Bond Implied Risks Around Macroeconomic Announcements *

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Abstract

Using a large panel of Treasury futures and options, I construct model-free measures of bond uncertainty and tail risks. I find that bond tail risk 1) positively correlates with stock tail risk before and around financial crises while negative correlation holds for other days; 2) increased dramatically before and around the financial crises foreshadowing the extreme challenges in the Treasury bond markets; 3) and has significantly decreased in recent years under zero-lower-bound and forward guidance. I then study the behavior of bond risk measures around FOMC announcements and document three novel findings: First, bond uncertainty risk displays rising and resolution similar to the stock VIX index, due to an increase in call option prices rather than puts. Second, pre-FOMC announcement drift exists in terms of Treasury yields declining by 1 bps on the day before the announcement. Third, uncertainty risk cannot help explain the pre-FOMC announcement drift.

Keywords: Treasury Implied Risks, Tail Risk, Pre-FOMC Announcement Drift

JEL Classification: E52, G12, G14

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The recent disruptions in global financial markets during Spring 2020 are a stark reminder of the significant uncertainty faced by investors after the default of Lehman Brothers in 2008. Option markets are particularly suited to gauge such manifestations because they capture market participants' future expectations. Particular attention is paid to the VIX index, an implied-volatility index calculated from S&P500 options, which climbed to new heights in March 2020. A second manifestation of market panics is the so-called Flight-to-Safety, which refers to the fact that investors shift their portfolios from risky to safer assets. However, during the financial crises, safe assets like US Treasuries are usually amid volatile demand and supply. While measures of uncertainty extracted from equity markets are in ubiquitous use, little is known about corresponding risks in Treasury bond markets. It is surprising given the paramount role of safe assets during periods of distress. This paper fills this gap.

In this paper, I estimate the term structure of bond uncertainty and tail risk from Treasury bond future option prices using a long time-series and large cross-section from Jan 2000 to June 2020. Applying the well-cited method by Bakshi, Kapadia, and Madan (2003) and the CBOE index construction practices, I obtain the analogous bond implied risks, and compare them with the equity market VIX and SKEW indexes.

Investigating the time series of bond risk measures, I pinpoint three primary characteristics of Treasury bond tail risks. First, while counter-cyclical bond uncertainty risks move together with the stock VIX index, bond tail risks are weakly and negatively correlated with the stock SKEW index. Surprisingly, this relationship turns positive before and around the three recent financial crises, indicating critical distress across different markets (seen in Figure 4). Second, as tail risks are forward-looking measures and shown in Figure 2, Treasury bond tail risks enlarged before the 2000 Internet Bubble Burst and 2008 Financial Crisis, and were especially substantial in early 2007, which demonstrated the enormous risk in the debt markets. For example, massive subprime mortgages default due to the housing bubble burst. Additionally, March 2020 witnessed the moment of selling pressure on the Treasury bond market, which reflects the uniqueness of Treasury bond risks and is well captured by the tail risk measures. Third, since 2016, tail risks embedded in the Treasury market have been much more modest, under the zero-lower-bound frames as well as the forward guidance to keep the interest rate low for the foreseeable future.

delaration, report, notification, publish, disclosure, revelation Beyond the time-series features, I gauge the movement of bond implied risks around various macroeconomic announcements such as the release of monetary policy by the Federal Market Open Committee (FOMC). Studying the dynamics of these measures around release days provides a unique laboratory because these events are highly anticipated and we expect notable uncertainty to be resolved upon release. Moreover, recent work in equity markets connects the heightened uncertainty before the announcement to the pre-announcement drift, see, e.g., Hu, Pan, Wang, and Zhu (2019). Also, papers by Ai and Bansal (2018) and Wachter and Zhu (2020) provide theoretical models rationalizing the announcement returns with uncertainty resolution. As for the bond market, Tillmann (2017) and De Pooter, Favara, Modugno, and Wu (2020) investigate the role of monetary policy uncertainty on the bond yield response to FOMC announcements. Following these strands of literature, I explore the relationship between bond and equity risks, and link these measures to risk premia earned around these days. To motivate my paper, I plot in Figure 6 the dynamics of stock and bond uncertainty risk 15 trading days before and after FOMC meetings. While it is well-known that equity market uncertainty increases before announcements, I find a very comparable pattern in the bond option market. In particular, I observe significant increments in Treasury bond option-implied volatility[1] two to three days before the FOMC announcements, the continued heightened level for one day, and a sharp fall to their mean upon release. Following a current paper from Beckmeyer, Branger, and Grünthaler (2019), who decompose the stock uncertainty risk into the left/right tail parts (using method from Bollerslev, Todorov, and Xu (2015)) and claim that it's the left tail of the uncertainty risk that drives the movement around FOMC days, I apply the equivalent steps by controlling the 3rd-moment tail risk instead, discovering that bond tail risk doesn't respond to the FOMC announcement. In this paper, I also extend this approach to the announcements of 25 economic indicators. Announcements of most fundamentals don't modify the bond implied risks, while the unemployment rate (or the non-farm payroll) stands out since it reduces the bond uncertainty risk in a clear manner.

Apart from the uncertainty resolution, what drives the upsurge of uncertainty before the FOMC announcements in the first place? As the uncertainty measure is derived by the weighted average of out-of-money options, and the options whose strike price are the closest to the underlying spot price are valued the most, I try to explain it through these option prices. Surprisingly, results show that it's the prices of call options rather than puts that are in line with the rising of uncertainty before FOMC announcements, showing that option-trading investors purchase call options with the expectation of rising equity and debt prices around the FOMC announcements, instead of buying puts to hedge with risks, contradicting some traditional thoughts about the construction of uncertainty risk. Furthermore, I look at the trading volume of options around the meetings, finding that call options are traded with a higher volume than puts before the announcements, supporting investor's trading behavior.

Keeping in mind the dynamics of Treasury bond risks around FOMC announcements, it's natural to follow the literature and look at the risk premia around those days. Lucca and Moench (2015), in their seminal paper, document a substantial return in the stock market 24 hours before the FOMC announces its new monetary policy. Interestingly, they do not find a similar pattern in Treasury bond markets. Prima facie, this misalignment may seem puzzling: Why does the stock market move while bonds remain unchanged? Exploring daily data, I uncover the existence of the pre-FOMC announcement drift in Treasury bond markets. As presented in Figure 9, yields on Treasury 5-year, 10-year, and 30-year bonds sharply decline the day before monetary policy releases. More specifically, similar to Lucca and Moench (2015), I find the stock index return increases by 28 bps before the announcement for the data period, while bond yields drop by 1 bp, a huge abnormal drift compared to 2 bps and -0.1 bp of daily change for equity and bonds on average. As I divide the data range from 2010, I find the diminishing pre-FOMC announcement return in the equity market, supporting the recent paper by Kurov, Wolfe, and Gilbert (2020), while the abnormal drifts in the Treasury bond market are not disappearing.

[1] I use the terms "implied volatility" and "uncertainty", as well as "implied skewness" and "tail risk" interchangeably in the paper.

With regard to the announcement premium, I also extend Neuhierl and Weber (2018)'s paper to examine the "monetary momentum" in the Treasury bond market. Compared with the stock index which keeps going upwards, bond yields shift down, after the significant bounce back in the week of the FOMC meeting (see Figure 9). Also, the cumulative yield drop becomes less substantial along with the tenors. To investigate the yield responses across tenors, I divide the bond yields into the expected rate and the term premia according to data provided by Adrian, Crump, and Moench (2013). Figure 11 in the later chapter shows that monetary policy alters investors' beliefs about the future expected rate rather than the term premia, so that the expected part drops near the same amount for bonds of all maturities. It's the increased term premia that cause the overall bond yield to respond differently, which is higher with longer maturities. Furthermore, the stock return and the bond yield shift downwards with expansionary monetary policies, and upwards with contractionary ones, yet the monetary momentum effect in bonds weakens as the maturity lengthens, consistent with the previous results.

The significant changes in bond yields and stock returns before the announcement follow significant increases in uncertainty risk in either of the two markets. To investigate this pre-announcement risk-return relationship, I extend two related hypotheses in the equity market to the field of Treasury bonds to examine the predictive power of uncertainty for these abnormal drifts.

One of the hypotheses is the "Heightened Uncertainty Premium" proposed by Hu, Pan, Wang, and Zhu (2019), who argue that the extraordinary increase in VIX (the so-called heightened uncertainty) predicts the next-day abnormal stock return, rationalizing the stock pre-FOMC drift. Following this paper's methodology, I find that the significant increase in bond uncertainty risk is followed by a positive yield change. Hence, given the reverse drift pattern observed in Treasury bond markets relative to the equity market, it is unlikely that the authors' hypothesis applies similarly to bonds. Also, the risk upsurge before the FOMC days is hardly "heightened", in other words, the heightened uncertainty days do not coincide with the pre-FOMC days. Looking at the distribution of pre-FOMC uncertainty risk and the following drift (see Table 10), the level of uncertainty enlargement before the FOMC days passes the cutoff bar on average twice per year, and these days are followed by positive stock return and negative bond yield changes, consistent with the pre-FOMC announcement drift but in contrast to the proposed heightened uncertainty premium. Therefore, this hypothesis is insufficient for explaining pre-FOMC announcement drift, although it gives rise to a positive relationship between the uncertainty change and the future returns.

To construct regressions, I follow Tillmann (2017) and De Pooter, Favara, Modugno, and Wu (2020)'s approach of adding the interaction term to capture the special uncertainty surge before the announcement days. Results (in Table 11) reveal that variation in uncertainty can hardly predict the stock return and bond yield change: 1% of the implied volatility rise can drive up the stock return, the 10-year and 30-year bond yield by 7.0 bps, 0.8 bp and 0.9 bp correspondingly from 2000 to 2009, but their influences are tempered afterward. As bond yield decreases rather than increases before the FOMC announcement, the effect from uncertainty risk cannot help explain the bond pre-announcement drift. Moreover, since the average uncertainty rises before the FOMC meetings are 0.5%, 0.2%, and 0.3% respectively, uncertainty has very minimal contribution to the pre-FOMC drifts even for stocks, leaving a large portion of drift unexplained. Concerning the interaction terms, the sudden jump in the 30-year implied volatility before the FOMC meeting decreases the bond yield, partially explaining the bond pre-announcement drift for the long-term bond only. I finally confirm the results by running regressions only on the FOMC days, the approach employed by Hu, Pan, Wang, and Zhu (2019). Nevertheless, as seen in Table 12, most of the drifts are still located in the intercept. Therefore, although the rise of uncertainty and drift are followed one by another, uncertainty itself is not sufficient for the documented pre-FOMC announcement in both the equity and Treasury bond markets.

Contribution to the Literature

In addition to the most relevant research mentioned above, my paper contributes to the literature in various domains. First, it is the first paper to produce the Treasury-implied tail risk. Similar option-implied methods from Breeden and Litzenberger (1978), Carr and Madan (2001) and Schneider and Trojani (2015) are used in the literature to generate pro-cyclical stock skewness risks but no one has touched on option-implied Treasury tail risk to my understanding. To be noted, some researchers point out the instability of option-implied skewness derived from all those methods due to the less liquid option markets so that they proceed with other methodologies. For example Bollerslev, Todorov, and Xu (2015) and Gao, Gao, and Song (2018) provide counter-cyclical stock tail risks using the out-of-money puts only. There are also methods such as the Bali, Cakici, and Whitelaw (2014)'s approach which treats the downside variance risk as the tail risk. The problem with other derivations of tail risk is that it's part of the uncertainty risk, so that it gives counter-cyclical risk measures without providing enough additional information about the tail risk. For a more consistent measure for bond uncertainty and tail risk together, I choose to proceed with Bakshi, Kapadia, and Madan (2003), but I apply the index calculation practice to overcome the potential issues of illiquidity and instability.

Researchers deploy the option-implied uncertainty and tail risk for various questions in equity markets, leaving only a few papers devoted to bond risks. This paper is mostly related to the work of Choi, Mueller, and Vedolin (2017), who derive the implied variance for the 5, 10, and 30-year Treasury bonds to construct the bond variance risk premium. The main difference between the two papers is that I implement the index calculation approach to provide a Treasury uncertainty and tail risk index, and that I focus on the movement of risks instead of trading strategy. As a result, the derived bond implied risks are comparable to the existing benchmarks with high correlation coefficients. Also, both the index and the derived bond implied volatilities increase together before the FOMC meetings, further validating this approach. Another paper which also works on the Treasury bond implied risk is from Cremers, Fleckenstein, and Gandhi (2017), who focus only on the 5-year at-the-money implied volatility and investigate its predictability for economic activity. Similarly, Dew-Becker, Giglio, and Kelly (2019) employ the at-the-money implied volatility in various markets, including bonds, to discuss the cost of hedging economic/financial uncertainties.

Bond uncertainty risk in this paper also relates to the market-based monetary policy uncertainty extracted from the derivatives of the short-term interest rates, yet I focus on the longer-term (2, 5, 10, and 30 years) implied risks from Treasury bonds. For instance, Swanson (2006) adopts the 90% width of probability distribution for the federal fund rate 1 year ahead; Bauer, Lakdawala, and Mueller

(2019) use the 1-year Eurodollar future options to compute the risk-neutral standard deviation of the interest rate change; And Kurov and Stan (2018) employ the realized volatility of the Eurodollar futures rate with 2 years to expiration. There are also other measures for monetary policy uncertainty: Husted, Rogers, and Sun (2019) have the news-based uncertainty using text searching and Istrefi and Mouabbi (2018) offer the subjective monetary policy uncertainty by gauging the disagreement among professional forecasts.

Another branch of research this paper relates to attempts to document and explain the risk premia earned before or around monetary policy release. When Lucca and Moench (2015) detect the pre-announcement return in the equity market, subsequent papers solving the puzzle are split into two channels: information leaking, and uncertainty resolution/compensation. Regarding the uncertainty-based theories, Hu, Pan, Wang, and Zhu (2019) introduce the premium for heightened uncertainty, claiming that the substantial increment in VIX is accompanied by the next-day abnormal excess return so that the rise in uncertainty risk ahead of the FOMC meetings rationalizes the drift. Also, Bauer, Lakdawala, and Mueller (2019) point out the uncertainty resolution on the FOMC announcement days. Theoretical papers by Ai and Bansal (2018) provide a model-based explanation of announcement premium by uncertainty resolution. Another statement in Lucca and Moench (2015)'s paper is that the pre-announcement drift doesn't exist in the Treasury bond market, which is even more puzzling because what the Fed targets is the interest rate, but we cannot capture the pre-drift in the interest rate assets. As papers have already validated the interest rate sensitivity to monetary shocks even for the long-term bonds (Kuttner (2001), Leombroni, Vedolin, Venter, and Whelan (2019), Gürkaynak, Sack, and Swanson (2005) and Hanson and Stein (2015)), the puzzles and possible uncertainty channel trigger me to revisit the bond pre-announcement drift. Surprisingly, the pre-FOMC announcement drift does exist in the Treasury bond markets. And because the paper from Kurov, Sancetta, Strasser, and Wolfe (2019) uncovers the bond yield drift in advance of macroeconomic news through the 5-min windows, it supports my finding from a different perspective since asset prices typically react more to monetary policy than to the release of other macroeconomic indicators.

Among the research about monetary policy uncertainty, some authors deploy the uncertainty measure to study its role in policy transmission. For instance, De Pooter, Favara, Modugno, and Wu (2020) apply Swanson (2006)'s uncertainty measure to understand how monetary policy shock [2] transmit to yields under different levels of uncertainty risk. They conclude that for a given shock, the reaction of yields is more pronounced when uncertainty is low. Also, Tillmann (2017) tries multiple existing monetary uncertainty measures with the daily change of the 2-year Treasury yield as the policy shock to study the yield curve response. Similarly, Bauer, Lakdawala, and Mueller (2019) introduce their measure of uncertainty, and use the first principal component of daily change in Eurodollar futures as the shock. All of their comparable results point to the fact that the high uncertainty tempers the yield curve reactions to the monetary policy shock. Learning from those papers, I contribute to investigating the role of bond uncertainty risk in monetary policy transmission under the context of the pre-announcement drift. In this paper, I question the relationship between

[2] The 2-year Treasury yield change around the 30-min FOMC announcement window, which is originally proposed by Hanson and Stein (2015).

the change of uncertainty and the future stock and bond drift before the announcements, confirming the insufficiency of uncertainty risk to solve the pre-announcement puzzle.

The rest of the paper is organized as follows: Section 1 starts with the data and methodology for measuring bond implied risks. Section 2 discusses the term structure features of bond uncertainty and tail risk, and the time-series charateristics of bond tail risks are discussed. Section 3 documents the uncertainty upsurge before FOMC days, and tries the explain these movements. Section 4 establishes pre-announcement drift in the Treasury bond markets. The bond monetary momentum effect as well as the source of the change are also investigated. Section 5 disconnects the uncertainty risk with the pre-announcement return. Section 6 concludes and proposes further research possibilities.

1 Measuring Bond Implied Risks

1.1 Data

The data used for constructing bond risk measures is derived from the daily trading information of 2-, 5-, 10-, and 30-year Treasury futures and options from the CME End-of-Day dataset, covering January 2000 to June 2020. The derivatives for S&P500 index are also used in this paper to justify the reliability of this methodology by comparing it with the CBOE indexes as benchmarks. As multiple contracts are listed on each date, I extract the future price by the rolling convention from Choi, Mueller, and Vedolin (2017), which rolls to the next future on the 28th of the month before the maturing month. Also, I select the nearest and the next series of option prices after data cleaning[3]. The Treasury constant-maturity 3-month interest rate is employed as the risk-free rate. For the stock index return as well as the Treasury bond yields utilized in the latter chapters, I obtain the data from Bloomberg and Federal Reserve website, respectively.

1.2 Implied Volatility and Skewness

To construct the bond risk measures, I implement the formulas from Bakshi, Kapadia, and Madan (2003) to calculate the risk-neutral expectation of moments of log returns — the first moment ($\mu(t,\tau) \equiv E^Q[e^{-r\tau}R(t,\tau)]$), the variance ($V(t,\tau) \equiv E^Q[e^{-r\tau}R(t,\tau)^2]$), cubic ($W(t,\tau) \equiv E^Q[e^{-r\tau}R(t,\tau)^3]$), and quartic ($X(t,\tau) \equiv E^Q[e^{-r\tau}R(t,\tau)^4]$) contract prices, where $R(t,\tau) \equiv \ln[S(t+\tau)] - \ln[S(t)]$, and τ is the time to maturity. Since options are written on futures, the spot price $S(t)$ is the future price in this setting. One thing to be noted is that Treasury and S&P500 options are American-style while the methodology of Bakshi, Kapadia, and Madan (2003) is based on European options. As Choi, Mueller, and Vedolin (2017) prove that the adjustment is small for options within one year to expiration, and I only use the options maturing in 1 and 2 months, I proceed with no adjustment. Based on Equation (1) to (4), the out-of-money call and put options are given different weights according to their moneyness before aggregating to approximate the value of contracts.

[3] Exhaustive details on data filtering are discussed in Appendix A.

Those equations are similar but different from the ones deployed by the CBOE indexes, in terms of the weights before the option prices, the calculation of $\mu(t,\tau)$, and one practical error adjustment, because artificial future prices from the Call-Put Parity is applied under the index calculation procedure instead of the real future prices. I choose the Bakshi, Kapadia, and Madan (2003) approach since it makes more sense by assigning higher weights to put options (since put options are used more often for hedges) and using the actual future price. [4]

$$V(t,\tau) = \int_{S(t)}^{\infty} \frac{2\left(1-\ln\left[\frac{K}{S(t)}\right]\right)}{K^2} C(t,\tau;K)dK + \int_{0}^{S(t)} \frac{2\left(1+\ln\left[\frac{S(t)}{K}\right]\right)}{K^2} P(t,\tau;K)dK \tag{1}$$

$$W(t,\tau) = \int_{S(t)}^{\infty} \frac{6\ln\left[\frac{K}{S(t)}\right] - 3\left(\ln\left[\frac{K}{S(t)}\right]\right)^2}{K^2} C(t,\tau;K)dK - \int_{0}^{S(t)} \frac{6\ln\left[\frac{S(t)}{K}\right] + 3\left(\ln\left[\frac{S(t)}{K}\right]\right)^2}{K^2} P(t,\tau;K)dK \tag{2}$$

$$X(t,\tau) = \int_{S(t)}^{\infty} \frac{12\left(\ln\left[\frac{K}{S(t)}\right]\right)^2 - 4\left(\ln\left[\frac{K}{S(t)}\right]\right)^3}{K^2} C(t,\tau;K)dK + \int_{0}^{S(t)} \frac{12\left(\ln\left[\frac{S(t)}{K}\right]\right)^2 + 4\left(\ln\left[\frac{S(t)}{K}\right]\right)^3}{K^2} P(t,\tau;K)dK \tag{3}$$

$$\mu(t,\tau) = e^{r\tau} - 1 - \frac{e^{r\tau}}{2}V(t,\tau) - \frac{e^{r\tau}}{6}W(t,\tau) - \frac{e^{r\tau}}{24}X(t,\tau) \tag{4}$$

Based on the above formulas, the risk-neutral implied variance and skewness are derived by:

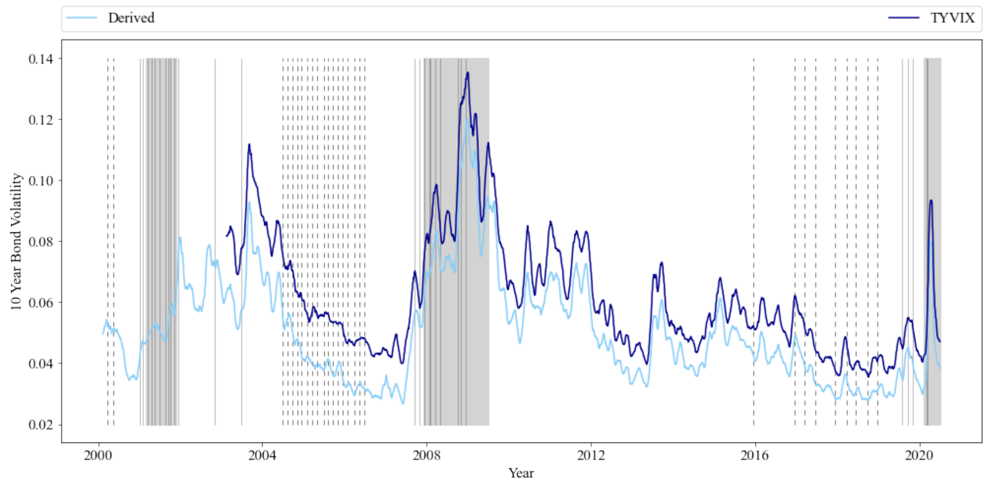
$$Vol(t,\tau) = E^Q[R(t,\tau)^2]) = e^{r\tau}V(t,\tau) \tag{5}$$

$$Skew(t,\tau) = \frac{E^Q(R((t,\tau) - E^Q[R(t,\tau)])^3}{\{E^Q(R(t,\tau) - E^Q[R(t,\tau)])^2\}^{\frac{3}{2}}} = \frac{e^{r\tau}W(t,\tau) - 3\mu(t,\tau)e^{r\tau}V(t,\tau) + 2\mu(t,\tau)^3}{[e^{r\tau}V(t,\tau) - \mu(t,\tau)^2]^{\frac{3}{2}}} \tag{6}$$

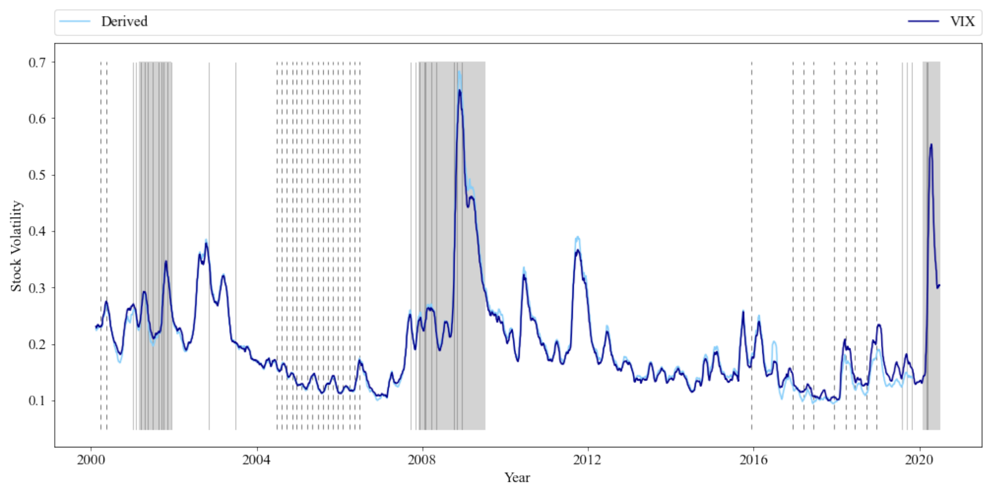
Using two series of options each day, we now have both the nearest and the next implied variance and skewness labeled by $Vol(t,\tau_1)$, $Vol(t,\tau_2)$ and $Skew(t,\tau_1)$, $Skew(t,\tau_2)$, respectively. Although I use the method from Bakshi, Kapadia, and Madan (2003) instead of the index calculation approach for the underlying risk contract prices, I follow the index practices to take the weighted average of the two implied risks for the 30-day uncertainty and tail risk to eliminate the potential illiquidity or instability effect. To be more specific, the nearest and next implied risks are weighted by how close their time-to-maturity is to 30 days (see Equation (7)), so the derived implied volatility denoted by V^{iy} is provided in Equation (8) after taking the square root of the annualized risk-neutral variance, and implied skewness S^{iy} is presented in Equation (9), for Treasury bond risks of 2, 5, 10, and 30 years.

$$w_1 = \frac{\tau_2 - \frac{30}{365}}{\tau_2 - \tau_1}, w_2 = 1 - w_1 = \frac{\frac{30}{365} - \tau_1}{\tau_2 - \tau_1} \tag{7}$$

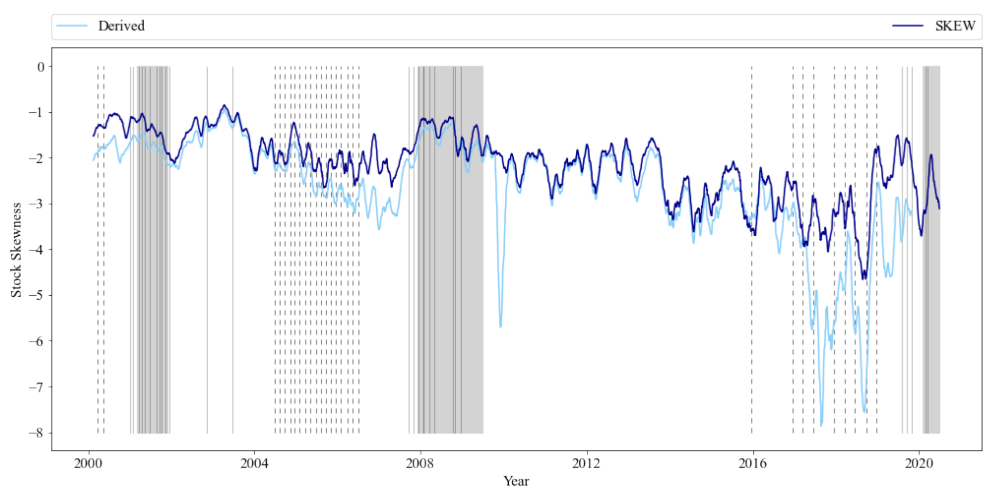
[4] More detailed comparisons and reasons are in Appendix B.



