The Stock-Bond Correlation: A Tale of Two Days in the U.S. Treasury Bond Market

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Abstract

Motivated by the central importance of U.S. Treasury (UST) and the increasing concern over its resilience, we construct a high-frequency measure of stock-bond correlation to capture UST safety, and more importantly, its riskiness. On days with highly negative stock-bond correlations, safety matters the most and the pricing of global assets is determined by their relative safety. For UST, the premier safe asset, the demand for safety widens its convenience yield, shrinks the term premium, and breaks the transmission from UST to USD. By contrast, on days with high stock-bond correlations, UST pauses its safety status and becomes a source of risk, with increased volatility and higher term premium. Prominent bond risky days captured by sudden and large increases of our stock-bond measure are FOMC announcements (interest-rate risk), 2020 dash for cash (dealer-capacity risk), and 2021 inflation surge. Overall, our measure is unique in capturing the dual and contrasting roles of UST – sounding the alarm when UST shifts abruptly from safety to risky.

Keywords: Flights-to-safety, stock-bond correlation, UST resilience, Treasury convenience

JEL Classification: G12, G15

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1. Introduction

The U.S. Treasury bond market is widely regarded as the world's deepest and most important market. The pricing of U.S. Treasury bonds establishes the benchmark yield curve for borrowing costs across different horizons and facilitates the price discovery of monetary policies, inflation risk, and other macroeconomic fundamentals. Beyond serving as a key economic indicator, the U.S. Treasury market carries significant political importance. It is critical in financing the U.S. government's expanding deficits, and attracts large foreign holdings because of the dollar's role as the primary reserve currency. Overall, a well-functioning U.S. Treasury market is important for the global economy and essential for the U.S.

In this paper, we examine the dual and contrasting roles of the U.S. Treasury bond market – both as a destination of safety and a source of risk. The safety nature of the U.S. Treasury has been well established in the literature, via episodes of flights-to-safety (Baele, Bekaert, Inghelbrecht, and Wei 2019) and the global safety demand for U.S. Treasury (Jiang, Krishnamurthy, and Lustig 2021). Contrary to its safe-asset role, however, the U.S. Treasury market can also, at times, poses substantial risks, as illustrated by the 2020 dash for cash. This is especially true when the U.S. Treasury market is mired in concerns over surging inflation, monetary policy uncertainty, or dealer-capacity risk. Indeed, while its status as a primary safe haven asset remains well-established, growing concerns about the resilience of the U.S. Treasury market and the sustainability of U.S. government debt have intensified in recent years (Duffie 2023; Duffie et al. 2023). These challenges call for improved surveillance of the U.S. Treasury market to better separate its safety attributes from potential vulnerabilities.

Motivated by the central importance of the U.S. Treasury market and the increasing concern over its resilience, we construct in this paper a simple stock-bond correlation measure that can capture not only UST safety, but, more importantly, its riskiness. Specifically, our UST risk measure ρ_t^{UST} is the day-t correlation between the five-minute returns on the S&P 500 Emini (SPX) futures and the U.S. Treasury 10-Year T-Note (UST) futures, both of which are traded on CME. Since 2000, the stock-bond correlation is in general negative, with UST serving as the safe-haven asset for the global risky assets (e.g., SPX). Against this backdrop, a higher ρ_t^{UST} indicates a pause of UST's safe-haven status and a shift toward UST becoming a source of risk. Following this intuition, we use our high-frequency stock-bond correlation ρ_t^{UST} to form "a tale of two days in UST" – respectively, bond safety days and bond risky days correspond to the lower and upper 20% of the ρ_t^{UST} distribution.[1]

[1]We select a fixed 20% cutoff mainly for its simplicity. We also explore methods that use conditional cutoffs based on a long rolling window. The bond safety and risky days identified through these methods are highly correlated with those using the unconditional cutoff and the main results are robust.

Focusing on the "tale of two days" captured by our ρ_t^{UST} measure, our hypothesis is that on bond safety days, the equity market is the source of risk with the bond market serving as the safe haven, while on bond risky days, the bond market itself becomes the source of risk. Among others, the drivers of the UST risk can be interest rate risk (e.g. FOMC announcements), inflation risk (e.g., 2021 inflation surge) and dealer capacity risk (e.g., 2020 dash for cash). Compared with the well-established liquidity and uncertainty measures, one unique feature of our ρ_t^{UST} measure is that it captures episodes of UST safety and riskiness with opposite signals. For example, ρ_t^{UST} is found to be highly *negative* amid the 2008-09 financial crisis and highly *positive* amid the 2020 dash for cash. By contrast, the implied volatilities of SPX and UST, as well as the noise measure of Hu, Pan, and Wang (2013), spike up in both types of episodes.

Bond Safety Days – On days when ρ_t^{UST} falls under the bottom 20%, the average stock-bond correlation is significantly negative at -0.64 and we find strong evidence of flights-to-safety. The aggregate U.S. stock market suffers with an average daily return of -36.20 bps (t-stat=-8.04), while the 10-year UST rallies with an average daily return of 13.60 bps (t-stat=9.57), both of which are economically large compared with the full-sample average returns of 3.37 bps and 1.52 bps, respectively. Moreover, absent of the bond safety days, the average daily return of UST becomes significantly negative, indicating the unique importance of such bond safety days in driving the secular decline in UST yield. Consistent with the standard pattern of flights-to-safety, option-implied volatilities increase significantly on bond safety days. This includes VIX for SPX, MOVE for UST, and the implied volatilities of the major currencies. Moreover, we find significant ETF flows out of SPX and into UST, and similarly for asset managers on their net futures positions.

Prominent among our bond safety days are the well-documented crisis periods characterized by clear flights-to-safety patterns, such as the peak of the 2008 financial crisis and the height of the 2011 European debt crisis. Additionally, the high-frequency nature of ρ_t^{UST} allows us to identify short-lived panic events triggered by unexpected shocks in risk appetite rather than economic fundamentals. The three bond safety days with the most negative ρ_t^{UST} in our sample include the May 6, 2010 Flash Crash ($\rho_t^{\text{UST}} = -0.85$), the April 23, 2013 false tweet by Associated Press about a White House attack ($\rho_t^{\text{UST}} = -0.94$), and the February 9, 2018 U.S. government shutdown due to a delay in passing the budget deal ($\rho_t^{\text{UST}} = -0.86$).

Bond Risky Days – On days when ρ_t^{UST} reaches the top 20%, the average stock-bond correlation is at 0.07, a significant deviation from the full-sample average of -0.31. We find that these are the days when the U.S. Treasury market is dominated by interest rate risk, inflation risk, and liquidity risk. Contrary to bond safety day, the UST market on bond risky day temporarily relinquishes its safe-haven status and becomes a source of risk. On average, UST experiences a significantly negative return of -6.05 basis points, compared with the full-sample average of positive 1.52 basis points, and an increase in intraday return volatility of 28 basis points. Using the weekly primary dealers data from the New York Fed, we find that primary dealers reduce their net Treasury position significantly during the weeks when ρ_t^{UST} is high. By contrast, their net Treasury position increases significantly during the weeks when ρ_t^{UST} is low and UST serves as the safe asset.

