, Strasser, and Wolfe (2017) find no evidence of informed trading on the day before FOMC and macroeconomic announcements.[10] Because substantial positive stock returns are realized on the day before the announcements and because there is little evidence of abnormal pre-announcement returns in Treasuries securities, the nature of information leakage, if it were present, must be subtler than information about the FOMC's interest rate decision itself. In addition, if the leakage is about the announcement itself, accompanying the abnormal return before the announcement, we should also see abnormal price volatility, which is not supported by data.

In contrast to leaks (about asset fundamentals), we propose the resolution of uncertainty as an alternative explanation for the pre-announcement drift. As explained above, the source of uncertainty could be orthogonal to asset fundamentals, and we model it as the variance of returns. Our simple model delivers the qualitative patterns of risks and returns pre- and

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and after FOMC announcements, although the pre-FOMC returns are larger in magnitude.

[10]These two papers find evidence consistent of informed trading about 30 minutes before scheduled announcements. In particular, Bernile, Hu, and Tang (2016) find evidence of informed trading during the embargo period before FOMC announcements, but they "find no evidence of informed trading prior to the start of FOMC news embargoes or during lockups ahead of nonfarm payroll, US Producer Price Index, and gross domestic product data releases." Kurov, Sancetta, Strasser, and Wolfe (2017) find that "nine of the 20 [macroeconomic] announcements that move markets show evidence of substantial informed trading before the official release time. Prices begin to move in the 'correct' direction about 30 minutes before the release time.

post-announcements observed in the data. The hump-shaped pattern of VIX around FOMC announcement is direct evidence of heightened uncertainty and its resolution. Our model, however, does require information arrival in resolving this uncertainty, and it is silent on the exact nature of this information and how it arrives to the market.[11]

Bauer, Lakdawala, and Mueller (2019) use the standard deviation of LIBOR as a proxy for monetary policy uncertainty, and they find that this measure of uncertainty declines substantially on the day of FOMC announcements and then gradually increases over the subsequent two weeks between FOMC meetings, a pattern qualitatively similar to VIX. While the empirical proxies of uncertainty differ, their evidence and ours both point to the resolution uncertainty as a possible explanation for the pre-FOMC announcement drift.

Finally, 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 horizon, by the variance risk premium (Bollerslev, Tauchen, and Zhou (2009) and Zhou (2018)) and simple variance swap (Martin (2017)). Bailey, Zheng, and Zhou (2014) and Fernandez-Perez, Frijns, and Tourani-Rad (2017) analyze high-frequency behavior of VIX, although their focus is not on expected equity returns. We find that a sufficiently large spike-up in daily VIX is already a strong predictor of positive equity returns on the next day.

2. Data

We use several data sources in our analysis. 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) to identify the actual news release time, and extend the sample period to May 2018.

We focus most of our analysis on the sample period from September 1994 to May 2018.

[11] Han (2018) models investors' dynamic learning about the asset fundamental and shows that the marginal value of learning is positively related to the risk-neutral variance of the asset fundamental, which is akin to heightened VIX. Laarits (2018) hypothesizes that the nature of each FOMC announcement depends on the state of the economy (good or bad), which is observed by investors before the announcement. In both models, there is still one source of risk (the fundamental), and contemporaneous return volatility would show up as investors receive the new information.

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
ΔVIX	-0.58	1.6	-13	4.5	190	0.02	1.6	-17	20	5780
ΔVol	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
ΔVIX	-0.43	1.5	-13	4.5	259	0.01	2.2	-66	114	7900
ΔVol	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. ΔVIX is the daily changes of the CBOE VIX index; and ΔVol 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.

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 hour and 45 minutes earlier than usual 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 inferred policy decisions through Fed's open market operations, usually on the day

after the FOMC meeting, with one exception in our sample period.[12]

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, relative to the last transaction price of the same contract before time t_1.[13] 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 the 5-minute frequency, 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 noise introduced by after-hour trading. 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 trading day. Since the standard S&P 500 futures data that we obtained from the CME do not 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.

[12] As 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.

[13] We 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.

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 five minutes before the news release, this pre-announcement window captures the market movement in anticipation of the FOMC announcements and 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.[14] 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

[14]Given that most of the macroeconomic data releases occur outside regular trading hours, the 24-hour window adopted by Lucca and Moench (2015) would involve measuring returns using two "illiquid" prices that are recorded outside regular trading hours.

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.

do not believe that the weaker pre-FOMC drift in the more recent period is a result of this "anomaly" being arbitraged away.[15]

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 FOMC days.[16] 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 reasons, we focus on the performance of the S&P 500 index before the release of other major 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 an 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.[17] 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 on the previous trading day to five minutes prior to the exact time of

[15]The weaker FOMC drift during the recent period is also documented in Gilbert, Kurov, and Wolfe (2018). Lucca and Moench (2018) show that if one focuses on FOMC announcements that are followed by a press conference, the pre-FOMC drift remains significantly positive. Detailed results for the sample period after 2011 are available upon request.

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

[17]The announcement times for CSI are based on the time-stamp of Bloomberg.

these macroeconomic announcements.[18] 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 NFP, 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; and 9.1 basis points for ISM with a t-value of 2.10. These drifts are robust to potential outliers. After removing the top 1% highest returns and the bottom 1% lowest returns, the average drift is 9.8 basis points for NPF, 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.[19] Significant drift only exists for the pre-announcement window. The average market returns after macroeconomic news releases are not significant for all such 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 time window over which the pre-announcement drift takes place, namely, between the close of the previous day and a few minutes before the actual announcement. Their choice of the time window for macroeconomic data release may 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),

[18]Due 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.