(a) 10-Year Derived Uncertainty Risk and TYVIX Index



(b) Stock Derived Uncertainty Risk and VIX Index



(c) Stock Derived Tail Risk and SKEW Index

Figure 1. Benchmark Comparison

Note: These figures compare derived implied risks with the corresponding indexes, where the daily data are taken the 30-day moving average. The daily correlations for each plot are 0.97, 0.99 and 0.78, respectively. The derived Treasury bond uncertainty and tail risk are from Equation (8) and (9), the construction of which is provided in Chapter 1. Data runs from Jan 2000 to June 2020. TYVIX, VIX and SKEW are from the CBOE webpage.

$$V^{iy} = \sqrt{\frac{365}{30}\left(w_1 \times Vol^{iy}(t,\tau_1) + w_2 \times Vol^{iy}(t,\tau_2)\right)}, i = 2, 5, 10, 30 \tag{8}$$

$$S^{iy} = w_1 \times Skew^{iy}(t,\tau_1) + w_2 \times Skew^{iy}(t,\tau_2), i = 2, 5, 10, 30 \tag{9}$$

Treating the existing CBOE indexes TYVIX, VIX, and SKEW as benchmarks, I verify the robustness of the measure in Figure 1, where you can find the 30-day moving average of the derived risks and their corresponding indexes. Figure 1a confirms that the calculated 10-year implied volatility follows well with the TYVIX (10-year Treasury note implied volatility) index, providing validation for bond uncertainty risks across tenors. Nevertheless, we could notice a parallel downward shift of the constructed 10-year Treasury uncertainty compared to the benchmark TYVIX, which could attribute to the smaller/larger weights given to the deep out-of-money call/put options.

To justify the skewness measure without a bond tail risk index, I derive the S&P500 implied risks to compare them with the VIX and SKEW indexes. We could see that the fitness of uncertainty risk is reasonably well and tail risk is also able to capture the trend, while the variation in recent years may attribute to the higher weights (compared to the indexes) given to the out-of-money put options. On a daily base, the correlations between the computed risks and the indexes are 0.97, 0.99 and 0.78, respectively, confirming the reliability of bond risk measures.[5]

2 The Time Series of Bond Implied Risks

2.1 Summary Statistics and Term Structure

In Table 1, I summarize the statistical comparison between equity and bond implied risks and the term structure characteristics. First, we can see that bond uncertainty risks are smaller in magnitude compared to the stock counterparts. The daily average of VIX from 2000 to 2020 is 19.81%, while the most magnificent 30-year bond implied volatility gives 8.66%. Also, the volatilities of volatility are smaller. Notwithstanding, if we divide the mean by the corresponding standard deviation, stock and bond uncertainty risks are comparable, suggesting that the uncertainty risks underneath the Treasury bond markets are not negligible. Bond tail risks, which are also smaller than the stock SKEW index on average, display more substantial variations in terms of the standard deviation and the 1% quantile distribution.

Concerning the term structure properties, longer maturity is with more substantial uncertainty risk, yet the 5-year is an exception, which is larger than the 10-year counterpart and comparable to the 30-year. From Figure 2, one can tell that the reason lies in the changing behavior of the 5-year uncertainty after the 2007-09 financial crisis, when it became much comparable to the 30-year risk, driving up the overall mean. From this perspective, maturity isn't the only determining factor for the term structure of bond implied risks. For the reason why 5-year uncertainty risk becomes larger,

[5] More details about the benchmark comparison, the reason of the discrepancies in the uncertainty and tail risk measures compared to the bencemarks, and the at-the-money implied volatility measures used by other literature are discussed in Appendix C.

Table 1. Summary Statistics of Stock and Bond Implied Risks

	VIX	V^{2y}	V^{5y}	V^{10y}	V^{30y}	$SKEW$	S^{2y}	S^{5y}	S^{10y}	S^{30y}
Mean	19.81%	3.50%	7.06%	5.06%	8.66%	-2.16	-0.17	-0.51	-1.76	-1.48
Std	8.99%	1.77%	4.06%	1.85%	3.29%	0.82	3.35	2.43	3.42	2.94
Mean/Std	2.20	1.98	1.74	2.75	2.63	-2.64	-0.05	-0.21	-0.51	-0.50
1%	55.77%	9.10%	20.47%	11.17%	20.74%	-4.54	-12.82	-10.99	-14.17	-16.67

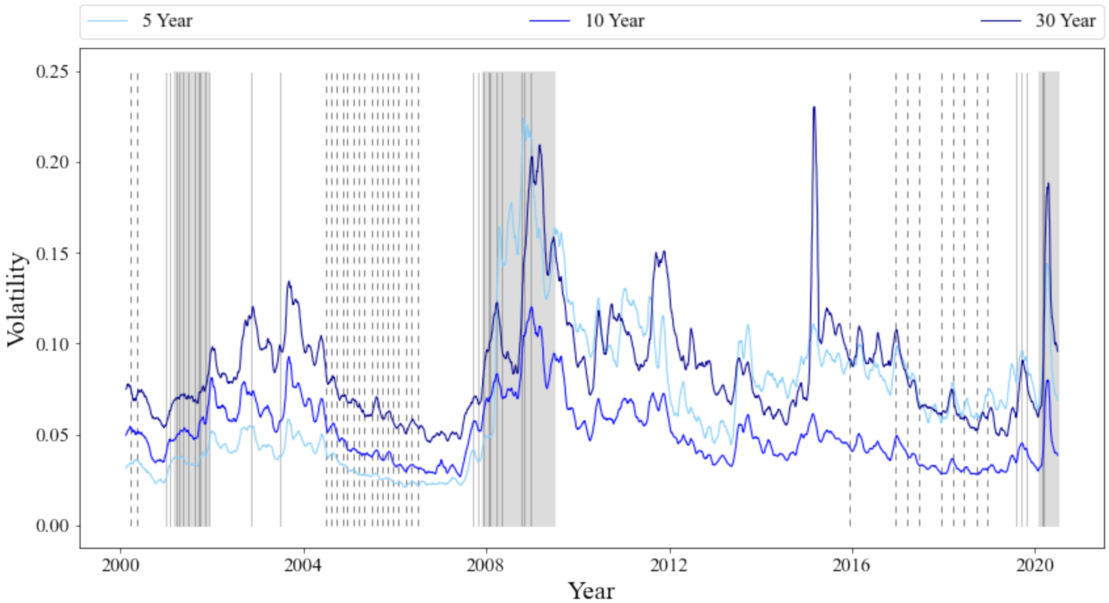
	VIX	V^{2y}	V^{5y}	V^{10y}	V^{30y}	$SKEW$	S^{2y}	S^{5y}	S^{10y}	S^{30y}
V^{2y}	**0.37*** **									
V^{5y}	**0.45*** **	0.44***								
V^{10y}	**0.70*** **	0.51***	0.61***							
V^{30y}	**0.64*** **	0.26***	0.64***	0.79***						
$SKEW$	**0.38*** **	0.27***	-0.08***	0.40***	0.17***					
S^{2y}	-0.15***	**-0.07*** **	-0.17***	-0.21***	-0.19***	**-0.02**				
S^{5y}	-0.05**	0.11***	**0.09*** **	-0.06***	-0.06***	**-0.12*** **	0.15***			
S^{10y}	-0.04***	-0.05***	0.01	**-0.18*** **	-0.11***	**-0.16*** **	0.19***	0.27***		
S^{30y}	0.08***	-0.03*	0.26***	0.08***	**0.18*** **	**-0.15*** **	0.01	0.12***	0.49***	

Note: The upper table provides the daily mean, standard deviation, mean divided by standard deviation and the largest 1% quantile of stock and bond implied risks from Jan 2000 to June 2020. Correlation is presented in the second table. VIX and $SKEW$ are available from the CBOE webpage, while V^{iy} together with S^{iy} denotes the derived Treasury bond implied volatility and skewness risks for 2, 5, 10 and 30 years from Equation (8) and (9), the construction of which is provided in Chapter 1. *p: 0.1, **p: 0.05, ***p: 0.01

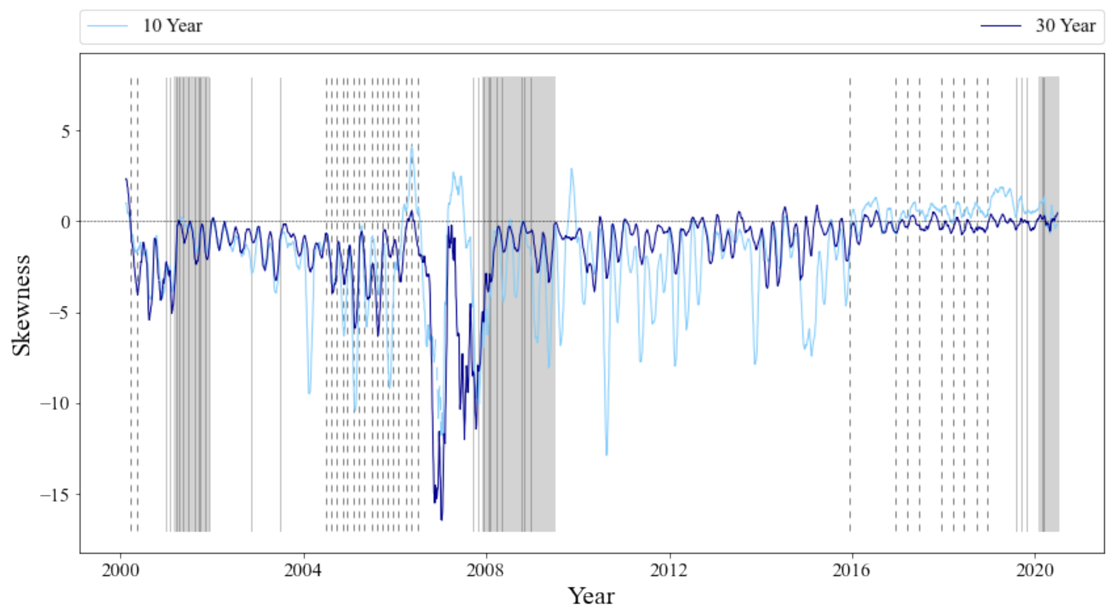
Cremers, Fleckenstein, and Gandhi (2017) points out that 5-year Treasury note is the largest and the most liquid market in recent years, so that it's reasonable to assume that the 5-year options are priced relatively higher, contributing to larger uncertainty risk because the option-implied uncertainty is calculated from the option prices.

Also, it's worth mentioning that the longer maturity is associated with higher tail risk, but the 10-year Treasury bond carries the most extensive tail risk. One of the possible explanations is that 10-year Treasury notes rather than the 30-year bonds are normally regarded as the benchmark representing the long-term interest rate. This attention makes it attract more trading and hedging, therefore coming with higher tail risk reflecting the market expectation about the long term rate.

As I provide in the lower table, Treasury implied risks across the term structure are positively correlated, in contrast with Cremers, Fleckenstein, and Gandhi (2017)'s argument of little uncertainty risk correlation, but the correlations among bond tail risks are smaller. Moreover, we could also look at the correlation between uncertainty and tail risk, which are small and unstable — 0.38, -0.07, 0.09, -0.18 and 0.18 for stock and 2-, 5-, 10- and 30-year bonds respectively — only that tail risks are more diversely distributed when uncertainty risks are low, as shown in the scatter plots in Figure 3. This pattern is consistent with the later finding that uncertainty is counter-cyclical while tail risk is forward-looking, such that before the financial crises happened in 2000 to 2020, uncertainty risks were moderate while tail risks accumulated a lot.



(a) Term Structure of Bond Uncertainty Risk



(b) Term Structure of Bond Tail Risk

Figure 2. Term Structure of Bond Implied Risk

Note: These figures present the 30-day moving average of the bond implied volatility and skewness term structure from Jan 2000 to June 2020. 2- And 5-year skewness are not graphed to provide a clearer picture. Grey bars represent recessions defined by NBER Business Cycle. The dot/dash lines label the announcements of expansionary/contractionary monetary policy. The derived Treasury bond uncertainty and tail risk are from Equation (8) and (9), the construction of which is provided in Chapter 1.

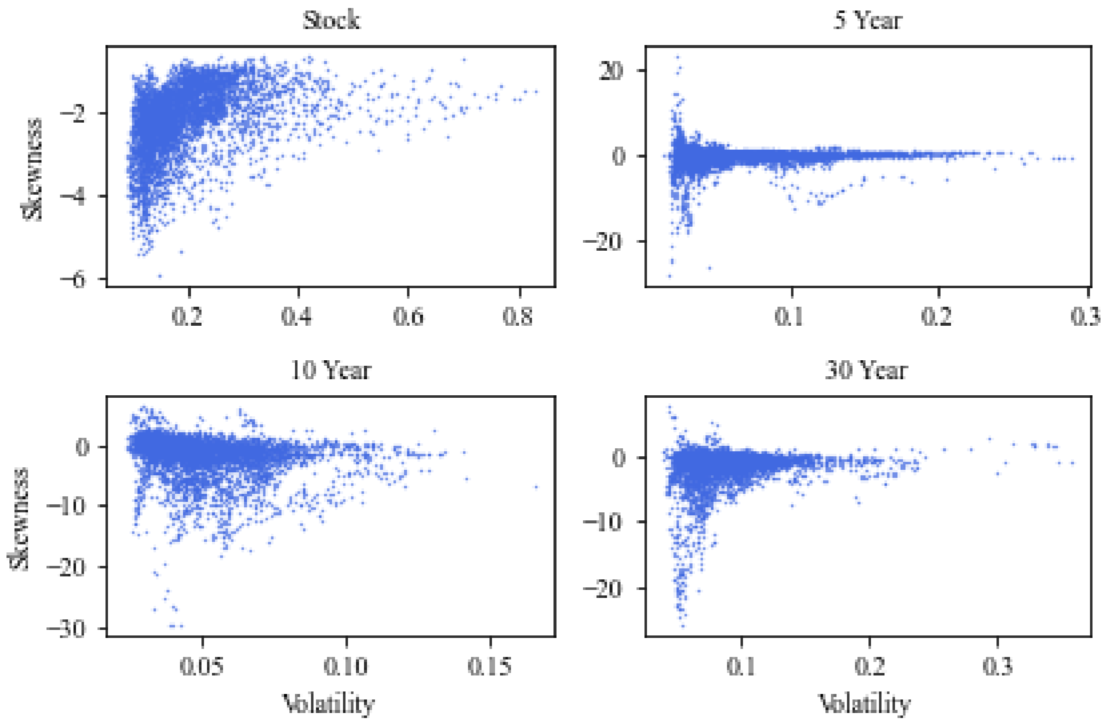


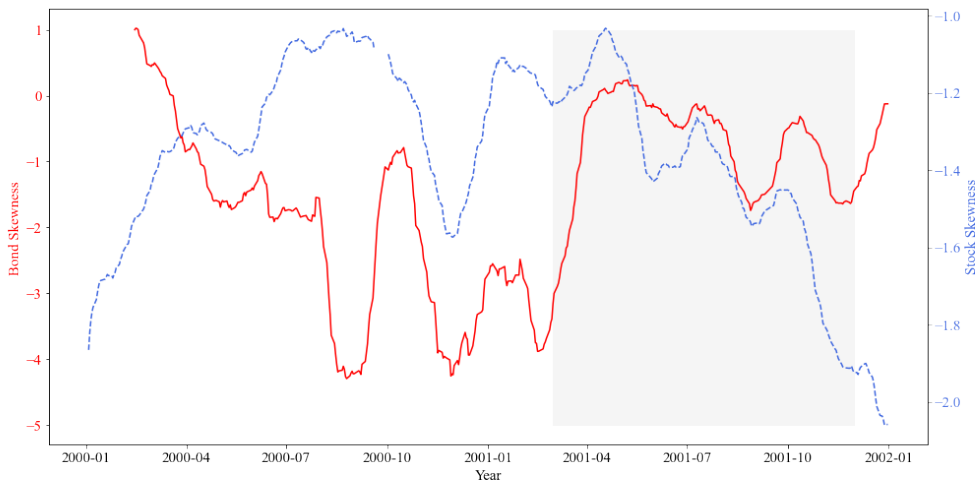
Figure 3. Uncertainty and Tail Risk in Scatter Plot

Note: These scatter plots manifest the distribution and co-movement of the uncertainty and tail risk in stock and bonds from Jan 2000 to June 2020. The points reflect the implied volatility and skewness on the same day. VIX and $SKEW$ are available from the CBOE webpage. The derived Treasury bond uncertainty and tail risk are from Equation (8) and (9), the construction of which is provided in Chapter 1.

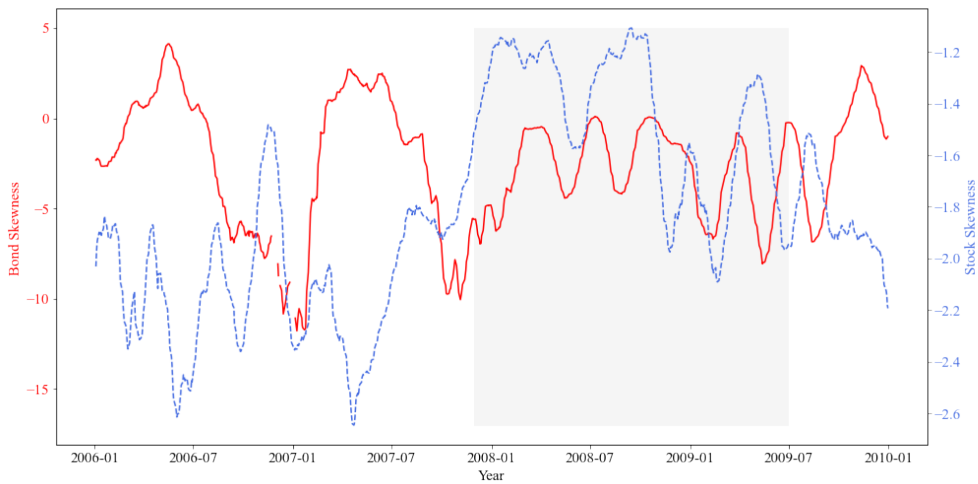
2.2 Three Characteristics of Bond Tail Risks

There are three main findings documented in this paper for Treasury bond tail risk. The first is that while the correlation between stock and bond uncertainty risk is positive, there is a negative correlation between tail risks. Shown in the lower part of Table 1, the correlations of uncertainty risk between the stock VIX index and bonds are 0.45, 0.70, and 0.64 for 5-, 10- and 30-year bonds correspondingly, while the numbers tied to the tail risk are -0.12, -0.16 and -0.15. From this perspective, while equity and Treasury bond market share similar 2nd-moment uncertainty risk, there's a disconnection between stock and bond tail risk.

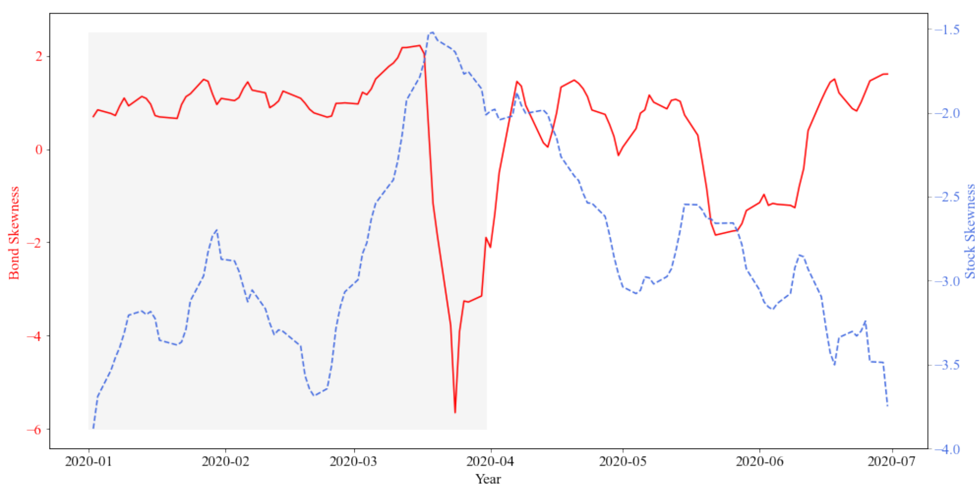
How can we interpret this negative correlation? In a moment of a typical financial disturbance, people reallocate their risky assets to safer ones — the so-called "Flight-to-Safety" phenomenon. Treasury bonds, the representative of global safety assets backed by the credit of U.S Treasury department, provide an accessible resort for both domestic and international cash flows. In this sense, except for the extreme financial crises which may cause a disastrous disruption across financial markets, higher tail risk for equity may be a good thing for Treasury bonds, with more cash flowing into the markets, driving up the prices as well as the returns. Therefore, the negative correlation between stock and bond tail risk holds and makes sense under the general context. For severe



(a) Tail Risks in 2000



(b) Tail Risks in 2008



(c) Tail Risks in 2020

Figure 4. Tail risk Around Financial Crises

Note: These figures compare the equity and Treasury bond market tail risk around three financial crises. The red lines represent the 10-Year Treasury tail risk constructed by Equation (9) and the blue dash lines represent equity tail risk derived from the CBOE SKEW index. The tail risks in the first two graphs are presented as a 30-day moving average, while a 5-day moving average is applied for 2020. Grey areas denote recessions defined by NBER Business Cycle.

financial crises, however, the correlation between stock and bond tail risk becomes positive, warning the serious stress everywhere. As seen in Figure 4, we can clearly see that prior to and around dramatic financial disturbance, the correlation between stock and bond tail risks turns positive, whereas they move in the opposite direction in the good times before and after recessions.

From 2000 to 2020, three major crises hit the financial market: the Internet Bubble Burst, the 2008 Great Financial Crisis, and the current recession brought by Covid-19. As shown in Figure 1 and 2, stock and bond uncertainty risks move together counter-cyclically: They rose during the crashes and fell afterward. By contrast, tail risks embedded in the Treasury bond market provide additional insights for the interest rate risks. Compared to stock tail risk which accumulated during good times and retreated under recessions, bond tail risks remained moderate most of the time and enlarged right before the first two financial crises, especially for the Great Financial Crisis, as it started with the subprime mortgage defaults due to the housing bubbles, so that the interest rate tail risks were mostly affected. Take the 30-year bond tail risk as an example, which suddenly rose above -15 before the crisis, when uncertainty was at its lowest level. We could also see this pattern before the Internet Bubble Burst, as in 2000, the bond tail risks were larger than their later magnitudes. Therefore, bond tail risk serves as a good signal for economic turbulence, since it's the worst case that the interest rate that impacts the economy in various aspects goes into trouble. When we're in recessions, the probability of seeing another black swan is low, so that both stock and bond tail risks retreat to a lower level. I supplement the above descriptive statements with regression results in Appendix D, which manifests the different performances of stock and bond implied risks during recessions.

To further illustrate, let us zoom into the dynamics of bond tail risks before the 2008 Financial crisis. Displayed in Figure 5, bond tail risk experienced sharp enlargement by the end of 2006, when 1/3 of the mortgages are low-standard, non-documentation, or subprime loans, accounting for 20% the obligation.[6] On Feb 27, reports revealed the decline of housing price and the increased rate of delinquency in subprime lending, shaking the stock market with the biggest loss since 2001. At that time, tail risk in Treasury interest rate reverted back, as the risks were already realized in the market and that investor tried to park their assets in a safer place. However, after February, tail risks resumed to accumulate and climb to another height on July 15, when two subprime mortgage funds from Bear Stearns lose nearly all their values. On October 9, as GDP was announced to contract by 1%, indicating the start of the recession, the Dow Jones index closed at the all-time high before crashing down into the period of crisis.