Prominent among our bond risky days are those when UST is dominated by elevated interest rate risk, dealer-capacity risk, and inflation risk. First, on interest rate risk, we find that the FOMC announcement days, with heightened anticipations of monetary policy decisions, have unusually high ρ_t^{UST}. Of the 147 pre-scheduled FOMC announcement days in our sample, the average ρ_t^{UST} is -0.03, which is 0.28 higher than the full-sample average of -0.31. Moreover, the vast majority of the FOMC days, 82 of 147, falls under the group of bond risky days, compared to just 13 belonging to the bond safety group. Similarly, ρ_t^{UST} is significantly higher on days when detailed FOMC meeting minutes are released.

Second, on dealer-capacity risk, we find increased ρ_t^{UST} on days when primary dealers are faced with increased balance sheet constraint. Specifically, on financial reporting dates such as quarter-ends and month-ends, our bond risk measure ρ_t^{UST} shows sizable spikes of about 0.04. This effect is even more pronounced on 10-year Treasury Note auction days, particularly when the offering sizes are larger than usual, driving ρ_t^{UST} up by as much as 0.13. These pressures are further amplified following the implementation of the Volcker Rule on July 21, 2015, which imposes stricter constraints on dealers' trading activities and balance sheet utilization. Post-Volcker, the increase in ρ_t^{UST} observed during quarter-ends, month-ends, and high-volume Treasury auction dates nearly doubled in magnitude, highlighting the importance of intermediation in the UST market.

Third, on inflation risk, we document increased ρ_t^{UST} when UST becomes a source of risk because of inflation concerns. During our sample period, bond risky days cluster during two key periods: 2004–2006, when the Federal Reserve hiked the federal funds target rate 17 times, from 1% to 5.25%, to combat inflation and cool an overheated economy; and post-2021, when surging inflation prompted rapid rate hikes from 0–0.25% to 1.5–1.75% within just three months. In both cases, heightened inflation risk concerns transform UST bonds into a source of risk. Many of the largest ρ_t^{UST} occur during these periods. For instance, ρ_t^{UST} surges to 0.42 on June 10, 2021 – ranking in the top 0.7% of observations in our sample – following the CPI announcement for May 2021.

Moreover, because of the high-frequency nature of our measure and its ability to capture the dual and contrasting roles of UST with opposite signals, our measure is the most effective in capturing the moment when UST suddenly shifts from safety to risky. The 2020 dash for cash is one such example. It starts out with Treasuries serving as the safe-haven asset in early March 2020, the initial stage of the Covid-19 crisis. As investors start to prioritize liquidity above all else, however, they begin selling off Treasuries in favor of cash. This unprecedented sell-off, exacerbated by dealers' capacity constraint, leads to a brief period of dysfunction in the UST market. Capturing this important moment of dash for cash, our ρ_t^{UST} measure spikes by 0.48 over just one day, from -0.62 on March 11, when UST was still serving as a safe-haven asset, to -0.14 on March 12, when UST becomes a source of risk. A similar abrupt shift occurs during the so-called taper tantrum, when Fed Chairman Bernanke's speech on potentially scaling back Fed's asset purchase program unnerves the bond market, triggering a wave of panic and volatility. Again, UST abruptly shifts from a safe-haven asset in to a source of risk, with highly elevated ρ_t^{UST}.

Comparison with Alternative Measures – Contrary to ρ_t^{UST}, which can capture both the safety of UST and, more importantly, its riskiness, other well known measures are not uniquely designed for UST riskiness. For example, the CBOE Volatility Index (VIX), which is based on the S&P 500 index options and commonly considered as a "fear" gauge of the market, are designed specifically for the equity market. The MOVE index, derived from the implied volatilities of Treasury options and often refereed to as the "VIX of bonds", is significantly influenced by the VIX. The volatility of the UST market could provide a useful signal for UST riskiness, but its information is not as sharp and responsive as the stock-bond correlation measure. Another alternative is the Noise measures introduced by Hu, Pan, and Wang (2013), which is based on price deviations in the UST bond market. However, as the Noise measure mainly reflects the overall market funding illiquidity, it tends to spike up during both flights-to-safety episodes and UST turmoils, making it less effective in distinguishing the two different roles of UST bonds.

We also examine the uniqueness of the correlation measure ρ_t^{UST} in capturing flights-to-safety by comparing its effectiveness against alternative correlation measures involving other safe assets. First, following the insight of Cieslak and Schrimpf (2019) on non-monetary news in Fed communication, we extend our comovement measure to the short-end of the yield curve. Using high-frequency data on 2-year UST futures and 3-month EuroDollar futures, the daily measures of ρ_t^{UST2Y} and ρ_t^{UST3M} are designed to capture the comovement between short-term interest rates and the SPX returns. Unlike ρ_t^{UST}, we find that neither ρ_t^{UST2Y} nor ρ_t^{UST3M} is capable of capturing the episodes of flights-to-safety, consistent with the observation by Cieslak and Schrimpf (2019) that the comovement of the stock market and the short-term rates is driven by their common exposure to growth shocks, not the opposing effect of flights-to-safety as captured by our ρ_t^{UST}. Moreover, ρ_t^{UST2Y} and ρ_t^{UST3M} are less effective at capturing days with heightened interest rate risk, especially those arising from dealers' balance sheet constraints. Secondly, to differentiate the safety of UST against that of the U.S. Dollar (USD), we construct an alternative daily measure ρ_t^{USD} using high-frequency data on the U.S. Dollar (USD) futures, to capture the comovement between the SPX returns and those of the USD. Contrary to our findings for ρ_t^{UST}, days of negative ρ_t^{USD} do not exhibit patterns of flight-to-safety, indicating that it is UST, not USD, that provides safety in the financial markets amid episodes of global risk-off.

Asset Pricing Under Bond Safety Days – The high frequency nature of ρ_t^{UST} allows us to further study the cross-asset and cross-sectional pricing under the "tale of two days". Expanding our analysis to include global bonds, equities, currencies, and commodities, we find that a strong pattern of safety-driven returns that is unique only on bond safety days and absent on normal days. To be more specific, lining up the global assets by their correlations with the U.S. equity market, with UST and SPX occupying the two opposite ends of the safety spectrum, we document a significant alignment between asset returns and asset safety on bond safety days. In other words, on such bond safety days, the relative pricing across the global assets is determined by their relative safety rather than their own fundamental risks.

Focusing on UST safety, we examine the impact of UST safety demand on its specialness, i.e., Treasury convenience yield. Following the works of Du, Im, and Schreger (2018) and Jiang, Krishnamurthy, and Lustig (2021), we focus on the Treasury basis measure, which is the yield differential between a cash position in U.S. Treasuries and the synthetic FX-hedged dollar yield derived from foreign government bond. Our analysis reveals that the Treasury convenience yield widens significantly on bond safety days, with the 1-year and 5-year Treasury basis decreasing on average by 0.66 bps and 0.51 bps, respectively. This widening of the Treasury basis is unique to bond safety days, highlighting the pivotal role of U.S. Treasuries in driving the convenience yield.[2] Outside of the bond safety days – when movements in Treasury yields are not driven by safe-haven demand for UST – synthetic dollar yields closely track U.S. Treasury yields, resulting in negligible changes in the Treasury basis.[3] Moreover, taking advantage of the high-frequency nature of ρ_t^{UST} and ρ_t^{USD}, we can further differentiate the safety demand for UST against USD. Including both ρ_t^{UST} and ρ_t^{USD} in our analysis, we find that the UST convenience is driven uniquely by the safety of UST, not that of USD.