[19]The 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 GPD announcements, and 4 pm to 9:55 am for ISM announcements.

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.[20]

Ai and Bansal (2018) also investigate the pre-announcement returns before the release of non-FOMC macroeconomic news and conclude that the pre-announcement drift is present only for FOMC announcements, but not for other macroeconomic announcements. They reach this conclusion by combining the four non-FOMC announcements (NFP, GDP, ISM, and PPI) together and focusing on the hourly returns over the last five regular trading hours before the announcement. Several factors may contribute to the insignificant results documented in Ai and Bansal (2018), but the most important factor is how the pre-announcement window is defined and how the pre-announcement return is measured in their paper. Unlike the FOMC announcements, which occur mostly around 2:15 pm, the release time for NPF, GDP, and PPI is at 8:30 am, one hour before the 9:30 am market open, and the release time for ISM is at 10 am, half hour after the market open. As such, the pre-announcement window for these macroeconomic indicators falls mostly under non-regular trading hours. The last five regular trading hours before the announcement might be too narrow to capture the full risk premium associated with the resolution of uncertainty. Indeed, using the same data source as Ai and Bansal (2018) and adopting their approach of combining the four non-FOMC macroeconomic indicators, we find that the average return over our definition of the pre-announcement window (from 4 pm on the previous day to 5 minutes before the announcement) is 11 basis points with a significant t-value of 3.81.[21]

Overall, our evidence reveals that the pre-FOMC drift is not unique and there is significant pre-announcement drift for other major macroeconomic announcements as well. Compared with that for FOMC, the magnitude of pre-announcement drift is smaller for the other macroeconomic indicators, which could be explained 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, the FOMC announcement is unique in that it is made in the afternoon, while many macroeconomic announcements are released either before or near the open of the regular trading hours. As such, the pre-announcement window for the non-FOMC indica-

[20]Lucca 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.

[21]Ai and Bansal (2018) use the S&P 500 SPDR, an exchange-traded fund, to measure pre-announcement returns. Compared with E-mini S&P 500 futures, this market is much less liquid, especially in the early sample period.

tors is largely made up of non-regular trading hours. The lack of liquidity in the after-hours market may also contribute to the weaker and 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 (past) transaction prices, the information contained in VIX is considered to have a risk aversion component and is also believed to be forward looking.[22] For these reasons, the VIX index is a reasonable proxy 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 average of VIX is 19.84%. The main variable in this section is the time-series of daily changes in VIX,

$$\Delta \text{VIX}_t = \text{VIX}_t - \text{VIX}_{t-1} \,.$$

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 heightened 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

[22] See, 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.

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

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

where

$$\mu_{t-1} = \lambda\,\mu_{t-2} + (1-\lambda)\,\text{VIX}_{t-1}\,,$$

with λ serving as the decay factor. When $\lambda = 0$, the simple version of daily change in VIX, $\text{VIX}_t - \text{VIX}_{t-1}$, 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 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 at 4:15 pm, 15 minutes after the close of the cash market at 4 pm.[23] 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

[23]Using 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 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 $\lambda = 0$				**1986-2018** $\lambda = 0.3$				**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 $\lambda = 0$				**1994-2018** $\lambda = 0.3$				**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 $\text{VIX}_t - \mu_{t-1} \geq \text{Cutoff}$, where $\mu_{t-1} = \lambda\,\mu_{t-2} + (1-\lambda)\,\text{VIX}_{t-1}$, 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.

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

Cutoff (%)	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
	3:30 pm			**3:45 pm**			**4 pm**			**Close**		
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 heigtened 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%.

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 bear the market risk. Only on the next day, when the heightened uncertainty is resolved (or partially 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 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

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 coverted 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 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.[24]

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

[24]Indeed, 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).

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.

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

	Event Days						**All Days**
	FOMC 95-17	NFP 98-17	GDP 98-17	ISM 95-17	HVIX 95-17	HVIX 86-17	SPX 95-17
Avg Return (%)	2.24	1.35	0.78	1.23	5.17	3.71	9.61
	[3.68]	[4.47]	[3.47]	[1.82]	[2.83]	[2.62]	[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	-1.71	-0.73	0.73	-0.08	0.12	-13.09
	[-2.59]	[-1.06]	[-0.68]	[0.68]	[-0.09]	[0.04]	[-2.64]
SPX Ret (%)	0.01	0.03	0.02	0.03	-0.01	0.06	-0.07
	[0.48]	[1.27]	[1.05]	[1.65]	[-0.84]	[1.68]	[-0.87]
VIX (%)	**0.34**	0.13	**0.10**	-0.01	0.04	0.06	**0.95**
	[4.21]	[1.49]	[1.99]	[-0.12]	[0.89]	[0.39]	[4.26]
HVIX Ret (%)		**0.22**		**0.10**	0.01	-0.12	
		[3.68]		[2.63]	[0.34]	[-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.

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 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 heightened 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.