Table 2. Important Timeline in 2007

Jan 1	Housing bubbles, 1/3 low standard, non-documentation and subprime loans
Feb 27	Declining housing prices, increasing subprime delinquency, biggest lose since 2001
July 15	Bear Stearns liquidated the two subprime mortgage funds
October 9	GDP contracted by 1%, Dow Jones hit its peak closing price before crashing

It's also interesting to understand what happened in the recent 2020 March crisis, when the

[6] From CNN post: https://money.cnn.com/2007/04/02/news/companies/new_century_bankruptcy/

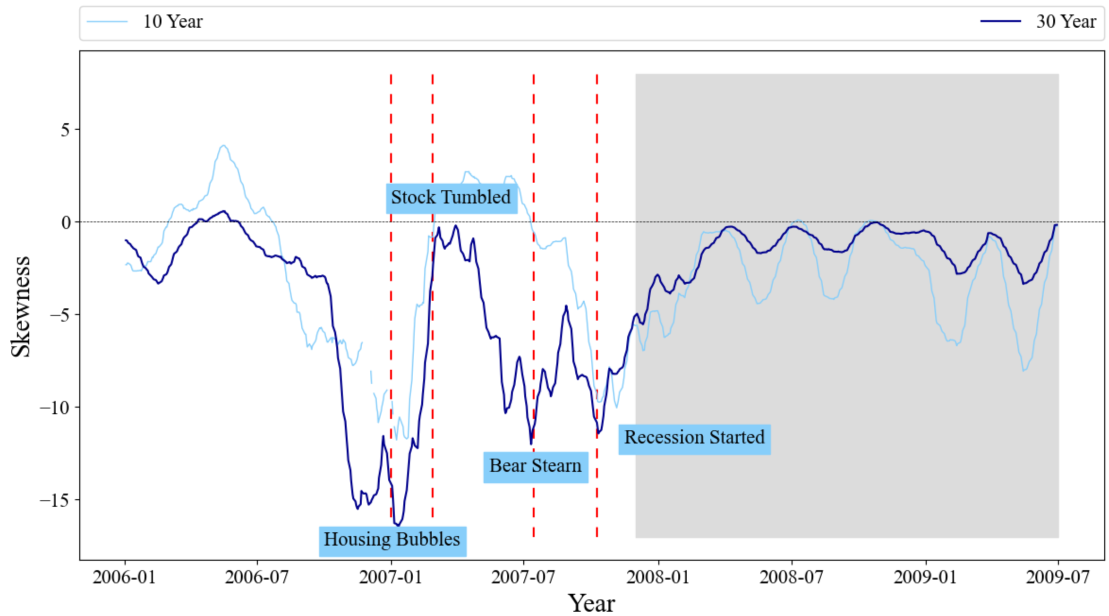


Figure 5. Bond Tail Risk Before 2008 Financial Crisis

Note: This figure zooms into the movement of bond tail risks before the 2008 Financial Crisis. The 4 red dash lines represent the date Jan 1, Feb 27, July 15 and Oct 9 in 2007.

government-backed Treasury bonds encountered selling pressure and liquidity issues. The desire to turn to short-term Treasury bills for a safer and more liquid asset has put severe selling pressure on the long-term bonds so that Treasury bond yields soared for a short moment in March. This tension is captured by bond tail risk measures to further point out the unique tail risk in the Treasury bond markets.

The third finding from the time series of the bond tail risk is that in recent years it has reduced significantly. As seen in Table 3, from 2016 to 2020, the average 2-year, 5-year and 10-year bond tail risks turned positive, and the 30-year bond tail risk becomes also a much lower number than before, while stock tail risks remain -2 to -3 in the same time. There could be two reasons why the Treasury bond tail risks are modest recently. After the 2008 Financial Crisis when the Federal Reserve set the target short-term interest rate as low as 0.25%, we are in the zero lower bound for more than 10 years. Restrictions in the short-run rate inevitably affect also the long-end. such that as we already are at the button line, there's little room for possible fluctuation of interest rate, or the associated tail risk. Therefore, Treasury bonds have become a good resort for safety, since they provide a positive skewness compared to the equity index. Secondly, not only the current interest rate but also the future expected rate matters. As the president of the Federal Reserve continues to indicate the prolonged time to keep interest rate low, (especially recently on Sep 16, Jomere Powell said the interest rate will be low as long as to 2023), tail risk underlying the Treasury bond markets are mitigated.

3 Bond Pre-FOMC Announcement Risk

Table 3. Annual Average of Stock and Bond Implied Risks

	VIX	V^{2y}	V^{5y}	V^{10y}	V^{30y}	$SKEW$	S^{2y}	S^{5y}	S^{10y}	S^{30y}
2000	23.40%	2.25%	2.98%	4.50%	6.64%	-1.27	3.36	-2.40	-1.85	-2.11
2001	25.70%	3.80%	3.78%	5.49%	7.38%	-1.46	0.99	-0.04	-0.99	-1.33
2002	27.24%	3.96%	4.63%	6.61%	9.39%	-1.45	-0.55	-1.10	-1.28	-0.83
2003	22.06%	3.38%	4.51%	6.76%	10.55%	-1.32	0.54	-0.91	-1.76	-1.34
2004	15.49%	3.41%	3.90%	5.55%	8.35%	-1.79	-1.84	-1.74	-3.23	-2.04
2005	12.80%	2.44%	2.68%	3.85%	6.25%	-2.12	1.29	-1.72	-4.19	-2.79
2006	12.81%	3.37%	2.29%	3.12%	5.21%	-2.11	-0.35	-1.22	-2.61	-4.74
2007	17.48%	4.60%	3.18%	4.35%	6.24%	-1.96	1.07	1.55	-2.50	-6.42
2008	32.69%	7.47%	15.76%	8.48%	11.96%	-1.37	0.55	0.21	-1.96	-1.09
2009	31.48%	5.48%	13.90%	8.13%	13.98%	-1.81	-3.91	-0.13	-2.65	-1.24
2010	22.55%	4.03%	10.44%	5.93%	10.09%	-2.11	-0.73	-0.58	-3.35	-1.61
2011	24.20%	3.11%	10.73%	6.38%	11.52%	-2.25	-1.63	-1.43	-3.20	-0.78
2012	17.80%	1.45%	5.89%	4.22%	9.12%	-2.08	-0.43	-0.34	-2.63	-0.82
2013	14.23%	1.48%	7.51%	4.50%	7.69%	-2.24	-0.01	-0.63	-1.85	-0.69
2014	14.18%	3.09%	8.16%	4.21%	6.48%	-2.98	0.06	-0.12	-2.17	-1.32
2015	16.67%	3.39%	9.36%	4.90%	11.87%	-2.75	0.24	-0.13	-2.60	-0.63
2016	15.83%	3.02%	8.63%	4.31%	9.62%	-2.76	0.20	-0.03	0.24	-0.25
2017	11.09%	2.36%	7.03%	3.44%	7.01%	-3.48	0.23	0.15	0.61	-0.09
2018	16.64%	3.11%	6.61%	3.08%	6.05%	-3.26	0.38	0.18	0.55	-0.28
2019	15.39%	4.12%	7.77%	3.50%	6.40%	-2.28	0.27	0.35	1.09	-0.07
2020	32.89%	3.24%	9.23%	4.83%	11.25%	-2.79	0.22	-0.98	0.39	0.17

Note: This table provides the annual average for stock and bond risks from Jan 2000 to June 2020. VIX and $SKEW$ are available from the CBOE webpage, while V^{iy} together with S^{iy} denotes the derived Treasury bond uncertainty and tail risk from Equation (8) and (9), the construction of which is provided in Chapter 1.

3.1 Bond Uncertainty Risk Before FOMC Announcement

Besides the distinct realization of bond uncertainty and tail risk around financial crises and in recent years, do bond implied risks perform uniquely around particular days, for example, days of the monetary policy announcement or the release of economic indicators? Targeting the FOMC days as the central date 0, I look into the average bond implied risks 15 trading days before and after. It represents the FOMC cycle with no overlap on the counted days, since 8 meetings are conducted every year, once one and a half months. As presented in Figure 6 and discussed in the introduction section, stock and bond uncertainty risk experience a sharp increase on the third and second day before the announcement, keep the heightened level for 1 day, before falling upon announcement.

$$\Delta Risk_t^{stock/2y/5y/10y/30y} = \alpha + \sum \beta_{FOMCdays} \times 1_{t,FOMCdays} + \epsilon_t \tag{10}$$

The movement of bond implied risks described above is supported by regressing the change of risks on the FOMC related days in Table 4, which manifests these notable difference: 3 Days before the FOMC meeting, uncertainty risk starts to rise; Including the following day, stock, 5-,10-, and 30-year bond implied volatilities upsurge by 0.50%, 0.18%, 0.18%, and 0.31% in total. On the days upon

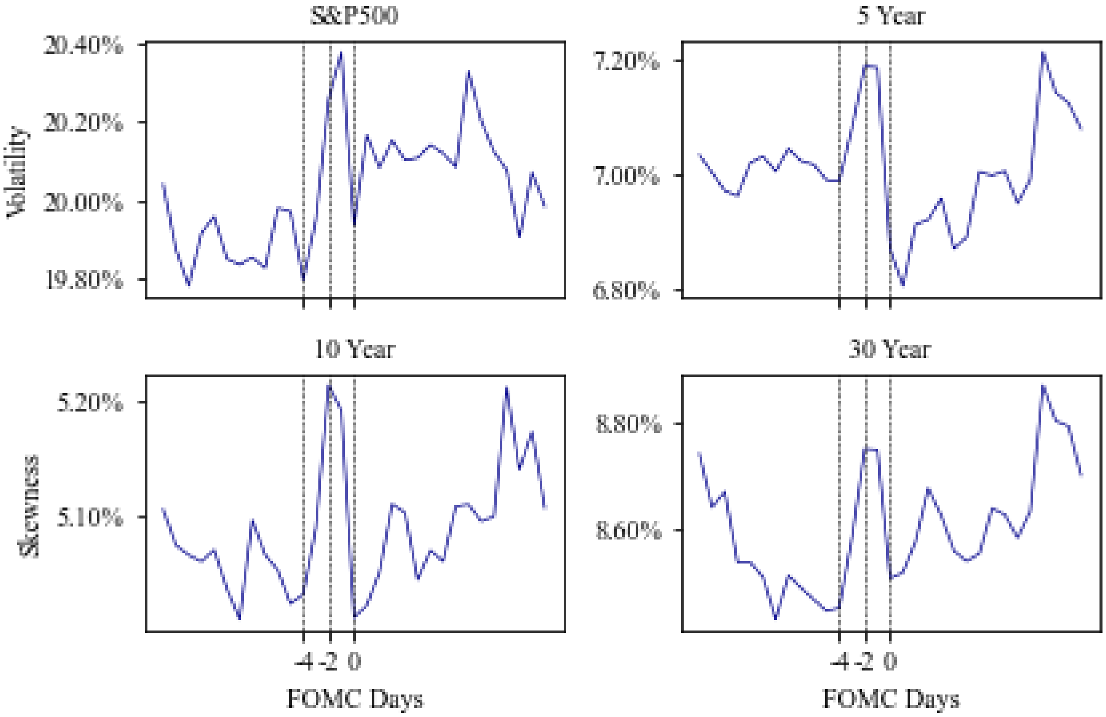


Figure 6. Stock and Bond Uncertainty Over FOMC Cycle

Note: These figures present the average uncertainty level for the stock index and Treasury bonds over the FOMC cycle, i.e., 15 trading days before and after the announcement. Stock uncertainty is akin to the VIX index, while the 5-, 10-, and 30-year bond uncertainty measures are calculated using Equation (8). Data runs from Jan 2000 to June 2020.

announcement, implied volatility drops by 0.50%, 0.33%, 0.20%, and 0.26% on average, getting back to the normal levels. The mean reversion of implied volatility on the announcement day agrees with the uncertainty resolution proposed by Bauer, Lakdawala, and Mueller (2019). This result is also in line with the recent paper by Ghaderi and Seo (2020) about the magnitude of the uncertainty resolution. However, although the authors argue about the small level of uncertainty change, it's relatively huge and therefore important when comparing under the context of the FOMC cycle, as shown in Figure 6. Also, all the regressions in this paper are processed further by controlling the recession period effect as well as decomposing the FOMC days into Expansionary, Contractionary, and No-Change days according to how the Fed alters the interest rate. The robust results are in Appendix K. Here, the movement of uncertainty risk is more pronounced with expansionary monetary policy. For other macro indicator announcements, I work on the release of 25 economic indicators and find that the announcement of the unemployment rate (or the non-farm payroll as they're located on the same day) reduces bond uncertainty risks. Details can be found in Appendix G.

Moreover, decomposing the data series from the year 2010, I find two notable changes: In terms of the bond implied risks, the increase of uncertainty occurred earlier after 2010, on the Day-3 before the announcement, while the coefficients for $1_{t,FOMCPre3}$ are close to zero during 2000 to 2009. Therefore, investors in the Treasury option markets may react to the FOMC announcement earlier than before. Secondly, in contrast with the decreased uncertainty resolution for the equity market

Table 4. Uncertainty Change Before FOMC Announcement

$$\Delta Risk_t^{stock/2y/5y/10y/30y} = \alpha + \sum \beta_{FOMCdays} \times 1_{t,FOMCdays} + \epsilon_t$$

	ΔVIX_t	ΔV_t^{2y}	ΔV_t^{5y}	ΔV_t^{10y}	ΔV_t^{30y}
Full Data: 2000 - 2020					
$1_{t,FOMCPre3}$	0.16	-0.01	**0.09***	**0.06****	**0.13*****
	(0.14)	(0.05)	(0.05)	(0.03)	(0.05)
$1_{t,FOMCPre2}$	**0.31*****	0.01	**0.10****	**0.12*****	**0.18*****
	(0.12)	(0.05)	(0.05)	(0.03)	(0.05)
$1_{t,FOMCPre1}$	0.13	0.02	-0.01	-0.02	0.00
	(0.16)	(0.04)	(0.05)	(0.03)	(0.04)
$1_{t,FOMC}$	**-0.50*****	**-0.21*****	**-0.33*****	**-0.20*****	**-0.26*****
	(0.14)	(0.06)	(0.06)	(0.02)	(0.04)
Sub Data: 2000 - 2009					
$1_{t,FOMCPre3}$	0.21	-0.03	0.02	0.01	-0.02
	(0.20)	(0.09)	(0.05)	(0.03)	(0.04)
$1_{t,FOMCPre2}$	0.22	0.07	0.11	**0.20*****	**0.20****
	(0.17)	(0.10)	(0.08)	(0.06)	(0.08)
$1_{t,FOMCPre1}$	0.03	-0.03	-0.04	-0.05	0.02
	(0.22)	(0.07)	(0.07)	(0.06)	(0.06)
$1_{t,FOMC}$	**-0.61*****	-0.11	**-0.28*****	**-0.21*****	**-0.21*****
	(0.18)	(0.10)	(0.08)	(0.03)	(0.05)
Sub Data: 2010 - 2020					
$1_{t,FOMCPre3}$	0.11	0.01	**0.15***	**0.11*****	**0.28*****
	(0.19)	(0.04)	(0.08)	(0.04)	(0.08)
$1_{t,FOMCPre2}$	**0.40****	-0.03	0.09	**0.05***	**0.15****
	(0.16)	(0.05)	(0.06)	(0.03)	(0.07)
$1_{t,FOMCPre1}$	0.23	0.06	0.03	0.01	-0.02
	(0.24)	(0.06)	(0.05)	(0.03)	(0.06)
$1_{t,FOMC}$	**-0.40***	**-0.31*****	**-0.37*****	**-0.19*****	**-0.32*****
	(0.21)	(0.08)	(0.08)	(0.03)	(0.06)

Note: This table illustrates how daily uncertainty changes around the FOMC announcement. VIX and $SKEW$ are available from CBOE webpage. The derived uncertainty and tail risk are from Equation (8) and (9), the construction of which are provided in Chapter 1. The unit of uncertainty is 1%. Newey and West (1986) standard errors in parentheses. Intercepts and R-squared are omitted in the panel but available upon request. *p: 0.1, **p: 0.05, ***p: 0.01

since the coefficients become smaller (a consistent result with Kurov, Wolfe, and Gilbert (2020)), the uncertainty pattern embedded in the Treasury bond markets remains unchanged.

In a very recent paper of Beckmeyer, Branger, and Grünthaler (2019), the authors argue that the movement of stock uncertainty risk around FOMC days is largely driven from the left tail of uncertainty (constructed from Bollerslev, Todorov, and Xu (2015)) and that they provide the uncertainty graphs with the tail "purged". More specifically, they run regressions of stock uncertainty on the indicators of FOMC related days with and without controlling the left tail of uncertainty, and use the difference in the coefficients to demonstrate that it's the left tail of uncertainty that drives the overall dynamics around the FOMC days. Learning from this paper, I apply the same step to graph the

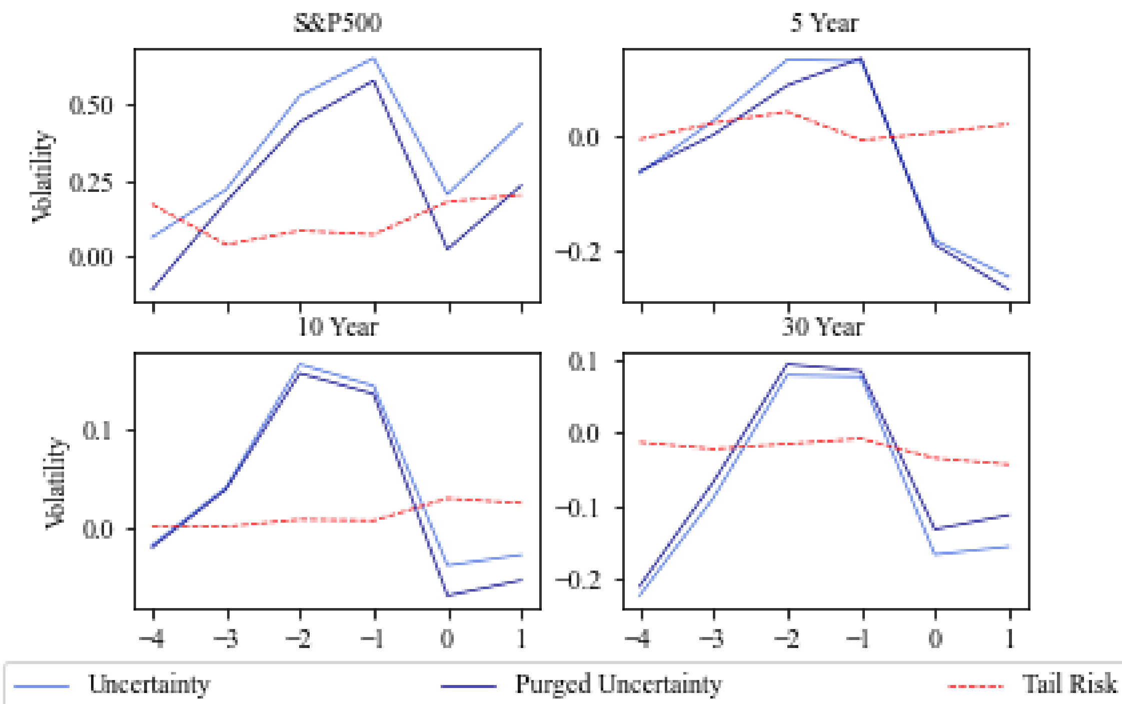


Figure 7. Stock and Bond Uncertainty Over FOMC Cycle: Controlling the Tail Risk

Note: These figures present the average uncertainty change using method from Beckmeyer, Branger, and Grünthaler (2019) for the stock S&P500 index and Treasury bonds. The lightblue line denotes the coefficients in regressions of uncertainty risk on the FOMC days. The darkblue line represents the regression coefficients after controlling the tail risk, and the red dashed line gives the difference between the coefficients.

uncertainty purged movement, with the actual third-moment tail risk controlled instead of the left tail of uncertainty risk. From Figure 7, we can see that tail risk has little effect on the overall movement of the uncertainty risk since the coefficients barely move after controlling the tail risk effect. This result is consistent with the indifference of tail risk around FOMC days, which I put the graphs and regressions in Appendix F.

3.2 Drivers of Uncertainty Movement

What drives these abnormal movements of the bond uncertainty risk? I try to answer this question using the option-market trading data by directly using the formula. In Equation (1), uncertainty risk is approximated by the weighted average of out-of-money call and put option prices, where the put options are given more weights. The implied variance depends also on the underlying futures prices, which in turn changes the moneyness of options and therefore the weights, but since the spot price changes in the 2 days before the FOMC announcements are not special, I focus only on the prices of call and put options.

To have an overview of the data, I first summarize the average prices for the equity index and 10-year Treasury bond options in Table 5, where the options are further divided into calls and puts.

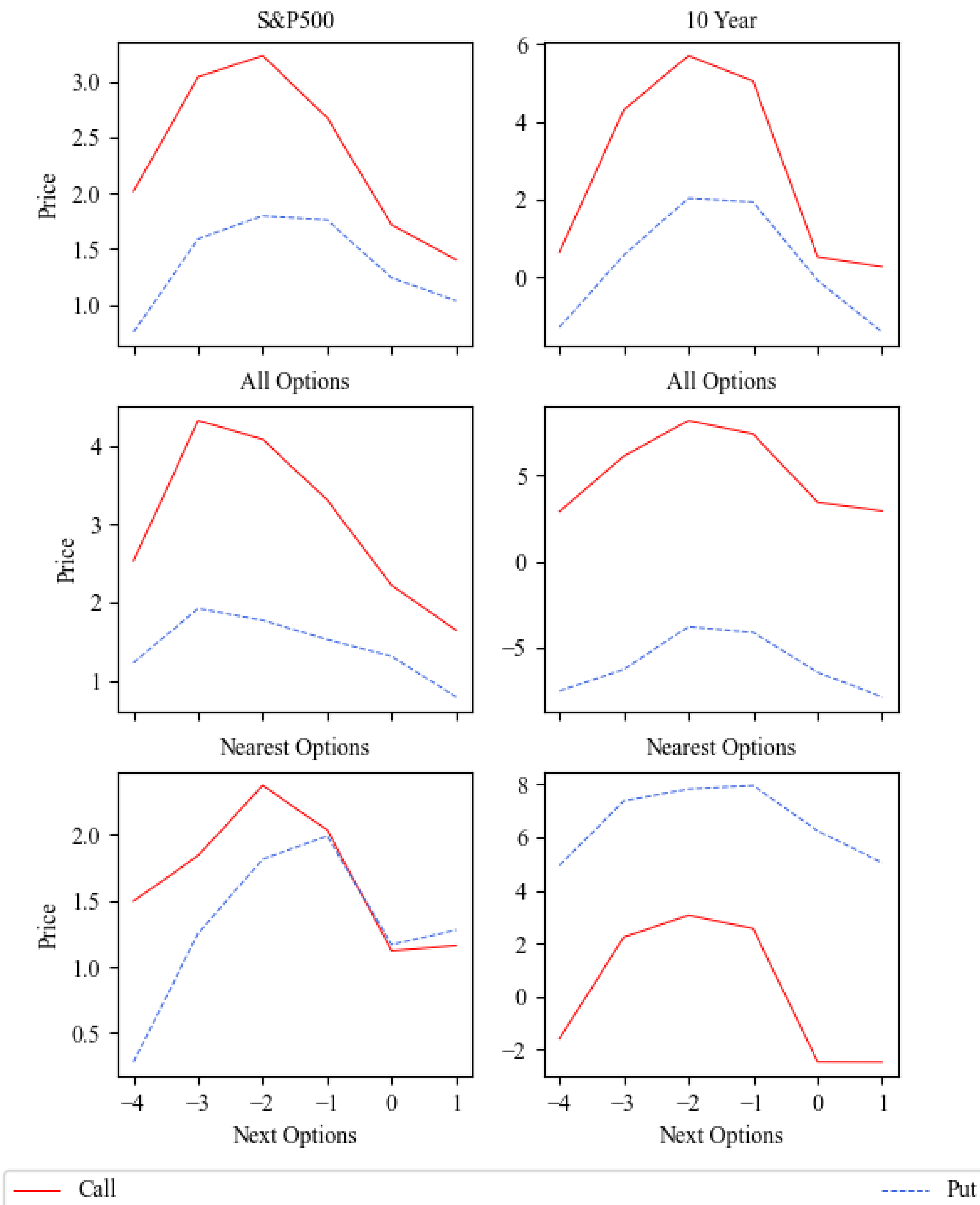


Figure 8. Stock and Bond Option Price Change Around FOMC Announcement

Note: These figures present the average out-of-money option price change for the S&P500 index and Treasury bonds around FOMC days. The most "at-the-money" options are selected to regress on the FOMC days, so that the blue dash line denotes the coefficients for put options, and the red solid line represents the coefficients for call options. Option prices are from CBOE End-of-Day dataset. Data runs from Jan 2000 to June 2020.

Table 5. Average Prices for Out-of-Money Stock and Bond Options

	SP500			10-Year		
	All	Nearest	Next	All	Nearest	Next
Option	8.16	5.20	11.13	12.74	7.50	11.97
Call	8.49	5.37	11.61	11.98	8.10	15.88
Put	8.32	5.33	11.30	13.34	7.08	19.61
ATM Call	33.03	25.05	41.02	52.73	40.44	65.07
ATM Put	26.45	21.53	31.36	56.93	36.06	77.82
OTM Call	0.27	0.09	0.45	1.57	1.09	2.04
OTM Put	0.42	0.19	0.64	1.64	1.03	2.25

Note: This table provides the average prices for the out-of-money equity index and 10-year Treasury bond out-of-the-money options. The data is divided by the nearest and the next option series based on the maturity. Also, Options are sub-grouped into call/put options, where the ”ATM” represents the options whose strike prices are are closest to the current spot price and the ”OTM” denotes the opposite.

