

Premium for Heightened Uncertainty: Explaining Pre-Announcement Market Returns

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

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Abstract

We show that the pattern of positive pre-announcement market drift is present not only for FOMC announcements, as documented by Lucca and Moench (2015), but also for other major macroeconomic announcements such as Nonfarm Payroll, ISM and GDP. This commonality in pre-announcement returns leads us to hypothesize that there are two kinds of risks associated with pre-scheduled macroeconomic announcements. The first risk arises from the uncertain content of the news itself and is directional in nature, while the second risk is associated with the “heightened uncertainty” in anticipation of a pre-scheduled announcement, relating in particular to its potential market impact. Theoretically, we show that it is the resolution of this second risk prior to an announcement that leads to the positive pre-announcement drift. Moreover, our model shows that this second risk can be captured by VIX and the positive pre-announcement drift occurs in the absence of increases in conventional risk measures. We further provide direct evidence on the heightened uncertainty and its later resolution prior to the macroeconomic releases including FOMC. In addition to the pre-scheduled announcements, heightened uncertainty can also be triggered unexpectedly. Indeed, we find abnormally large returns on days following large spike-ups in VIX, with magnitudes comparable to the pre-announcement returns.

Keywords: Pre-Announcement Drift, FOMC, Macroeconomic Announcements, Heightened Uncertainty, VIX

JEL Classification: G12, G14

*Hu (hux@pbcfs.tsinghua.edu.cn) is from PBC School of Finance at Tsinghua University; Pan (junpan@saif.sjtu.edu.cn) is from Shanghai Advanced Institute of Finance at Shanghai Jiao Tong University, CAFR and NBER; Wang (wangj@mit.edu, corresponding author) is from Sloan School of Management at MIT, CAFR, and NBER; Zhu (zhuh@mit.edu) is from Sloan School of Management at MIT and NBER. An earlier draft of this paper was circulated under the title “Premium for Heightened Uncertainty: Solving the FOMC Puzzle.” We are grateful to Brad Barber, Ricardo Caballero, Peter Carr, Zhanhui Chen, Darrell Duffie, Valentin Haddard, Toomas Laarits, David Lucca, Ian Martin, Annette Vissing-Jorgensen, Jessica Wachter for valuable discussions. We also thank seminar participants at the 2019 NBER Asset Pricing Program Spring Meeting, the 2019 ABFER Annual Meeting, the 2019 Eastern Conference on Financial Mathematics, the 2020 AFA annual meeting, Tsinghua University, Shanghai Jiao Tong University, Peking University, Chinese University of Hong Kong, Cheung Kong Graduate School of Business, Southern Methodist University, Dartmouth College, and Federal Reserve Board for comments. We thank Meiling Chen and Zhe Geng for research assistance.

1. Introduction

In a recent paper, Lucca and Moench (2015) find that over the 24-hour time 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 from 1994 to 2013, more than ten times the daily average return of 4 basis point on the same index. Moreover, by conventional measures of risk—return volatility, skewness, kurtosis, etc.—markets exhibit no additional risk during this period. The implication of these striking results in the asset pricing context very much depends on whether they are special to FOMC or part of a more general phenomenon.

We start our analysis by examining in detail equity returns ahead of other macroeconomic announcements.¹ In order to properly capture the pre-announcement returns, we define the pre-announcement period to be from the market close (4 pm) of the previous day to 5 minutes before the scheduled release of the macroeconomic news, including FOMC. Since most of these releases occur before or near the market open (e.g., 8:30, 9:15 or 10:00am), we use index futures, which are traded overnight, to obtain the market return over this period as the pre-announcement return. Covering a list of widely followed macroeconomic indicators, we find that Nonfarm Payroll (NFP), ISM, and GDP also exhibit significant positive pre-announcement returns.² Compared with return on non-event days over this time window, which is -0.85 basis points and insignificant, the pre-announcement returns around macroeconomic data releases are both statistically and economically significant: 10.10 basis points for Nonfarm Payroll, 9.14 basis points for ISM, and 7.46 basis points for GDP over the sample period of 1994 to 2018. They are smaller than the pre-FOMC return, which is 27.14 basis points by our measurement over our sample period, but comparable in magnitude.³

Therefore, the pre-announcement market drift is not unique to FOMC. It is also present among other important macroeconomic news. This commonality in pre-announcement re-

¹Lucca and Moench (2015) also looked at nine macroeconomic announcements and found no significant equity return on the day before the announcement, from market close to market close. Since many macro announcements occur early in the morning before trading starts in the equity market, the period immediately before the announcement is the overnight period. The daily returns considered by Lucca and Moench do not include this period, which turns out to be critical in capturing pre-announcement returns.

²Obviously, we do not expect substantial pre-announcement equity returns for all news. Some of them may well be inconsequential for the market, hence deemed unimportant for our purpose. In fact, even for the same indicator, such as FOMC and NFP, we do not always observe pre-announcement returns.

³While Lucca and Moench (2015) also include the 2-hour window from 2 pm to 4 pm (on the day before FOMC), which does contribute to the positive pre-FOMC drift (9.29 basis points with a t-stat of 1.58), we use the market close as the starting point of the pre-announcement window in order to provide a unified framework to examine the pre-announcement returns for other macroeconomic news.

turns suggests a more general and richer risk-return relationship behind the observed return patterns surrounding major macro announcements, including FOMC.

We then hypothesize that the pre-announcement drift is a result of heightened uncertainty prior to the announcement and its resolution. In particular, we propose that market-moving news carries two risks: the first risk is associated with the news realization itself, directional in nature, and the second risk is associated with the potential magnitude of the news' market impact, which we also refer to as uncertainty for distinction.⁴ Each risk carries its own risk premium, yielding a positive price drift when the risk is resolved. If the uncertainty about a news' potential impact is resolved before its actual release, a positive return will be realized, which is separate from the news realization itself. Because this uncertainty is not directly tied to the actual news release, conventional risk measures may not accurately capture the level of this uncertainty. Consequently, we will observe an upward price drift during this period without a higher read in conventional risk measures. However, as we show in Section 6 through a simple model, the VIX index can provide a good measure for the uncertainty.

The risk dynamics proposed above lead to two sets of new predictions. First, there should be a decrease in VIX accompanying the pre-announcement return for important macro announcements (including FOMC, Nonfarm Payroll, ISM, and GDP), reflecting the dissolution of the heightened uncertainty associated with the announcement. Second, prior to the pre-announcement period, there should be an accumulation of uncertainty about the announcement. During this accumulation period, there should be an increase in VIX, accompanied by a downward price drift. We empirically test these predictions and find the evidence to be overall consistent.

Since not all announcements bring the same level of uncertainty, we focus on the announcements yielding the highest 30% pre-announcement returns, which we call the high-return group. This group corresponds to announcements with relatively higher levels of heightened uncertainty. For FOMC, the pre-announcement return is 97.08 basis points for the high-return group, and we observe a drop in VIX by 1.04 percentage points during the same period, both highly significant. Given that the pre-announcement period return is smaller for Nonfarm Payroll, ISM, and GDP compared to FOMC, we pool them together in our tests and refer to them as Macro. For the high-return group of the Macro news, we find a pre-announcement return of 82.97 basis points, together with a drop in VIX of 0.55

⁴Due to the lack of a better terminology, our use of "uncertainty" here is in an intuitive sense and mainly to differentiate from the first type of risk. It does not necessarily imply that we are using it in the sense of Knight (1921) or Savage (1954).

percentage points, both statistically significant. In terms of magnitude, they are comparable to that for FOMC.

The uncertainty concerning an announcement is accumulated over time prior to its dissolution during the pre-announcement period. We consider the window from -6 days to the pre-announcement day (market close to market close) to be this accumulation period. Not knowing the actual length of the accumulation period, which can vary from announcement to announcement, picking such a fixed window inevitably weakens our results. Nonetheless, we find that VIX increases substantially during this accumulation period, accompanied by a significant decrease in price. In particular, for the high-return group of FOMC, VIX increases by 1.88 percentage points while return is -81.80 basis points during the accumulation period. For the high-return group of Macro announcements, the change in VIX is 0.90 percentage points and the return is -40.40 basis points over the accumulation period.

As an additional test to avoid potential bias by looking only at the high-return group, we further use the change in VIX during the accumulation period to forecast the return over the pre-announcement period and find significant results for both FOMC and Macro announcements. For example, an one standard deviation increase in the lagged change in VIX from -3 days to -1 day would result in a 9.15 basis points increase in the pre-announcement return for FOMC announcements. That is, announcements that bring higher level of heightened uncertainty are indeed associated with larger drift at the pre-announcement period. By comparison, lagged VIX changes can not predict future return on Non-Event days that do not have pre-scheduled news releases. These out-of-sample tests provide strong support to the heightened uncertainty explanation of the pre-announcement returns.

Heightened uncertainty can also be triggered unexpectedly by adverse market conditions. As an additional “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 VIX 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 large price drops, as investors anxiously await the next trading day. Akin to the result on scheduled news, we find disproportionately large returns on the S&P 500 index after sudden spikes in VIX. Using data from September 1994 to May 2018, we find that the next-day return is on average 57.22 basis points per day with a t-stat of 3.24.⁵

⁵The average VIX is around 20% on announcement days as well as normal days. By contrast, the average

Overall, these results provide compelling evidence that the pre-announcement returns for macro news releases, including FOMC, Nonfarm Payroll, ISM, GDP, are a manifestation of an 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 Macro 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.

Although we have little direct information about the exact nature of the underlying uncertainty, VIX provides a natural proxy. Our results clearly 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 return/risk premium can be complex. A more coherent model of risk and return is needed in order to explain the observed return patterns rather than a simple static return-risk relationship using conventional risk measures.

To further demonstrate this point, in the last part of the paper, we construct a simple asset pricing model with two risks: the macro news itself, denoted by ε , which is directional (with zero mean), and how much the news will impact asset payoff. We refer to the second risk as uncertainty and denote it by σ , which is always positive but random. The asset payoff D is then given by $D = \sigma \varepsilon$, depending on the realization of both risks. Each risk carries its own premium in equilibrium. If how much the news may impact asset payoff (i.e., σ) is learned before the announcement, then the resolution of this uncertainty will lead to a positive pre-announcement return. Indeed, we show that VIX provides a measure of this uncertainty, which declines together with the pre-announcement return, while the corresponding return volatility, as a common measure of risk, remains low. We show that at high levels of uncertainty, the pre-announcement risk premium is higher and the pre-announcement return volatility is lower than their post-announcement counterparts. The model also implies a heightening of uncertainty as reflected by an increase in VIX and a price drop prior to the realization of high pre-announcement returns. In the paper, we first hypothesize the risk-return dynamics from the model in its reduced form to formulate the testable predictions before our empirical analysis, and return to the formal model at the end.