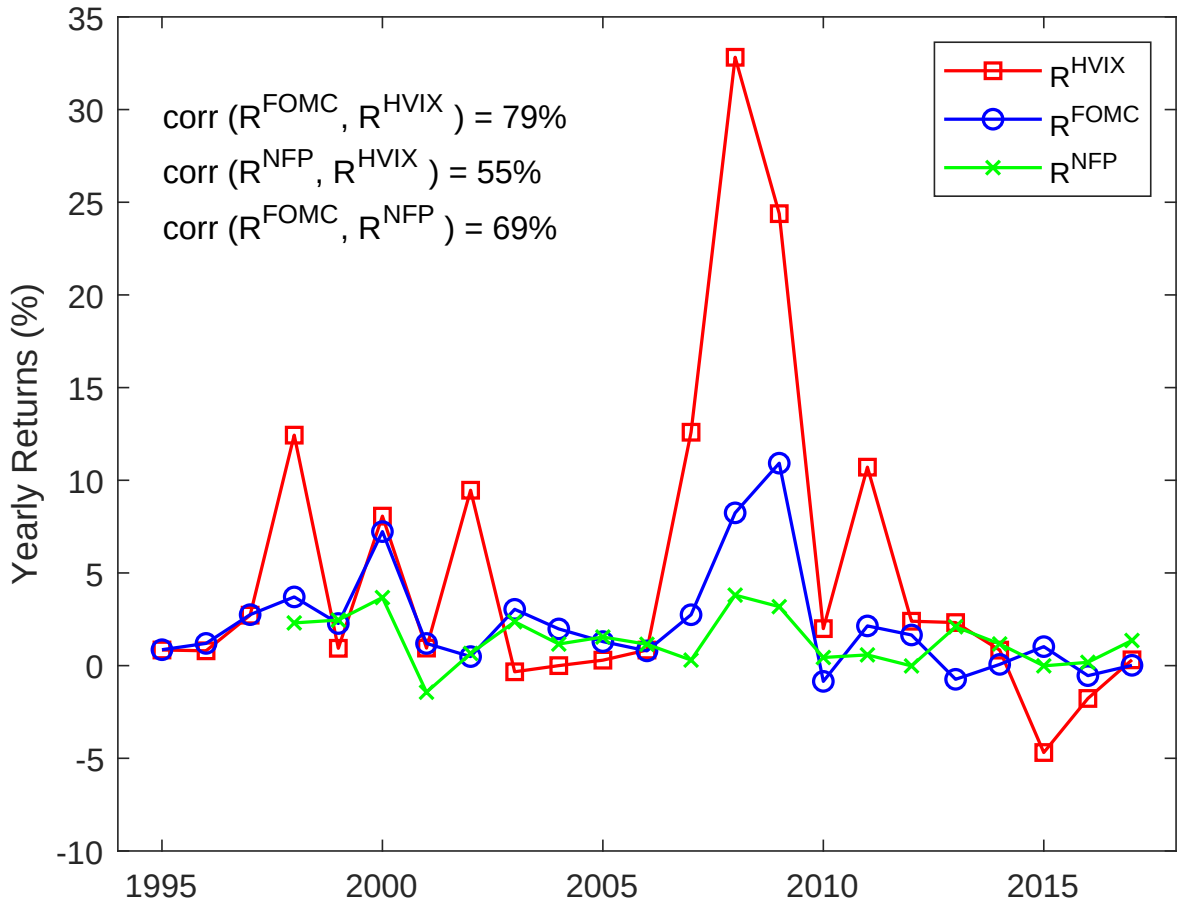

Figure 1: Time-series of yearly S&P 500 index returns realized pre-announcement on event days. For FOMC and NFP (Nonfarm Payroll), the pre-announcement returns realized within each calendar year are used to calculate the respective yearly returns. For HVIX (heightened VIX), the next-day returns after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

3.4.2. Comparison in Mechanism: Build-up and Release of Heightened 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. In the case of heightened VIX, uncertainty as proxied by VIX increases quickly and then dissolves. Coupled with this pattern of initial build-up and later release of uncertainty, there is an initial decrease

and then increase in return. These patterns of reversal in VIX and return provide a direct mechanism over which the premium for heightened uncertainty arises. In particular, it is the resolution of uncertainty that gives rise to the significant increase in price; it is also the initial spike up in uncertainty that gives rise to the initial decrease in price. Completing the circle, the large increase in price is in fact a reversal of the initial price depression. Inspired by these observations, we argue in this section that the same mechanism applies in the case of FOMC.

To draw a direct comparison between these two cases, we plot in Figure 2 patterns in cumulative returns and VIX for FOMC (in the upper panels) and heightened VIX (in the lower panels). Tables 8 and 9 provide additional evidences of the patterns in VIX and return surrounding the event days. We label the event day as Day 0, when the resolution of uncertainty occurs. As shown in the upper panels of Figure 2, the resolution of uncertainty occurs in two stages on the FOMC day, before and after the announcement. Our focus is on the first stage which occurs before the announcement. As a parallel to this first stage, we label in the lower panels of Figure 2 the day after the heightened VIX as Day 0. In both cases, we see a clear pattern of significant increase in price coupled with large reduction in VIX. As reported in Table 8, in the FOMC case, the Day-0 reduction in VIX before the announcement is -0.27% with a t-stat of -3.81, compared with the Day-0 reduction in VIX of -1.15% with a t-stat of -4.61 for the case of heightened VIX. As reported in Table 9, in the FOMC case, the Day-0 increase in price (relative to the non-FOMC days) before the announcement is 26 basis points with a t-stat of 5.47, compared with the Day-0 increase in price of 56 basis points with a t-stat of 3.54.