Here all the options are selected to be out-of-the-money since the uncertainty risk only takes them for calculation. Among all the out-of-the-money options, I also elect the most ”at-the-money” and ”out-of-the-money” call/put options for each day, such that the ”ATM Call” and ”ATM Put” denotes the options whose strike prices are the closest to the current spot price, while ”OTM Call” and ”OTM Put” denotes the options whose strike prices are the farthest. Furthermore, for all the option prices used in the calculation of uncertainty risks, I provide the average prices for both the nearest and the next option series, separately and jointly. From the summary panel, we can see that options with longer maturities enjoy higher prices since these American options are with more time value. Also, the most ”at-the-money” options are priced the highest, as they're most likely to be exercised for profits. Since their prices are much larger, they have a huge impact on the derived uncertainty risk. For this reason, I proceed to regress the most ”at-the-money” options prices around FOMC announcement days.

$$OptionPrice_t^{stock/2y/5y/10y/30y} = \alpha + \sum \beta_{FOMCdays} \times 1_{t,FOMCdays} + \epsilon_t \tag{11}$$

Here, I use the coefficients in Equation (11) to graph the ”at-the-money” option prices around FOMC announcements. In Figure 8, I provide the plots of regression coefficients not only for all the option series but also separately for the nearest and the next options. To one's surprise, call options are the ones with a considerable price upsurge, for the whole data sample as well as the nearest options. Also, the corresponding regression results show that the coefficients for call options are significant while the coefficients for put options are not.[7] This finding is very interesting because the uncertainty measure earns its name under the assumption that investors use out-of-money put options more to hedge against risks, or ”uncertainty”. However, option prices show that the prices for the nearest out-of-money calls move more dramatically to match with the risk changes before the FOMC announcements. It seems that in the expectation of FOMC meetings, investors expect the average increased prices in the spot equity and Treasury bond markets so that they purchase with

[7] Regression tables are in Appendix H.

the call options which are most likely to be in-the-money and exercised. For this reason, the rise of uncertainty risks comes from a profit-driven goal rather than hedging risks.

In the meanwhile, I find the flipped pattern in the Treasury bond market for the options with longer maturities (the next option series, maturing less than 2 months): the put option prices are very high and significant around FOMC days, while the coefficients for call options become insignificant. This may imply that investors in the Treasury markets not only expect the increased price change and trade with the nearest options, but also hedge with longer-maturity out-of-money puts.

$$TradingVolume_t^{stock/2y/5y/10y/30y} = \alpha + \sum \beta_{FOMCdays} \times 1_{t,FOMCdays} + \epsilon_t \tag{12}$$

To justify, I also look at the trading volume of the out-of-money options around the FOMC announcement using Equation (12). Results in the Appendix Figure A-3 show that Treasury options are less traded before the FOMC announcement and more traded on and afterward, consistent with what other authors have found in the equity market. Beyond that, trading volumes for call options are higher than puts before the announcement, showing support for investors' higher demand for out-of-money call options before the meetings.

4 Bond Pre-FOMC Announcement Drift

4.1 Pre-FOMC Announcement Drift

The influential paper by Lucca and Moench (2015) uncovers the pre-announcement drift in the equity markets but not bonds, while monetary policy targets the interest rate. Puzzled by the ill-matched responses, I revisit the pre-FOMC announcement drift for both markets. I derived the daily stock returns from S&P500 index and the bond yield changes from the Treasury yield curve, same as what Lucca and Moench (2015) use, except that they work on the intraday data instead of the daily ones. Accordingly, we define the "pre-FOMC announcement time" differently: They confine to the 24-hour interval ahead of 2 pm, the time for the announcement, while I utilize the simple 1-day change.

In Figure 9, I provide the average accumulated stock return and bond yield change starting from 15 trading days before the FOMC meeting. We can see that S&P500 stock return enlarges on the FOMC days, seemingly contradictory to the pre-drift argument. A closer look into the most cited figure in their paper, one can notice that the pre-drift takes place mostly on the announcement days, just before 2 pm. Therefore, the surge of stock return on FOMC days in the plot is equivalent to the pre-announcement drift in their paper.

$$R_t^{stock/2y/5y/10y/30y} = \alpha + \sum \beta_{FOMCdays} \times 1_{t,FOMCdays} + \epsilon_t \tag{13}$$

But the most unexpected finding is that the pre-announcement drift also exists in bonds: The 3-month Treasury yield falls on the FOMC days, and the 5-,10-, and 30-year bond yields start going down one day earlier. In Table 6, I regress the daily stock return and bond yield change R_t specifying the FOMC days (See Equation (13)). On the announcement days, stock collects 25.6 bps of return, and the 3-month yield shrinks by 2 bps. One day before the meeting, the 5, 10, and 30-year yields decline

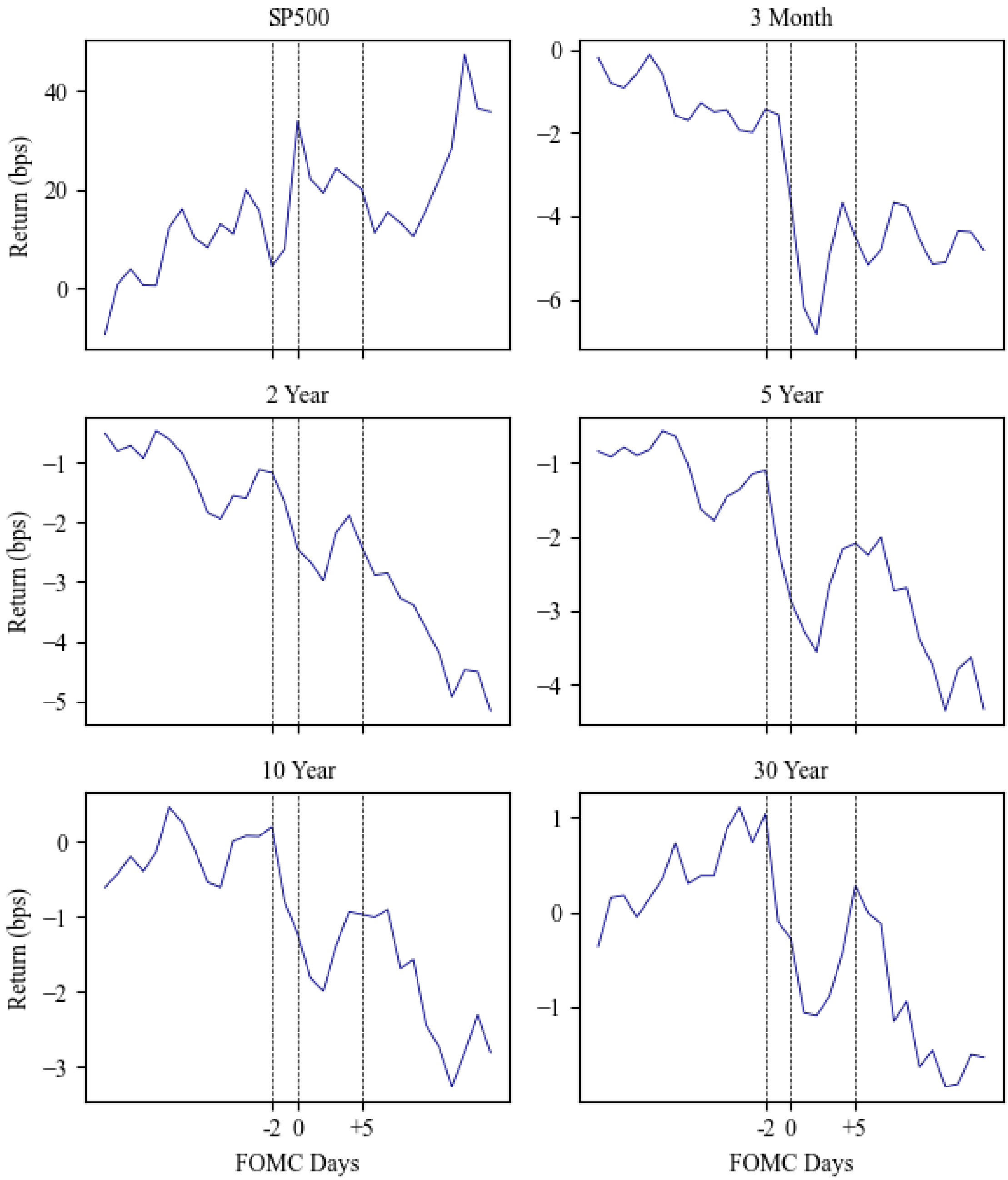


Figure 9. Stock Return and Bond Yield Drift Over FOMC Cycle

Note: These figures plot cumulative stock index returns and bond yield changes over the FOMC cycle, i.e., 15 days before and after the announcement. Cumulative stock returns are calculated from S&P500 index prices. Bond yield changes are computed from Treasury yield curve available at the Federal Reserve Board webpage. Data runs from Jan 2000 to June 2020.

around 1 bp. The different conclusions regarding the bond pre-announcement drift may attribute to how we define the pre-announcement time. Bonds may react even earlier than stocks so that the simple end-of-day yield change is better suited than the 24-hour interval.

$$R_{t-1,t}^{stock/2y/5y/10y/30y} = \alpha + \beta_{FOMC} \times 1_{t,FOMC} + \epsilon_t \tag{14}$$

Table 6. Stock and Bond Return Around FOMC Announcement

$$R_t^{stock/2y/5y/10y/30y} = \alpha + \sum \beta_{FOMCdays} \times 1_{t,FOMCdays} + \epsilon_t$$

	R_t^{stock}	R_t^{3m}	R_t^{2y}	R_t^{5y}	R_t^{10y}	R_t^{30y}
Full Data: 2000 - 2020						
$1_{t,FOMCPre1}$	3.63	-0.06	-0.44	**-1.03****	**-0.94****	**-1.10****
	(11.60)	(0.42)	(0.42)	(0.43)	(0.41)	(0.43)
$1_{t,FOMC}$	**25.56****	**-2.02*****	-0.71	-0.71	-0.44	-0.18
	(10.47)	(0.46)	(0.54)	(0.65)	(0.60)	(0.54)
Sub Data: 2000 - 2009						
$1_{t,FOMCPre1}$	10.96	-0.17	-0.71	-1.23	-0.90	-1.36
	(19.69)	(0.82)	(0.79)	(0.76)	(0.67)	(0.83)
$1_{t,FOMC}$	**41.60****	**-3.52*****	-0.77	-0.41	-0.11	0.30
	(17.33)	(0.84)	(0.96)	(1.05)	(0.96)	(0.97)
Sub Data: 2010 - 2020						
$1_{t,FOMCPre1}$	-3.62	0.06	-0.16	**-0.83****	**-0.99****	**-0.94****
	(12.02)	(0.15)	(0.24)	(0.40)	(0.47)	(0.48)
$1_{t,FOMC}$	9.38	**-0.47****	-0.64	-1.02	-0.77	-0.48
	(11.42)	(0.22)	(0.48)	(0.77)	(0.72)	(0.63)

Note: This table regresses daily stock return and bond yield changes around FOMC days. Stock return is derived from S&P500 index. Bond yield changes are computed from the daily Treasury yield curve available from the Federal Reserve Board webpage. The unit is bp. Intercepts and R-squared are omitted in the panel but available upon request. Newey and West (1986) standard errors in parentheses. *p: 0.1, **p: 0.05, ***p: 0.01

Table 7. Pre-FOMC Announcement Drift in Stock and Bond

$$R_{t-1,t}^{stock/2y/5y/10y/30y} = \alpha + \beta_{FOMC} \times 1_{t,FOMC} + \epsilon_t$$

	$R_{t-1,t}^{stock}$	$R_{t-1,t}^{3m}$	$R_{t-1,t}^{2y}$	$R_{t-1,t}^{5y}$	$R_{t-1,t}^{10y}$	$R_{t-1,t}^{30y}$
Full Data: 2000 - 2020						
$1_{t,FOMC}$	**27.89****	**-2.01*****	**-1.11***	**-1.69****	**-1.33***	**-1.23***
	(13.65)	(0.70)	(0.62)	(0.73)	(0.70)	(0.66)
Sub Data: 2000 - 2009						
$1_{t,FOMC}$	**50.29****	**-3.56*****	-1.43	-1.58	-0.97	-1.03
	(23.85)	(1.34)	(1.12)	(1.19)	(1.11)	(1.22)
Sub Data: 2010 - 2020						
$1_{t,FOMC}$	5.40	-0.40	-0.78	**-1.79****	**-1.70****	**-1.37***
	(12.63)	(0.26)	(0.50)	(0.84)	(0.86)	(0.75)

Note: This table regresses stock return and bond yield changes on FOMC days. To capture the pre-FOMC announcement drift at the same time, 2-day rolling versions $R_{t-1,t}$ are extracted by $R_{t-1,t}^{stock} = (1 + R_{t-1}^{stock}) \times (1 + R_t^{stock}) - 1$ and $R_{t-1,t}^{bond} = R_{t-1}^{bond} + R_t^{bond}$ respectively, so that $1_{t,FOMC}$ represents the pre-FOMC announcement drift . Stock return is derived from S&P500 index. Bond yield changes are computed from the daily Treasury yield curve available from the Federal Reserve Board webpage. The unit is bp. Intercepts and R-squared are omitted in the panel but available upon request. Newey and West (1986) standard errors in parentheses. *p: 0.1, **p: 0.05, ***p: 0.01

To capture both the stock and bond pre-announcement drift at the same time since they locate on different days, I transform the daily drift to the rolling 2-day version $R_{t-1,t}$, where $R^{stock}_{t-1,t} = (1 + R^{stock}_{t-1}) \times (1 + R^{stock}_{t}) - 1$ and $R^{bond}_{t-1,t} = R^{bond}_{t-1} + R^{bond}_{t}$. In this way, I'm not sacrificing the precision of pre-drift by covering the post-announcement time, since according to Lucca and Moench (2015) and many following papers, the post-announcement drifts are insignificant. Here, Table 7 shows that this method successfully merges the pre-drift: 1 day earlier and on the day of the FOMC announcement, stock return enlarges 27.9 bps more than other days, and bond yields lessen about 1 bp accordingly. [8]

4.2 Non-Diminishing Bond Pre-FOMC Announcement Drift

Since I study a more recent period (2000-2020) compared to the original paper (1994-2011), the size of the stock drift (27bps) is different from theirs (49 bps). My result is more comparable to what Hu, Pan, Wang, and Zhu (2019) obtain (27bps) from the year 1994 to 2018. This return discrepancy points to the diminishing pre-FOMC announcement return in the equity market, as documented in the paper of Kurov, Wolfe, and Gilbert (2020), such that starting from 2011, the size of this abnormal return become insignificant. As I divide the data to run the regressions using subsample, similar results reveal and help explain the relatively small drift with the recent data.

More specifically, for days from 2000 to 2009, this abnormal return in the equity market is much larger and significant than days starting 2010. The S&P500 index accumulates 50 bps on average before 2010, but it only gets 5 bps afterward, indifferent from zero from the statistical inference' angle. Comparing with the equity market, the drop of bond yield is more significant after 2010, as the coefficients become larger and more significant. Therefore, I claim that although pre-FOMC announcement drift diminishes in the equity market, the Treasury bond drift still holds.

4.3 Bond Monetary Momentum

What presented in Figure 9 is also related to the recent paper by Neuhierl and Weber (2018), who document that the stock market return continues to grow after the FOMC announcement, and call it "monetary momentum". Here, beyond the consistent equity market results, I also add bond yields into consideration, which keep decreasing after the FOMC announcement.

Moreover, they discover that the stock return drifts upwards with expansionary monetary surprises and downwards on other FOMC days, where the surprise measure is the 30-minute window price change of the 30-day Fed Fund futures around the announcement. As I replicate their results and also extend to bonds with the daily and 1-hour monetary policy surprise [9] as well as the actual monetary policy change, the results are similar to what they get: The actual change and surprise measure of monetary policy produce the opposite effect: Days with actual expansionary policy lead to

[8] I also try to control for the business cycle effect and decompose the FOMC days, results in Appendix Table A-22 show that the pre-FOMC announcement drifts hold universally.

[9] The reason for choosing the daily and the 1-hour future price change instead of the 30-min window is the data availability. Without access to the tick data from CME which the authors obtain, I extract the data from Thomson Reuters DataScope, but their high-frequency trading dataset for 30-day Treasury future price is not ample, resulting in a lot of NaNs if I use the 30-min window. So I proceed with 1-hour and daily change.

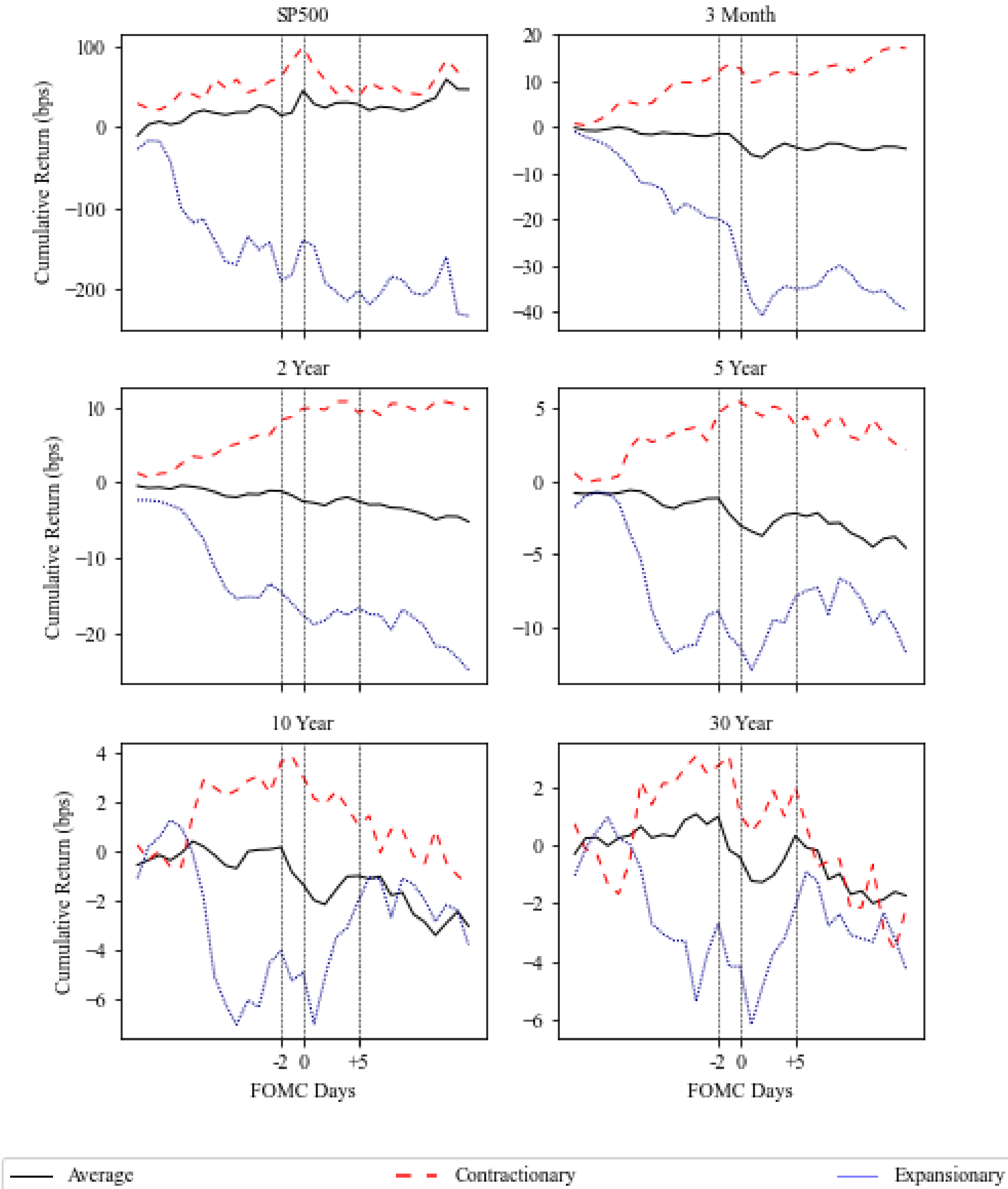


Figure 10. Bond Monetary Momentum: Decomposed by Monetary Policy Change

Note: These figures present the diverging movement of cumulative stock return and bond yields with monetary policy change. The solid black line represents the average level; The blue dotted line/red dash line provides the yield change around expansionary/contractionary monetary policy. Stock return is derived from SP500 index prices. Bond yield changes are computed from the daily Treasury yield curve available from the Federal Reserve Board webpage. Data runs from Jan 2000 to June 2020.

Table 8. Cumulative Return Over FOMC Cycle

$$CumulativeReturn^{stock/3m/2y/5y/10y/30y} = \alpha + \sum \beta_{MonetaryPolicy} \times 1_{MonetaryPolicy} + \epsilon_t$$

Stock	Pre15	Pre10	Pre5	Pre1	FOMC	Post1	Post5	Post10	Post15
1_{Expand}	-11.81	**-186.53*** **	**-211.73*** **	**-273.40*** **	**-267.56*** **	**-255.58** **	**-322.84*** **	**-312.58** **	**-402.37*** **
	(28.85)	(62.26)	(77.71)	(93.12)	(98.11)	(105.35)	(110.89)	(122.60)	(138.22)
$1_{Contract}$	45.21	-6.41	-10.34	25.95	15.04	7.61	-49.57	-36.97	-46.68
	(28.0010)	(60.43)	(75.41)	(90.37)	(95.21)	(102.24)	(107.61)	(118.98)	(134.15)
3 Month									
1_{Expand}	-0.76	**-8.90*** **	**-16.57*** **	**-21.41*** **	**-29.88*** **	**-36.59*** **	**-35.46*** **	**-31.20*** **	**-39.71*** **
	(1.69)	(1.83)	(2.72)	(3.12)	(3.50)	(4.67)	(3.71)	(4.69)	(4.40)
$1_{Contract}$	0.95	**5.45*** **	**10.26*** **	**14.08*** **	**13.84*** **	**11.86*** **	**12.39*** **	**13.80*** **	**18.71*** **
	(1.64)	(1.78)	(2.64)	(3.03)	(3.40)	(4.53)	(3.60)	(4.55)	(4.27)
2 Year									
1_{Expand}	**-2.05* **	**-5.16* **	**-15.55*** **	**-15.60*** **	**-16.13*** **	**-17.43*** **	**-15.04*** **	**-14.38** **	**-21.46*** **
	(1.14)	(2.86)	(3.59)	(4.24)	(4.24)	(4.47)	(4.52)	(5.57)	(5.64)
$1_{Contract}$	1.59	3.71	5.53	**9.32** **	**11.66*** **	**11.64*** **	**11.13** **	**13.52** **	**13.33** **
	(1.12)	(2.78)	(3.48)	(4.12)	(4.11)	(4.34)	(4.39)	(5.40)	(5.48)
5 Year									
1_{Expand}	-1.11	-2.62	**-11.01*** **	**-8.59* **	**-8.30* **	**-9.85* **	-5.58	-2.46	-7.55
	(1.30)	(3.28)	(3.92)	(4.56)	(4.80)	(5.12)	(5.06)	(5.95)	(6.14)
$1_{Contract}$	1.42	3.01	3.96	**7.35* **	**8.59* **	8.16	6.20	7.42	6.37
	(1.26)	(3.18)	(3.81)	(4.43)	(4.66)	(4.97)	(4.91)	(5.77)	(5.96)
10 Year									
1_{Expand}	-0.92	-0.14	**-6.79* **	-4.28	-3.37	-5.33	-1.09	2.16	-1.01
	(1.23)	(3.07)	(3.74)	(4.35)	(4.68)	(5.20)	(5.16)	(5.72)	(5.90)
$1_{Contract}$	0.79	1.25	2.18	4.85	4.63	3.97	2.29	3.25	1.67
	(1.20)	(2.98)	(3.62)	(4.22)	(4.54)	(5.04)	(5.00)	(5.56)	(5.72)
30 Year									
1_{Expand}	-1.08	-0.51	-4.80	-4.33	-4.51	-6.25	-3.64	-2.40	-4.19
	(1.17)	(2.66)	(3.33)	(4.15)	(4.48)	(5.07)	(5.07)	(5.49)	(5.73)
$1_{Contract}$	1.00	-1.12	1.27	3.00	0.84	0.70	1.30	-1.06	-1.43
	(1.47)	(3.34)	(4.18)	(5.21)	(5.62)	(6.36)	(6.36)	(6.68)	(6.97)

Note: This table regresses the cumulative stock return and bond yield change starting from 15 days beforehand to 15 days after the FOMC announcement, on whether it's related to the expansionary/contractionary monetary policy. Cumulative stock returns are calculated from S&P500 index. Bond yield changes are computed from the daily Treasury yield curve available from the Federal Reserve Board webpage. Data runs from Jan 2000 to June 2020. Intercept and R-squares are omitted but available upon request. Newey and West (1986) standard errors in parentheses. *p: 0.1, **p: 0.05, ***p: 0.01

the negative accumulated stock return and 10-year bond yield change, while expansionary surprises are driving up the drifts. [10]

In this paper, I focus on the actual monetary policy change instead of the surprise measure for the following reasons. First, the shock measure could easily change signs when different approaches are adopted.[11] Whether it's an expansionary or contractionary surprise could easily be switched just because a different window is chosen. Second, the monetary surprises may be attributed to the reversal trading behavior. For example, as investors expect an expansionary policy to come, the prices may already move ahead. After the announcement, some reversed trading may be followed, so that the actual change and surprise offer the opposite trend. Third, the bond yield drop is more consistent with the expansionary policy change as the Fed decreases the target rate.