Despite what the model delivers, we by no means claim that VIX is an accurate measure

VIX is 33% on days after heightened VIX. One might be tempted to explain the next-day average return of 57 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.

of uncertainty in a more general context. It is entirely possible that VIX is merely a partial reflection of some underlying uncertainty when it rises and dissolves.⁶

Although our proposed explanation of the pre-announcement returns is both theoretically and empirically coherent and supported by several sets of “out-of-sample” tests, open questions remain. For example, our empirical analysis does not reveal the precise nature of the uncertainty around announcements, what drives its resolution, and how.⁷ These questions are important but beyond the scope of this paper, especially with the data we have. We 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 presents a reduced form risk-return dynamics surrounding macro news and its testable predictions. Section 3 describes in detail the data we use. Section 4 and Section 5 present our main empirical results and related discussions. Section 6 introduces an illustrative model that can generate the observed risk-return patterns around important macroeconomic announcements as well as VIX hikes. Section 7 concludes.

Relation to the Literature

Our analysis demonstrates three important points in analyzing the risk and return patterns generated by macroeconomic news. First, the risk and return dynamics surrounding these announcements involves three phases/periods, the accumulation period, the pre-announcement period, and the announcement or post-announcement period. The risks concerning an announcement accumulates over the first period and then resolve, possibly separately, over the following two periods. Second, the right choice of the time window for each period is important in order to best capture the corresponding risk and return properties. For example, using windows encompassing different periods may miss or mix the risk and return patterns we want to identify. Third, we need to consider return and risk jointly. In particular, since

⁶For example, Han (2018) shows that VIX squared can emerge as an endogenous measure of uncertainty in a model of dynamic information acquisition and asset prices. Fisher, Martineau, and Sheng (2018) find a positive correlation between VIX and their “macroeconomic attention index” based on news articles at the daily frequency. One can also try to construct other empirical measures of uncertainty. For example, for FOMC, Bauer, Lakdawala, and Mueller (2019) use the standard deviation of LIBOR as a proxy for monetary policy uncertainty, and find this measure of uncertainty declines substantially on the day of FOMC announcements. These explorations are beyond the focus of this paper and left for future work.

⁷Recent evidence about news consumption provides a possible interpretation. Using a dataset on the clicks on news articles, Benamar, Foucault, and Vega (2018) find that investors’ demand for information is stronger when the market’s response to Nonfarm Payroll surprises is larger. Their evidence suggests that high uncertainty leads to more learning by investors, which could be one of the underlying reasons of uncertainty reduction ahead of announcements.

an announcement may involve additional risks in addition to the news realization itself, we need to go beyond the more conventional risk measures.

Lucca and Moench (2015) first document a significant equity return during the 24-hour pre-announcement period before FOMC releases.⁸ We complement their results by showing that pre-announcement return has a broad presence among high-impact macroeconomic news releases. Prior to our paper, Lucca and Moench (2015) and Ai and Bansal (2018) have also examined macroeconomic announcements. But they focused merely on the return over the day prior to the releases and found no pre-announcement returns.⁹ As many of these announcements are made prior or around market opening, both papers have missed the overnight return immediately preceding the news releases. This turns out to be critical. By zooming in on a more precise pre-announcement window, i.e., from 4 pm in the previous day to 5 minutes before the announcement, we do find a robust and economically important pre-announcement drift for Nonfarm Payroll, ISM, and GDP releases.

The commonality of equity premium before FOMC and other important macro announcements calls for a coherent explanation for both. Because the pre-macro-announcement returns have escaped discovery until now, more research has focused on explaining the pre-FOMC return alone, with special attention paid to its unique features. For example, Cieslak, Morse, and Vissing-Jorgensen (2019) propose that information about the Federal Reserve’s “unexpected accommodating” monetary policy is leaked ahead of the FOMC announcement, which causes a pre-announcement equity market rally. Jiang, Pan, and Qiu (2019) propose informed trading ahead of FOMC announcements to deliver a premium as proprietary information is incorporated into prices. While explanations based on leakage and/or informed trading can potentially explain pre-FOMC returns, they face two challenges. First, the leakage story has difficulty in explaining the other side of the phenomenon, the lack of pre-announcement return volatility. If directional news about the market were leaked and incorporated into prices, pre-announcement volatility becomes unavoidable. Second, leakage seems less relevant for most of the other macroeconomic announcements, which are

⁸Also see Gilbert, Kurov, and Wolfe (2018) and Lucca and Moench (2018) for the robustness of the pre-FOMC announcement returns. International evidence on pre-announcement equity return for other central banks is mixed. While Guo, Jia, and Sun (2019) find positive evidence for the People’s Bank of China, Brusa, Savor, and Wilson (2018) find no evidence for the Bank of England, the Bank of Japan, and the European Central Bank.

⁹Lucca and Moench (2015) use the close-to-close equity return on the day prior to the macroeconomic announcements. Ai and Bansal (2018) use the last five regular trading hours prior to the announcement, which for their set of non-FOMC announcements, including Nonfarm Payroll, PPI, GDP, and ISM, actually belong mostly to the previous trading day.

less prone to potential leaks. Indeed, Bernile, Hu, and Tang (2016) and Kurov, Sancetta, Strasser, and Wolfe (2019) find little evidence of informed trading on the day before FOMC and macroeconomic announcements.¹⁰

Our paper is closely related to the recent literature on *announcement day* equity returns. For example, Savor and Wilson (2013) examine returns on days of CPI, PPI, employment, and FOMC announcements; Ai and Bansal (2018) analyze returns on days of Nonfarm Payroll, PPI, FOMC, GDP, and ISM releases; Ernst, Gilbert, and Hrdlicka (2019) study returns on days of FOMC and a range of macroeconomic announcements. While we emphasize the importance in distinguishing the pre-announcement and the post-announcement periods, they all use daily data, so their announcement-day returns include both pre- and post-announcement returns. Although our sample of announcements does not overlap perfectly with theirs, we find that pre-announcement returns are typically a large fraction of the announcement-day returns.¹¹ In addition, the post-announcement return typically exhibits significantly higher volatility. It is the large pre-announcement return together with no abnormal volatility that requires better understanding, hence the focus of our study.

Parallel to the empirical literature on announcement-day returns are recent theoretical models aiming at explaining them. In a representative agent model, Ai and Bansal (2018) characterize the class of preferences under which an announcement is accompanied by positive risk premium. In Wachter and Zhu (2019), investors learn from the announcement about whether a rare disaster event has occurred. In both models, a positive equity premium is realized *after* the announcement, not before.¹² For this reason, their models explain the announcement-day (post-announcement) returns but not the *pre-announcement returns* that Lucca and Moench (2015) and we document.

The key contribution of our theory is the introduction of an additional risk, referred to as uncertainty, which is about the magnitude of the announcement's market impact. Because

¹⁰These two papers find evidence consistent with informed trading only until about 30 minutes before scheduled macro announcements, but not before. This evidence on informed trading is so close to the actual announcement that it is difficult to explain the returns hours before the announcements. Bilyi (2018) proposes a model of disagreement to explain the pre-FOMC drift. However, any explanation based on disagreement will also imply substantial pre-announcement trading volume, which is opposite to what the data shows.

¹¹For Nonfarm Payroll, ISM, and GDP, the announcement-day return (from 4pm of the previous day to 4pm of the announcement day) is about 12 bps in our sample, of which 9 bps are realized from 4pm of the previous day to 5 minutes before the announcement. Ai and Bansal (2018) find that the announcement-day return of Nonfarm Payroll, PPI, GDP, and ISM is on average 9.28 bps in their sample, which is quite similar to the announcement-day return in our sample.

¹²To connect to the pre-announcement return observed in the data, Ai and Bansal (2018) suggest information leakage. It then faces the same challenges as the other leakage explanations discussed above.

uncertainty is not directional, its resolution need not lead to a substantial increase in return volatility, but nonetheless carries a risk premium. Not only does heightened uncertainty explain the positive pre-announcement stock returns in the absence of high volatility, it also leads to a set of sharp and coherent predictions on the risk and return dynamics during the three phases surrounding an announcement: the accumulation period, the pre-announcement period, and the announcement or post-announcement period.¹³ Using VIX as a measure of uncertainty, we provide convincing empirical evidence in support of these predictions. As an additional “out-of-sample” test, we also find consistence evidence when heightened uncertainty rise stochastically rather than deterministically.

To the best of our knowledge, we are the first in the literature to model and empirically test the joint dynamics of VIX and pre-announcement returns for pre-scheduled news releases. The dynamics of VIX around FOMC announcements are studied sporadically earlier. Carr and Wu (2006) find that VIX peaks on the day before FOMC announcement, although their evidence is at the daily level and hence does not distinguish pre- and post-announcement VIX drops. Using intraday data on FOMC days, Fernandez-Perez, Frijns, and Tourani-Rad (2017) find that VIX starts to decline before the announcement and continues thereafter. We make two contributions relative to these papers. First, we connect VIX dynamics with the corresponding returns. Second, we show that the same VIX and return dynamics apply more broadly around other important macroeconomic announcements.

The connection between VIX and stock returns across different types of announcements paints a coherent picture of uncertainty and equity risk premium. In this aspect, our paper is also related to the literature on 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)). Cheng (2019) provides a dynamic model of VIX and characterizes the VIX premium embedded in VIX futures. The main connection of our paper to this literature is the evidence that a sufficiently large spike-up in daily VIX is already a strong predictor of positive equity returns on the next day, which is indeed a risk premium, realized as heightened uncertainty dissolves.

¹³Laarits (2019) also proposes a two-risk model for the pre-FOMC return. He 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. He then explores the exact nature of the FOMC announcements by examining FOMC transcript, stock-bond correlations, and FX returns, among others. Our model is aimed at a broader set of announcements/news, not tied to a particular one, and leads more general and richer predictions on the corresponding risk and return behavior.

2. Empirically Testable Hypothesis

In this section, we formulate an empirically testable hypothesis, linking the pre-announcement risk-and-return patterns explicitly to heightened uncertainty and its later resolution. The formal development of the hypothesis is given in Section 6.

Our hypothesis can be best illustrated via a simple asset pricing model that contains two types of risk. The first kind of risk is directional in nature and captures the actual macro-economic news, while the second kind of risk captures the potential impact of this news on asset payoff. Key to our hypothesis is the presence of this second kind of risk, which we refer to as uncertainty for distinction. The resolution of these two risks can occur at different times, and their resolution over time leads to positive expected returns, or risk premia. We demonstrate that the resolution of heightened uncertainty (the second kind of risk) followed by the resolution of the news itself (the first kind of risk) can generate return and risk patterns similar to those around the times of FOMC and other macroeconomic announcements, as well as times of sharp rises in VIX.

More formally, let P_t be the asset price at time t . We hypothesize the following process for P_t :

$$P_t = F_t - aV_t - bU_t, \tag{1}$$

where F_t represents the asset's fundamental, e.g., its expected future payoff, and a and b are two positive constants, reflecting the risk premia associated with the two risks, denoted by V_t and U_t , respectively.¹⁴ The first risk, V_t , can be measured by the variance of news at t . The second risk/uncertainty, U_t , is about the magnitude of the news' impact on asset payoff.