We further examine the transmission from UST to USD under the bond safety days.

[2]A recent related work by Acharya and Laarits (2023) shows that the convenience yield of UST tends to be low when the covariance of Treasury returns with the aggregate stock market returns is high.

[3]Moreover, we find no significant changes in the Treasury basis on non-Bond Safety Days with comparable daily returns of the 10-year UST, the S&P 500 index, or changes in the VIX index, further pining down the impact of safety demand for UST on its specialness.

Contributing to the robust comovement between UST and USD is the flow of global capital – falling U.S. interest rates drive global capital away from the U.S. and lead to a weakened USD. Conversely, increasing UST yields draw capital back to the U.S., strengthening the USD. Interestingly, this strong UST-to-USD relation breaks down on bond safety days. When the decline in UST yields is driven by a global risk-off, rather than fundamental changes in long-term U.S. interest rates, we do not see a corresponding weakening of USD. In relative terms, associated with the flight to UST is a strengthening of USD.[4]

Asset Pricing Under Bond Risky Days – Focusing first on U.S. Treasuries, we examine the relative pricing between the long- and short-term U.S. Treasury bonds using the term premium measures of Adrian, Crump, and Moench (2013) and Kim and Wright (2005). We find significant increases in both measures of term premium on bond risky days, indicating increased risk premium for long-term bonds. In other words, investors seek higher compensations for bearing the duration risk when the U.S. Treasury market is perceived as a source of risk. By contrast, when long-term bonds are valued as a safe haven asset on bond safety days, we observe a significant drop in both measures of term premium.

We find that the UST to USD channel strengthens on bond risky days. Specifically, as the heightened concern over interest-rate risk turns UST into a source of risk, the sensitivity of USD to UST increases by three fold from its normal level. As the bond risky days are marked by significantly negative UST returns, our result indicates that as UST loses its safe-haven status on UST risky days, USD appreciates more significantly and replaces UST as the safety destination. Consistently, the USD risky measure ρ_t^{USD} averages to about -0.12 on UST risky days, significantly lower than its full-sample average of -0.06. Similarly, the USD risk measure ρ_t^{USD} decreases significantly during the 2021-2022 inflation surge to an average level of -0.21 when the rapid monetary-policy tightening turns UST into a source of risk.

Turning to global assets, we find that a two-factor model incorporating both stocks and bonds significantly outperforms the traditional one-factor CAPM model on bond risky days, particularly for asset classes such as currencies, commodities, and global equities. For non-US G10 currencies, the improvement in R-squared of the two-factor model decreases almost monotonically, starting from 17.25% for funding currencies like the Japanese Yen to 3.94% for asset currencies such as the Australian Dollar. When it comes to explaining the returns of the Dollar Index (DXY), the two-factor model achieves an R-squared improvement of 9.70% over the CAPM model. The increase in explanatory power ranges from 0.08% to 5.27% for global equities and 0.34% to 6.66% for commodities. This supports the notion that

[4] We further find that this unique safety nature of UST is not shared by other non-US G10 sovereign bonds, whose bond/currency correlations strengthen during the flight-to-UST days.

when U.S. Treasuries themselves become a source of risk on bond risky day, they become a critical factor in explaining global asset returns. In contrast, on bond safety days – when UST movements are driven by safe-haven demand due to equity market originated risks – adding a bond factor offers minimal improvement, with R-squared gains below 2.47% for most assets. The only exception is the Japanese Yen, which, as a key funding currency for global investors, remains a notable outlier.

To further differentiate the source of risk, we zoom into the intra-day pricing dynamics to examine the lead-lag relations between stocks and bonds at higher frequency. Consistent with the observation that U.S. Treasuries are the source of risk on bond risky days, we find that movements in UST can positively predict subsequent movements in the S&P 500 (SPX), but not the other way around.[5] Our analysis shows that a 1 bps increase in UST returns positively predicts a 0.15 bps change in SPX returns in the next five minutes, with a statistically significant t-stat of 2.65. In contrast, a 1 bps increase in SPX returns predicts only a 0.01 bps movement in UST returns, small in magnitude and with an insignificant t-stat of 1.63. These findings confirm that the UST market acts as the primary source of risk on bond risky days, leading the equity market. Outside of the bond risky days, SPX can negatively predict UST, while UST does not significantly predict SPX. That suggests that, outside of bond risky days, the equity market is the dominant driver of risk, further highlighting the distinct risk dynamics present on the bond risky days captured by our stock-bond correlation measure.

Related Literature – Our paper contributes to the extensive literature on the U.S. Treasury market by highlighting its dual roles: as a destination of safety and, more critically, as a potential source of risk. Our paper therefore adds to recent discussions on limited dealer capacity and the resilience of the UST market (Duffie 2023; Duffie et al. 2023), and, more broadly, to studies on UST liquidity (Hu, Pan, and Wang 2013) and UST term premium (Adrian et al. 2013; Kim and Wright 2005).

We also contribute to the literature on U.S. Treasury by showing that demand for UST safety helps explain time-series variations in Treasury convenience yields, including the Treasury basis (Du, Im, and Schreger 2018; Jiang, Krishnamurthy, and Lustig 2023; Acharya and Laarits 2023) and Treasury-swap spreads (Adrian, Fleming, Shachar, and Vogt 2017). Our observation that UST can abruptly swing from a safe-haven asset to a source of risk is consistent with the notation of Treasury inconvenience yields, as documented by He, Nagel, and Song (2022) during the Covid-19 period. Additionally, our paper provides new insights into the relationship between the safety of UST and USD, showing that it is UST safety, rather

[5] Specifically, we proxy intraday UST returns using 5-minute returns on 10-year Treasury futures, and intraday SPX returns using 5-minute returns on E-mini S&P 500 futures.

than USD safety, that drives the UST convenience.

Our paper complements the literature on flights-to-safety,[6] and is closely related to the recent paper by Baele, Bekaert, Inghelbrecht, and Wei (2019), which uses multiple criteria such as return impact, correlation, and volatility spikes in global equity and bond markets to identify flight-to-safety episodes. We take a different approach by constructing a simple stock-bond correlation measure that, unlike Baele, Bekaert, Inghelbrecht, and Wei (2019), captures not only flight-to-safety episodes but also bond risky episodes when UST becomes a source of risk. Our finding on the UST and USD co-movement aligns with Kekre and Lenel (2024), who show theoretically that flight-to-safety episodes lead to dollar appreciation and global output declines under nominal rigidity.

Finally, our paper adds to the literature on the stock-bond correlation. Existing papers, including Campbell, Pflueger, and Viceira (2020), David and Veronesi (2013), D.E.Shaw (2019), Cieslak and Schrimpf (2019), Ermolov (2022), Laarits (2022), and Li, Zha, Zhang, and Zhou (2022), have proposed different channels to explain the time-variations in the stock-bond correlations. We build on these observation to construct our measure and explore the information contained in the daily variations of the stock-bond correlations.