A more instructive comparison is what happens prior to Day 0. In the case of heightened VIX, the substantial increase in VIX on Day -1 helps us identify the days of heightened uncertainty. What happens over one day in the case of heightened VIX might take many days to develop in the case of FOMC since investors are aware of the announcement well in advance and can plan accordingly. 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. As shown in Table 8, over the window from Day -6 through Day -1, the average build-up in VIX leading up to the FOMC day is 0.60% with a t-stat of 2.60. 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 to the 6.50% build-up picked up by the heightened VIX (HVIX) dummy. This is not surprising because, by construction, the heightened VIX days are days when investors are caught off guard by the 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

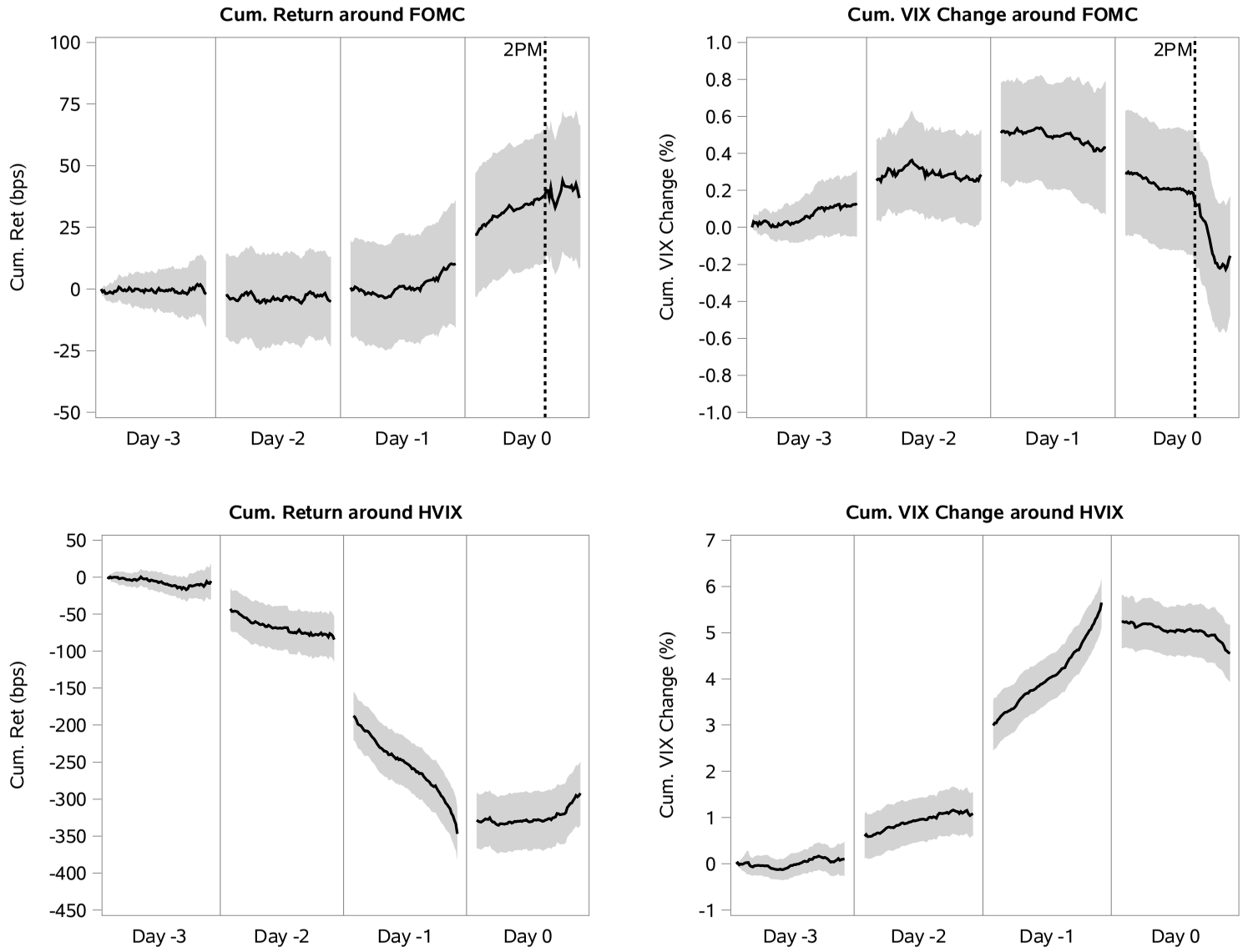

Figure 2: Cumulative VIX Change and Return around FOMC and HVIX Days.

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	**-0.26**	0.00	-0.01	**-0.23**	0.00	0.02	**0.10**	**0.04**	**0.05**
	[0.02]	[-0.23]	[-3.87]	[0.02]	[-0.32]	[-5.74]	[0.01]	[1.10]	[4.53]	[2.90]	[3.38]
FOMC Days		**0.60**	**0.59**		**0.48**	**0.47**		**-0.60**	**-0.62**		**-0.27**
		[2.60]	[2.85]		[2.52]	[2.94]		[-5.02]	[-5.35]		[-3.81]
Matched			0.11			0.28			**-0.30**		
			[0.60]			[1.82]			[-3.04]		
NFP			0.10			-0.11			**-0.42**		
			[0.69]			[-0.83]			[-4.28]		
GDP			0.00			-0.01			-0.21		
			[0.01]			[-0.04]			[-1.93]		
ISM			0.22			0.20			-0.03		
			[1.22]			[1.55]			[-0.23]		
HVIX			**6.50**			**6.04**			**-1.15**		
			[12.57]			[18.49]			[-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.