As indicated by Equation (1), news impacts asset price not only through its impact on asset payoff F_t , but also through its influences on the levels of the two risks, V_t and U_t , respectively. Accompanying an increase in each risk, the asset price decreases. This can happen, for example, as the risk/uncertainty, U_t , accumulates and builds up in anticipation of the pre-scheduled announcement of market moving news. Likewise, accompanying a decrease

¹⁴The price process in (1) is canonical in asset pricing models. Using the classic Gordon model, the price of an asset can be written as $P_t = D_t(1 + g_t)/(r_t - g_t)$, where D_t is the current dividend, g_t its expected growth rate, and r_t the discount rate. If there are two separate risks, measured by V_t and U_t , we can express the discount rate by $r_t = r_F(1 + aV_t + bU_t)$. Take the log of the price equation and expand in g_t , V_t and U_t , we have: $p_t \simeq d_t + (1 + 1/r_F)g_t - \log r_F - aV_t - bU_t$ (to the first order). This is (1) if we replace P_t by p_t and F_t by $d_t + (1 + 1/r_F)g_t - \log r_F$. We use price levels here rather than its logs to be consistent with the formal model in Section 6.

in each risk, the asset price increases. In particular, this price appreciation can happen at the resolution of the uncertainty.

Important for our hypothesis is the fact that these two risks, V_t and U_t , are of different origin, and the difference in the timing of their accumulation and resolution leads to unique and testable patterns in asset return and risk. More specifically, we have the following return and risk dynamics:

$$R_t = P_t - P_{t-1} = \Delta F_t - a \Delta V_t - b \Delta U_t. \quad (2)$$

To test the implications of the above hypothesis, we need empirical measures for both the news risk V_t and its impact uncertainty U_t . While V_t can be estimated using returns, U_t may not. However, as we show in the model in Section 6, VIX provides a good proxy for uncertainty of U_t .¹⁵

We further map out the timing by considering four dates/times, $t = -1, 0, 1, 2$, with the news announcement pre-scheduled to occur at $t = 1$:

Window [1, 2): The announcement (or post-announcement) window when the news is released and V_t drops.

Window [0, 1): The pre-announcement window when uncertainty U_t is mostly resolved.

Window [-1, 0): The accumulation window, with $t = -1$ representing a suitable earlier date when uncertainty U_t starts accumulating.

Correspondingly, in the return space, R_2 is the return on the news announcement, R_1 is the pre-announcement return, and R_0 is the return over the accumulation period.

In the risk space, U_t rises during the accumulation window and then drops during the pre-announcement window as the uncertainty dissipates. Thus, $\Delta U_0 = U_0 - U_{-1} > 0$ and $\Delta U_1 = U_1 - U_0 < 0$. On the other hand, V_t stays constant during both the accumulation and pre-announcement windows, and decreases only during the announcement window when the announcement arrives and the news risk is resolved. Hence, $\Delta V_t = 0$ for $t = 0, 1$ and $\Delta V_2 = V_2 - V_1 < 0$. This risk dynamics then leads to the following predictions:

¹⁵If return realization/variance is mostly driven by the news' impact on asset fundamental, we can then use the variance of realized returns as a proxy for V_t . On the other hand, VIX squared or the price variance swaps can be used as a proxy for U_t .

Prediction 1 *During the pre-announcement period, there is an increase in asset price (P_t) and a decrease in uncertainty (U_t). That is, $R_1 > 0$ and $\Delta VIX_1 < 0$. There need not to be a higher return variance (V_t) accompanying this positive return.*

Prediction 2 *During the accumulation period, there is an increase in uncertainty, which leads a build-up in VIX, and a decrease in asset price. That is, $\Delta VIX_0 > 0$ and $R_0 < 0$.*

We omit the predictions for the announcement date ($R_2 > 0$, $\Delta V_2 < 0$), which is the focus of standard event studies. Our focus is on the pre-announcement return and VIX dynamics.

Macro announcements are pre-scheduled. Thus, the timing of the corresponding heightened uncertainty is deterministic, which makes the predictions simpler. However, our hypothesis on price and risk dynamics also leads to predictions on return and VIX behavior when the timing of the heightened uncertainty is stochastic. In particular, we have the following prediction:

Prediction 3 *When there is an unanticipated spike in VIX at date 0, reflecting a heightened uncertainty, it will be followed by an increase in asset price as the heightened uncertainty resolves itself. That is, for a large, positive ΔVIX_0 , $R_1 > 0$ and $\Delta VIX_1 < 0$.*

We will test the above predictions using macro announcements, FOMC and others, as well as VIX spikes, capturing both deterministic and stochastic arrival of heightened uncertainty.

3. Data

We use several data sources in our analysis. We obtain transaction-level data on E-mini S&P 500 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. For daily returns on the S&P 500 index, we use data from the Center for Research in Security Prices (CRSP). We obtain the intraday VIX values from the Chicago Board Options Exchange (CBOE). The intraday VIX data start from January 1992, and contain only VIX values within the regular trading hours for most of our sample period. For calculations involving VIX values during the off-hours, we rely on the transaction level data on VIX futures from CBOE which start from May 2004 and contain off-hours transaction data from December 2010. 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 Dow Jones news wires. We follow the same methods of Lucca and Moench (2015) and Fleming and Piazzesi (2005), and extend the sample period to May 2018. The announcement times for CSI are based on the time-stamp of Bloomberg. We focus most of our analysis on the sample from September 1994 to May 2018. During this period, there are in total 190 scheduled releases of FOMC statements. From September 1994 to March 2011, 131 releases are consistently made within a few minutes around 2:15 pm, with only one exception, March 26, 1996, on which the release time was pre-announced to be in the morning because of the Chairman’s other duties. From April 2011 to January 2013, seven releases are around 2:15 pm and eight releases are around 12:30 pm, one hour and forty five minutes earlier to accommodate the Chairman’s press briefings at 2:15 pm. From February 2013 to May 2018, all of the 43 FOMC releases are around 2:00 pm. For the period before 1994, there is no official announcement and market participants need to infer policy decisions through Fed’s open market operations, usually on the day after the FOMC meeting,

In addition to FOMC announcements, we also consider the release of other major U.S. macroeconomic indicators. These economic indicators are: total Nonfarm Payroll employment (NFP), the Institute for Supply Management’s manufacturing index (ISM), Gross Domestic Production (GDP), industrial production (IP), personal income (PI), housing starts (HST), initial claims for unemployment insurance (INC), producer price index (PPI), consumer price index (CPI), and the preliminary release of the Consumer Sentiment Index (CSI). Except for ISM and CSI, all other economic indicators are public indexes released by government agencies at either 8:30 am or 9:15 am (only for IP). ISM and CSI are economic indicators released by private institutions. ISM is released at 10:00 am, while CSI’s release time varies from 9:35 am to 10:00 am during our sample period. We exclude macroeconomic announcement days that coincide with FOMC announcement days to avoid potential confounding effect.

Most of these macroeconomic indicators are released in the morning, often not within the regular trading hours of US equity markets (9:30 am - 4 pm). We therefore rely on the S&P 500 index futures, which are traded almost around the clock, to obtain the returns from the market close on the previous trading day (4 pm) to five minutes prior to the exact time (ann-5min) of these announcements.¹⁶ Using the market close as a natural starting point,

¹⁶Due 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.

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.

To calculate market returns over a given time horizon $[t_1, t_2]$, we first pick the most active S&P 500 index 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 .¹⁷ 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.

For FOMC, ISM and CSI, the release time are within the regular trading hours and we use the intra-day value of VIX provided by CBOE to calculate the change in VIX during both the pre-announcement and announcement windows.¹⁸ For other announcements whose releases fall outside the regular trading hours, we calculate the change in VIX based on VIX futures, using method similar to how we calculate returns from S&P 500 index futures prices. The VIX futures data are available for non-regular trading hours only after December 2010. For this reason, the number of news releases that we can calculate VIX changes are significant fewer for announcements released outside of the regular trading hours.

In addition to pre-scheduled FOMC and macroeconomic releases, we also consider days with unexpected heightened uncertainty. For this, we first select days on which the daily increase in VIX larger than a constant cutoff value and define the next trading day as the heightened VIX (HVIX) days. To match the FOMC frequency, we choose a constant cutoff value so that there are on average approximately eight days of heightened VIX days per calendar year. The daily increase in VIX at day t is calculated as the difference between VIX at day t and the exponentially weighted moving average (EWMA) of past VIX up to day $t-1$. More details on the selection of heightened VIX days are discussed at Section 5. For our baseline results, we use the heightened VIX days selected based on an EWMA decay factor

¹⁷We 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.

¹⁸The VIX tick data provided by CBOE starts to provide intra-day VIX values from 10:00 am to market close (varying from 4:00 pm to 4:15 pm) since April 1992. The data set extends the coverage to 9:30 am since January 2004 and 3:15 am since April 2016.

η equals to 0.3 and a cutoff value equals to 3%. Lastly, we consider the remaining trading days, i.e., neither pre-scheduled FOMC and macroeconomic release days nor heightened VIX days, as the Non-Event days.

Tables 1 reports the summary statics of pre-announcement returns from September 1994 to May 2018. For FOMC and Macroeconomic release days, we report the pre-announcement returns from 4 pm on the previous day to 5 minutes before announcement time based on the S&P 500 index futures. For heightened VIX (HVIX) and Non-Event days, we report the close-to-close daily returns on the S&P 500 index.

The average pre-announcement return for FOMC is 27.14 basis points with a t-stat of 5.95. Our calculation of the pre-announcement returns for FOMC is lower than those reported in Lucca and Moench (2015). This is due to two reasons. The first reason is that our pre-announcement window starts from 4 pm on the previous day, shorter than the 24-hours window used by Lucca and Moench (2015). Our calculation does not include the small run-up from 2 pm to 4 pm on the day prior to the announcement. The second reason is that the pre-announcement returns for FOMC are on average smaller for the period after 2011 and we extend the sample period in Lucca and Moench (2015) to 2018.

We also find significant pre-announcement returns for Non-farm Payroll, ISM, and GDP announcements. The average pre-announcement return is 10.10 basis points for NFP with a t-stat of 3.63; 9.14 basis points for ISM with a t-stat of 2.10; 7.46 basis points for GDP with a t-stat of 2.08. These drifts are robust to potential outliers. After removing the top 1% highest returns and the bottom 1% lowest returns, the average drift is 9.80 basis points for NPF, 10.31 basis points for ISM, and 6.09 basis points for GDP. All pre-announcement returns remain statistically significant at the 5% level. Compared with FOMC, the magnitudes of the pre-announcement return on these macroeconomic announcements are indeed smaller. Though with smaller magnitudes, these drift are quite large economically. The average return on Non-Event days, by comparison, is not statistically significant.

The daily close-to-close return on HVIX days is on average 57.22 bps with a t-stat of 3.24, larger than the pre-announcement return on FOMC and macroeconomic announcements. After removing the top 1% highest returns and the bottom 1% lowest returns, the average return on HVIX days is 54.73 bps and remains statistically significant with a t-stat of 3.73.