In Figure 10, I provide an overall assessment about how the bond yields change around the different monetary policies. Days around an expansionary monetary policy have witnessed the drop in yields, the magnitude of which becomes smaller as the maturity extends. The 3-month Treasury yield decreases by 40 bps over the FOMC cycle, followed by 20 bps, 10 bps, 6 bps, and 6 bps for longer-term bonds. Also, a noticeable bounce back happens in the week after the announcement, and the relative level of the rally becomes stronger with longer tenors. For example, there is a moderate increase in the 5-year yield. However, the upsurge is more magnificent for the 10-year and 30-year bonds. On the contrary, days with a contractionary monetary policy are accompanied by the increase in stock return and bond yields, the change of which is less prominent than what the cut in interest rate can cause. Similarly, despite the upward movement, the bond yields also modify after the announcement, and the reversal becomes more noticeable with longer maturity bonds.

$$CumulativeReturn^{stock/3m/2y/5y/10y/30y} = \alpha + \sum \beta_{MonetaryPolicy} \times 1_{MonetaryPolicy} + \epsilon_t \tag{15}$$

I further verify this argument through the return dynamics over the FOMC cycle, by rearranging the time series data into different groups denoting their position relative to the FOMC announcement days. Then I regress each group on whether it's around expansionary or contractionary monetary policy so that the coefficients reflect the different responses compared to FOMC days with no interest rate change. As shown in Table 8, the cumulative stock return and the short-term bond yield around the expansionary monetary policy become significantly lower 2 weeks before the announcement, by 187 bps, 9 bps and 5 bps for stock, 3-month and 2-year bond respectively. This disparity enlarges further into the FOMC announcement until 3 weeks after, to reach 402 bps, 40 bps and 21 bps in the end. As the maturity lengthens, the yield drop is less notable. The yields of the 5-year, 10-year, and 30-year bonds are 11 bps, 7 bps, and 5 bps lower one week before the announcement. Also, because of the rebound, cumulative changes of the long-term bond yields on expansionary days are not distinctive after the announcements.

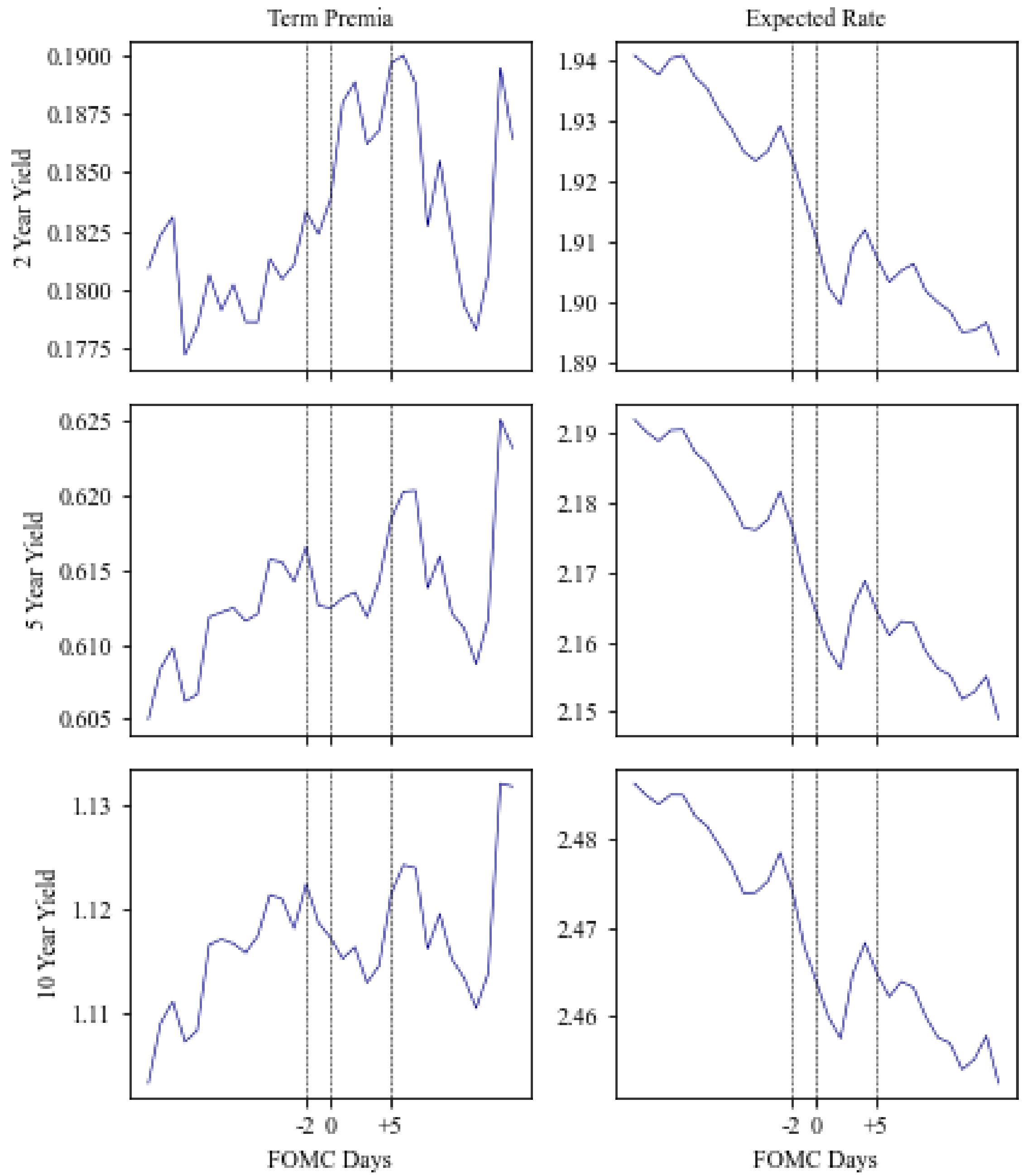


Figure 11. Term Premia and Expected Return Over FOMC Cycle

Note: These figures decompose the 2-year, 5-year and 10-year bond yield changes into the term premia and expected rate by Adrian, Crump, and Moench (2013) for their dynamics over the FOMC cycle, i.e., 15 trading days before and after the announcement. The data is available from New York Fed webpage. The unit of bond yield is 1%. Data runs from Jan 2000 to June 2020.

4.4 Term Premium or Expected Rate

According to Adrian, Crump, and Moench (2013), bond yields can be decomposed into two parts: the expected rate and the term premia. Which part of the bond yields determines the movement around the FOMC announcement? To answer this question, I download the data from New York Fed to see their corresponding dynamics over the FOMC cycle. From Figure 11, it's the expected rate that mainly responses to the monetary policy news and determines the pattern of the bond yields around announcements. After subtracting the term premia from the bond yields, the movements for 2-year, 5-year, and 10-year expected rate look extremely similar — they decrease the same amount over the FOMC cycle by around 5 bps. Compared with the Figure 9, the different response of bond yields attributes to their increased term premia around the FOMC cycle, which is higher with longer maturities, so that it explains why longer maturity bonds have a smaller response to the announcement and the rebound in the week after.

5 Risk-Return Relationship for the Pre-FOMC Announcement Drift

5.1 Premium for Heightened Uncertainty

Many researchers are exploring the reasons for the pre-FOMC announcement drift. They can be divided into two channels: information leaking, and uncertainty. As for the uncertainty channel, Hu, Pan, Wang, and Zhu (2019) discover that the VIX index increases in the 3 days before the announcements, followed by the pre-FOMC stock return. Therefore, they propose the premium for the heightened uncertainty and extend this phenomenon to any day with a sharp increment in uncertainty risk.

Following the paper, I implement their approach to the bond implied risks and yield changes, and days with risk reduction are also checked. Here, the positive cutoff implies that risks on these days are greater than the previous exponential moving average μ_{t-1} by the cutoff rate (Equation 16), and the negative cutoff indicates that the magnitude of the risk drop is larger than the threshold (Equation 17). η In μ_{t-1} is the decay factor. When $\eta = 0$, μ_{t-1} is set to be the previous risk $Risk_{t-1}$, so the left hand side converts to the daily change (see formula 19). As the implied skewness is negative most of the time, the enlargement in tail risk associates with the negative cutoff. I then calculate the average number of days in one year within the range of heightened risks and their next-day average return, with t-statistics comparing the mean to the ordinary days.

$$Risk_t - \mu_{t-1} > +cutoff \tag{16}$$

$$Risk_t - \mu_{t-1} < -cutoff \tag{17}$$

[10] Readers can find the pattern in the Appendix I.

[11] I summarize the existing measures for monetary policy surprises in Appendix I, and demonstrate how they provide different results for the same day.

$$\mu_{t-1} = (1-\eta)\sum_{\tau=0}^{\tau=t-1} \eta^{\tau} VIX_{t-\tau-1} \tag{18}$$

$$Risk_t - Risk_{t-1} = \Delta Risk_t > +cutoff(< -cutoff), \text{When } \eta = 0, \mu_{t-1} = Risk_{t-1} \tag{19}$$

After checking the consistency with Hu, Pan, Wang, and Zhu (2019)'s paper for the equity market [12], I show in Table 9 that heightened increment in 10-year uncertainty is joined by the next-day lift in yield.[13] Stock and bond heightened tail risk are not triggering distinctive stock return or bond yield adjustment.

Table 9. 10-Year Bond Yield Change After Heightened Risk Days

Cutoff Vol (%)	N Days (/year) $\eta = 0$	Return (bps)	T-stat	N Days (/year) $\eta = 0.15$	Return (bps)	T-stat	N Days (/year) $\eta = 0.30$	Return (bps)	T-stat
+0.8	4.6	0.94	1.78	4.8	**-0.14**	2.54	5.2	**1.88**	3.60
+0.6	10.2	**0.77**	2.25	10.7	**1.07**	3.10	10.8	**1.07**	3.11
+0.4	22.4	**0.39**	1.96	21.9	**0.48**	2.29	21.5	**0.47**	2.21
+0.2	52.4	0.10	1.33	52.0	0.09	1.25	52.6	0.17	1.76
+0.0	115.4	0.01	1.42	114.6	0.04	1.73	114.9	-0.01	1.13
-0.0	133.5	-0.22	1.45	134.9	-0.24	1.73	134.6	-0.19	1.13
-0.2	54.2	-0.33	1.43	54.2	**-0.42**	2.05	55.7	-0.38	1.81
-0.4	20.8	-0.59	1.80	19.6	**-0.70**	2.13	19.2	**-0.74**	2.28
-0.6	8.7	**-0.96**	2.00	8.4	-0.92	1.88	7.9	-0.93	1.84
-0.8	4.1	-1.05	1.52	3.7	-1.00	1.36	3.9	0.03	0.13
Cutoff Skew	**N Days (/year) $\eta = 0$**	**Return (bps)**	**T-stat**	**N Days (/year) $\eta = 0.15$**	**Return (bps)**	**T-stat**	**N Days (/year) $\eta = 0.30$**	**Return (bps)**	**T-stat**
+3.0	5.2	**-1.37**	2.28	4.4	**-1.40**	2.15	4.0	-1.04	1.50
+2.0	10.8	-0.64	1.42	10.0	-0.66	1.40	9.6	-0.57	1.20
+1.0	31.8	-0.21	0.46	30.4	-0.11	0.01	30.2	0.07	0.71
+0	119.1	-0.10	0.16	120.2	-0.07	0.52	120.9	-0.02	0.82
-0	129.1	-0.13	0.21	127.6	-0.16	0.64	126.8	-0.17	0.83
-1.0	32.0	-0.10	0.05	30.9	-0.17	0.27	31.1	-0.32	0.99
-2.0	9.7	0.15	0.65	8.7	-0.02	0.22	9.0	-0.02	0.21
-3.0	4.1	-0.39	0.45	3.6	-0.63	0.78	3.5	-1.01	1.34

Note: This table presents the 10-year Treasury bond yield change after heightened risk days, which are determined by Equation (16) and (17), so that risk is higher than the previous exponential moving average μ_{t-1} (Equation (18)) by the cutoff bar. "N Days" represents how many days in one year on average belong to the heightened risk days. "Return" gives the next-day bond yield change. "T-stat" compares the mean of yield change to ordinary days. Bond yield changes are computed from the daily Treasury yield curve available from the Federal Reserve Board webpage. Data runs from Jan 2000 to June 2020.

However, the highlighted uncertainty premium hypothesis is not adequate to explain the pre-

[12] Results are in Appendix Table A-14.

[13] I put the results for 2-, 5-, and 30-year risks in Appendix table A-15 to A-17.

FOMC announcement drift. First of all, the surge of uncertainty risk is followed by the upward drift for both stocks and bonds, whereas the bond yields fall before the announcement instead of rising. Therefore, uncertainty cannot be utilized to explain the bond pre-drift due to the opposite sign. Secondly, the uncertainty surging preceding the FOMC meetings is not considerable enough to be named "heightened." To recall, the average 2-day increase of uncertainty risk 0.5% and 0.2% for stock and 10-year bond, both of which just fall into the loosest threshold. The average 2-day increments for the 2-year, 5-year, and 30-year bonds also barely qualify for the most relaxed cutoff bar for significant next-day yield increase.

Table 10. Distribution of Pre-FOMC Uncertainty Change and Drift

Cutoff VIX(%)	N Days (/year)	Return (bps)	T-stat	Cutoff V^{5y}(%)	N Days (/year)	Return (bps)	T-stat
+1.00	1.9	10.23	0.23	+0.40	1.6	-2.00	1.21
+0.75	2.6	26.83	1.00	+0.30	2.0	-1.50	0.99
+0.50	3.1	26.72	1.09	+0.20	2.6	-1.26	0.92
+0.25	3.8	30.01	1.38	+0.10	3.8	-1.51	1.36
+0.00	4.9	32.61	1.74	+0.00	4.7	**-1.90**	1.98
V^{10y}(%)				V^{30y}(%)			
+0.40	1.0	2.645	1.47	+0.60	1.6	-2.40	1.64
+0.30	1.7	-1.54	0.95	+0.45	1.9	-1.96	1.43
+0.20	2.4	**-2.56**	2.05	+0.30	2.5	**-2.59**	2.27
+0.10	3.9	-1.95	1.92	+0.15	3.4	-1.96	1.95
+0.00	4.8	-1.57	1.67	+0.00	4.76	**-1.73**	1.96

Note: This table provides the distribution of uncertainty increase on the 3rd and 2nd day ($\Delta V_{t-3,t-2}$) before the FOMC announcement, and their corresponding pre-FOMC announcement drift ($R_{t-1,t}$). There are total 173 scheduled FOMC meetings from Jan 2000 to June 2020, averagely 8 meetings per year. "N Days" presents how many FOMC meetings are preceded with certain level of uncertainty increase.

For further justification, I summaries the distribution of uncertainty increase before the FOMC meetings ($\Delta V_{t-3,t-2}$) and their followed pre-announcement drift ($R_{t-1,t}$) in Table 10. We could see that on average, only 2 days out of 8 FOMC meetings in a year are with "heightened" risks. Also, they're followed by negative bond yield change, consistent with the pre-announcement drift, but contrary to the heightened uncertainty premium hypothesis. Therefore, although the hypothesis works for general cases, it cannot be used to explain the drift before the FOMC announcements.

5.2 Pre-FOMC Risk-Return Relationship

Even though the heightened uncertainty premium is incompetent to explain the pre-FOMC announcement drift, it is still possible that uncertainty variation can predict the future return. Moreover, instead of investigating the direct risk-return relationship, Bauer, Lakdawala, and Mueller (2019), De Pooter, Favara, Modugno, and Wu (2020) and Tillmann (2017) use their constructed monetary policy uncertainty measure to research its role in policy transmission, namely the yield curve response to the monetary policy surprise[14] under different levels of monetary policy uncertainty. In their regressions, the bond yield changes are regressed on the level of uncertainty risk and an interaction term with the monetary policy surprise. They reach a similar conclusion that high uncertainty depresses the yield curve response to the monetary policy shocks. In this paper, I applied a similar setup to the pre-announcement risk and drift with two alternations.

Table 11. Pre-FOMC Risk-Return Relationship

$$R^{stock/2y/5y/10y/30y}_{t-1,t} = \alpha + \beta_1 \Delta V_{t-3,t-2} + \beta_2 1_{t,FOMC} + \beta_3 1_{t,FOMC} \times \Delta V_{t-3,t-2} + \epsilon_t$$

	$R^{stock}_{t-1,t}$	$R^{2y}_{t-1,t}$	$R^{5y}_{t-1,t}$	$R^{10y}_{t-1,t}$	$R^{30y}_{t-1,t}$
Full Data: 2000 - 2020					
$\Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	1.45	**0.32****	0.01	0.41	0.31
	(2.20)	(0.16)	(0.25)	(0.48)	(0.23)
$1_{t,FOMC}$	**28.32****	**-1.47****	**-1.95*****	**-1.27***	-0.73
	(12.29)	(0.65)	(0.74)	(0.75)	(0.69)
$1_{t,FOMC} \times \Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	-2.93	0.25	1.41	-0.66	**-1.41****
	(15.54)	(1.39)	(0.89)	(1.65)	(0.70)
Sub Data: 2000 - 2009					
$\Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	**6.72***	0.33	0.36	0.80	**0.90****
	(3.84)	(0.21)	(0.40)	(0.51)	(0.44)
$1_{t,FOMC}$	**47.04****	**-2.29***	**-1.97***	-0.97	-0.68
	(20.97)	(1.27)	(1.19)	(1.19)	(1.29)
$1_{t,FOMC} \times \Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	-0.43	0.57	2.41	-0.64	-0.98
	(24.67)	(1.70)	(1.58)	(1.88)	(1.14)
Sub Data: 2010 - 2020					
$\Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	-2.86	0.31	-0.22	0.04	0.17
	(2.37)	(0.23)	(0.30)	(0.77)	(0.33)
$1_{t,FOMC}$	11.13	-0.79	**-1.75****	-1.40	-0.69
	(12.45)	(0.50)	(0.82)	(0.91)	(0.77)
$1_{t,FOMC} \times \Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	-8.62	-0.92	0.06	-2.02	**-1.76****
	(6.58)	(1.31)	(1.05)	(3.31)	(0.79)

Note: This table regresses 2-day stock return and bond yield changes ($R_{t-1,t}$) on the lagged 2-day uncertainty change ($\Delta V_{t-3,t-2}$), with indicators denoting the pre-FOMC announcement drift and their interaction terms. Stock return is calculated from S&P500 index. Bond yield changes are computed from the daily Treasury yield curve available from the Federal Reserve Board webpage. The 2-day rolling returns $R_{t-1,t}$ are extracted by $R^{stock}_{t-1,t} = (1+R^{stock}_{t-1}) \times (1+R^{stock}_{t}) - 1$ and $R^{bond}_{t-1,t} = R^{bond}_{t-1} + R^{bond}_{t}$ for stock and bonds respectively. VIX and $SKEW$ are available from CBOE webpage. The units of uncertainty and return are 1% and 1 bp, respectively. Intercept and R-squares are omitted but available upon request. Newey and West (1986) standard errors in parentheses. *p: 0.1, **p: 0.05, ***p: 0.01

Firstly, I focus on the pre-announcement drift, not the bond yield change after the FOMC meeting, so different regressors are applied. I use the dummy variable indicating the pre-FOMC days to replace monetary policy surprise measure since the surprise components derived from the post price change

[14] it is obtained from the short-term interest rate (Federal Fund rate or Eurodollar) future price change around the announcement, either in the 30-min window or the daily change.

of short-term interest rate futures are not related to the pre-announcement drift. Secondly, instead of the market-based monetary policy uncertainty measures constructed from the interest rate futures and options by various methods, I use the corresponding Treasury bond implied risks for the term structure of the yield curve change. In summary, the 2-day stock return and bond yield change are regressed on the lagged 2-day change of the corresponding uncertainty risk, the indicator denoting the pre-FOMC days, and their interaction term.

$$R_{t-1,t}^{stock/2y/5y/10y/30y} = \alpha + \beta_1 \Delta V_{t-3,t-2}^{stock/2y/5y/10y/30y} + \beta_2 1_{t,FOMC} + \beta_3 1_{t,FOMC} \times \Delta V_{t-3,t-2}^{stock/2y/5y/10y/30y} + \epsilon_t \tag{20}$$

In this area of research, another way to construct regression is to regress the announcement return on the uncertainty resolution. In other words, it regresses the return on the same day uncertainty change instead of in a predictive way. Intuitively, this method should be equivalent to the predictive regression, but there's a special difference under the context of the Treasury bond market: The uncertainty resolution happens on the dates of FOMC announcement, while the pre-FOMC announcement drift is located on the day beforehand. To recall the previous result, the uncertainty surges in the 3rd and 2nd days before the announcement, followed exactly by the Treasury bond yield drop. Because of it, I proceed with the predictive regressions.

From Table 11, one can know that 1% of the uncertainty rise help drive up the stock return, 10-year and 30-year bond yield by 6.7 bps, 0.8 bps, and 0.9 bp from 2000 to 2009. However, the effects are indistinguishable from zero after 2010, resulting in the overall insignificant effect. Based on the sign of the coefficients, variation in uncertainty attributes to positive change in the future stock returns and bond yields. In this way, the uncertainty variation cannot help explain the pre-FOMC announcement drift in the Treasury bond markets due to the opposite sign. Moreover, as the average uncertainty changes before the FOMC meeting are 0.5%, 0.2%, and 0.3% for stock and long-term bonds respectively, it can only attribute a small part of the changes even if we ignore the significance level. We could also see that the indicator $1_{t,FOMC}$ is still not spanned by uncertainty change for stock, 2-year, and 5-year bonds. The only exception is the 30-year bond yield, for which adding uncertainty into the regression consumes the indicator's significance.

Looking through the interaction term, we can find that the special upsurge of uncertainty risk before FOMC announcement has some offsetting effect for the longer-term bonds, consistent with other authors' research for the post-announcement drift, while the coefficients are statistically significant only for the 30-year yield. Together with the positive influence, only the 30-year uncertainty change can help explain the decrease in the bond yield, while still, with a very little amount.

Another way to look into the Pre-FOMC risk-return relationship is to look at the special FOMC days only, which is also the approach employed by Hu, Pan, Wang, and Zhu (2019). Under this context, the previous dummy variables become 1 and the coefficient before uncertainty change $\Delta V_{t-3,t-2}$ summaries the overall effect from uncertainty risk. As we can see from Table 12 that much of the drift remains unexplained in the intercept and that we cannot arrive at an ultimate conclusion about the uncertainty effect.

Table 12. Pre-FOMC Risk-Return Relationship: FOMC Days Only

$$R_{t-1,t}^{Pre,stock/2y/5y/10y/30y} = \alpha + \beta_1 \Delta V_{t-3,t-2}^{stock/2y/5y/10y/30y} + \epsilon_t$$

	$R_{t-1,t}^{Pre,Stock}$	$R_{t-1,t}^{Pre,2y}$	$R_{t-1,t}^{Pre,5y}$	$R_{t-1,t}^{Pre,10y}$	$R_{t-1,t}^{Pre,30y}$
Full Data: 2000 - 2020					
$\Delta V_{t-3,t-2}^{stock/2y/5y/10y/30y}$	-1.48	0.57	1.42	-0.25	-1.10
	(6.14)	(1.01)	(0.88)	(1.46)	(0.72)
Intercept	**31.74****	**-1.59****	**-2.14*****	**-1.46***	-0.90
	(13.99)	(0.65)	(0.75)	(0.76)	(0.70)
Sub Data: 2000 - 2009					
$\Delta V_{t-3,t-2}^{stock/2y/5y/10y/30y}$	6.29	0.90	**2.77****	0.17	-0.07
	(10.19)	(1.49)	(1.36)	(1.87)	(1.45)
Intercept	**45.12***	**-2.51***	**-2.23***	-1.18	-0.81
	(24.50)	(1.28)	(1.18)	(1.19)	(1.26)
Sub Data: 2010 - 2020					
$\Delta V_{t-3,t-2}^{stock/2y/5y/10y/30y}$	**-11.47***	-0.61	-0.16	-1.98	**-1.59****
	(5.92)	(1.38)	(1.08)	(2.72)	(0.79)
Intercept	19.56	-0.83	**-1.86****	-1.58	-0.892
	(12.67)	(0.50)	(0.89)	(0.96)	(0.81)

Note: In this table, only the pre-announcement drift and its associated previous uncertainty risk are regressed together. Stock return is available from daily returns on the CRSP S&P500 value-weighted portfolio. Bond yield changes are computed from the daily Treasury yield curve available from the Federal Reserve Board webpage. The 2-day rolling returns $R_{t-1,t}$ are extracted by $R_{t-1,t}^{stock} = (1 + R_{t-1}^{stock}) \times (1 + R_t^{stock}) - 1$ and $R_{t-1,t}^{bond} = R_{t-1}^{bond} + R_t^{bond}$ for stock and bonds respectively. VIX and $SKEW$ are available from CBOE webpage. The derived uncertainty and tail risk are from Equation (8) and (9), the construction of which are provided in Chapter 1. The units of uncertainty and return are 1% and 1 bp, respectively. Standard errors in parentheses. *p: 0.1, **p: 0.05, ***p: 0.01

$$R_{t-1,t}^{Pre,stock/2y/5y/10y/30y} = \alpha + \beta_1 \Delta V_{t-3,t-2}^{stock/2y/5y/10y/30y} + \epsilon_t \tag{21}$$

Investigating the risk-return relationship through the above three angles — heightened uncertainty premium, the uncertainty effect on monetary policy transmission, and the special pre-FOMC risk-return relationship — I conclude that the early upsurge in stock and bond uncertainty cannot justify the pre-announcement drifts in both equity and Treasury bond markets.