The rest of our paper is organized as follows. Section 2 describes the construction of the bond risk measure and the characteristics of the bond safety and bond risky episodes. Section 3 and Section 4 investigate asset pricing under bond safety and bond risky days. Section 5 concludes the paper. Further details are provided in the appendices.

2. High-Frequency Stock-Bond Correlations – A Tale of Two Days

2.1. Constructing the Stock-Bond Correlation Measures ρ_t^{UST}

We construct our bond risk measure ρ_t^{UST} as the correlation between the intraday 5-minute returns of the U.S. equity (SPX) and the U.S. Treasury (UST) on a trading day t:

$$\begin{aligned}\rho_t^{\text{UST}} &= corr(R_{i,t}^{\text{SPX}}, R_{i,t}^{\text{UST}})|_{fixed\ t} \\ &= \frac{\frac{1}{N_t-1}\sum_{i=1}^{N_t}(R_{i,t}^{\text{SPX}} - \overline{R_t^{\text{SPX}}})(R_{i,t}^{\text{UST}} - \overline{R_t^{\text{UST}}})}{\sqrt{\frac{1}{N_t-1}\sum_{i=1}^{N_t}(R_{i,t}^{\text{SPX}} - \overline{R_t^{\text{SPX}}})^2}\sqrt{\frac{1}{N_t-1}\sum_{i=1}^{N_t}(R_{i,t}^{\text{UST}} - \overline{R_t^{\text{UST}}})^2}},\end{aligned} \tag{1}$$

where $R_{i,t}^{\text{SPX}}$ and $R_{i,t}^{\text{UST}}$ are the 5-minute returns of the most liquid E-mini S&P 500 index futures and the 10-year Treasury futures contracts traded on the Chicago Mercantile Exchange

[6]See, for example, Connolly, Stivers, and Sun (2005), Baur and Lucey (2009), Baele, Bekaert, and Inghelbrecht (2010), Bansal, Connolly, and Stivers (2010), Goyenko and Sarkissian (2014), Beber, Brandt, and Cen (2014), Adrian, Crump, and Vogt (2019), among others.

(CME) for each of the 5-minute interval i within the regular trading hours (9:30 AM to 4:00 PM Eastern Time) of day t; $\overline{R_t^{\text{SPX}}}$ and $\overline{R_t^{\text{UST}}}$ are the daily averages of the 5-minute returns $R_{i,t}^{\text{SPX}}$ and $R_{i,t}^{\text{UST}}$ on day t; N_t is the number of 5-minute returns within the regular trading hours of day t, which equals 78 for a typical trading day. We require a minimum N_t of 30 for the estimation of the bond risk measure ρ_t^{UST} on a trading day t.[7] Our sample covers the period from January 2004 to June 2022, during which the S&P 500 E-mini futures and 10-year Treasury futures are traded with high liquidity and have reliable minute-end prices.[8]

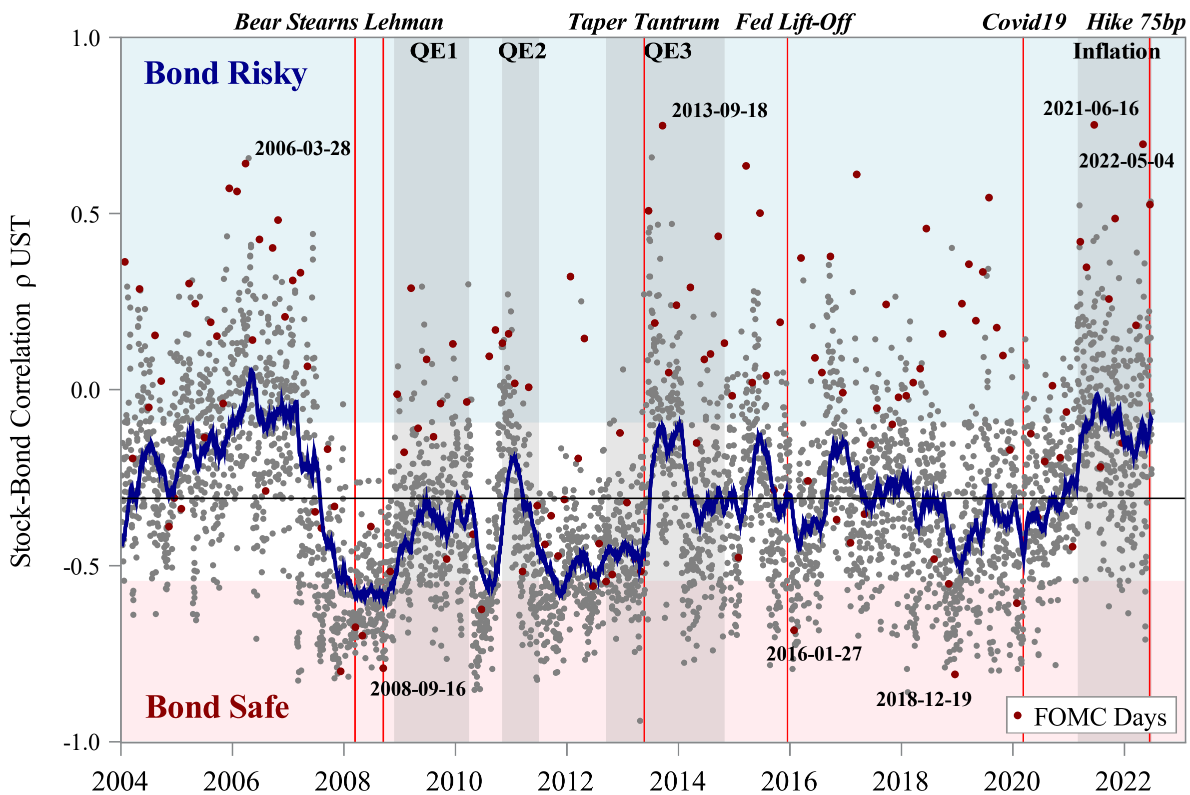
We present the time series of ρ_t^{UST} (gray dots) from January 2004 to June 2022 in Figure 1. FOMC announcement days are highlighted in red, while the overall trend is captured using an exponential weighted moving average of ρ_t^{UST} with a decay factor of 0.98 (blue line). The pink shaded region denotes periods when ρ_t^{UST} falls below its bottom 20% percentile (-0.54), and the light blue shaded region corresponds to periods when ρ_t^{UST} exceeds its top 20% percentile (-0.10). Throughout the sample period, ρ_t^{UST} is dominantly negative, with an average value of -0.31, reflecting the safe-haven status of the U.S. Treasury. Notably, ρ_t^{UST} plummets to approximately -0.6 during the 2008 financial crisis, briefly rises at the onset of the first and second rounds of QE, as well as following the Fed's announcement of QE tapering in June 2013, but remains negative for an extended period until the onset of the Covid-19 pandemic. Since 2021, ρ_t^{UST} has being steadily increasing, approaching near-zero levels amid heightened inflation concerns and the Fed's interest rate hikes.