Table 1: 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	27.14	5.95	62.9	1.3	5.2	-163.8	335.7	190	25.05	6.35	53.9	0.8	2.1	-145.2	261.5	187
NFP	10.10	3.63	43.4	-0.2	3.0	-165.1	177.1	243	9.80	4.00	37.8	-0.2	1.4	-118.4	128.6	238
ISM	9.14	2.10	72.5	-1.1	7.0	-461.0	212.7	277	10.31	2.69	63.3	-0.3	1.6	-213.0	196.0	273
GDP	7.46	2.08	54.7	0.9	10.4	-232.8	355.7	233	6.09	2.24	41.1	-0.3	2.0	-159.6	162.7	228
IP	5.23	1.19	68.0	-0.7	4.8	-338.8	290.6	240	5.09	1.34	58.3	-0.7	2.2	-227.3	153.7	235
PI	3.50	0.94	58.3	-1.0	3.8	-248.1	190.5	244	5.01	1.55	49.9	-0.6	1.8	-165.5	162.1	239
HST	2.46	0.69	53.9	-0.2	4.2	-177.0	279.0	230	1.61	0.52	46.8	-0.9	1.8	-166.9	104.7	225
INC	1.56	0.95	53.8	-0.1	5.4	-258.8	355.7	1073	1.74	1.25	45.1	-0.4	1.4	-171.9	130.3	1052
PPI	-0.58	-0.17	52.3	-2.4	14.3	-391.9	129.1	241	1.45	0.55	40.3	-0.8	1.6	-181.6	81.5	235
CPI	-2.14	-0.69	47.1	-0.8	2.8	-207.8	129.7	232	-1.58	-0.56	42.5	-0.6	1.6	-166.8	110.0	228
CSI	-4.03	-0.88	68.7	0.9	8.1	-232.2	438.9	226	-4.37	-1.15	56.4	-0.2	0.8	-160.3	149.6	221
HVIX	57.22	3.24	251.1	0.6	3.5	-761.7	1158.0	202	54.73	3.73	205.6	0.3	0.9	-574.0	692.1	196
Non-Event	-0.85	-0.56	106.3	-0.6	6.1	-903.5	647.2	4814	-0.13	-0.10	88.9	-0.3	0.8	-308.0	270.7	4716

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 pre-announcement day to five minutes before indexes' releases. The macroeconomic announcements include: total nonfarm payroll employment (NFP), the Institute for Supply Management's manufacturing index (ISM), Gross Domestic Production (GDP), 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). Macroeconomic announcement days that coincide with FOMC days are excluded for all other macroeconomic announcements. HVIX are the next trading day following days with unexpected spikes in VIX. Non-Event refers to all trading days that are not FOMC, macroeconomic, and HVIX days. For HVIX and Non-Event days, the daily close-to-close percentage returns (in basis points) on the S&P 500 index are reported. The sample period is from September 1994 to May 2018.

4. FOMC and Macro Announcements

Our theory predicts that FOMC is not unique and all pre-scheduled news releases that bring large impact to the market should share similar pattern of return and uncertainty. For this reason, we examine FOMC and other important macroeconomic news together in this section. As detailed in Section 2, to understand the asset-pricing implications of the pre-scheduled announcements of market moving news, we break the time window prior to the news announcements into two separate periods. During the accumulation period, we expect to observe a gradual buildup in uncertainty accompanied by a downward drift in market prices. During the pre-announcement periods, we expect uncertainty starts to get resolved, resulting a positive drift in market prices. The separation of these two periods is critical for our empirical tests because return and uncertainty are expected to behave oppositely during the two time windows. In this section, we first discuss the joint dynamics of return and uncertainty during the pre-announcement period at section 4.1 and then discuss the accumulation period at section 4.2.

4.1. *Pre-Announcement Drift and VIX Drop*

The Prediction 1 of our model predicts that there is a positive drift in market price and a negative drop in uncertainty before all pre-scheduled announcements with high-impact to the market. To test this prediction, we report the average returns and changes in VIX around FOMC and ten other pre-scheduled major macroeconomic announcements from September 1994 to May 2018 in Table 2. In order to have a consistent comparison across all announcements, we define the time from the market close of the previous day to 5 minutes before the scheduled release as the pre-announcement window. We define the announcement window as the period from 5 minutes before to 5 minutes after the index releases.

The pre-announcement returns for Nonfarm Payroll, ISM, and GDP are statistically significant: 10.10 basis points for Nonfarm Payroll, 9.14 basis points for ISM, and 7.46 basis points for GDP. Compared with the FOMC result, which averages to 27.14 basis points by our measurement, the magnitudes of pre-announcement returns around macroeconomic data releases are smaller but significant and comparable in magnitude. The smaller magnitudes could be due to the fact that these pieces of news are not as impactful as FOMC and bring less uncertainty to the market.¹⁹ For the same reason, many other less impactful macroeconomic

¹⁹FOMC is also unique in being released in the afternoon while other macroeconomic announcements are

Table 2: Returns and changes in VIX around FOMC and Other Macroeconomic Releases

	FOMC	NFP	ISM	GDP	IP	PI	HST	INC	PPI	CPI	CSI
Pre-Announcement [4pm, ann-5min]											
Ret	27.14	10.10	9.14	7.46	5.23	3.50	2.46	1.56	-0.58	-2.14	-4.03
	[5.95]	[3.63]	[2.10]	[2.08]	[1.19]	[0.94]	[0.69]	[0.95]	[-0.17]	[-0.69]	[-0.88]
Δ VIX	-0.22	-0.05	0.18	-0.06	-0.01	0.03	-0.05	-0.02	0.05	-0.03	-0.04
	[-3.18]	[-1.24]	[1.91]	[-1.07]	[-0.19]	[0.53]	[-1.30]	[-1.00]	[1.12]	[-0.72]	[-0.48]
Announcement [ann-5min, ann+5min]											
Ret	2.84	4.93	2.9	-0.46	-0.35	0.29	1.18	0.14	-1.51	1.56	-2.17
	[1.07]	[1.58]	[1.53]	[-0.27]	[-0.52]	[0.36]	[1.28]	[0.25]	[-1.14]	[0.87]	[-1.36]
Δ VIX	-0.09	-0.06	-0.04	0.01	-0.01	0.01	-0.02	0.00	0.01	0.02	0.01
	[-2.82]	[-1.89]	[-1.41]	[0.66]	[-0.57]	[0.68]	[-2.12]	[0.10]	[0.91]	[1.18]	[0.41]
Ret	25.66	35.97	22.61	15.84	6.73	8.03	9.33	11.27	13.8	17.46	16.6

This table reports the returns (in basis points) and changes in VIX (in percentages) 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-5min], the announcement window is from 5 minutes before index release to 5 minutes after index release [ann-5min, ann+5min]. The returns are percentage returns based on futures prices. For the day prior to the announcement day. The macroeconomic announcements include: total nonfarm payroll employment (NFP), the Institute for Supply Management's manufacturing index (ISM), the Gross Domestic Production (GDP), 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. For FOMC, ISM and CSI, the release time are within the regular trading hours and we use the intraday value of VIX provided by CBOE to calculate change in VIX. For other announcements with release time fall outside of the regular trading hours, we calculate change in VIX based on VIX futures. The VIX futures data during non-regular trading hours start from December 2010. The sample period is from September 1994 to May 2018.

announcements do not have significant pre-announcement returns. Indeed, measuring market impact by the absolute market return during the announcement window, all of the three macroeconomic announcements (NPF/GDP/ISM) with significant pre-announcement return are among the news releases with the highest market impact.

In addition to the positive price drift, we also find evidences that there is a significant drop in VIX during the pre-announcement window, reflecting that the dissolution of the heightened uncertainty risk happens prior to the actual news releases. For FOMC, the average drop in VIX during the pre-announcement window is 0.22 percentage points, statistically significant with a t-stat of -3.18 . Since not all FOMC announcements bring the same level of heightened uncertainty, we also consider the announcements with the highest 30% pre-announcement returns, which is referred to as the high-return group. The results are reported in Table 3. For the high-return FOMC announcements, the pre-announcement return is 97.08 basis points and the corresponding drop in VIX is -1.04 percentage points, both highly significant. Associated with relatively higher levels of heightened uncertainty, the high-return group serves as a “turbo” version of the average FOMC results and paints a sharper picture of our theory predictions.

Given that the pre-announcement return is smaller for Nonfarm Payroll, GDP and ISM compared to FOMC, we pool them together in our tests and refer to the group as Macro. For this group, the average pre-announcement return is 9.01 basis points and statistically significant with a t-stat of 4.41. The corresponding change in VIX, though, is on average only 0.03 and statistically insignificant. This weak result on VIX is likely due to the fact that Macro announcements are on average less impactful and bring lower uncertainty to the market, the same reason why they have smaller pre-announcement returns. Also, as many of the Macro announcements fall into the non regular trading hours, the lack of precise VIX data could also contribute to the weak result. To mitigate these issues, we focus on Macro announcements with the highest 30% pre-announcement returns, corresponding to those with relatively higher levels of heightened uncertainty. For this high-return group, the average pre-announcement return is 64.74 basis points and the average drop in VIX is 0.55 percentage points, both highly significant. The magnitudes of the pre-announcement returns and the changes in VIX are also in proportion to those of the high-return group of FOMC.

To the best of our knowledge, we are the first in the literature to show that the pre-

released either before or near the open of the regular trading hours. As such, the pre-announcement window for the non-FOMC news largely consists of non-regular trading hours. The lack of liquidity in the after-hours market may also contribute to the weaker and less precise results.

announcement drift is not unique to FOMC and has a broad presence in major macroeconomic announcements. We propose a new risk-based explanation that connects the pre-announcement drift with the dissolution of heightened uncertainty during the pre-announcement period. The overall empirical evidences are consistent with our theory prediction that the pre-announcement drift, as a premium for heightened uncertainty, will occur whenever there is a heightened uncertainty, and hence exist for both FOMC and Macro announcements. Compared with FOMC, the magnitude of the pre-announcement return for macro announcements are indeed smaller, but still comparable to FOMC and economically important.

Several existing papers also have investigated macroeconomic announcements but do not find significant pre-announcement returns. The key difference of our approach is that we look at a time window immediately before these announcements, that is, from 4 pm on the previous trading day to 5 minutes before news releases. As macro announcements are made at 8:30 am, 9:15 am, and 10:00 am, all before or close to the market opening time, our pre-announcement window includes the critical overnight returns before announcements. By comparisons, Lucca and Moench (2015) use the daily return on the previous trading day and Ai and Bansal (2018) use the return for the last five regular trading hours, which also fall mostly on the previous trading day. To mitigate the concern that overnight returns might be quite noisy, we base our return calculations on the transaction prices of S&P 500 futures, which are traded almost around-the-clock and have good liquidity during the non-regular trading hours.²⁰

4.2. Uncertainty Build-Up Prior to the Pre-Announcement Period

The Prediction 2 of our theory predicts that there should be an accumulation period when uncertainty concerning an announcement gradually builds up. For this accumulation period, we should observe an increase in uncertainty, captured by an increase in VIX, accompanied by a downward price drift. We discuss the dynamics of uncertainty and return during the accumulation period in this subsection.