6 Future Extensions

In this paper, I construct the term structure of bond implied volatility and skewness to explore the characteristics of risks across different tenors and investigate how bond implied risks move under financial conditions and change over macroeconomic announcements. The first finding is that while bond uncertainty risks move with the stock's counter-cyclically, tail risk in Treasury bonds is weakly and negatively correlated to the stock counterpart because of Flight-to-Safety. However, the relationship between stock and bond tail risks turn positive before and around financial crises to signal severe stress. Also, bond tail risk sheds additional light on the market because the dramatic enlargement of bond tail risks before the 2008 Financial crisis reflects extreme challenges in debt markets. The recent crisis brought by Covid-19 also tests the riskiness of Treasury bond markets. Moreover, from 2016 to the present, relatively small and even positive bond tail risks coincide with the zero-lower-bound period as well as the Fed's forward guidance to keep the interest rate low into the future. When focusing on the risk movement around macroeconomic announcements, I find that stock and bond uncertainty jump 3 and 2 days before the FOMC meetings and drop back on the FOMC days, the driver of which comes more from the price increase of call options rather than puts. Furthermore, the pre-announcement drift in bonds exists such that 5-, 10- and 30-year bond yields drop 1 bp one day before the announcements. When I examine the uncertainty increase and the drift through three approaches, I validate that uncertainty risk cannot explain the pre-announcement drift.

An extension of this paper could focus on explaining the monthly return instead of the daily pre-FOMC drift. As Adrian, Crump, and Vogt (2019) discover the non-linearity between the stock return and VIX, and Martin (2017) offers the theoretical foundation, a similar relationship might also be found in Treasury bond portfolios with the corresponding bond uncertainty risks. Also, we can look at the correlation between stock and bond returns, and try to explain it with the option-implied risks.

Furthermore, an increasing number of papers build up connections between risk premium and tail risk in the equity market, theoretically and empirically, domestically and globally, by adding tail risk as a factor and construct the tail risk portfolio to examine the abnormal alphas. For example, Schneider, Wagner, and Zechner (2017) relate the stock tail risk to explain the betting against beta as well as the low variance risk abnormality, and Borochin and Zhao (2020) link the stock tail risk to explain the momentum effect. Also, Borochin, Chang, and Wu (2020) explore the short-term and long-term risk-neutral skewness, which have different impacts on the cross-section stock returns. As for possible applications in the bond markets, the paper by Choi, Mueller, and Vedolin (2017) investigating the bond variance risk premium can be extended to the tail risk version. A very recent paper by Rubin and Ruzzi (2020) investigates stock tail risk's effect on the Treasury bond market, which can also be replaced by the bond tail risk instead.

But the most interesting question to ask is: Does this unique relationship between stock and bond tail risk help us understand the investors' "Flight-to-Safety" behavior? For example, during financial crises, investors reallocate their equity assets to the bond markets, but what if Treasury bonds are also risky at the same time? Just as what happened in March 2020? Is it already considered by the investors and incorporated in their behavior, and reflected in the stock-bond return correlation? I'm currently working on this subject and hopefully will find an answer soon.

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Bond Implied Risks Around Macroeconomic Announcements
Online Appendix

Xinyang Li[15]

Appendix A Data Cleaning

The CBOE End-of-Day dataset provides the daily trading information for S&P500 and Treasury futures and options. As options are written on futures, the spot price $S(t)$ here is the future price. Futures are quarterly listed and rolled. On average, two future contracts are in the market. To get the most liquid future price, I apply the convention from Choi, Mueller, and Vedolin (2017) to roll the future on the 28th of the month preceding the maturity month. Compared to futures, options are more diverse. Typically, there are 2 to 3 monthly serial options, 1 to 2 quarterly ones, sometimes with the additional 1 to 2 options maturing half a year or one year later. On average, options with 4 different maturity dates are listed in a day, but not all are traded in a large amount. The two options with the shortest time-to-maturity are most actively traded based on trading volume, so I use them separately to calculate risks before merging into one risk measure. But I also apply a rolling method here to the next options with the time-to-maturity of fewer than 7 days. Since the actual traded price rather than all listed prices should be the one to use, I clean the data by deleting the ones with zero open interest, settlement price, or trading volume. Next, option prices are matched with the same-day future price, and out-of-money options are selected for the risk contracts calculation.

Appendix B Procedure Comparison With Index Calculation Approach

There are several differences between the Bakshi, Kapadia, and Madan (2003) method and the index calculation approach from CBOE. For indexes, the same weights are offered on the call and put (in Equation (B.1)), while Bakshi, Kapadia, and Madan (2003) employ more weights to the put options since the out-of-money puts are what investors use more to hedge for risks. Also, for calculating indexes, the actual future price is not used at all. Instead, Call-Put parity is utilized for constructing an artificial one, then the closest strike price to the artificial future price is denoted as the "at-the-money" option price, and both of the "at-the-money" call and put options are included in the deviation. In contrast, only the out-of-money options are utilized in the paper. Since the artificial future price and the at-the-money strike price is not the same, an error-correcting term is introduced in Equation (B.2). Finally, they differ in how to calculate $\mu(t,\tau)$, the expectation of the first-moment return. I choose the Bakshi, Kapadia, and Madan (2003) methodology rather than the index calculation approach since it is more reasonable for putting different weights and using actual future prices.

$$V_{TYVIX}(t,\tau) = \int_{S(t)}^{\infty} \frac{2}{K^2} C(t,\tau;K)dK + \int_{0}^{S(t)} \frac{2}{K^2} P(t,\tau;K)dK \tag{B.1}$$

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$$V_{TYVIX}^{iy} = \sqrt{\frac{365}{30}\left(w_1 \times Vol_{TYVIX}^{iy}(t,\tau_1) + w_2 \times Vol_{TYVIX}^{iy}(t,\tau_2)\right) - \left(\frac{F}{K_{ATM}} - 1\right)^2}, i = 2, 5, 10, 30 \tag{B.2}$$

Appendix C Risk Measure Robustness

To verify that this calculation procedure captures the risks implied in the market, I compare the computed 10-year volatility with TYVIX, the CBOT 10-year U.S. Treasury note volatility index. I adjust the indexes (see Equation C.1) to reflect the real risks. Plotted together in Figure 1a, they share a similar pattern along the time. The daily correlation is 0.97. Since the same method is applied to calculate risks across maturities, the comparison with TYVIX as the benchmark justifies the term structure of bond uncertainty risk. However, one can notice that there's a parallel downward shift of the derived Treasury bond uncertainty risks, which could attribute to the fact that the Bakshi, Kapadia, and Madan (2003) method give higher weights on more out-of-money put options $(1 + ln(S/K))$ and smaller weights on more out-of-money call options $(1 - ln(K/S))$ while the index approach gives all the options the same weight.

$$TYVIX = TYVIX_{index}/100 \tag{C.1}$$

$$VIX = VIX_{index}/100 \tag{C.2}$$

$$SKEW = (100 - SKEW_{index})/10 \tag{C.3}$$

As there's no bond skewness index, I calculate the implied volatility and skewness of S&P500 using the same approach, to compare them with the stock indexes VIX and SKEW (after transforming them by C.2 and C.3), so that the term structure of bond implied skewness is valid if this method captures both the dynamics of VIX and SKEW. Displayed in Figure 1b, the derived stock implied volatility replicates the VIX index well, with a substantial daily correlation of 0.99. The corresponding correlation for stock skewness is 0.79, but the derived skewness measure could catch up with the movement.

The reason for the relatively lower correlation between the stock SKEW index and the calculated implied skewness is the different formulas applied for the underlying risk contract prices, and the additional error-correcting term, as mentioned above. Those differences cause a small divergence for implied volatility, but when I use the underlying contracts to calculate skewness further, this discrepancy enlarges.

There is also one paper from Dew-Becker, Giglio, and Kelly (2019) who only use the "at-the-money" implied volatility, the average implied volatility of two out-of-money call and put option whose strike prices are nearest to the future price. When I apply their approach and use the implied volatility provided by the dataset, it matches TYVIX considerably well with the correlation of 0.95.

The reason behind this is that the bond options that close to the spot prices are mostly traded so that they could represent much of the risks. However, the implied volatility data in CME started in 2010 and began stable to be used from 2011, limiting the data range and the later regression construction. When I try to calculate implied volatility by myself through the Black-Scholes formula and root-finding approach to supplement the data, the results are volatile and incompatible with the existing ones. Besides, even if I proceed with the at-the-money method, the methodology from Bakshi, Kapadia, and Madan (2003) is still needed for tail risk. After examining and replicating the three procedures, I find that the Bakshi, Kapadia, and Madan (2003) method is the most reliable one. With the most extensive data possibility and available tail risk calculation formula, so I choose to proceed with it in this paper.

Appendix D Risks Under Recessions

Table A-1. Risks Under Recessions: NBER Business Cycle

	VIX_t	V_t^{2y}	V_t^{5y}	V_t^{10y}	V_t^{30y}
$1_{t,Bust}$	13.1720***	1.8975***	2.0434***	2.3996***	2.6829***
	(0.5049)	(0.1076)	(0.2693)	(0.0918)	(0.1830)
Intercept	17.0232***	3.1143***	6.6131***	4.5522***	8.0903***
	(0.1208)	(0.0303)	(0.0706)	(0.0311)	(0.0621)
R-squared	0.3592	0.1867	0.0420	0.2828	0.1103
	$SKEW_t$	S_t^{2y}	S_t^{5y}	S_t^{10y}	S_t^{30y}
$1_{t,Bust}$	0.7723***	-0.6279***	0.1483*	0.1832	0.5435***
	(0.0295)	(0.1581)	(0.0814)	(0.1302)	(0.0912)
Intercept	-2.3230***	-0.0365	-0.5406***	-1.7972***	-1.5924***
	(0.0174)	(0.0749)	(0.0544)	(0.0786)	(0.0703)
R-squared	0.1480	0.0055	0.0004	0.0003	0.0055

To validate the descriptive claims made in the main paper, I regress the level of stock and bond risks on dummy variables to see if the bond implied risks exhibit meaningful distinction under recessions. According to the NBER Business Cycle specification, I define the economic contractions, from March 2001 to November 2001, from December 2007 to June 2009, and from Feb 2020 to June 2020, as the ”Bust” period, leaving the other time as expansions or ”Boom” periods. Displayed in Table A-1, the stock and bond implied uncertainty are higher by 13.2%, 1.9%,2.0%, 2.4% and 2.7% in the recessions. As skewness is negative in mean, the crashes witness the stock tail risk shrinking by 0.8, and the 5-year and 30-year tail risk decline by 0.2 and 0.5 during the contractions. In this paper, I proceed with the NBER definition of recessions as the control variable and for the interaction terms.

Appendix E Risks on the FOMC Days

Table A-2. Risk on the FOMC Days

	VIX_t	V_t^{2y}	V_t^{5y}	V_t^{10y}	V_t^{30y}
$1_{t,FOMC}$	0.1402	-0.0067	-0.1814	-0.0474	-0.1566
	(0.6908)	(0.1499)	(0.3094)	(0.1413)	(0.2278)
Intercept	19.7945***	3.5005***	7.0497***	5.0594***	8.6613***
	(0.1776)	(0.0358)	(0.0806)	(0.0365)	(0.0656)
R-squared	-0.0002	-0.0002	-0.0001	-0.0002	-0.0001
	$SKEW_t$	S_t^{2y}	S_t^{5y}	S_t^{10y}	S_t^{30y}
$1_{t,FOMC}$	0.0434	0.1414	-0.0427	-0.2765	-0.1548
	(0.0618)	(0.3095)	(0.2351)	(0.3054)	(0.2271)
Intercept	-2.1613***	-0.1698**	-0.5079***	-1.7494***	-1.4727***
	(0.0161)	(0.0663)	(0.0448)	(0.0658)	(0.0574)
R-squared	-0.0001	-0.0002	-0.0002	0.0000	-0.0001

Appendix F Tail Risk Around FOMC Announcement

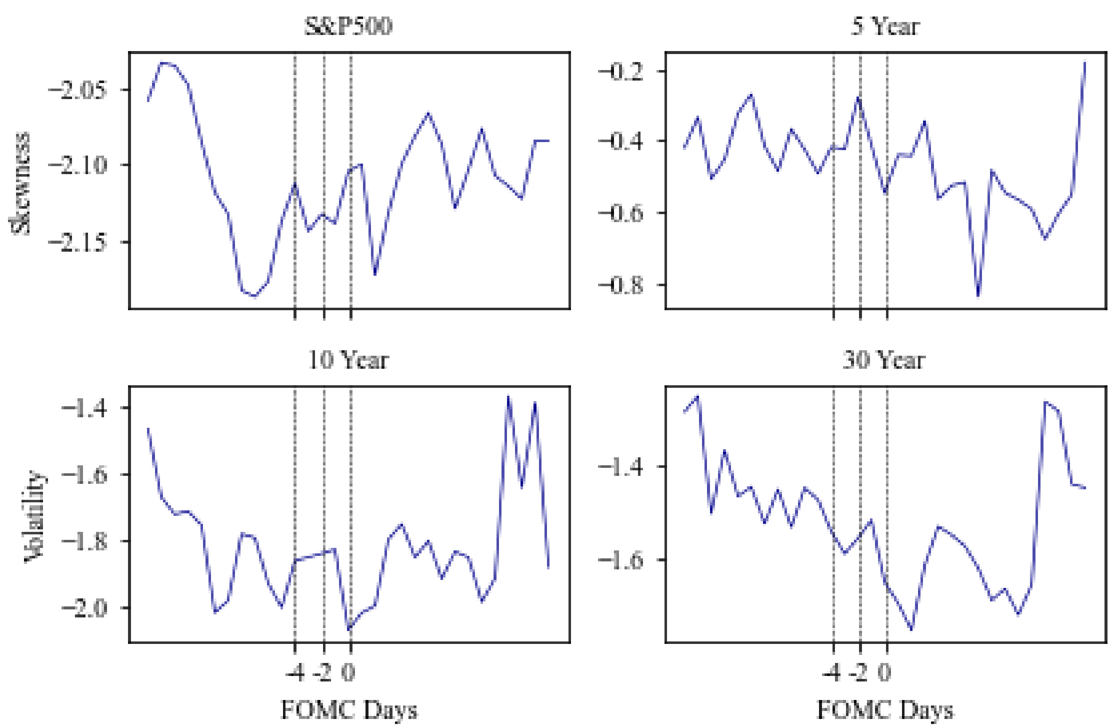

Figure A-1. Stock and Bond Tail Risk Over FOMC Cycle

Table A-3. Tail Risk Change Around FOMC Announcement

	$\Delta SKEW_t$	ΔS_t^{2y}	ΔS_t^{5y}	ΔS_t^{10y}	ΔS_t^{30y}
$1_{t,FOMCPre3}$	-0.0265	0.1531	-0.0733	-0.0159	-0.0259
	(0.0294)	(0.1425)	(0.1154)	(0.1111)	(0.0750)
$1_{t,FOMCPre2}$	0.0116	0.0403	0.1342	0.1391	0.0033
	(0.0238)	(0.1167)	(0.1700)	(0.1300)	(0.1075)
$1_{t,FOMC}$	0.0347	-0.1719	-0.1397	-0.2477**	-0.1427***
	(0.0244)	(0.1598)	(0.1359)	(0.1021)	(0.0553)
Intercept	-0.0018	-0.0331	0.0073	0.0136	0.0089
	(0.0038)	(0.0230)	(0.0221)	(0.0194)	(0.0162)
R-squared	0.0007	0.0006	0.0004	0.0012	0.0005
R-squared Adj.	0.0001	-0.0000	-0.0002	0.0006	-0.0001

Appendix G Economic Indicators

Applying the same approach, I extend the previous analysis beyond the FOMC announcements. I select 25 economic indicators by importance, covering various categories of macroeconomic outcomes. As listed in Table A-4, these data reflect economic conditions in the areas of national accounts, consumer/producer prices, labor market, economic activity, business condition, housing market, consumer confidence,retail sector, personal sector and external sector, with also one leading indicator index. Most of the numbers are released monthly, except for quarterly announced GDP and weekly data of initial jobless class and MBA mortgage application.

Here, instead of looking for 15 trading days before and after the announcement, I shrink the data size to 10 days. For weekly data of initial jobless claim and MBA mortgage application, I apply 3 days before and after for their announcement cycle. Looking through all the graphs[16], I find that for most economic indicators, uncertainty and tail risk don't response to them specifically. However, one single indicator stands out, the unemployment rate. Shown in Figure A-2, we could notice that bond uncertainty risks across maturities drop specifically on the announcement of unemployment rate, reaching the local minimal point. Therefore, the release of unemployment data reduces the uncertainty. The release of unemployment rate and the non-farm payroll take place on the same day, so the uncertainty resolution captures both of the indicators. As supported in Table A-5, stock, 5-year, 10-year, and 30-year uncertainty risks decline by 0.3%, 0.2%, 0.2% and 0.3% respectively. In Table A-6, I show that days with the decline in unemployment rate are with higher bond uncertainty resolution.

[16] The plots are available upon request.

Table A-4. Economic Indicators

Category	Name	Unit	Frequency	Time	Period
National Accounts	Real GDP	%	Quarterly	8:30	2000-2020
Consumer Prices	Consumer Price Index	%	Monthly	8:30	2000-2020
Producer Prices	PPI Final Demand	%	Monthly	8:30	2014-2020
Labor Market	Unemployment Rate	%	Monthly	8:30	2000-2020
	Initial Jobless Claims	K	Weekly	8:30	2000-2020
	Chg. in Non-Farm Payrolls	K	Monthly	8:30	2000-2020
	ADP Employment Change	K	Monthly	8:15	2006-2020
Economic Activity	Industrial Production	%	Monthly	9:15	2000-2020
	Factory Orders	%	Monthly	10:00	2000-2020
	Durable Goods Orders	%	Monthly	10:00	2000-2020
	Wholesale Inventories	%	Monthly	10:00	2000-2020
Business Conditions	ISM Manufacturing Index	%	Monthly	10:00	2000-2020
	Empire Mfg. Business Condition Index	%	Monthly	8:30	2002-2020
	MNI Chicago Business Barometer	1	Montly	9:45	2000-2020
Leading Indicators	Conf. Board Leading Indicator	%	Monthly	10:00	2000-2020
Housing Market	Housing Starts	K	Monthly	8:30	2000-2020
	New Home Sales	K	Monthly	10:00	2000-2020
	Existing Home Sales	M	Monthly	10:00	2005-2020
	MBA Mortagage Applications	%	Weekly	7:00	2004-2020
Retail Sector	Retail Sales Advance	%	Monthly	8:30	2000-2020
Consumer Confidence	Conf. Board Consumer Confidence	100	Monthly	10:00	2000-2020
	U. Michigan Consumer Sentiment Index	100	Monthly	10:00	2000-2020
Personal Sector	Personal Income	%	Monthly	8:30	2000-2020
	Personal Expenditure	%	Monthly	8:30	2000-2020
External Sector	Trade Balance	B	Monthly	8:30	2000-2020

Table A-5. Uncertainty Change Around Unemployment Announcement

	ΔVIX_t	ΔV_t^{2y}	ΔV_t^{5y}	ΔV_t^{10y}	ΔV_t^{30y}
$1_{Unemployment}$	**-0.2921***	-0.0699	**-0.2015***	**-0.2092***	**-0.2886***
	(0.1018)	(0.0448)	(0.0405)	(0.0217)	(0.0320)
Intercept	0.0094	0.0044	0.0103	0.0085*	0.0115
	(0.0228)	(0.0085)	(0.0084)	(0.0046)	(0.0088)
R-squared	0.0012	0.0003	0.0046	0.0164	0.0100
	0.0014	0.0006	0.0048	0.0166	0.0102

Table A-6. Uncertainty Change Around Unemplyment Announcement: Decomposed

	VIX_t	V_t^{2y}	V_t^{5y}	V_t^{10y}	V_t^{30y}
$1_{BadChange}$	**-0.4511****	-0.0749	**-0.1651****	**-0.2048*****	**-0.2250*****
	(0.2175)	(0.0591)	(0.0830)	(0.0376)	(0.0616)
$1_{GoodChange}$	**-0.2824****	-0.0659	**-0.2512*****	**-0.2215*****	**-0.3373*****
	(0.1237)	(0.0836)	(0.0540)	(0.0348)	(0.0497)
Intercept	0.0080	0.0035	0.0082	0.0060	0.0078
	(0.0227)	(0.0084)	(0.0083)	(0.0045)	(0.0087)
R-squared	0.0013	-0.0000	0.0037	0.0126	0.0074
	0.0017	0.0004	0.0041	0.0130	0.0078

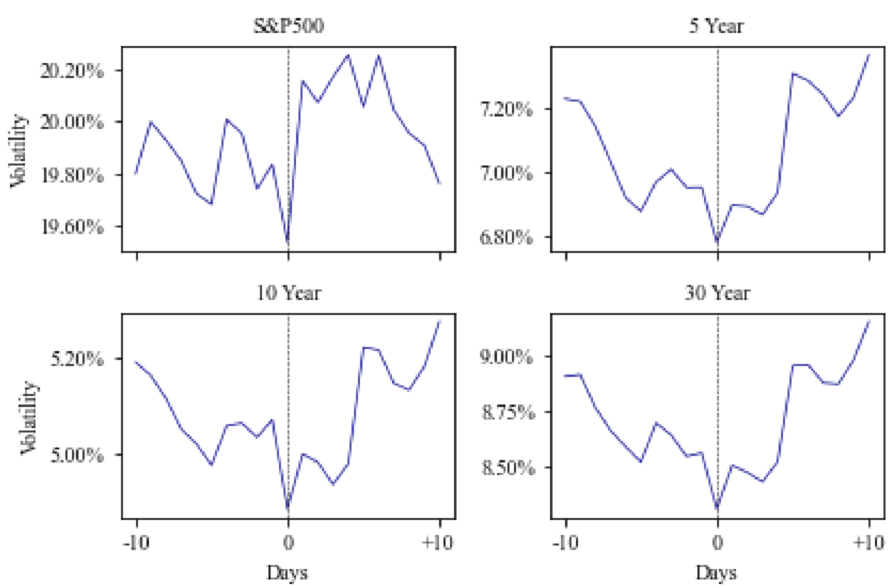

Figure A-2. Uncertainty Risk Over Announcement Cycle: Unemployment Rate

Table A-7. At-the-Money Call Option Prices Around FOMC Announcement: All Options

	$Price_t^{stock}$	$Price_t^{2y}$	$Price_t^{5y}$	$Price_t^{10y}$	$Price_t^{30y}$
Intercept	32.5719***	139.9722***	209.6326***	52.2003***	110.5596***
	(0.2662)	(1.6261)	(3.1038)	(0.4692)	(1.2304)
$1_{t,FOMCPre4}$	2.0155	8.6307	2.0781	0.6543	-4.2717
	(1.3444)	(8.6572)	(15.9046)	(2.4019)	(6.2929)
$1_{t,FOMCPre3}$	3.0391**	11.2778	7.5498	4.3088*	4.6040
	(1.3444)	(8.6572)	(15.9046)	(2.4019)	(6.2929)
$1_{t,FOMCPre2}$	3.2300**	17.3562**	15.1724	5.6906**	7.2646
	(1.3444)	(8.6572)	(15.9046)	(2.4019)	(6.2929)
$1_{t,FOMCPre1}$	2.6740**	18.3121**	15.7794	5.0361**	3.9676
	(1.3444)	(8.6572)	(15.9046)	(2.4019)	(6.2929)
$1_{t,FOMC}$	1.7137	0.5180	3.6378	0.5330	-2.9687
	(1.3444)	(8.6572)	(15.9046)	(2.4019)	(6.2929)
$1_{t,FOMCPost1}$	1.4031	-0.3889	-5.7301	0.2785	-1.9687
	(1.3444)	(8.6572)	(15.9046)	(2.4019)	(6.2929)
R-squared	0.0022	0.0013	-0.0008	0.0012	-0.0006
	0.0034	0.0030	0.0004	0.0024	0.0006

Appendix H Option Prices and Trading Volumes

Table A-8. At-the-Money Put Option Prices Around FOMC Announcement: All Options

	$Price_t^{stock}$	$Price_t^{2y}$	$Price_t^{5y}$	$Price_t^{10y}$	$Price_t^{30y}$
Intercept	26.1809***	51.3948***	165.7048***	56.8703***	125.2641***
	(0.2879)	(1.0061)	(2.8323)	(0.6140)	(1.0167)
$1_{t,FOMCPre4}$	0.7537	-0.3604	-10.3622	-1.2763	-7.7126
	(1.4541)	(5.2556)	(14.5476)	(3.1445)	(5.2004)
$1_{t,FOMCPre3}$	1.5887	3.3465	6.2736	0.5813	-1.9671
	(1.4541)	(5.2556)	(14.5476)	(3.1445)	(5.2004)
$1_{t,FOMCPre2}$	1.7945	2.2833	7.7211	2.0358	1.0571
	(1.4541)	(5.2556)	(14.5476)	(3.1445)	(5.2004)
$1_{t,FOMCPre1}$	1.7570	1.9006	4.3355	1.9388	-2.0368
	(1.4541)	(5.2268)	(14.5476)	(3.1445)	(5.2004)
$1_{t,FOMC}$	1.2397	-3.2698	-12.8496	-0.0733	-6.0308
	(1.4541)	(5.2268)	(14.5476)	(3.1445)	(5.2004)
$1_{t,FOMCPost1}$	1.0351	-7.4176	-9.2328	-1.4006	-6.1308
	(1.4541)	(5.2268)	(14.5476)	(3.1445)	(5.2004)
R-squared	-0.0002	-0.0010	-0.0007	-0.0009	-0.0002
	0.0010	0.0012	0.0005	0.0002	0.0009