Table 9: **SPX Returns Surrounding FOMC Announcements**

	Cum Days [−6 −2]			Day -1			Day 0			Day 0, Before Ann	
Intercept	**17.58**	**17.99**	**22.80**	**3.59**	**3.21**	**13.11**	**3.61**	2.72	-1.61	1.92	1.10
	[3.12]	[3.18]	[4.12]	[2.65]	[2.32]	[9.02]	[2.66]	[1.95]	[-1.00]	[1.67]	[0.92]
FOMC Days		-12.92	-10.89		11.89	12.51		**27.76**	**28.79**		**26.04**
		[-0.74]	[-0.62]		[1.19]	[1.40]		[3.29]	[3.45]		[5.47]
Matched			-6.80			-0.77			**25.30**		
			[-0.40]			[-0.10]			[3.43]		
NFP			19.09			-1.80			10.64		
			[1.56]			[-0.30]			[1.44]		
GDP			-19.50			1.42			7.64		
			[-1.29]			[0.20]			[0.93]		
ISM			1.64			-7.58			**18.09**		
			[0.12]			[-1.28]			[2.21]		
HVIX			**-148**			**-281**			**56.10**		
			[-4.03]			[-23.04]			[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**	**30.48**	**30.48**	**57.22**	**57.22**	**57.22**	**3.60**	**3.60**	**3.60**
	[3.84]	[3.31]	[3.71]	[4.32]	[3.82]	[4.18]	[2.62]	[2.48]	[2.47]
VIX_{t-1}	**3.12**		2.65	**4.13**		**3.51**	0.49		0.27
	[2.07]		[1.39]	[3.05]		[2.72]	[1.47]		[0.81]
VIX_{t-1}-VIX_{t-7}		6.19	4.31		7.03	4.34		**2.95**	**2.81**
		[1.04]	[0.67]		[1.76]	[1.11]		[3.59]	[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 (in basis points) 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.

uncertainty.[25]

3.4.3. Comparison in Return Predictability

In both cases, large risk premiums are captured using predictive information. In the case of heightened VIX, the predictive signal is the change in VIX, and in the case of FOMC, the knowledge of the event day itself is the signal. In this section, we view these results from the angle of predictive regression. We argue that to predict returns across all days, it is the information contained in heightened uncertainty, as proxied by cumulative changes in VIX, that is useful, further strengthening the link between the premium and the risk.

In Table 10, daily returns on the S&P 500 index are regressed on lagged VIX and lagged cumulative changes in VIX:

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

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

[25]It is interesting to note that the overall change in VIX on the FOMC day is -0.60%, on par with the long build-up of 0.60% in VIX prior to Day 0. The change in VIX on Day 0 before the announcement is -0.27%, which accounts for half of the Day 0 reduction in VIX.

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.

3.4.4. 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 basis points lower than the full-sample average, but it is statistically insignificant.

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%

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.