A challenge of our empirical tests is that we do not know the exact time of the accumulation period. As FOMC and Macro announcements are pre-scheduled, investors can trade

²⁰Lucca and Moench (2015) use the intra-day tick data on the S&P 500 index; Ai and Bansal (2018) use the prices of S&P 500 SPDR, an exchange-traded fund. Although with different data sources, we think the key driver for our results is the definition of the pre-announcement window. In fact, using the same data source as Ai and Bansal (2018) and adopting their approach of combining the four non-FOMC macroeconomic indicators (NFP, GDP, ISM, and PPI), we find that the average return over our definition of the pre-announcement window is 11 basis points with a significant t-stat of 3.81.

Table 3: Returns and Changes in VIX Leading up to Announcements

	Announcement				Matched (Placebo)			
	FOMC		Macro		FOMC		Macro	
	High	All	High	All	High	All	High	All
Event Day								
[4pm, ann-5min]								
Ret	97.08	27.14	64.72	9.01	46.94	13.66	25.30	8.03
	[12.43]	[5.95]	[21.63]	[4.11]	[3.45]	[2.21]	[6.05]	[3.72]
Δ VIX	-1.04	-0.22	-0.55	0.03	-0.63	-0.11	-0.37	-0.07
	[-7.63]	[-3.18]	[-6.57]	[0.54]	[-3.18]	[-1.26]	[-6.02]	[-2.03]
[4pm, 4pm]								
Ret	88.99	28.77	82.97	12.37	70.82	22.68	70.55	12.40
	[4.38]	[3.44]	[10.39]	[2.59]	[4.45]	[3.17]	[10.10]	[3.11]
Δ VIX	-1.47	-0.58	-0.96	-0.17	-0.88	-0.22	-0.69	-0.05
	[-4.88]	[-5.07]	[-8.58]	[-2.70]	[-3.88]	[-2.15]	[-8.11]	[-0.95]
VIX Level	25.4	20.3	22.5	20.5	24.3	19.7	21.8	20.3
Prior to Event Day								
Cum Day [-3, -1]								
Ret	-51.90	6.40	-14.50	11.44	19.51	7.90	26.22	19.53
	[-1.59]	[0.46]	[-1.00]	[1.64]	[0.65]	[0.59]	[1.90]	[2.81]
Δ VIX	1.22	0.47	0.23	0.00	-0.06	-0.04	-0.35	-0.23
	[2.32]	[2.43]	[1.18]	[-0.03]	[-0.14]	[-0.28]	[-1.85]	[-2.70]
Cum Day [-6, -1]								
Ret	-81.80	19.54	-40.40	9.50	8.56	28.74	23.78	24.54
	[-2.18]	[1.04]	[-2.12]	[1.03]	[0.21]	[1.62]	[1.35]	[2.57]
Δ VIX	1.88	0.59	0.90	0.14	0.04	-0.19	-0.37	-0.22
	[3.27]	[2.46]	[3.55]	[1.14]	[0.10]	[-0.98]	[-1.75]	[-2.00]
N Obs	57	190	216	718	57	190	216	718

'Announcement' are pre-scheduled FOMC and macro (NFP, GDP, and ISM) announcement days. 'High' is a subsample of announcement days with the highest 30% pre-announcement returns; 'All' is the full sample of announcements days. 'Matched' is a matched sample of non-event days to match announcement days close-to-close returns. The sample period is from September 1994 to May 2018.

well in advance. As a result, the real impact on the market price and uncertainty is masked over a relatively long time window. Moreover, not all announcements bring the same level of uncertainty to the market and the accumulation period differs from announcement to

announcement. For our empirical tests, we consider two time windows for this accumulation period, one is from -3 days to the pre-announcement day (-1 day) and the other is from -6 days. Using a fixed window across all announcements inevitably introduces noises in our measurement and weakens the results. To compensate, we focus on the high-return group for both FOMC and Macro announcements, which correspond to cases with more heightened uncertainty. The results are reported in the bottom pattern of Table 3.

During the first accumulation period from -3 days to -1 day, VIX increases by 1.22 percentage points for the high-return group of FOMC, which is statistically significant with a t-stat of 2.32. The corresponding return during this accumulation period is -51.90 basis point, as predicted, but not statistically significant with a marginal t-stat of -1.59 . For the high-return group of Macro announcements, VIX increases by 0.23 percentage points during the accumulation period and the corresponding return is -14.50 basis points, as predicted. But neither is significant. When we extend the accumulation period to -6 days to -1 day, all results become significant. In particular, for the high-return group of FOMC, VIX increases by 1.88 percentage points and return is -81.80 basis points during the accumulation period, both statistically significant. For the high-return group of Macro announcements, the change in VIX is 0.90 percentage points and the return is -40.40 basis points over the accumulation period, both statistically significant. In other words, there are indeed subtle but significant price depression and uncertainty build-up during a relatively long accumulation period.

One potential concern of our results is that we use the pre-announcement return, which might contain forward-looking information, to identify announcements associated with high uncertainty. Could it be the case that there is always an increase in VIX prior to days with large returns? To address this concern, we provide a set of placebo tests to show that Non-Event days, with returns comparable to announcement days, do not experience heightened uncertainty. We match each pre-scheduled announcement with a nearby Non-Event day based on their close-to-close returns. The matched days are chosen from all non-event trading days between two adjacent announcements so that the overall market conditions are also similar. The results are reported in Table 3. Unlike pre-scheduled announcements, these matched Non-Event days do not have significant price depression and VIX build-up during the accumulation period. Put differently, the build-up in uncertainty is unique to pre-scheduled announcements and is not a mechanical result that always precedes days with large positive returns.

As an additional test to avoid potential bias by looking only at the high-return group,

we run a set of predictive regressions by using the changes in VIX during the accumulation period to forecast future returns over the pre-announcement period. We find that lagged VIX changes can indeed positively predict future pre-announcement return for FOMC and Macro announcements. That is, announcements that bring higher level of heightened uncertainty are associated with larger drift later at the pre-announcement period. By comparison, lagged VIX changes can no longer predict future return on Non-Event days without pre-scheduled announcements.

In Table 4, the pre-announcement returns on FOMC and macro announcements are regressed on lagged cumulative changes in VIX:

$$R_t = a + b \Delta \text{VIX}_{[t-3, t-1]} + \epsilon_t, \quad (3)$$

and

$$R_t = a + b \Delta \text{VIX}_{[t-6, t-1]} + \epsilon_t, \quad (4)$$

where the independent variable is demeaned so that the intercept can be read as the average event day pre-announcement return. For both FOMC and Macro announcements, the lagged cumulative changes in VIX is a significant predictor of future pre-announcement returns on announcement days. For FOMC days, the regression coefficient is 3.66 with a t-stat of 2.20 for the cumulative changes in VIX from -3 days to -1 day. Given that the sample standard deviation of the cumulative 3-day change in VIX is 2.50%, this result indicates that one standard deviation increase in the lagged change in VIX results in a 9.15 basis points increase in the pre-announcement return. Extending the lagged accumulation period to -6 days, the coefficient drops to 2.48 and no longer statistically significant. For Macro days, the regression coefficient is 0.43 and not statistically significant for the accumulation period from -3 days to -1 day. However, extending the accumulation period to -6 days, the coefficient increases to 3.63 with a t-stat of 2.50. Though the length of the accumulation period differs for FOMC and Macro announcements, the overall results are consistent with the hypothesis that lagged changes in VIX can predict future pre-announcement returns on event days.

We also provide a placebo test by running the above predictive regression on Non-Event days, with the independent variable being the daily close-to-close S&P 500 index returns. These Non-event days do not include pre-scheduled FOMC, high-impact macroeconomic announcements (Non-farm Payroll, ISM, and GDP), or HVIX days. Without heightened uncertainty, the lagged change in VIX should not predict future returns. Indeed, the re-

Table 4: **Daily S&P 500 Index Returns on Lagged Changes in VIX**

	FOMC		Macro		Non-Event	
Intercept	27.14 [3.67]	27.14 [3.69]	9.01 [4.29]	9.01 [4.24]	-0.85 [-0.52]	-0.85 [-0.52]
Δ VIX [-3, -1]	3.66 [2.20]		0.43 [0.32]		-0.61 [-0.52]	
Δ VIX [-6, -1]		2.48 [1.39]		3.63 [2.50]		0.33 [0.43]
Adj R-Sqr (%)	1.88	1.16	-0.11	3.70	-0.01	-0.01
N Obs	190	190	718	718	4814	4814

Pre-announcement returns (in basis points) on FOMC and Macroeconomic (NFP, ISM, and GDP) are regressed on lagged changes in VIX (in percentage). Non-Event refers to all trading days that are not FOMC, NFP, ISM, GDP, and HVIX days. For Non-Event days, close-to-close returns on S&P 500 indexes (in basis points) are regressed on lagged changes in VIX (in percentage). The regressands are demeaned so that the intercept reflects the average event day returns. The sample period is from September 1994 to May 2018. The reported t-stat's use Newey-West standard errors, adjusting for serial correlations.

gression coefficients are -0.61 and 0.33 for the respective accumulation periods, both are statistically insignificant.

To better illustrate the joint dynamics of return and uncertainty, we plot the cumulative return and the cumulative changes in VIX from -3 days to the announcement day (day 0), with Figure 1 for FOMC and Figure 2 for Macro announcements. Consistent with our theory, for the high-return groups of both FOMC and macro announcements, there is a build up in VIX during the accumulation period from -3 days to -1 day, followed by a drop in VIX during the pre-announcement period from -1 day up to the announcement time.²¹

Consistent with the VIX pattern, market prices drift downward as uncertainty builds up during the accumulation period, and subsequently drift upward as uncertainty releases during the pre-announcement period. The fact that both the high-return groups of FOMC and macro announcements show similar pattern also confirm our theory prediction that the pre-announcement drift is not unique to FOMC and should exist for all high impact macroeconomic announcements.

²¹The cumulative changes in VIX are based on the intra-day VIX tick value provided by CBOE. For majority of our sample period, this dataset only covers the regular trading hours from 9:30 am to 4 pm. For this reason, we do not plot the VIX values during the non-regular trading hours. The time 2:15 pm is plotted as the announcement time for FOMC announcements. The announcement time is not plotted for macro announcements as Nonfarm Payroll and GDP announcements are released at 8:30 am (before market open) and ISM announcements are released at 10:00 am.