Table A-9. At-the-Money Call Option Prices Around FOMC Announcement: Nearest Options

	$Price_t^{stock}$	$Price_t^{2y}$	$Price_t^{5y}$	$Price_t^{10y}$	$Price_t^{30y}$
Intercept	24.4580***	130.0042***	180.5217***	39.4486***	82.3851***
	(0.2239)	(1.5487)	(2.6455)	(0.4109)	(1.1620)
$1_{t,FOMCPre4}$	2.5332**	10.7150	10.9631	2.9211	-3.2154
	(1.1310)	(7.8269)	(13.5489)	(2.1048)	(5.9493)
$1_{t,FOMCPre3}$	4.2347***	17.8040**	17.7692	6.1514***	7.1482
	(1.1310)	(7.8269)	(13.5489)	(2.1048)	(5.9493)
$1_{t,FOMCPre2}$	4.0853***	18.2150**	29.6904**	8.2059***	10.0391*
	(1.1310)	(7.8269)	(13.5489)	(2.1048)	(5.9493)
$1_{t,FOMCPre1}$	3.3106***	19.3794**	24.9813*	7.4241***	6.3785
	(1.1310)	(7.8269)	(13.5489)	(2.1048)	(5.9493)
$1_{t,FOMC}$	2.2167*	4.5506	10.2177	3.4605	-2.1002
	(1.1310)	(7.8269)	(13.5489)	(2.1048)	(5.9493)
$1_{t,FOMCPost1}$	1.6457	2.5301	-2.0248	2.9575	-1.1063
	(1.1310)	(7.8269)	(13.5489)	(2.1048)	(5.9493)
R-squared	0.0067	0.0024	0.0008	0.0060	-0.0000
	0.0079	0.0038	0.0020	0.0072	0.0011

Table A-10. At-the-Money Put Option Prices Around FOMC Announcement: Nearest Options

	$Price_t^{stock}$	$Price_t^{2y}$	$Price_t^{5y}$	$Price_t^{10y}$	$Price_t^{30y}$
Intercept	21.2526***	35.9144***	115.2367***	37.2128***	86.6784***
	(0.2398)	(0.7855)	(2.2976)	(0.5296)	(0.9648)
$1_{t,FOMCPre4}$	1.2294	-0.4222	-17.2489	-7.5279***	-13.6299***
	(1.2110)	(3.8153)	(11.7674)	(2.7128)	(4.9393)
$1_{t,FOMCPre3}$	1.9236	2.2296	-3.5519	-6.2491**	-7.9026
	(1.2110)	(3.8164)	(11.7674)	(2.7128)	(4.9393)
$1_{t,FOMCPre2}$	1.7739	2.4947	-5.0731	-3.7764	-4.5753
	(1.2110)	(3.8164)	(11.7674)	(2.7128)	(4.9393)
$1_{t,FOMCPre1}$	1.5236	0.2220	-8.7043	-4.1097	-8.0420
	(1.2110)	(3.8164)	(11.7674)	(2.7128)	(4.9393)
$1_{t,FOMCPre0}$	1.3117	-3.8310	-23.0363*	-6.4249**	-12.3996**
	(1.2110)	(3.8164)	(11.7674)	(2.7128)	(4.9393)
$1_{t,FOMCPost1}$	0.7891	-4.9642	-22.3743*	-7.8734***	-13.0723***
	(1.2110)	(3.8153)	(11.7674)	(2.7128)	(4.9393)
R-squared	0.0003	-0.0006	0.0006	0.0040	0.0033
	0.0015	0.0010	0.0018	0.0052	0.0045

Table A-11. At-the-Money Call Option Prices Around FOMC Announcement: Next Options

	$Price_t^{stock}$	$Price_t^{2y}$	$Price_t^{5y}$	$Price_t^{10y}$	$Price_t^{30y}$
Intercept	40.6857***	147.6448***	243.7433***	65.0310***	139.0650***
	(0.3294)	(1.8272)	(3.8172)	(0.5919)	(1.4680)
$1_{t,FOMCPre4}$	1.4978	6.4329	-4.4477	-1.5886	-5.6590
	(1.6636)	(9.8100)	(19.5624)	(3.0302)	(7.5082)
$1_{t,FOMCPre3}$	1.8436	10.7533	-0.8440	2.2478	1.7289
	(1.6636)	(9.8100)	(19.5624)	(3.0302)	(7.5082)
$1_{t,FOMCPre2}$	2.3746	16.6756*	4.7661	3.0660	4.1592
	(1.6636)	(9.8100)	(19.5624)	(3.0302)	(7.5082)
$1_{t,FOMCPre1}$	2.0375	17.8892*	8.2944	2.5690	1.2259
	(1.6636)	(9.8100)	(19.5624)	(3.0302)	(7.5082)
$1_{t,FOMC}$	1.2106	0.5105	-2.1710	-2.4734	-4.1681
	(1.6636)	(9.8100)	(19.5624)	(3.0302)	(7.5082)
$1_{t,FOMCPost1}$	1.1606	0.0251	-10.5232	-2.4795	-3.1620
	(1.6636)	(9.8100)	(19.5624)	(3.0302)	(7.5082)
R-squared	-0.0001	0.0004	-0.0011	-0.0004	-0.0009
	0.0011	0.0021	0.0001	0.0008	0.0003

Table A-12. At-the-Money Put Option Prices Around FOMC Announcement: Next Options

	$Price_t^{stock}$	$Price_t^{2y}$	$Price_t^{5y}$	$Price_t^{10y}$	$Price_t^{30y}$
Intercept	31.1092***	62.9926***	217.4993***	76.5548***	164.2160***
	(0.3737)	(1.1648)	(3.7268)	(0.8216)	(1.2705)
$1_{t,FOMCPre4}$	0.2780	1.8012	2.8093	4.9482	-2.1615
	(1.8873)	(6.2434)	(19.1447)	(4.2076)	(6.4989)
$1_{t,FOMCPre3}$	1.2539	4.3270	16.2600	7.3846*	3.6021
	(1.8873)	(6.2434)	(19.1447)	(4.2076)	(6.4989)
$1_{t,FOMCPre2}$	1.8152	2.0590	20.2229	7.8210*	6.3234
	(1.8873)	(6.2434)	(19.1447)	(4.2076)	(6.4989)
$1_{t,FOMCPre1}$	1.9905	2.4714	15.7736	7.9604*	3.6021
	(1.8873)	(6.2434)	(19.1447)	(4.2076)	(6.4989)
$1_{t,FOMC}$	1.1676	-1.1369	-4.0857	6.2513	-0.0282
	(1.8873)	(6.2434)	(19.1447)	(4.2076)	(6.4989)
$1_{t,FOMCPost1}$	1.2810	-5.5183	3.2638	5.0452	0.4446
	(1.8873)	(6.2434)	(19.1447)	(4.2076)	(6.4989)
R-squared	-0.0006	-0.0013	-0.0007	0.0013	-0.0009
	0.0006	0.0005	0.0005	0.0025	0.0003

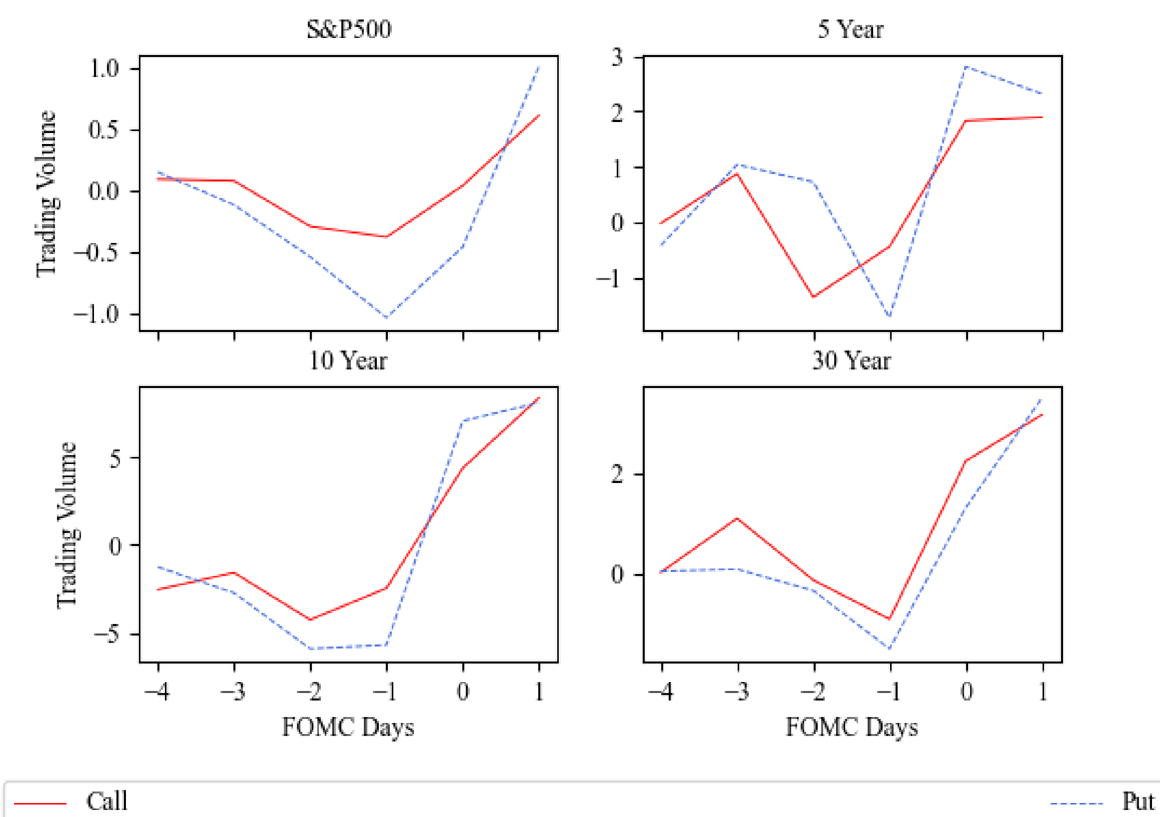

Figure A-3. Stock and Bond Option Trading Volume Around FOMC Announcement

Appendix I Monetary Policy Surprise

Table A-13. Summary Statistics of Monetary Policy Change and Surprise

Times	Actual Change	Daily Surprise	1-Hour Surprise
Expansionary	23	46	37
Contractionary	28	37	27

Correlation		Actural Change		1 Day Surprise		1 Hour Surprise	
		Expand	Contract	Expand	Contract	Expand	Contract
Actual Change	Expand	1	-0.19	0.33	0.07	0.19	0.05
	Contract		1	-0.12	0.13	0.09	0.14
1 Day Surprise	Expand			1	-0.36	0.33	-0.11
	Contract				1	-0.20	0.34
1 Hour Surprise	Expand					1	-0.25
	Contract						1

Literature has mainly two approaches to constructing the monetary policy shocks. Kuttner (2001) as a pioneer, uses the Treasury future daily price change on the FOMC days. Followers such as Neuhierl and Weber (2018) adopt this method and extend it using high-frequency identification: the 30-min window around the announcement. Nakamura and Steinsson (2018) expand it further to aggregate 5 elements of interest rate future prices, including the current and the next Treasury fund rate futures, and 3 Eurodollar futures. Hanson and Stein (2015) and Gertler and Karadi (2015), instead, use the 2-year Treasury yield change, and Tillmann (2017) follows to the narrow 30-min window.

In this paper, I try the daily and 1-hour change of Federal Fund Future around the announcement as the monetary policy surprise. The reason that I do not deploy the 30-minute window is because of the data scarcity. Instead of the tick data from CME that other authors use, I extract prices from Thomson Reuters DataScope, which provides infrequent data points with a lot NaNs. It becomes better when I extend the time range to 1 hour, which is the 30-min before and after the announcement, while there are still empty data for some FOMC meetings. Therefore, I use the daily future prices and the 1-hour version. Then following Kuttner (2001), the surprise measure is constructed by:

$$\text{Monetary Policy Surprise} = \frac{M}{M-D} * (ff_{post} - ff_{pre}) \tag{I.1}$$

where ff_{post} and ff_{pre} denote Fed Fund future prices before and after the announcement, M represents how many days in the month of FOMC announcement, and D denotes the day of the month, so that adjustment $\frac{M}{M-D}$ is put to extract the surprise component because the federal funds futures settle on the average funds rate over the month. Readers can find the deviation of this formula from Kuttner (2001) and Nakamura and Steinsson (2018).

Various approaches could lead to different results for each announcement. As shown in A-13, with 157 times of FOMC meeting from 2000 to 2018, 23 of them are with the expansionary monetary policy change, and the expansionary surprises do not coincide with them. As I check the summary statistics of monetary policy change and surprises, their correlations are low. Also, monetary policy surprise and the actual change gives the opposite pattern for the cumulative returns. Shown in Figure 10, stock return and bond yield shifts downwards with expansionary policy. In Figure A-4, however, stock and 10-year bond yield shift upwards with expansionary surprises. For reasons listed in the main paper, I choose to proceed with the actual change.

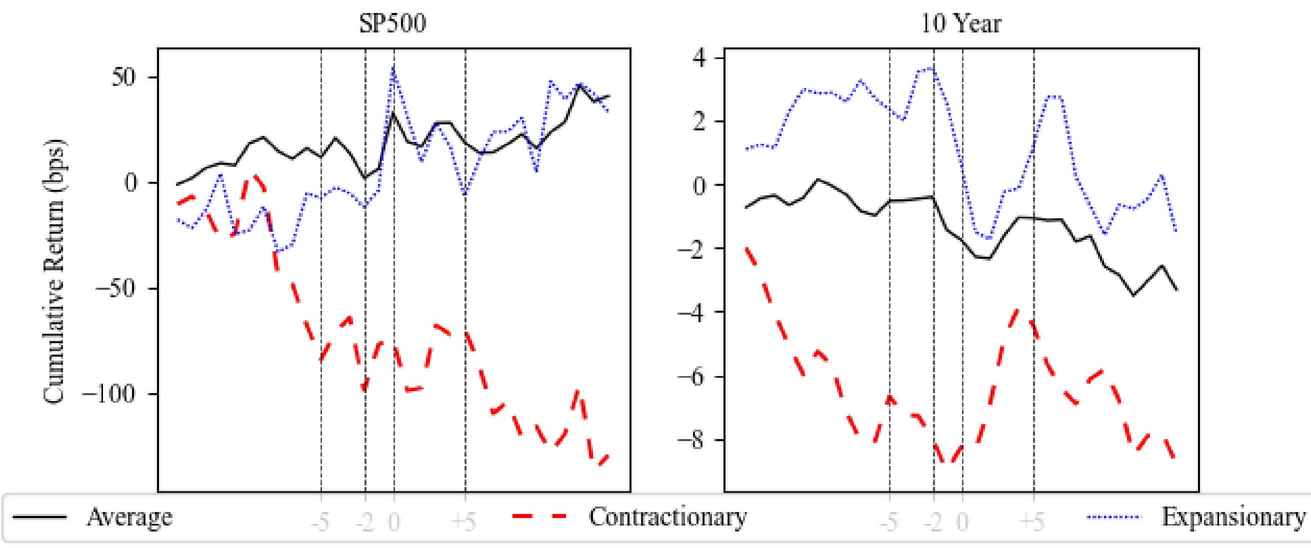

Figure A-4. Cumulative FOMC Days Return: Under Monetary Policy Surprise

Appendix J Stock and Bond Return After Heightened Risk Days

Table A-14. Stock Return After Highlighted Risk Days

Cutoff Vol (%)	N Days (/year) $\eta = 0$	Return (bps)	T-stat	N Days (/year) $\eta = 0.15$	Return (bps)	T-stat	N Days (/year) $\eta = 0.30$	Return (bps)	T-stat
+4.0	4.4	**43.97**	3.36	4.8	**33.47**	2.62	5.0	**51.52**	4.24
+3.5	6.2	**23.49**	2.03	6.2	**38.86**	3.50	6.7	**44.71**	4.24
+3.0	8.2	**35.35**	3.68	8.5	**45.84**	4.93	9.0	**53.73**	6.00
+2.5	11.6	**27.92**	3.41	11.8	**35.97**	4.53	12.7	**26.40**	3.37
+2.0	16.6	**23.14**	3.36	17.2	**24.49**	3.65	17.6	**22.79**	3.42
+1.5	25.4	**17.72**	3.15	25.6	**15.71**	2.75	26.4	**17.99**	3.27
+1.0	39.8	**9.77**	1.99	39.8	**11.10**	2.34	41.5	**12.74**	2.84
+0.5	66.5	**8.02**	2.13	66.9	**7.84**	2.07	67.0	**7.81**	2.06
+0.0	114.7	4.29	1.19	113.9	4.78	1.45	112.2	**6.51**	2.37
-0.0	133.2	0.55	1.02	135.6	-0.10	1.46	137.3	**-1.45**	2.37
-0.5	77.2	2.91	0.31	78.8	0.42	0.70	81.0	0.06	0.86
-1.0	43.1	1.25	0.24	44.2	-0.16	0.64	44.8	0.62	0.42
-1.5	24.6	-3.12	1.04	24.6	0.08	0.41	25.4	-5.44	1.53
-2.0	14.8	-4.12	0.94	14.6	**-12.69**	2.12	15.1	**-14.75**	2.56
-2.5	9.1	-1.61	0.44	8.8	-9.74	1.36	9.1	-16.16	2.13
-3.0	5.8	14.36	1.12	5.7	-4.49	0.58	5.8	-3.43	0.52
-3.5	3.8	12.51	0.77	3.8	9.94	0.58	4.0	-19.28	1.65

Cutoff Skew	N Days (/year) $\eta = 0$	Return (bps)	T-stat	N Days (/year) $\eta = 0.15$	Return (bps)	T-stat	N Days (/year) $\eta = 0.30$	Return (bps)	T-stat
+0.7	4.7	12.54	0.86	4.0	19.18	1.30	3.5	14.45	0.88
+0.6	6.7	14.55	1.23	6.4	13.98	1.15	6.0	21.42	1.81
+0.5	10.9	**21.17**	2.45	10.1	17.81	1.93	9.6	13.24	1.33
+0.4	16.9	11.26	1.48	16.2	**22.45**	3.21	15.7	**18.02**	2.47
+0.3	26.1	6.26	0.84	25.5	**12.56**	2.11	24.9	**16.03**	2.77
+0.2	44.3	7.42	1.47	42.8	8.97	1.86	43.1	**11.81**	2.65
+0.1	75.7	6.56	1.75	76.3	**8.33**	2.46	77.2	**7.64**	2.65
+0.0	123.8	4.47	1.39	124.6	5.27	1.87	124.9	4.26	1.27
-0.0	123.1	0.25	1.12	122.7	-0.90	1.79	122.3	0.12	1.18
-0.1	75.5	1.70	0.17	74.4	1.63	0.20	75.0	1.67	0.18
-0.2	45.1	-1.09	0.91	43.9	-2.56	1.30	43.6	-1.42	0.98
-0.3	26.3	-5.36	1.54	25.8	-3.53	1.15	25.7	-0.66	0.57
-0.4	16.4	-0.37	0.40	15.8	-6.99	1.42	15.6	-7.39	1.47
-0.5	10.6	-4.70	0.86	10.4	-11.25	1.68	10.4	-10.82	1.62
-0.6	7.0	-15.73	1.82	6.7	-3.23	0.53	6.5	-2.38	0.44
-0.7	4.8	-8.10	0.86	4.0	-9.73	0.91	4.0	-11.53	1.04

Table A-15. 2 Year Bond Yield Change After Highlighted Risk Days

Cutoff Vol (%)	N Days (/year) $\eta = 0$	Return (bps)	T-stat	N Days (/year) $\eta = 0.15$	Return (bps)	T-stat	N Days (/year) $\eta = 0.30$	Return (bps)	T-stat
+1.5	5.2	-0.61	1.05	4.8	-0.24	0.30	4.7	-0.09	0.00
+1.2	6.8	0.51	1.37	6.8	0.26	0.79	6.8	0.24	0.74
+0.9	9.6	-0.13	0.13	9.2	0.03	0.30	10.0	0.29	1.04
+0.6	15.9	0.21	1.06	16.0	0.30	1.40	17.8	0.34	1.62
+0.3	35.0	**0.35**	2.44	33.8	**0.42**	2.76	35.5	**0.40**	2.75
+0.0	108.7	**-0.28**	3.04	103.5	**-0.26**	2.86	103.6	**-0.24**	2.49
-0.0	119.2	**-0.27**	2.43	116.5	-0.18	1.26	116.5	-0.02	0.89
-0.3	32.3	**-0.50**	2.19	33.1	-0.36	1.47	34.8	-0.38	1.61
-0.6	14.2	-0.28	0.66	13.4	-0.27	0.62	15.2	**-0.89**	2.82
-0.9	8.8	-0.29	0.54	7.6	-0.78	1.69	8.6	**-0.95**	2.26
-1.2	6.2	-0.93	1.85	5.9	-0.97	1.91	5.6	-0.86	1.61
-1.5	4.7	-0.27	0.35	4.2	-0.35	0.49	4.0	-0.43	0.61
Cutoff Skew	**N Days (/year) $\eta = 0$**	**Return (bps)**	**T-stat**	**N Days (/year) $\eta = 0.15$**	**Return (bps)**	**T-stat**	**N Days (/year) $\eta = 0.30$**	**Return (bps)**	**T-stat**
+2.0	5.7	-0.39	0.63	4.2	0.13	0.39	4.5	**1.30**	2.59
+1.5	7.5	-0.24	0.37	6.0	0.12	0.44	6.7	0.69	1.77
+1.0	10.6	-0.31	0.66	9.3	0.05	0.36	9.8	0.28	1.03
+0.5	18.6	-0.07	0.0	17.6	0.22	1.16	20.1	0.17	1.05
+0.0	110.0	-0.07	0.21	103.8	-0.04	0.53	103.4	-0.01	0.89
-0.0	112.2	-0.03	0.65	104.3	0.03	1.35	104.8	-0.00	0.99
-0.5	20.8	0.16	1.02	17.9	0.25	1.28	20.6	0.14	0.92
-1.0	12.1	-0.26	0.53	10.6	-0.00	0.23	11.2	0.17	0.75
-1.5	8.1	-0.45	0.91	7.0	0.04	0.28	7.5	0.01	0.24
-2.0	6.5	**-0.98**	2.02	5.2	-0.39	0.62	5.3	-0.37	0.57

Table A-16. 5 Year Bond Yield Change After Highlighted Risk Days

Cutoff Vol (%)	N Days (/year) $\eta = 0$	Return (bps)	T-stat	N Days (/year) $\eta = 0.15$	Return (bps)	T-stat	N Days (/year) $\eta = 0.30$	Return (bps)	T-stat
+1.5	4.3	-0.15	0.10	4.5	0.01	0.16	4.7	-0.09	0.72
+1.2	8.1	-0.04	0.09	7.8	0.15	0.50	7.7	-0.05	0.08
+0.9	13.8	-0.20	0.34	13.5	-0.08	0.01	13.7	-0.00	0.23
+0.6	23.9	0.02	0.41	23.6	0.01	0.37	23.5	0.11	0.75
+0.3	47.1	0.03	0.64	47.8	0.06	0.83	49.0	0.11	1.14
+0.0	118.0	-0.05	0.42	117.5	-0.08	0.05	116.2	-0.05	0.43
-0.0	130.7	-0.12	0.48	132.1	-0.09	0.05	133.3	-0.12	0.43
-0.3	50.2	-0.14	0.34	50.8	-0.08	0.02	51.6	-0.09	0.06
-0.6	22.6	-0.28	0.74	22.1	-0.28	0.71	22.8	-0.15	0.24
-0.9	11.7	-0.27	0.49	11.5	-0.23	0.37	11.4	-0.12	0.10
-1.2	6.3	-0.12	0.06	6.2	-0.09	0.01	6.2	-0.27	0.36
-1.5	3.6	0.03	0.16	3.6	0.19	0.40	3.5	-0.39	0.43

Cutoff Skew	N Days (/year) $\eta = 0$	Return (bps)	T-stat	N Days (/year) $\eta = 0.15$	Return (bps)	T-stat	N Days (/year) $\eta = 0.30$	Return (bps)	T-stat
+3.0	4.6	-0.61	0.85	3.9	-0.47	0.57	3.6	-0.43	0.50
+2.0	7.8	-0.00	0.18	7.0	0.01	0.20	7.0	-0.13	0.09
+1.0	17.0	0.20	0.93	15.7	0.24	0.99	16.2	0.12	0.65
+0.5	33.7	-0.04	0.23	32.3	-0.18	0.44	33.5	-0.10	0.07
+0.0	121.5	-0.03	0.60	122.2	0.01	1.10	122.9	0.04	1.42
-0.0	126.3	-0.13	0.55	122.2	-0.16	0.82	121.4	-0.18	1.14
-0.5	33.3	0.23	1.49	31.2	0.19	1.22	32.5	0.06	0.65
-1.0	17.0	-0.08	0.03	16.2	-0.26	0.53	16.1	-0.24	0.48
-2.0	8.0	0.16	0.54	6.7	0.19	0.54	6.7	0.39	0.93
-3.0	4.5	0.34	0.69	3.4	0.09	0.24	3.5	0.15	0.34