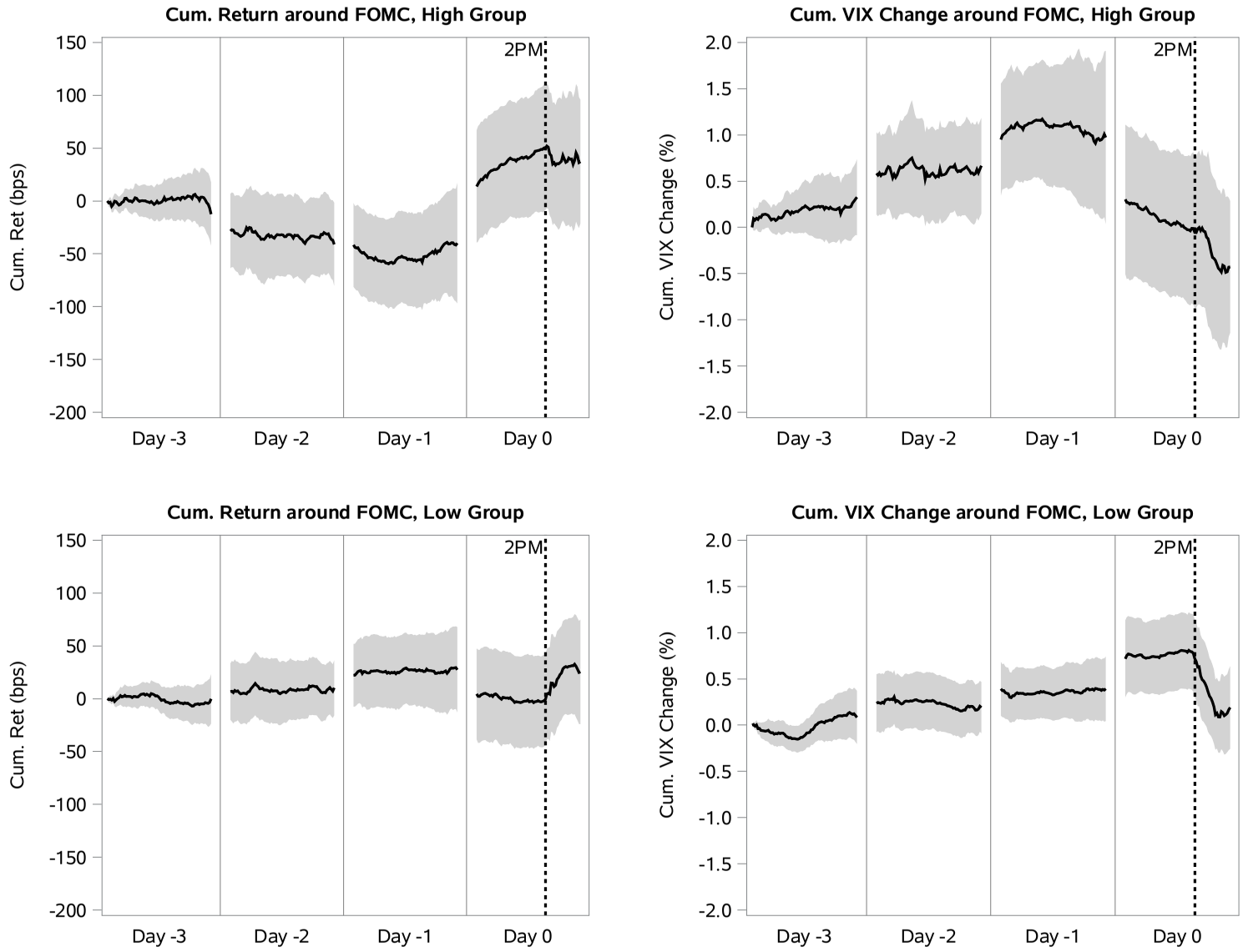

Figure 3: Cumulative VIX Change and Return around High and Low FOMC Days.

in VIX, but the post-announcement return is insignificant.[26] 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.

4. An Illustrative Model

In this section, we construct a simple asset pricing model, which captures two types of risks. One risk is about the asset's payoff, as measured by its variance, and the other risk is about the size of the variance (that is, payoff variance is uncertain). The resolution of these two risks can occur at different times. The intertemporal resolution of these two risks leads to positive expected returns, or risk premia, as well as price volatility, respectively. We demonstrate that the resolution of heightened uncertainty followed by the resolution of payoff itself can generate the return and volatility pattern similar to those around the times of FOMC and other macroeconomic announcements as well as times of sharp rises in VIX.

Setup

Consider an economy with three dates, $t \in \{0, 1, 2\}$. There is a unit mass of identical, infinitesimal, and competitive investors, who are endowed with zero unit of a riskless bond and one share of a risky asset, also referred to as the stock. Each unit of the bond yields a terminal payoff of 1 at $t = 2$. Each share of the stock pays a terminal dividend D at $t = 2$, where D has a normal distribution with mean $\bar{D}$ and variance σ_D^2. It is further assumed that the variance σ_D^2 is a random variable, following an exponential distribution with a mean of λ, where $\lambda > 0$. The variance σ_D^2 and the actual dividend $D$are independent random variables.

In the context of this paper, we can also write $D = \sigma_D \varepsilon$, where ε, a standard normal, captures the realization of market-moving news and σ_D captures its impact on asset fundamentals, which is uncertain ex ante. Heightened uncertainty prior to a news is represented

[26]We 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.

by a high ex ante variance of σ_D. The resolution of this uncertainty can occur before the realization of ε, the news itself.

Let $\mathrm{E}[\cdot]$ and $\mathrm{V}[\cdot]$ denote the mean/expectation and the variance of a random variable, respectively. We then have:

$$\mathrm{E}[\sigma_D^2] = \lambda, \qquad \mathrm{V}[\sigma_D^2] = \lambda^2. \tag{1}$$

Thus, a larger value of λ corresponds to a higher unconditional mean and variance of σ_D^2.

At $t = 0$, investors observe neither σ_D^2 nor D. At $t = 1$, investors observe σ_D^2 but not D. At $t = 2$, D is realized.

Both the bond and shares of the stock are traded in a competitive financial market, at dates 0, 1 and 2. We will use the bond as the numeraire and denote the price of the stock at date t as S_t, $t \in \{0, 1, 2\}$. (Since the bond is the numeraire, its price is always one and its return is always zero.)

The time line for the economy is summarized as follows:

$t = 0$**:** Investors observes neither σ_D^2 nor σ_D^2. Based on the probability distributions of σ_D^2 and D, they trade the risky asset (against the bond) by submitting competitive demand functions.

$t = 1$**:** Investors observe σ_D^2 but still not D. With the resolution of uncertainty about variance, they trade in the market again, with competitive demand functions.

$t = 2$**:** The dividend D is paid on the stock and investors consume their terminal wealth.

In addition, we assume that all investors have CARA utility over their terminal wealth:

$$-\exp\{-\alpha W_2\}, \tag{2}$$

where $\alpha > 0$ is the risk aversion coefficient and W_2 is the wealth at $t = 2$.

Furthermore, for the model to be well-defined, as seen later, the following parameter condition is needed:

$$\lambda < \frac{2}{\alpha^2}. \tag{3}$$

Since both the mean and variance of σ_D^2 are increasing in λ, condition (3) imposes upper bounds on both of them.