Despite the overall trend of negative values, there are many notable instances of large positive values in ρ_t^{UST}. Many of these occur on FOMC announcement days, which are noticeably concentrated in the upper range of the time-series, often within the top 20% percentile. This can also be seen from the histogram of the bond risk measure ρ_t^{UST} presented in Figure 2. The distribution peaks around its average of -0.31 but exhibits a relatively long right tail, reflecting rare but extreme cases where Treasuries exhibit a near-zero or positive co-movement with the SPX. On FOMC announcement days, ρ_t^{UST} is predominantly concentrated on the right side of the distribution. By comparison, on the worst 20% SPX performance days, ρ_t^{UST} is largely distributed on the left side, reflecting large negative stock-bond correlations associated with the flight-to-safety phenomenon during large equity market

[7]Considering the limited liquidity during the overnight period, we use the returns within the regular trading hours to construct the bond risk measures. In appendix A, we construct a bond risk measure from the returns of the entire trading day, including both the regular trading hours and the overnight period. Our main results stay quantitatively similar.

[8]In our data obtained from the CME, the E-mini S&P 500 index futures data starts from September 1997; the 10-year treasury note futures data starts from January 1995. However, before the electronic trading system becomes popular, majority of the futures used to be traded in the pit using the open outcry system. To mitigate noises introduced by price non-synchronization across different futures contracts, our baseline results start from January 2004, which is first year when the CME volume on its electronic trading platform "Globex" surpassed the physical pit volume.

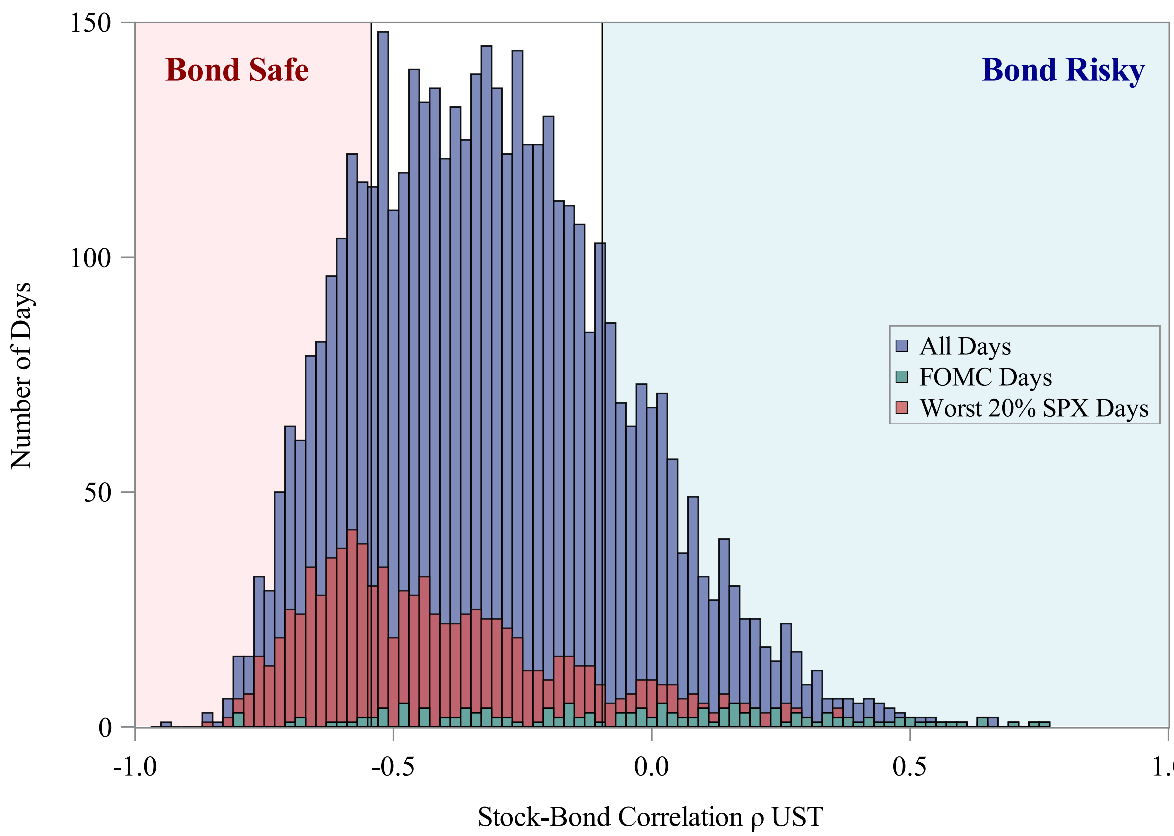
Figure 1: **Time Series of the Bond Risk Measure $\rho_t^{\textbf{UST}}$**



This figure presents the bond risk measure, ρ_t^{UST} (gray dots), along with exponentially weighted moving averages (EWMA) with a decay parameter of 0.98 (blue line), over the period from January 2004 to June 2022. Red dots denote days with FOMC announcements. Blue shaded areas represent periods when ρ_t^{UST} is in the top 20% percentile, while pink shaded areas correspond to periods when ρ_t^{UST} is in the bottom 20% percentile.

declines. However, the histogram also reveals that the information captured by ρ_t^{UST} is not identical to the equity market return – many of the worst equity performance days do not exhibit strong negative stock bond correlations.

Figure 2: **Histogram of the Bond Risk Measure ρ_t^{UST}**



This figure shows the histogram of the bond risk measure, ρ_t^{UST} (blue bars), alongside FOMC announcement days (green bars) and the worst 20% SPX performance days (red bars), defined as days when the SPX daily return falls below the full-sample 20th percentile (-59 basis points). The sample period spans from January 2004 to June 2022. Blue shaded areas represent periods when ρ_t^{UST} is in the top 20th percentile, while pink shaded areas correspond to periods when ρ_t^{UST} is in the bottom 20th percentile.

The summary statistics of the the daily bond risk measures are reported in Panel A of Table 1. Over our sample period from January 2004 to June 2022, the stock-bond correlation measure ρ_t^{UST} is generally negative, with an average of -0.31, a median of -0.33, and a standard deviation of 0.26. Panel B of Table 1 further reports the summary statistics of the key variables used in the paper. This includes the returns of several major asset classes: SPX is the daily return of the S&P 500 index; UST is the daily return of the CRSP Fixed Term Index at the 10-year maturity; DXY is the daily log changes of the U.S dollar index provided by the Intercontinental Exchange (ICE); EUR/USD and YEN/USD are the daily log changes of the exchange rates of Euro and Japanese Yen relative to the U.S. Dollar at 4 PM Eastern Time and are obtained from Bloomberg.

In addition to the returns of major asset classes, we also include several key volatility indexes. The VIX index measures the risk-neutral expected volatility of the S&P 500 index. The MOVE index measures the bond market volatility and is constructed as the yield curve weighted average of the normalized implied volatility of 1-month Treasury options. EUR/USD IV is the 1-month at-the-money implied volatility on the exchange rates of Euro relative to the U.S. Dollar, YEN/USD IV is the 1-month at-the-money implied volatility on the exchange rates of the Japanese Yen relative to the U.S. Dollar. The implied volatility of DXY (DXY IV) is the average of the 1-month at-the-money implied volatilities of the component currencies, weighted by their respective index component weights: 0.576 for Euro (EUR/USD IV), 0.136 for Japanese Yen (YEN/USD IV), 0.119 for British Pound (GBP/USD IV), 0.091 for Canadian Dollar (CAD/USD IV), 0.042 for Swedish Krona (SEK/USD IV) and 0.036 for Swiss Franc (CHF/USD IV).