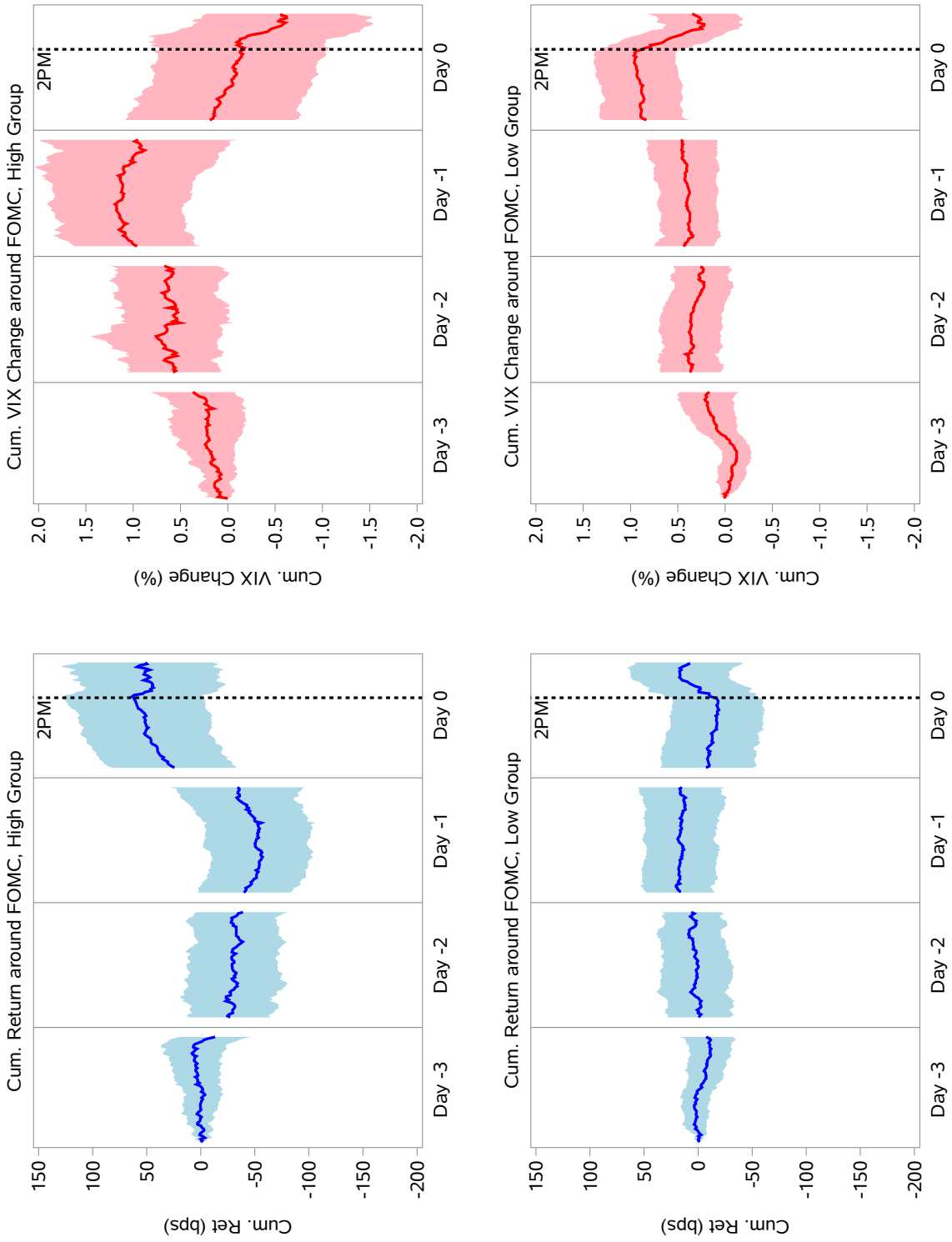


Figure 1: Cumulative Return and VIX change around High and Low FOMC Days.

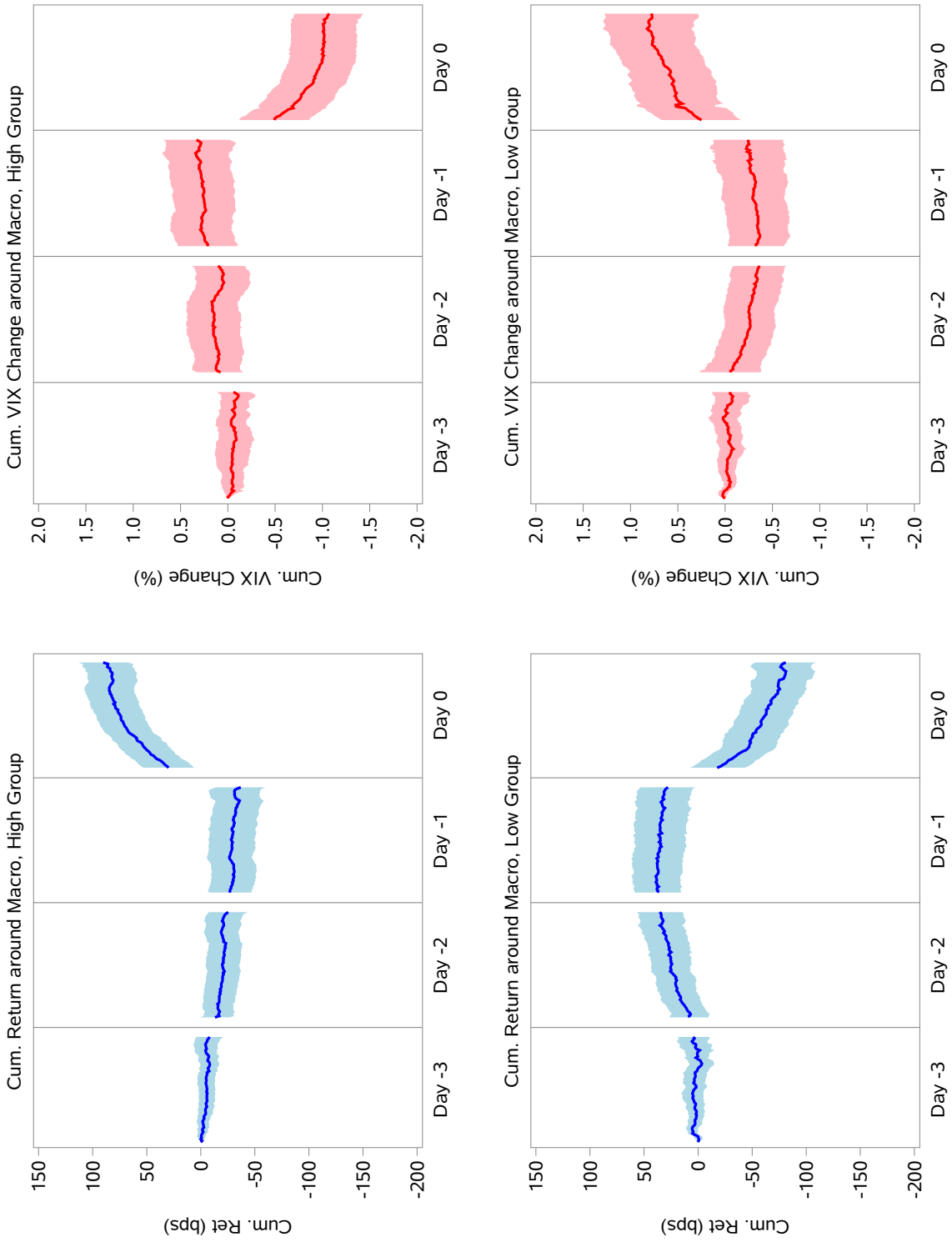


Figure 2: Cumulative Return and VIX change around High and Low Macro Days.

For comparison, we also plot the the announcements with the lowest 30% pre-announcement returns, refereed to as the low-return group, in the bottom panels of Figure 1 and Figure 2. By construction, these announcements have negative pre-announcement returns and are associated with relatively lower levels of heightened uncertainty. Indeed, we do not observe similar level of VIX build-up during the accumulation period, suggesting that uncertainty associated with these announcements do not rise as sharply as the high-return groups. Without the build-up of heightened uncertainty during the accumulation period, there is also no dissolution of uncertainty during the pre-announcement window.

5. VIX Spikes

In addition to pre-scheduled announcements that naturally bring heightened uncertainty to the market, heightened uncertainty can also be triggered unexpectedly by adverse market conditions. Prediction 3 of our hypothesis predicts that there is a premium for such unexpected heightened uncertainty days as well. That is, although the heightened uncertainty is triggered by a mechanism different from pre-scheduled announcements, they should have similar premium as uncertainty dissolves. In this section, we first discuss how we select these heightened uncertainty days based on VIX spikes in Section 5.1; then compare our method with several alternatives based on extreme movements in price and volatility in Section 5.2; and discuss the connection between heightened VIX days and the pre-scheduled announcements in Section 5.3.

5.1. *Capturing Heightened Uncertainty using VIX Spikes*

Heightened uncertainty can be triggered by severe, adverse market conditions, including sudden drops in market price or sudden increases in market volatility. While both indicators will be investigated later in the section, the main measure to be used in our investigation is the CBOE VIX index. Computed from the prices of S&P 500 index options, VIX has been widely monitored as the “fear gauge” of the overall financial markets. Unlike market volatility, measured directly from the cash market, the information contained in VIX is considered to have a risk aversion component and is also believed to be forward looking (see, for example, Pan (2002) and references therein). For these reasons, this index, among all market indicators, offers the best opportunity for us to identify days of heightened uncertainty.

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

average of VIX is 19.84%. To compare with FOMC and Macro announcements, we also report results for the sub-period from September 1994 to May 2018. The main variable in this section is the time-series of daily changes in VIX:

$$\Delta\text{VIX}_t = \text{VIX}_t - \text{VIX}_{t-1}. \quad (5)$$

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 $t+1$ as of heightened VIX (HVIX) if ΔVIX_t is larger than a pre-determined constant cutoff value. As shown in Table 5, we experiment with different cutoff values, ranging from 0% to 4%. With higher cutoff values, fewer days are selected, making the events rarer. To smooth out the potential noise in daily changes in VIX, we also compare the level of VIX relative to a exponentially weighted moving average (EWMA) of its recent past. More specifically, day $t + 1$ is defined as a heightened VIX day if:

$$\text{VIX}_t - \mu_{t-1} \geq \text{cutoff}, \quad (6)$$

where

$$\mu_{t-1} = (1 - \eta) \sum_{\tau=0}^{t-1} \eta^\tau \text{VIX}_{t-\tau-1}, \quad (7)$$

with η serving as the decay factor. When $\eta = 0$, 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 $\eta = 0.3$.²²

²²Using the exponentially weighted moving average of past VIX to select heightened VIX days is equivalent to assuming an ARIMA(0,1,1) model for the VIX process. For the sample from January 1986 to May 2018, η is estimated to be 0.14 with a standard error of 0.01. We therefore also report the results based on $\eta = 0.15$ in Table 5. However, it worth emphasizing that our results are robust to a wide range of values of η .