Table A-17. 30 Year Bond Yield Change After Highlighted Risk Days

Cutoff Vol (%)	N Days (/year) $\eta = 0$	Return (bps)	T-stat	N Days (/year) $\eta = 0.15$	Return (bps)	T-stat	N Days (/year) $\eta = 0.30$	Return (bps)	T-stat
+1.5	3.8	0.51	0.98	4.0	0.64	1.23	4.3	**1.30**	2.47
+1.2	6.2	0.25	0.72	6.3	**0.83**	1.96	6.8	**1.03**	2.51
+0.9	11.3	-0.22	0.41	12.2	0.02	0.32	12.4	0.15	0.71
+0.6	21.4	0.12	0.84	21.8	0.19	1.14	22.3	0.21	1.23
+0.3	49.0	0.02	0.69	49.1	0.19	1.81	49.2	**0.38**	3.03
+0.0	115.4	-0.04	0.49	113.8	0.05	1.61	113.7	**0.10**	2.15
-0.0	133.1	-0.12	0.62	133.6	-0.18	1.46	133.6	**-0.22**	2.00
-0.3	56.1	**-0.41**	2.34	55.9	**-0.44**	2.59	57.5	-0.28	1.46
-0.6	20.9	**-0.84**	3.06	19.9	**-0.74**	2.60	20.5	**-1.02**	3.78
-0.9	7.0	-1.23	2.61	6.9	-0.79	1.60	7.0	-0.73	1.47
-1.2	3.1	-0.29	0.31	2.9	-0.6	0.76	3.1	-0.35	0.40

Cutoff Skew	N Days (/year) $\eta = 0$	Return (bps)	T-stat	N Days (/year) $\eta = 0.15$	Return (bps)	T-stat	N Days (/year) $\eta = 0.30$	Return (bps)	T-stat
+2.0	5.5	0.00	0.16	5.0	-0.13	0.10	5.5	0.04	0.25
+1.5	9.2	0.16	0.63	8.5	0.08	0.40	9.1	0.03	0.30
+1.0	16.8	**0.54**	2.23	16.1	**0.53**	2.15	16.6	0.38	1.64
+0.5	40.9	-0.01	0.44	39.2	0.08	0.91	38.9	0.08	0.94
+0.0	121.2	-0.12	0.53	121.2	-0.05	0.39	119.9	-0.09	0.06
-0.0	127.3	-0.05	0.44	126.2	-0.10	0.24	127.4	-0.07	0.20
-0.5	43.6	-0.04	0.26	41.5	0.04	0.70	41.0	-0.08	0.00
-1.0	16.1	-0.23	0.52	14.3	-0.34	0.86	14.3	-0.42	1.12
-1.5	7.0	-0.26	0.40	6.7	-0.08	0.01	6.7	-0.15	0.16
-2.0	3.4	-0.21	0.20	3.5	-0.10	0.03	3.6	-0.14	0.10

Appendix K All Regression Decomposed

I decompose the FOMC days through two approaches. Firstly, I add the business cycle effect $1_{t,Bust}$ as the control variable according to the NBER business cycle definition, and include its interaction term with the FOMC days $1_{t,Bust} \times 1_{t,Pre3/Pre2/FOMC}$ to see if risks response to the announcement under recessions. In the second method, I divide the FOMC days into "Expansionary" days, "Contractionary" days, and "No Change" days according to how the Fed alter the target interest rate —increases, decreases or keeps the rate unchanged. In this regression, I also control the period effect but without the interaction terms $1_{t,Bust} \times 1_{t,Expand}$, $1_{t,Bust} \times 1_{t,Contract}$ and $1_{t,Bust} \times 1_{t,NoChange}$, because from the figures we can see that the expansionary monetary policy normally comes with the recessions, and $1_{t,Bust} \times 1_{t,Contract}$ equals zero. The difference between the two approaches is that the interaction term $1_{t,Bust} \times 1_{t,FOMC}$ combines some of the "Expansionary" and the "No Change" days together, focusing on the recession effect, while the latter method pays more attention to the specific monetary policies.

Table A-18. Uncertainty on the FOMC Days: Decomposed

	VIX_t	V_t^{2y}	V_t^{5y}	V_t^{10y}	V_t^{30y}
$1_{t,FOMC}$	-0.2588	-0.1360	-0.1966	-0.1359	-0.2174
	(0.4577)	(0.1109)	(0.2704)	(0.1193)	(0.2177)
$1_{t,Bust}$	**12.4053*****	**2.1191*****	**1.9319*****	**2.5766*****	**2.5082*****
	(0.5038)	(0.1123)	(0.2932)	(0.0912)	(0.1831)
$1_{t,Bust} \times 1_{t,FOMC}$	1.5859	0.3480	0.0780	0.2001	0.3147
	(1.8764)	(0.4492)	(1.0639)	(0.3117)	(0.6249)
Intercept	**17.0477*****	**3.1147*****	**6.6183*****	**4.5639*****	**8.1066*****
	(0.1224)	(0.0308)	(0.0717)	(0.0314)	(0.0632)
R-squared	0.3421	0.2193	0.0353	0.3148	0.0982
	VIX_t	V_t^{2y}	V_t^{5y}	V_t^{10y}	V_t^{30y}
$1_{t,Expand}$	2.3967	0.4158	-0.6697	-0.0163	-0.5148
	(2.2546)	(0.4822)	(1.1377)	(0.3434)	(0.5897)
$1_{t,Contract}$	**-2.6577*****	-0.1837	**-2.5043*****	**-0.8148*****	**-1.6912*****
	(0.7287)	(0.2089)	(0.3789)	(0.1392)	(0.2129)
$1_{t,NoChange}$	0.2387	-0.1484	0.5216	0.0722	0.3257
	(0.5417)	(0.1398)	(0.3359)	(0.1367)	(0.2641)
$1_{t,Bust}$	**12.4029*****	**2.1213*****	**1.9314*****	**2.5784*****	**2.5181*****
	(0.4975)	(0.1116)	(0.2906)	(0.0901)	(0.1813)
Intercept	**17.0481*****	**3.1143*****	**6.6184*****	**4.5636*****	**8.1047*****
	(0.1224)	(0.0308)	(0.0717)	(0.0314)	(0.0631)
R-squared	0.3427	0.2194	0.0377	0.3157	0.0999

Table A-19. Tail Risk on FOMC Days: Decomposed

	$SKEW_t$	S_t^{2y}	S_t^{5y}	S_t^{10y}	S_t^{30y}
$1_{t,FOMC}$	0.0081	0.3091	-0.0767	-0.4005	-0.1815
	(0.0679)	(0.3462)	(0.2984)	(0.3791)	(0.2857)
$1_{t,Bust}$	**0.8927*** **	**-0.7092*** **	**0.2446*** **	-0.0243	**0.4239*** **
	(0.0244)	(0.1712)	(0.0807)	(0.1342)	(0.0936)
$1_{t,Bust} \times 1_{t,FOMC}$	0.0466	-0.6074	0.0841	0.6306	0.1471
	(0.0889)	(0.7924)	(0.3772)	(0.5555)	(0.3778)
Intercept	**-2.3188*** **	**-0.0487**	**-0.5437*** **	**-1.7990*** **	**-1.5970*** **
	(0.0176)	(0.0755)	(0.0545)	(0.0787)	(0.0710)
R-squared	0.1885	0.0067	0.0010	-0.0002	0.0028
	$SKEW_t$	S_t^{2y}	S_t^{5y}	S_t^{10y}	S_t^{30y}
$1_{t,Expand}$	**0.1620***	**1.9728***	0.3065	0.2868	-0.4965
	(0.0889)	(1.1677)	(0.2468)	(0.5791)	(0.4751)
$1_{t,Contract}$	-0.1859	0.3938	0.1220	-0.1401	-0.1576
	(0.1715)	(0.6365)	(0.6675)	(0.8364)	(0.4522)
$1_{t,NoChange}$	0.0364	-0.3287	-0.1892	-0.4232	-0.0664
	(0.0642)	(0.3204)	(0.3067)	(0.3871)	(0.3017)
$1_{t,Bust}$	**0.8905*** **	**-0.7706*** **	**0.2417*** **	-0.0115	**0.4358*** **
	(0.0242)	(0.1753)	(0.0801)	(0.1339)	(0.0936)
Intercept	**-2.3184*** **	-0.0373	**-0.5431*** **	**-1.8015*** **	**-1.5993*** **
	(0.0176)	(0.0760)	(0.0544)	(0.0787)	(0.0709)
R-squared	0.1483	0.0069	0.0001	0.0000	0.0051

Table A-20. Uncertainty Change Around FOMC Announcement: Decomposed

	ΔVIX_t	ΔV_t^{2y}	ΔV_t^{5y}	ΔV_t^{10y}	ΔV_t^{30y}
$1_{t,FOMCPre3}$	0.1442	-0.0087	**0.1023****	**0.0785*****	**0.2189*****
	(0.1372)	(0.0389)	(0.0520)	(0.0292)	(0.0544)
$1_{t,FOMCPre2}$	**0.2243***	-0.0218	**0.0920****	**0.0814*****	**0.1594*****
	(0.1167)	(0.0408)	(0.0440)	(0.0315)	(0.0558)
$1_{t,FOMC}$	**-0.4988*****	**-0.1941*****	**-0.2786*****	**-0.1765*****	**-0.2664*****
	(0.1524)	(0.0638)	(0.0534)	(0.0231)	(0.0429)
$1_{t,Bust}$	-0.0266	0.0016	0.0272	-0.0017	0.0108
	(0.0786)	(0.0290)	(0.0288)	(0.0150)	(0.0231)
$1_{t,Bust} \times 1_{t,FOMCPre3}$	0.2334	-0.0209	-0.0821	-0.0606	**-0.3225*****
	(0.4197)	(0.1907)	(0.1130)	(0.0631)	(0.0878)
$1_{t,Bust} \times 1_{t,FOMCPre2}$	0.3669	0.2564	-0.0027	**0.1879***	0.1137
	(0.3505)	(0.1808)	(0.1796)	(0.1138)	(0.1552)
$1_{t,Bust} \times 1_{t,FOMC}$	0.0068	-0.0244	-0.2360	-0.0923	0.0293
	(0.3860)	(0.1906)	(0.1822)	(0.0692)	(0.1091)
Intercept	0.0006	0.0068	0.0006	-0.0008	-0.0066
	(0.0231)	(0.0087)	(0.0083)	(0.0046)	(0.0098)
R-squared	0.0035	0.0027	0.0103	0.0170	0.0115
	ΔVIX_t	ΔV_t^{2y}	ΔV_t^{5y}	ΔV_t^{10y}	ΔV_t^{30y}
$1_{t,ExpandPre3}$	0.0711	-0.2430	0.0245	-0.0258	-0.0111
	(0.4891)	(0.2203)	(0.1321)	(0.0690)	(0.1236)
$1_{t,ExpandPre2}$	**0.8307****	0.2623	0.2831	**0.4062*****	**0.4172****
	(0.3736)	(0.2125)	(0.2271)	(0.1238)	(0.1753)
$1_{t,Expand}$	-0.4475	-0.1918	**-0.4029****	**-0.2597*****	**-0.3552*****
	(0.5351)	(0.1434)	(0.1606)	(0.0575)	(0.0968)
$1_{t,ContractPre3}$	0.1654	0.1163	-0.0134	0.0232	0.0697
	(0.2460)	(0.0774)	(0.0614)	(0.0440)	(0.0661)
$1_{t,ContractPre2}$	0.0582	-0.0992	**0.1892****	0.1267	**0.2513****
	(0.2273)	(0.1322)	(0.0938)	(0.1067)	(0.1243)
$1_{t,Contract}$	**-0.3904****	-0.0634	**-0.3085*****	**-0.1535*****	**-0.3359*****
	(0.1728)	(0.1719)	(0.0994)	(0.0381)	(0.0674)
$1_{t,NoChangePre3}$	0.2313	0.0097	**0.1235****	**0.0972*****	**0.2060*****
	(0.1560)	(0.0447)	(0.0584)	(0.0324)	(0.0588)
$1_{t,NoChangePre2}$	**0.2427***	0.0087	0.0224	**0.0549***	**0.1125***
	(0.1334)	(0.0374)	(0.0465)	(0.0292)	(0.0592)
$1_{t,NoChange}$	**-0.5359*****	**-0.2363*****	**-0.3180*****	**-0.1926*****	**-0.2183*****
	(0.1624)	(0.0755)	(0.0705)	(0.0297)	(0.0514)
$1_{t,Bust}$	-0.0143	0.0099	0.0146	-0.0029	0.0042
	(0.0737)	(0.0280)	(0.0273)	(0.0144)	(0.0225)
Intercept	-0.0018	0.0052	0.0030	-0.0006	-0.0054
	(0.0229)	(0.0087)	(0.0083)	(0.0046)	(0.0097)
R-squared	0.0033	0.0035	0.0101	0.0195	0.0112

Table A-21. Tail Risk Change Around FOMC Announcement: Decomposed

	$\Delta SKEW_t$	ΔS_t^{2y}	ΔS_t^{5y}	ΔS_t^{10y}	ΔS_t^{30y}
$1_{t,FOMCPre3}$	-0.0275	0.1025	-0.1244	-0.0138	0.0128
	(0.0375)	(0.1593)	(0.1477)	(0.1376)	(0.0945)
$1_{t,FOMCPre2}$	0.0047	0.0109	0.2322	0.1305	0.0104
	(0.0298)	(0.1405)	(0.2166)	(0.1641)	(0.1348)
$1_{t,FOMC}$	0.0414	0.0250	-0.1866	**-0.3260****	**-0.1602****
	(0.0301)	(0.1000)	(0.1730)	(0.1284)	(0.0667)
$1_{t,Bust}$	-0.0008	0.0036	0.0017	-0.0156	0.0083
	(0.0071)	(0.0497)	(0.0350)	(0.0406)	(0.0294)
$1_{t,Bust} \times 1_{t,FOMCPre3}$	-0.0104	0.2632	0.1521	0.0478	-0.1855
	(0.0438)	(0.3779)	(0.1711)	(0.2088)	(0.1251)
$1_{t,Bust} \times 1_{t,FOMCPre2}$	0.0380	0.1588	-0.4315	0.0525	-0.0375
	(0.0421)	(0.2481)	(0.2634)	(0.2187)	(0.1896)
$1_{t,Bust} \times 1_{t,FOMC}$	-0.0122	-0.9139	0.1667	**0.3287****	0.0613
	(0.0442)	(0.6613)	(0.2139)	(0.1632)	(0.1140)
Intercept	-0.0016	-0.0352	0.0079	0.0166	0.0075
	(0.0046)	(0.0275)	(0.0275)	(0.0229)	(0.0199)
R-squared	-0.0004	0.0009	-0.0005	0.0001	-0.0007

	$\Delta SKEW_t$	ΔS_t^{2y}	ΔS_t^{5y}	ΔS_t^{10y}	ΔS_t^{30y}
$1_{t,ExpandPre3}$	-0.0215	0.5012	-0.0185	**-0.2909***	**-0.2731*****
	(0.0248)	(0.4472)	(0.0970)	(0.1748)	(0.0853)
$1_{t,ExpandPre2}$	0.0422	-0.0477	-0.0524	0.5084	0.1111
	(0.0296)	(0.1782)	(0.1700)	(0.5026)	(0.4006)
$1_{t,Expand}$	0.0234	0.1596	0.0320	-0.0387	-0.1623
	(0.0421)	(0.2088)	(0.1983)	(0.1668)	(0.1386)
$1_{t,ContractPre3}$	-0.0026	**-0.3874***	-0.2388	-0.2307	-0.1804
	(0.0665)	(0.2083)	(0.4029)	(0.2185)	(0.1498)
$1_{t,ContractPre2}$	-0.0434	0.1898	0.4920	-0.1547	0.1164
	(0.0685)	(0.3623)	(0.6952)	(0.2129)	(0.1984)
$1_{t,Contract}$	-0.0448	0.3587	-0.1443	-0.1714	**-0.3337*****
	(0.0646)	(0.2731)	(0.1644)	(0.2470)	(0.1259)
$1_{t,NoChangePre3}$	-0.0386	0.2068	-0.0704	0.1222	0.0690
	(0.0402)	(0.1763)	(0.1374)	(0.1502)	(0.1023)
$1_{t,NoChangePre2}$	0.0206	0.0340	0.0936	0.1306	-0.0525
	(0.0303)	(0.1447)	(0.1805)	(0.1452)	(0.1217)
$1_{t,NoChange}$	**0.0636****	**-0.3725***	-0.1943	**-0.3260****	-0.0959
	(0.0304)	(0.2214)	(0.1933)	(0.1318)	(0.0667)
$1_{t,Bust}$	-0.0013	-0.0258	-0.0024	-0.0083	0.0042
	(0.0067)	(0.0548)	(0.0331)	(0.0399)	(0.0292)
Intercept	-0.0015	-0.0299	0.0087	0.0152	0.0083
	(0.0045)	(0.0278)	(0.0271)	(0.0226)	(0.0197)
R-squared	-0.0002	0.0003	-0.0011	0.0005	-0.0007

Table A-22. Pre-FOMC Annoucement Drift in Stock and Bond: Decomposed

	$R^{stock}_{t,t+1}$	$R^{3m}_{t,t+1}$	$R^{2y}_{t,t+1}$	$R^{5y}_{t,t+1}$	$R^{10y}_{t,t+1}$	$R^{30y}_{t,t+1}$
$1_{t,Bust}$	**-22.5132****	**-1.1833*****	**-0.8003***	-0.3472	-0.1242	0.2622
	(9.8684)	(0.4568)	(0.4514)	(0.4933)	(0.4570)	(0.5248)
$1_{t,FOMCPre1}$	**20.4115****	**-0.6755****	-0.5133	-1.0074	-0.9883	-1.0587
	(10.3862)	(0.3305)	(0.5059)	(0.6464)	(0.6518)	(0.6632)
$1_{t,Bust} \times 1_{t,FOMCPre1}$	33.6931	**-6.3607****	-2.6836	-2.9041	-1.3939	-0.8400
	(52.1373)	(2.8584)	(2.2538)	(2.5244)	(2.3711)	(2.2224)
Intercept	**7.7188*****	0.1639	0.0250	-0.0468	-0.1047	-0.1635
	(2.4747)	(0.1078)	(0.1094)	(0.1376)	(0.1366)	(0.1418)
R-squared	0.0033	0.0124	0.0034	0.0018	0.0005	0.0003

	$R^{stock}_{t,t+1}$	$R^{3m}_{t,t+1}$	$R^{2y}_{t,t+1}$	$R^{5y}_{t,t+1}$	$R^{10y}_{t,t+1}$	$R^{30y}_{t,t+1}$
$1_{t,ExpandPre1}$	55.9841	**-9.7239*****	-2.4488	-2.0006	-0.5416	-1.5086
	(58.5815)	(3.0861)	(2.6222)	(2.5265)	(2.1080)	(1.8163)
$1_{t,ContractPre1}$	28.6837	0.3943	1.6071	0.8162	-0.4784	-1.6261
	(22.2678)	(0.7623)	(1.1940)	(1.3111)	(1.1923)	(1.5237)
$1_{t,NoChangePre1}$	20.8963	-0.8863	**-1.4633****	**-2.1737****	**-1.6715***	-1.0814
	(14.1260)	(0.6268)	(0.6137)	(0.8524)	(0.8850)	(0.7854)
$1_{t,Bust}$	**-21.8398****	**-1.2519*****	**-0.8559***	-0.4311	-0.1842	0.2375
	(9.8132)	(0.4682)	(0.4492)	(0.4917)	(0.4573)	(0.5219)
Intercept	**7.5878*****	0.1772	0.0358	-0.0305	-0.0931	-0.1597
	(2.4803)	(0.1084)	(0.1098)	(0.1379)	(0.1370)	(0.1420)
R-squared	0.0031	0.0151	0.0035	0.0015	0.0003	0.0000

Table A-23. Pre-FOMC Risk-Return Relationship: Decomposed

	$R^{stock}_{t-1,t}$	$R^{2y}_{t-1,t}$	$R^{5y}_{t-1,t}$	$R^{10y}_{t-1,t}$	$R^{30y}_{t-1,t}$
$\Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	**4.0206***	**0.3669****	0.2748	**0.8283****	**0.5685****
	(2.1933)	(0.1626)	(0.2143)	(0.3671)	(0.2332)
$1_{t,FOMC}$	**20.3686***	-0.5730	**-1.3284****	-0.9495	-0.2896
	(12.0206)	(0.5357)	(0.6623)	(0.6926)	(0.6774)
$1_{t,FOMC} \times \Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	-4.3243	0.7385	1.2780	-1.1418	**-2.0773*****
	(16.7608)	(1.5673)	(0.9254)	(1.6979)	(0.7203)
$1_{t,Bust}$	**-21.4972****	**-0.8793***	-0.5198	-0.2591	0.1616
	(9.9148)	(0.4925)	(0.4874)	(0.4502)	(0.5191)
$1_{t,FOMC} \times 1_{t,Bust}$	32.8433	**-4.3578***	-2.6841	-1.2202	-1.2643
	(48.2489)	(2.3398)	(2.4532)	(2.3899)	(2.2220)
Intercept	**7.8740*****	0.0964	-0.0294	-0.0939	-0.1533
	(2.5060)	(0.1089)	(0.1374)	(0.1367)	(0.1418)
R-squared	0.0057	0.0075	0.0031	0.0022	0.0051

	$R^{stock}_{t-1,t}$	$R^{2y}_{t-1,t}$	$R^{5y}_{t-1,t}$	$R^{10y}_{t-1,t}$	$R^{30y}_{t-1,t}$
$\Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	**4.0211***	**0.3671****	0.2754	**0.8280****	**0.5686****
	(2.1934)	(0.1628)	(0.2141)	(0.3671)	(0.2332)
$1_{t,Expand}$	50.8492	-3.2089	-2.8277	-0.6196	-1.4859
	(43.6647)	(2.4258)	(2.4552)	(2.5936)	(2.3296)
$1_{t,Contract}$	29.4605	1.8147	1.0859	-0.1867	-1.7068
	(23.1205)	(1.1738)	(1.3825)	(1.2217)	(1.7346)
$1_{t,NoChange}$	21.9439	**-1.7931*****	**-2.2993*****	**-1.6205***	-0.1359
	(14.6428)	(0.6075)	(0.8696)	(0.9447)	(0.7438)
$1_{t,Expand} \times \Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	0.8588	**5.3846*****	**2.5089***	-0.3901	-0.4585
	(39.1147)	(1.5394)	(1.5076)	(3.5561)	(1.7188)
$1_{t,Contract} \times \Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	-8.3284	-3.5507*	-1.8477	**-2.8580****	-0.4223
	(23.0926)	(1.8181)	(2.5062)	(1.1329)	(1.6886)
$1_{t,NoChange} \times \Delta V^{stock/2y/5y/10y/30y}_{t-3,t-2}$	-6.9424	**-3.0756*****	0.5874	-1.1018	**-2.8624*****
	(9.5564)	(0.9943)	(1.4847)	(2.8506)	(0.7971)
$1_{t,Bust}$	**-20.9051****	**-1.0058****	-0.5976	-0.3162	0.1185
	(9.8225)	(0.4893)	(0.4859)	(0.4511)	(0.5162)
Intercept	**7.7586*****	0.1193	-0.0143	-0.0828	-0.1465
	(2.5108)	(0.1092)	(0.1376)	(0.1371)	(0.1420)
R-squared	0.0051	0.0112	0.0031	0.0018	0.0048

Table A-24. Pre-FOMC Risk-Return Relationship: FOMC Days Only, Decomposed

	$R_{t-1,t}^{Pre,Stock}$	$R_{t-1,t}^{Pre,2y}$	$R_{t-1,t}^{Pre,5y}$	$R_{t-1,t}^{Pre,10y}$	$R_{t-1,t}^{Pre,30y}$
$\Delta V_{t-3,t-2}^{stock/2y/5y/10y/30y}$	-0.3037	1.1054	**1.5528***	-0.3135	**-1.5088***
	(6.6056)	(1.0404)	(0.9000)	(1.4992)	(0.7808)
$1_{t,Bust}$	11.3461	**-5.2371*****	**-3.2038***	-1.4793	-1.1027
	(33.8610)	(1.5955)	(1.7681)	(1.7443)	(1.6915)
Intercept	**28.2426***	-0.4767	-1.3578	-1.0434	-0.4428
	(15.9145)	(0.7236)	(0.8443)	(0.8442)	(0.8010)
R-squared	-0.0116	0.0568	0.0259	-0.0073	0.0144
$\Delta V_{t-3,t-2}^{stock/2y/5y/10y/30y}$	-0.2629	0.6009	**1.5963***	-0.5651	**-1.4373***
	(6.6099)	(1.0459)	(0.9076)	(1.5182)	(0.7810)
$1_{t,Contract}$	11.0675	**3.7621****	3.0154	1.2207	-0.5579
	(37.8949)	(1.7729)	(1.9943)	(1.9527)	(2.1801)
$1_{t,Expand}$	22.5809	-1.6539	-0.3610	1.1507	-0.3036
	(39.1001)	(1.8008)	(2.0609)	(2.0405)	(1.7406)
Intercept	25.2618	**-1.9326****	**-2.5199*****	**-1.7080***	-0.5639
	(17.2693)	(0.8030)	(0.9062)	(0.9055)	(0.8280)
R-squared	-0.0163	0.0239	0.0154	-0.0143	0.0041