2.2. Characteristics of Bond Safety and Bond Risky Days

Leveraging the daily risk measures, we classify all days into quintiles, with "bond safety days" representing the bottom 20% of ρ_t^{UST} values and "bond risky days" representing the top 20%. Our hypothesis is that bond safety days correspond to periods when risk originates in the U.S. equity market, prompting a flight-to-safety toward U.S. Treasuries. In contrast, bond risky days reflect periods when the U.S. Treasury market itself becomes a source of risk. To further emphasize the unique information captured by the bond risk measure, Figure 3 reports the annual proportions of bond safety and risky days for the worst SPX performance days (Panel a) and FOMC announcement days (Panel b). From 2007 to 2020, bond safety days account for over 20% of the worst SPX performance days (with the only exception of 2009), exceeding 50% in six years (2007, 2008, 2010, 2011, 2018, 2019). In contrast, outside of the period, bond safety days constitute less than 8% of the worst equity days, while bond risky days comprise 24–48%. Notably, 22–78% of these worst equity days are neither bond safety nor risky days, highlighting that ρ_t^{UST} captures information distinct from equity returns. In terms of FOMC announcement days, bond risky days dominate, with 82 such days (56%) during our sample period, compared to only 13 bond safety days (9%).

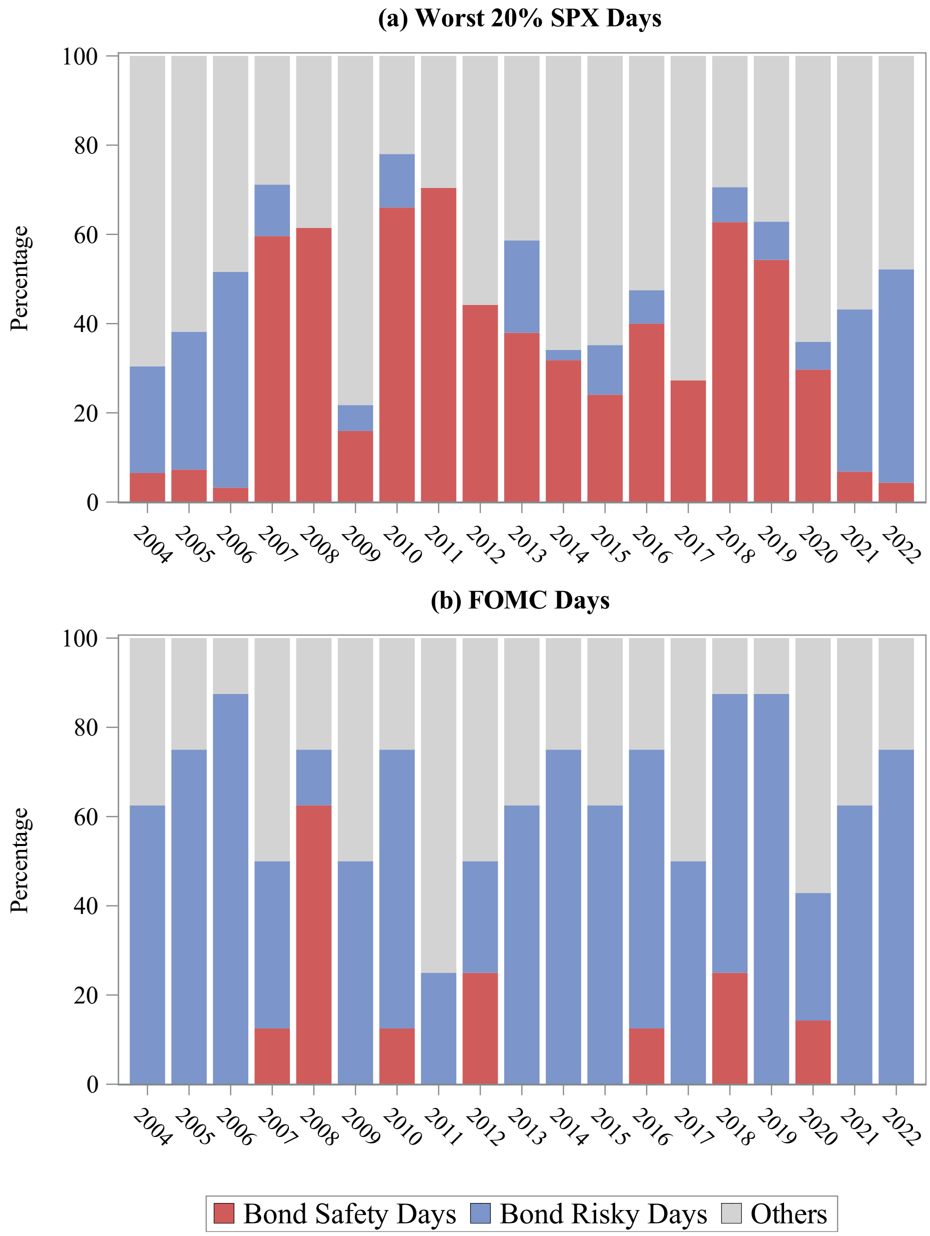
Table 2 compares the performance of major global assets and volatility indices on bond safety and risky days. Additionally, we also report the market liquidity of the U.S. equity and Treasury markets, using key metrics such as realized volatility (Vol), estimated from intraday returns following Bollerslev, Tauchen, and Zhou (2009), and trading volume. Figure 4 presents the cumulative changes in the 10-year Treasury yield and realized volatility,

Table 1: **Summary Statistics**

	Mean	Std	Min	Q1	Med	Q3	Max
Panel A: The main bond risk measure							
ρ_t^{UST}	-0.31	0.26	-0.94	-0.51	-0.33	-0.14	0.75
Panel B: Return and volatility of major assets							
Return of major assets							
SPX	3.37	121.40	-1198.4	-40.2	7.0	55.6	1158.0
UST	1.52	44.75	-291.9	-25.4	2.3	27.9	355.5
DXY	0.40	48.54	-272.6	-27.2	-0.1	27.5	252.0
EUR/USD	-0.39	58.07	-277.4	-33.4	0.0	31.9	345.1
YEN/USD	-0.51	61.57	-547.4	-33.4	0.0	31.2	381.1
Volatility of major assets							
VIX	19.11	9.00	9.1	13.3	16.4	22.1	82.7
MOVE	81.44	30.44	36.6	60.3	74.0	93.1	264.6
DXY IV	9.13	3.05	4.3	7.1	8.6	10.6	29.7
EUR/USD IV	8.99	3.25	3.8	6.7	8.5	10.5	28.9
YEN/USD IV	9.51	3.35	3.9	7.2	8.9	11.1	38.4
Panel C: Alternative risk measures							
ρ_t^{USD}	-0.06	0.28	-0.77	-0.27	-0.04	0.14	0.75
ρ_t^{UST2Y}	-0.16	0.23	-0.81	-0.30	-0.15	-0.02	0.74
ρ_t^{UST3M}	-0.16	0.24	-0.84	-0.32	-0.15	0.00	0.75