Several comments are in order before moving forward. First, our model is intentionally simple, aimed at capture two important risks, news risk and the uncertainty about its market impact, and their intertemporal resolution. Our main goal is to show qualitatively how such

a simple model can lead to the possible return and volatility dynamics observed in the data. One can extend it into a fully intertemporal model to allow richer dynamics for the two risks. Second, since we mainly care about the price implications of the model, we have abstracted away from potential heterogeneity among investors and the actual trading among themselves. It is fairly straightforward to allow different types of heterogeneity, such as heterogeneous endowment shocks or signals on σ_D^2, but still obtain similar pricing implications. Third, assumptions on probability distributions and investors' preferences are made mainly for tractability. Thus, our results are not meant to be robust but only illustrative.

Equilibrium

We solve the model backwards. Because investors are all identical, we can solve the problem of a generic investor, without loss of generality. We denote by W_t the wealth of a generic investor at the end of date t, and denote by θ_t the investor's demand of the risky asset at date-t trading.

Solution for date 1. A generic investor's consumption at date 2 is:

$$W_2 = W_1 + \theta_1(D - S_1). \tag{4}$$

At date 1, the final dividend D is normally distributed with a known variance σ_D^2. So the investor's problem is:

$$\max_{\theta_1} \; J_1, \tag{5}$$

where

$$\begin{aligned} J_1 &= -\mathrm{E}\left[\exp\left\{-\alpha\left[W_1 + \theta_1(D - S_1)\right]\right\}\right] \\ &= -\exp\left\{-\alpha\left[W_1 + \theta_1(\bar{D} - S_1) - \tfrac{1}{2}\alpha\sigma_D^2\theta_1^2\right]\right\}. \end{aligned} \tag{6}$$

The investor's demand function is then given by:

$$\theta_1 = \frac{\bar{D} - S_1}{\alpha\sigma_D^2}. \tag{7}$$

From the market clearing condition $\theta_1 = 1$, the equilibrium stock price is:

$$S_1 = \bar{D} - \alpha\sigma_D^2. \tag{8}$$

Solution for date 0. Substituting the date-1 equilibrium strategies into J_1, we get:

$$J_1 = -\exp\left\{-\alpha\left[W_0 + \theta_0(\bar{D} - \alpha\sigma_D^2 - S_0) + \tfrac{1}{2}\alpha\sigma_D^2\right]\right\}, \tag{9}$$

where we have also used $W_1 = W_0 + \theta_0(S_1 - S_0)$.

Recall that at $t = 0$, investors have an exponential probability distribution over σ_D^2 with mean λ and variance λ^2. So the investor's expected continuation value is:

$$\begin{aligned} J_0 = \mathrm{E}[J_1] &= -\int_0^\infty e^{-\alpha[W_0 + \theta_0(\bar{D} - \alpha x - S_0) + \frac{1}{2}\alpha x]} \frac{1}{\lambda} e^{-x/\lambda} dx \\ &= -e^{-\alpha W_0 - \alpha\theta_0(\bar{D} - S_0)} \frac{1}{1 + \left(\frac{1}{2} - \theta_0\right)\alpha^2\lambda}, \end{aligned} \tag{10}$$

under the technical condition that $1 + \left(\frac{1}{2} - \theta_0\right)\alpha^2\lambda > 0$, which guarantees the convergence of the integral. It should be pointed out that for $\theta_0 = 1$, which holds in equilibrium, this condition is the same as the parameter condition in equation (3). Taking the first-order derivative, we then have:

$$\frac{dJ_0}{d\theta_0} = -e^{-\alpha W_0 - \alpha\theta_0(\bar{D} - S_0)} \frac{1}{1 + \left(\frac{1}{2} - \theta_0\right)\alpha^2\lambda} \left[\frac{\alpha^2\lambda}{1 + \left(\frac{1}{2} - \theta_0\right)\alpha^2\lambda} - \alpha(\bar{D} - S_0)\right]. \tag{11}$$

Hence, if $\bar{D} - S > 0$, which is verified in equilibrium, $\frac{dJ_0}{d\theta_0}$ is positive if and only if $\theta_0 < \frac{1}{2} + \frac{1}{\alpha^2\lambda} - \frac{1}{\alpha(\bar{D} - S_0)}$. The optimal demand is:

$$\theta_0 = \tfrac{1}{2} + \frac{1}{\alpha^2\lambda} - \frac{1}{\alpha(\bar{D} - S_0)}. \tag{12}$$

The market clearing condition $\theta_0 = 1$ then implies:

$$S_0 = \bar{D} - \frac{\alpha\lambda}{1 - \frac{1}{2}\alpha^2\lambda}. \tag{13}$$

The following proposition summarizes the equilibrium stock prices.