Table 5: 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
1994-2018											
$\eta = 0$											
4.0	3.9	58.91	2.07	4.0	4.1	49.63	1.73	4.0	4.5	65.68	2.29
3.5	5.4	38.17	1.65	3.5	5.4	51.34	2.19	3.5	5.9	58.18	2.56
3.0	7.7	42.70	2.46	3.0	7.8	52.92	3.08	3.0	8.5	57.22	3.24
2.5	11.1	36.58	2.83	2.5	11.1	46.06	3.34	2.5	11.6	34.56	2.50
2.0	15.9	24.03	2.45	2.0	16.0	29.38	2.80	2.0	16.4	28.30	2.70
1.5	24.6	19.63	2.68	1.5	24.5	16.64	2.14	1.5	25.4	19.92	2.70
1.0	39.7	10.34	2.01	1.0	39.3	11.70	2.17	1.0	41.2	11.80	2.23
0.5	68.0	7.87	2.28	0.5	68.1	7.14	2.02	0.5	68.6	7.24	2.05
0.0	117.9	3.47	1.46	0.0	116.7	4.33	1.85	0.0	115.3	6.06	2.53
1986-2018											
$\eta = 0$											
4.0	3.6	35.98	1.19	4.0	3.7	36.29	1.18	4.0	4.0	52.64	1.74
3.5	4.9	22.29	0.95	3.5	4.9	38.67	1.58	3.5	5.3	45.65	1.93
3.0	6.9	30.55	1.73	3.0	7.0	43.14	2.41	3.0	7.6	48.04	2.71
2.5	9.8	29.35	2.27	2.5	9.9	39.45	2.86	2.5	10.4	29.45	2.17
2.0	14.3	16.94	1.78	2.0	14.4	24.51	2.42	2.0	14.9	21.70	2.16
1.5	22.2	14.22	2.07	1.5	22.2	12.30	1.68	1.5	23.0	15.56	2.23
1.0	36.5	6.59	1.41	1.0	36.7	8.83	1.82	1.0	38.2	9.71	2.03
0.5	65.4	4.84	1.62	0.5	65.2	5.33	1.73	0.5	65.7	5.79	1.88
0.0	118.6	3.03	1.54	0.0	117.7	4.03	2.05	0.0	115.8	5.07	2.51
1986-2018											
$\eta = 0.30$											

VIX changes are calculated as $VIX_t - \mu_{t-1} \geq \text{Cutoff}$, where μ_{t-1} is the exponentially weighted moving average of past VIX up to day $t - 1$. $\mu_{t-1} = (1 - \eta) \sum_{\tau=0}^{t-1} \eta^\tau VIX_{t-\tau-1}$, with η serving as the decay factor. Daily returns on the S&P 500 index at day $t + 1$ are reported. “N Days” measures the average number of such “Heightened VIX” days per year. The sample period is from September 1994 to May 2018 for the top panel and January 1986 to May 2018 for the bottom panel. The sample standard deviation of daily changes in VIX is 1.59% for the first sample from September 1994 to May 2018 and is 2.16% for the second sample period from January 1986 to May 2018.

Our results are summarized in Table 5, 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 bottom right panel, with $\eta = 0.3$ 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 48.04 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.

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 6, 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 3.0%, there are on average 6.5 heightened VIX days per year using daily changes in VIX measured at 3:45pm, and 7.0 days per year using daily changes in VIX Close. The average daily returns are 46.94 basis points and 43.32 basis points, respectively, and both statistically significant.

Our result indicates that using information as early as 3:45 pm, we can identify whether heightened uncertainty has been triggered, and it leaves plenty time to buy S&P 500 index futures or other cash products on the index at 4 pm to capture the average next-day return of 46.94 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 46.94 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 27.14 basis points pre-FOMC return.

²³Using 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 6: Average Daily S&P 500 Index Returns After Heightened VIX, Using Intraday VIX

Cutoff (%)	3:30 pm			3:45 pm			4 pm			Close		
	N Days (/year)	Ret (bps)	T-stat	N Days (/year)	Ret (bps)	T-stat	N Days (/year)	Ret (bps)	T-stat	N Days (/year)	Ret (bps)	T-stat
4.0	3.2	47.50	1.63	3.5	69.74	2.66	3.8	62.00	2.34	3.6	58.73	2.09
3.5	4.3	37.47	1.59	4.8	64.64	3.09	4.9	58.12	2.68	4.9	38.20	1.67
3.0	6.7	41.00	2.32	6.5	46.94	2.65	7.1	48.59	2.83	7.0	43.31	2.53
2.5	9.0	32.58	2.25	9.5	33.38	2.46	10.0	33.47	2.61	10.2	37.17	2.95
2.0	14.1	21.24	2.09	14.5	24.41	2.41	14.7	27.54	2.87	14.9	23.85	2.51
1.5	22.8	13.17	1.84	22.4	16.58	2.30	23.1	21.87	3.13	22.9	18.64	2.63
1.0	37.8	11.42	2.33	36.6	10.62	2.12	36.9	12.47	2.55	37.6	10.11	2.05
0.5	65.8	6.40	2.01	65.7	6.23	1.94	65.9	6.51	2.04	66.1	7.22	2.25
0.0	117.8	2.24	1.07	118.1	3.21	1.54	117.5	2.97	1.42	118.3	3.11	1.44

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

5.2. 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 7 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.

Table 7: 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	27.96	1.26	16	4.4	-26.18	-1.04
-2.3	6.0	16.93	0.85	15	5.2	-18.32	-0.85
-2.2	7.0	14.70	0.84	14	5.8	-19.24	-0.96
-2.1	7.7	12.15	0.74	13	6.9	-17.05	-1.00
-2.0	8.6	12.68	0.86	12	8.3	-18.12	-1.24
-1.9	9.5	19.23	1.40	11	9.6	-17.39	-1.32
-1.8	11.1	15.37	1.27	10	11.2	-13.32	-1.14
-1.7	12.6	17.85	1.65	9	13.5	-6.82	-0.68
-1.6	14.2	14.16	1.45	8	16.6	-3.75	-0.44
-1.5	16.3	15.48	1.77	7	20.5	0.77	0.11

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

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 7 shows that, after large increase in volatility, the next-day returns are on average negative but statistically insignificant. In other words, although the daily correlation between VIX and volatility is as high as 77%, they contain very different information for the purpose of capturing heightened uncertainty. In particular, the volatility component in VIX is not helpful in identifying heightened uncertainty.

Compared with VIX, the volatility measure using the intraday returns is noisier. But the result in Table 7 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

5.3. Connection with Pre-scheduled Announcements: Buildup and Release of Heightened Uncertainty

Although the heightened uncertainty are triggered unexpectedly by adverse market conditions on HVIX days, the underlying mechanism that drives the joint dynamics of return and uncertainty is similar to pre-scheduled FOMC and Macro announcements. In the case of HVIX days, uncertainty, proxied by VIX, increases quickly and then dissolves. Coupled with this pattern of VIX, there is an initial drop and then an increase in market prices. 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.

To draw a direct comparison between heightened VIX days and pre-scheduled announcements, we plot the patterns of cumulative returns and VIX in Figure 3. As a parallel to

²⁴Indeed, prior to important news announcements such as the FOMC days, markets are usually quiet with low trading volume and low volatility, documented in the literature as “quiet-before-the-storm” by Bomfim (2003) and Jones, Lamont, and Lumsdaine (1998).

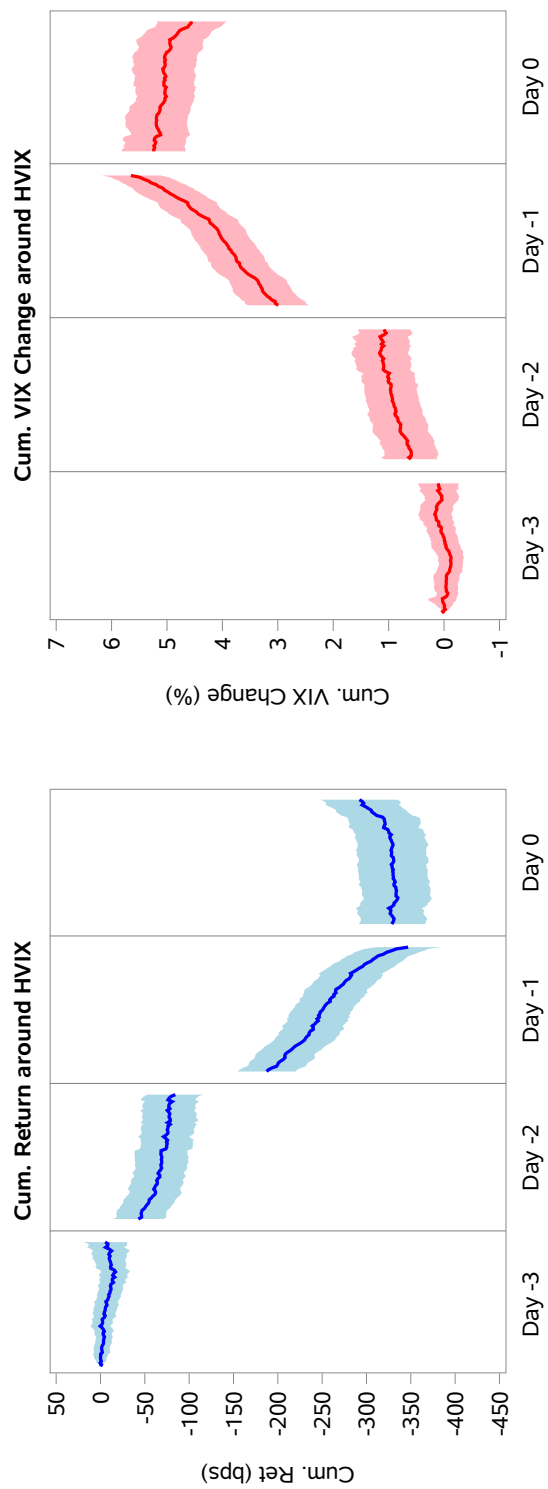


Figure 3: Cumulative Return and VIX Change around Heightened VIX Days.

pre-scheduled announcements, we label the selected heightened VIX days as Day 0.²⁵ Similar to the high-return groups of FOMC and Macro announcements, we see a clear pattern of significant increase in price coupled with large reduction in VIX on Day 0. The average return is 57.22 basis points and the average changes in VIX is -1.11 percentage points on Day 0, both highly statistically significant.

A more interesting 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 and other macro announcements since investors are aware of the announcement well in advance and can plan accordingly. Over the window from -6 days to -1 day, the average build up in VIX is 1.88% for the high-return group of FOMC and 0.90% for the high-return group of Macro announcements. The build-up in VIX is much subtler compared to the 6.28% build-up picked up by the heightened VIX days during the same accumulation window. This is not surprising because, by construction, the heightened VIX days are days when investors are caught off guard by the adverse market conditions.

6. An Illustrative Model

In this section, we construct a simple asset pricing model, which captures two types of risks. One risk is a directional news on the asset payoff; the other risk, also referred to as uncertainty for distinction, is the magnitude of the impact of news on the asset payoff. The resolution of these two risks occur at different times. We demonstrate that the resolution of heightened uncertainty, followed by the resolution of the news itself can generate the return and risk pattern similar to those around the times of FOMC and other macroeconomic announcements as well as times of sharp rises in VIX, as outlined in Section 2.

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 $t = 2$.

²⁵We plot the case for heightened VIX days selected based on exponentially weighted moving average of past VIX with the decay factor η equals to 0.3. The pattern is robust to different choices of values for η .

D is given by:

$$D = \bar{D} + \sigma \varepsilon \quad (8)$$

where \bar{D} is a positive constant, and σ and ε are two independent random variables. In addition, σ^2 follows an exponential distribution with a mean of $\lambda > 0$, and ε follows a standard normal distribution. \bar{D} then gives the expected dividend.

In the context of this paper, ε captures the realization of a market-moving news, and σ captures the size of its impact on asset fundamentals, which is uncertain ex ante. Heightened uncertainty prior to news is represented by a high ex ante variance of σ . The resolution of this uncertainty can occur before the realization of ε , the news itself.