This table shows summary statistics of the bond risk measures and major asset performances. Panel A reports summary statistics of key risk measure ρ_t^{UST} as estimated in equation (1). Panel B reports major asset returns and volatilities. For return of assets, SPX is the daily return of the S&P 500 index; UST is the daily return of the CRSP Fixed Term Index at the 10-year maturity; DXY is the daily log changes of the U.S dollar index provided by the Intercontinental Exchange (ICE); EUR/USD and YEN/USD are the daily log changes of the exchange rates of Euro and Japanese Yen relative to the U.S. Dollar at 4 PM Eastern Time and are obtained from Bloomberg. For volatilities, the VIX index measures the risk-neutral expected volatility of the S&P 500 index; the MOVE index measures the bond market volatility and is constructed as the yield curve weighted average of the normalized implied volatility of 1-month Treasury options; EUR/USD IV is the 1-month at-the-money implied volatility on the exchange rates of Euro relative to the U.S. Dollar; YEN/USD IV is the 1-month at-the-money implied volatility on the exchange rates of the Japanese Yen relative to the U.S. Dollar; The implied volatility of DXY (DXY IV) is the weighted average of 1-month at-the-money implied volatilities of DXY's constitutes currencies: 0.576 for Euro (EUR/USD IV), 0.136 for Japanese Yen (YEN/USD IV), 0.119 for British Pound (GBP/USD IV), 0.091 for Canadian Dollar (CAD/USD IV), 0.042 for Swedish Krona (SEK/USD IV) and 0.036 for Swiss Franc (CHF/USD IV). Panel C reports alternative risk measures ρ_t^{USD} as estimated in equation (2) and ρ_t^{UST2Y}, ρ_t^{UST3M} as estimated in equation (13). Returns are in unit of basis point. The sample period is from January 2004 to June 2022.

Figure 3: **Distribution of Bond Safety and Risky Days**



This figure shows the percentage of bond safety days (bottom 20% ρ_t^{UST} days in red), bond risky days (top 20% ρ_t^{UST} days in blue) and other days (middle 20% to 80% ρ_t^{UST} days in gray) within (a) the worst 20% SPX days and (b) the FOMC announcement days. The sample period ranges from January 2004 to June 2022. For every year from 2004 to 2022, we report the percentage of bond safety and risky days within the lowest 20% SPX return (daily returns less than -59 basis point) days and the FOMC announcement days in that year. For year 2022, the calculation is based on the half year sample from January to June.

separately for bond safety days (red), bond risky days (blue), and the full sample (gray).[9]

Bond Safety Days – Focusing first on bond safety days, we observe a clear picture of flight-to-UST. The stock market drops an average return of -36.20 bps (t-stat=-8.04), while the bond market rallies with an average return of 13.60 bps (t-stat=9.57). With a significant decline in yields, the 10-year Treasuries function as the safety destination. In fact, the reduction in Treasury yields during our sample period predominantly comes from bond safety days. Excluding the bond safety days, there is actually an upward trend in the 10-year Treasury yields.

Turning to other assets, the safe-haven currency Japanese Yen appreciates relative to the USD with an average daily return of 15.83 bps (t-stat=6.72). Controlling for their exposure to the U.S. equity market, the CAPM αs remains significantly positive, 6.11 bps for the Japanese Yen. On the other hand, there is no significant flight to the Euro nor the dollar index, as neither of them have significant returns or CAPM αs on the bond safety days. The volatility across all three markets hike up on the bond safety days. The average increase in the implied volatility is 0.51% for the equity market, 0.79 for the U.S. Treasury, and 0.07% for the dollar index, 0.07% for the Euro/USD exchange rates, and 0.14% for the Yen/USD exchange rates. The increase accounts for 1% to 3% of the average level of the implied volatilities in our sample period.

On the bond safety days, both the Treasury and equity markets have significant higher trading volume. However, only the equity futures market experiences significant higher volatility of 1.11% (t-stat=4.22). The pattern of trading volume and volatility is consistent with a flight-to-UST, for which the equity market is the source of risk and the Treasury market is the destination of the flight. In Appendix B, we provide additional evidence of significant ETF outflows from SPX and inflows into UST, as well as similar patterns in asset managers' net futures positions.

Bond Risky Days – In contrast to the bond safety days, the bond risky days are characterized by a drop in the U.S. Treasury market and a rise in the equity market. The average return is -6.05 bps for the UST and 13.75 bps for the SPX. In the FX market, the Japanese Yen exchange rates depreciate relative to the U.S. dollar by 8.29 bps. The dollar index and the EUR/USD exchange rates don't move significantly on the bond risky days. But, after controlling their exposure to the U.S. equity market, the dollar index appreciates by 3.61 bps and the Euro depreciate by 4.99 bps relative to the dollar. The implied volatilities for

[9]The realized volatility and trading volume are calculated based on the most-liquid S&P 500 E-mini and 10-year Treasury Note futures. The 10-Year Treasury yield is the 10-Year Constant Maturity yields obtained from Federal Reserve Bank of St. Louis (FRED). The annualized realized volatility is estimated based on intra-day returns of the most liquid 10-Year Treasury futures traded on CME, following Bollerslev, Tauchen, and Zhou (2009).

the equity and the FX markets drop slightly on the bond risky days, while the change is not significant for the U.S. Treasury market. The return and volatility pattern suggests that the Treasury market is likely the source of risk on the bond risky days.

Interestingly, the Treasury market becomes significantly more volatile on the bond risky days. On average, the volatility of the Treasury market increases by 0.28% (t-stat=3.64). The Treasury market also has higher trading volume on the bond risky days. In contrast, the equity market has slightly lower volatility and similar trading volume. The liquidity pattern is consistent with our hypothesis that the Treasury market turns into a source of risk on the bond risky days.[10] Using the weekly primary dealers data from the New York Fed, we find that primary dealers reduce their net Treasury position significantly during bond risky weeks. The detailed results are reported in Appendix B.

2.3. Alternative Measures

Considering that the U.S. Dollar (USD) is often referred as safe-haven assets, we first investigate whether the co-movement between stocks and USD provides insights comparable to or surpassing those offered by our stock-UST correlation measure.

Comovement of Global Assets – We begin by examining the roles of UST and USD in shaping the co-movement of global assets. Abstracting from the enormity of the global financial markets, Figure 5 focuses on the core building blocks of the global markets – U.S. Equity (SPX in red), U.S. Treasury (UST in blue), U.S. Dollar (USD in green), and Commodity (GSCI in yellow). Plotted in the foreground are their relative contributions to the first principal component (PC1), while the extent of their comovement is plotted in the background.

Each month, the principal component analysis is performed on the correlation matrix, estimated using daily returns on SPX, UST, USD, and GSCI over a three-year rolling window. Under the assumption of zero comovements across all four asset returns, one single factor accounts for 25%. As shown in Figure 5, the explanatory powerful of the first principal component (PC1) is consistently above 25%, reflecting a non-trivial amount of comovement among the four assets. Also interesting is the fact that, after the 2008 financial crisis, the relative importance of PC1 shifted from an average of 35.95% to 45.91%, reflecting increased comovement.

Although we perform the principal component analysis dynamically by re-estimating the correlation matrix every month, apparent in Figure 5 is the stable relation between the SPX and UST pair, whose alliance switches sides only once around 2000 and behind this shift

[10] We provide more details on the dynamics of yield levels and volatilities in Appendix C.