Proposition 1 *Suppose that condition* (3) *holds. The stock price at date 0 is given by* (13) *and the price at date 1 is given by* (8)*.*

Return and Volatility

An immediate implication from the model is that there is a positive return or risk premium realized from the stock at date 1:

$$\mathrm{E}[S_1 - S_0] = \frac{\alpha\lambda}{1 - \frac{1}{2}\alpha^2\lambda} - \alpha\mathrm{E}[\sigma_D^2] = \alpha\left(\frac{\lambda}{1 - \frac{1}{2}\alpha^2\lambda} - \lambda\right) > 0, \tag{14}$$

where we have used the fact that the random variable σ_D^2 has a mean of λ. The associated return variance at date 1 is:

$$\mathrm{V}[S_1 - S_0] = \alpha^2\mathrm{V}[\sigma_D^2] = \alpha^2\lambda^2. \tag{15}$$

Likewise, the price drift and variance at date 2 are:

$$\mathrm{E}[S_2 - S_1] = \mathrm{E}[D - \bar{D} + \alpha\sigma_D^2] = \alpha\lambda, \tag{16}$$

$$\begin{aligned}\mathrm{V}[S_2 - S_1] &= \mathrm{E}[(S_2 - S_1)^2] - [\mathrm{E}[S_2 - S_1]]^2 = \mathrm{E}[(D - \bar{D} + \alpha\sigma_D^2)^2] - \alpha^2\lambda^2 \\ &= \mathrm{E}[\sigma_D^2 + \alpha^2\sigma_D^4] - \alpha^2\lambda^2 = \lambda + \alpha^2\lambda^2.\end{aligned} \tag{17}$$

The following proposition summarizes the return and volatility on the stock in the two dates.

Proposition 2 *Suppose that condition* (3) *holds. The date-1 return is higher than the date-2 return, i.e.,* $\mathrm{E}[S_1 - S_0] > \mathrm{E}[S_2 - S_1]$*, if and only if* $\lambda > \frac{1}{\alpha^2}$*. The date-1 variance is always lower than the date-2 variance, i.e.,* $\mathrm{V}[S_1 - S_0] < \mathrm{V}[S_2 - S_1]$*.*

Interpreting the Empirical Results Using the Model

In the context of our empirical evidence, a natural way to interpret the model is that date 2 corresponds to an important news event such as the FOMC announcements or macroeconomic announcements, which reveal important information about the economy's fundamentals, as captured by D. Prior to the event, there is a heightened uncertainty regarding this event, as captured by the uncertainty about σ_D^2. In our model, this uncertainty about variance is resolved ahead of the announcement, say at date 1. The resolution of this variance uncertainty can generate a significant positive pre-announcement drift, in absence of substantial payoff news or price volatility.

In the data, the FOMC announcement exhibits the highest pre-announcement drift, followed by non-farm payroll, GDP, and ISM, whereas other macroeconomic announcements have statistically insignificant pre-announcement drift. In the model, a larger λ corresponds to a higher uncertainty about the variance of post-announcement payoffs. So we could

interpret the FOMC announcement as having a largest λ, followed by non-farm payroll, GDP, and ISM.

Focusing on FOMC announcement, the data also show that post-announcement returns are not statistically significant. This is perhaps not surprising. Proposition 2 shows that post-announcement returns are always noisier than pre-announcement returns, and the difference, λ, is larger if the uncertainty about return variance is higher. Moreover, Proposition 2 shows that for $\lambda > \frac{1}{\alpha^2}$, the pre-announcement return is always higher than its post-announcement counterpart, and so is the Sharpe ratio.

In the case of VIX spike, we can apply the model similarly. An increase in VIX corresponds to an increase in λ or the uncertainty about σ_D^2 in the model. We will then see a positive return as the uncertainty about σ_D^2 resolves, accompanied by relatively low return volatility. In this case, the VIX spike is stochastic, different from the case of announcements with deterministic timing, and the resolution of the fundamental risk (i.e., about D) is gradual over time, not within a given time frame.

Although our model is overly simplified, it can be extended into a richer intertemporal model with more dimensions including investor heterogeneity, learning and information asymmetry. These extensions may lead to additional testable implications to shed more light on the nature of the underlying uncertainty and its resolution mechanism that are driving the price patterns.

5. Conclusions

Our results provide compelling evidence that the FOMC days are not unique in yielding the disproportionately large returns. 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. When viewed from the perspective of heightened uncertainty, the FOMC puzzle is not really a puzzle, but a manifestation of risk and return trade-off in an environment of time-varying uncertainty.

In addition to providing a compelling explanation to the FOMC puzzle, our paper also adds to the growing literature on the pre-announcement returns by documenting, for the first time, economically and statistically significant pre-announcement returns for the pre-scheduled releases of macroeconomic indicators such as total nonfarm payroll employment (NFP), the advance and final releases of GDP, and the Institute for Supply Management's manufacturing index (ISM).

We provide further evidence on heightened uncertainty and its asset pricing implications

by showing that, in addition to pre-scheduled announcements such as FOMC and NFP, heightened uncertainty can also be triggered unexpectedly by adverse market conditions. Using the CBOE VIX index as a proxy, we find disproportionately large returns on days following large increases in VIX. Akin to the FOMC result, such heightened-uncertainty days occur on average only eight times per year, but account for more than 30% of the average annual return on the S&P 500 index. While important in its own right, our results on heightened VIX offer further insight on the mechanism over which the FOMC risk premium arises. Inspired by this result, we search for direct evidence of heightened uncertainty using VIX as a proxy, and show for the first time in the literature the presence of a gradual but significant build-up in VIX over a window of up to six business days prior to the FOMC announcement.

Finally, we formalize the idea of heightened uncertainty using a simple model, in which the asset fundament is revealed at the announcement but the variance of asset returns is observed before that. The resolution of uncertainty about return variance leads to a positive risk premium, but it need not be accompanied by high volatility. We provide parameter conditions under which the pre-announcement period has a higher mean return and yet a lower volatility than the post-announcement period.

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