Let $E_t[\cdot]$ and $V_t[\cdot]$ denote the conditional mean/expectation and variance of a random variable at time t ($t = 0, 1$), respectively. The conditional mean and variance at $t = 0$ also give the unconditional mean and variance, respectively, for which we drop the time subscript for convenience. We then have:

$$E[\sigma^2] = \lambda, \quad V[\sigma^2] = \lambda^2. \quad (9)$$

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

Both the bond and 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 P_t , $t \in \{0, 1, 2\}$. Since the bond is the numeraire, its price is always one and its return is zero.

The time line for the economy is summarized as follows:

$t = 0$: Investors observe neither σ^2 nor ε . Based on the probability distributions of σ^2 and ε , they trade the stock (against the bond) by submitting competitive demand functions.

$t = 1$: Investors observe σ^2 but still not ε . With the resolution of uncertainty about the variance, they trade in the market again.

$t = 2$: The news ε is realized and 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:

$$-\exp\{-\alpha W_2\}, \quad (10)$$

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

For the model to be well-defined, the following parameter condition is needed:

$$\lambda < \frac{2}{\alpha^2}. \quad (11)$$

Since both the mean and variance of σ^2 are increasing in λ , condition (11) imposes upper bounds on both of them. For now on, we assume (11) holds without repeating it.

Several comments are in order before moving forward. First, our model is intentionally simple, aimed at capturing two important risks, news risk and the uncertainty about its 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 between them. One may add different types of heterogeneity, such as heterogeneous endowment shocks or signals on σ^2 , and still obtains similar pricing implications. Third, assumptions on probability distributions and investor 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 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 .

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

$$W_2 = W_1 + \theta_1(D - P_1). \quad (12)$$

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

$$\max_{\theta_1} J_1, \quad (13)$$

where

$$J_1 = -E_1 [\exp \{-\alpha [W_1 + \theta_1(D - P_1)]\}] = -\exp \left\{ -\alpha \left[W_1 + \theta_1(\bar{D} - P_1) - \frac{1}{2} \alpha \sigma^2 \theta_1^2 \right] \right\}. \quad (14)$$

The investor's demand function is then given by:

$$\theta_1 = \frac{\bar{D} - P_1}{\alpha\sigma^2}. \quad (15)$$

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

$$P_1 = \bar{D} - \alpha\sigma^2. \quad (16)$$

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

$$J_1 = -\exp\left\{-\alpha\left[W_0 + \theta_0(\bar{D} - \alpha\sigma^2 - P_0) + \frac{1}{2}\alpha\sigma^2\right]\right\}, \quad (17)$$

where we have also used $W_1 = W_0 + \theta_0(P_1 - P_0)$.

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

$$\begin{aligned} J_0 = \mathbb{E}_0[J_1] &= -\int_0^\infty e^{-\alpha[W_0 + \theta_0(\bar{D} - \alpha x - P_0) + \frac{1}{2}\alpha x]} \frac{1}{\lambda} e^{-x/\lambda} dx \\ &= -e^{-\alpha W_0 - \alpha\theta_0(\bar{D} - P_0)} \frac{1}{1 + (\frac{1}{2} - \theta_0)\alpha^2\lambda}, \end{aligned} \quad (18)$$

under the technical condition that $1 + (\frac{1}{2} - \theta_0)\alpha^2\lambda > 0$, 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 (11). Taking the first-order derivative, we then have:

$$\frac{dJ_0}{d\theta_0} = -e^{-\alpha W_0 - \alpha\theta_0(\bar{D} - P_0)} \frac{1}{1 + (\frac{1}{2} - \theta_0)\alpha^2\lambda} \left[\frac{\alpha^2\lambda}{1 + (\frac{1}{2} - \theta_0)\alpha^2\lambda} - \alpha(\bar{D} - P_0) \right]. \quad (19)$$

Hence, if $\bar{D} - P_0 > 0$, which is verified in equilibrium, $\frac{dJ_0}{d\theta_0}$ is positive if and only if $\theta_0 < \frac{1}{2} + \frac{1}{\alpha^2\lambda} - \frac{1}{\alpha(\bar{D} - P_0)}$. The optimal demand is:

$$\theta_0 = \frac{1}{2} + \frac{1}{\alpha^2\lambda} - \frac{1}{\alpha(\bar{D} - P_0)}. \quad (20)$$

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

$$P_0 = \bar{D} - \frac{\alpha\lambda}{1 - \frac{1}{2}\alpha^2\lambda}. \quad (21)$$

The following proposition summarizes the equilibrium stock prices.

Proposition 1 *The equilibrium stock price at dates 0 and 1 are given by (21) and (16), respectively.*

In order to capture the uncertainty about σ , we consider a forward-looking variance swap, which pays $(D - P_1)^2$ at $t = 2$. Its price, denoted by v_t , is given by:

$$v_t = \frac{\mathbb{E}_t [J'_{t+1} v_{t+1}]}{\mathbb{E}_t [J'_{t+1}]}, \quad t = 0, 1, \quad v_2 = (D - P_1)^2, \quad (22)$$

where J'_{t+1} is a shorthand for $J'_{t+1}(W_{t+1})$, and $J_2 = -\exp\{-\alpha W_2\}$. We then have the following result for the price of the variance swap:

Proposition 2 *The equilibrium price of variance swap at dates 0 and 1 are given by:*

$$v_1 = \sigma^2, \quad v_0 = \frac{\lambda}{1 - \frac{1}{2}\alpha^2\lambda}, \quad \mathbb{E}[v_1 - v_0] = -\frac{\frac{1}{2}\alpha^2\lambda^2}{1 - \frac{1}{2}\alpha^2\lambda} < 0. \quad (23)$$

The price of the variance swap can be viewed as equivalent to VIX squared as a measure of uncertainty.

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, as the uncertainty about σ resolves:

$$\mathbb{E}[P_1 - P_0] = \frac{\alpha\lambda}{1 - \frac{1}{2}\alpha^2\lambda} - \alpha\mathbb{E}[\sigma^2] = \alpha \left(\frac{\lambda}{1 - \frac{1}{2}\alpha^2\lambda} - \lambda \right) = -\alpha \mathbb{E}[v_1 - v_0] > 0, \quad (24)$$

where we have used the fact that $\mathbb{E}[\sigma^2] = \lambda$. The associated return variance at date 1 is:

$$\mathbb{V}[P_1 - P_0] = \alpha^2\mathbb{V}[\sigma^2] = \alpha^2\lambda^2. \quad (25)$$

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

$$\mathbb{E}[P_2 - P_1] = \mathbb{E}[D - \bar{D} + \alpha\sigma^2] = \alpha\lambda, \quad (26)$$

$$\begin{aligned} \mathbb{V}[P_2 - P_1] &= \mathbb{E}[(P_2 - P_1)^2] - [\mathbb{E}[P_2 - P_1]]^2 = \mathbb{E}[(D - \bar{D} + \alpha\sigma^2)^2] - \alpha^2\lambda^2 \\ &= \mathbb{E}[\sigma^2 + \alpha^2\sigma^4] - \alpha^2\lambda^2 = \lambda + \alpha^2\lambda^2, \end{aligned} \quad (27)$$

when the news (ε) is realized. Here, we use the unconditional moments because they match the empirical tests.

The following proposition summarizes the stock's return and its variance in the two dates.

Proposition 3 *The date-1 return is higher than the date-2 return, i.e., $\mathbb{E}[P_1 - P_0] > \mathbb{E}[P_2 - P_1]$ when $\lambda > \frac{1}{\alpha^2}$. The date-1 return variance is always lower than the date-2 return variance, i.e., $\mathbb{V}[P_1 - P_0] < \mathbb{V}[P_2 - P_1]$.*

Price Dynamics Hypothesis in Section 2

The solution of the model easily maps back to the reduced-form formulation of price and risk dynamics hypothesized in Section 2. In particular, for (2), we have

$$P_2 - P_1 = \underbrace{(D - \bar{D})}_{\Delta F_2} - \underbrace{(-\alpha\sigma^2)}_{a\Delta V_2}, \quad (28a)$$

$$P_1 - P_0 = -\underbrace{\alpha(\sigma^2 - \lambda)}_{a\Delta V_1} - \underbrace{\alpha\lambda \left(-\frac{\frac{1}{2}\alpha^2\lambda}{1 - \frac{1}{2}\alpha^2\lambda} \right)}_{b\Delta U_1}. \quad (28b)$$

That is, at $t = 2$, there is direct news about the asset payoff, which implies a reduction in the variance of the asset payoff from σ^2 to zero. At $t = 1$, there is no directly news about the asset payoff, but there is information about its variance (jumping from the prior λ to σ^2), which reduces the uncertainty about the return variance as captured by ΔU_1 . In our model, this change in uncertainty is given by the change in the price of the variance swap (i.e., $v_1 - v_0$, up to a constant multiplier).

Empirical Evidence

As shown above, our model delivers directly the price and risk dynamics hypothesized in Section 2. It also yields the corresponding predictions.

In the case of macro announcements, we can identify the announcement period as from date 1 to 2, when the macro announcement (ε) is made, the pre-announcement period as from date 0 to 1, when the uncertainty (about σ) is resolved, and the accumulation period as from date -1 to 0, when uncertainty (λ) hikes up. Proposition 3 and 2 then immediately leads to Prediction 1 and 2 when VIX is used instead of the price of variance swap.

In the case of VIX spike, we can apply the model similarly. An unanticipated increase in VIX corresponds to an increase in λ , the uncertainty about σ^2 . This will then be followed by a positive return as σ^2 realizes and the uncertainty about it resolves, accompanied by a decrease in VIX and a relatively low return volatility. Prediction 3 follows from the above propositions. 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 ε) is gradual over time, not necessarily within a given time frame.

Our empirical analysis of the return and risk (including both VIX and return variance) patterns around macro announcements (FOMC, NFP, ISM and GDP) and VIX spikes are clearly supportive of the model's predictions.

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.

7. Conclusions

In this paper, we provide compelling evidence that FOMC days are not unique in yielding the disproportionately large returns. We document, for the first time in the literature, economically and statistically significant pre-announcement returns for the pre-scheduled releases of macroeconomic indicators such as Nonfarm Payroll, ISM, and GDP. Motivated by this commonality in pre-announcement returns, we propose a simple risk-based explanation. In particular, we argue that there are two different risks: the news itself and the uncertainty associated with the news' impact. We hypothesize that pre-scheduled announcements naturally bring heightened uncertainty to the market during a relatively long accumulation period and this heightened uncertainty starts to dissolve at a condensed pre-announcement period prior to the actual news releases. While the accumulation of the heightened uncertainty depress market prices, its dissolution leads to significant positive return during the pre-announcement period. Using CBOE VIX as an empirical gauge for uncertainty, the joined pattern of uncertainty and return are overall consistent with our model predictions. In addition, we show that heightened uncertainty can also be triggered unexpectedly by adverse market conditions. The next-day return following days with large VIX spike-ups are significant and with magnitudes comparable to the pre-announcement returns on news release days. That is, as long as we focus our attention on such heightened uncertainty 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.

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