Table 2: **Performance of Key Assets on Bond Safety and Risky Days**

Panel A: Bond risk measures

	ρ_t^{UST}	# Days		ρ_t^{UST}	# Days
Bond Safety Days	-0.64***	926	Non-FOMC	-0.32***	4509
	[-201.95]			[-36.74]	
Bond Risky Days	0.07***	926	FOMC	-0.03	147
	[13.03]			[-0.83]	

Panel B: Major market performance

(a) Return

	SPX	UST	DXY	EUR/USD	YEN/USD
Bond Safety Days	-36.20***	13.60***	1.20	-2.08	15.83***
	[-8.04]	[9.57]	[0.63]	[-0.90]	[6.72]
Bond Risky Days	13.75***	-6.05***	2.14	-1.93	-8.29***
	[4.76]	[-3.92]	[1.22]	[-0.98]	[-4.16]

(b) CAPM α

		UST	DXY	EUR/USD	YEN/USD
Bond Safety Days		5.03***	-0.89	0.96	6.11***
		[4.42]	[-0.49]	[0.44]	[3.13]
Bond Risky Days		-7.96***	3.61**	-4.99**	-9.97***
		[-4.92]	[2.06]	[-2.53]	[-5.06]

(c) Δ***Implied Vol***

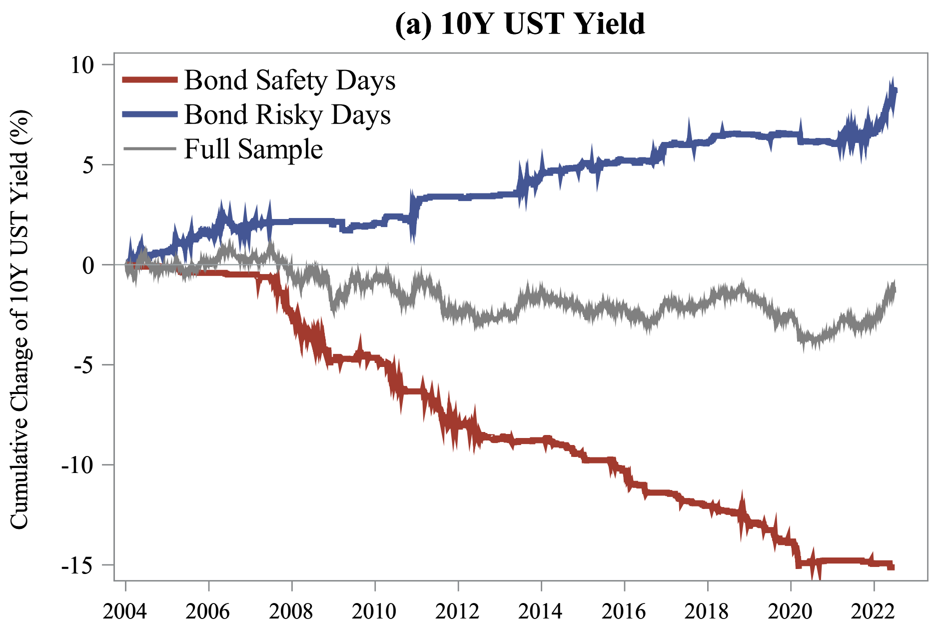
	VIX	MOVE	DXYV	EURV	YENV
Bond Safety Days	0.51***	0.79***	0.07***	0.07***	0.14***
	[6.48]	[4.68]	[3.75]	[3.42]	[4.28]
Bond Risky Days	-0.16***	-0.11	-0.03***	-0.03**	-0.04***
	[-4.12]	[-0.96]	[-3.13]	[-2.47]	[-3.04]

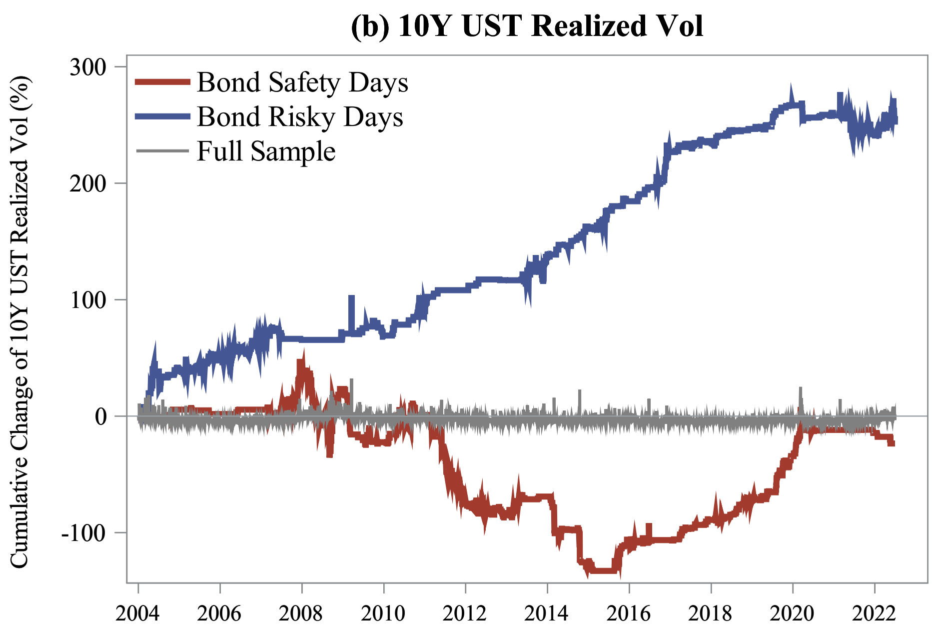
Panel C: Major market liquidity

	SPX		UST	
	ΔVol	ΔVolume	ΔVol	ΔVolume
Bond Safety Days	1.11***	0.25***	-0.02	0.15***
	[4.22]	[7.29]	[-0.21]	[5.22]
Bond Risky Days	-0.25**	-0.00	0.28***	0.12***
	[-2.12]	[-0.12]	[3.64]	[3.97]

This table summarizes the performances of major assets on bond safety (bottom 20% ρ_t^{UST}) and bond risky (top 20% ρ_t^{UST}) days. Panel A reports the average bond risk measure ρ_t^{UST} on the bond safety and risky days and the FOMC announcement days, respectively. For major asset classes, Panel B reports their average return, CAPM α, and the daily change of their implied volatilities on the bond safety and risky days. SPX is the daily return of the S&P 500 index; UST is the daily return of the CRSP Fixed Term Index at the 10-year maturity; DXY is the daily log change of the U.S dollar index provided by the Intercontinental Exchange (ICE); EUR/USD and YEN/USD are the daily log changes of the exchange rates of Euro and Japanese Yen relative to the U.S. Dollar at 4 PM Eastern Time and are obtained from Bloomberg. Panel C summarizes the change of the market liquidity measures on the bond safety and risky days. ΔVol denotes the daily change of the annualized realized volatility estimated based on the 5-minute intra-day returns and 4pm-9:30am overnight return of most liquid futures following Bollerslev, Tauchen, and Zhou (2009) (in unit of percent). ΔVolume denotes the daily change of trading volume of most liquid futures (in unit of the respective full sample standard deviation). The sample period is from January 2004 to June 2022. The t-statistics are reported in the square brackets and are based on the Newey-West standard errors.

Figure 4: **10-Year U.S. Treasury Performance on Bond Safety and Risky Days**

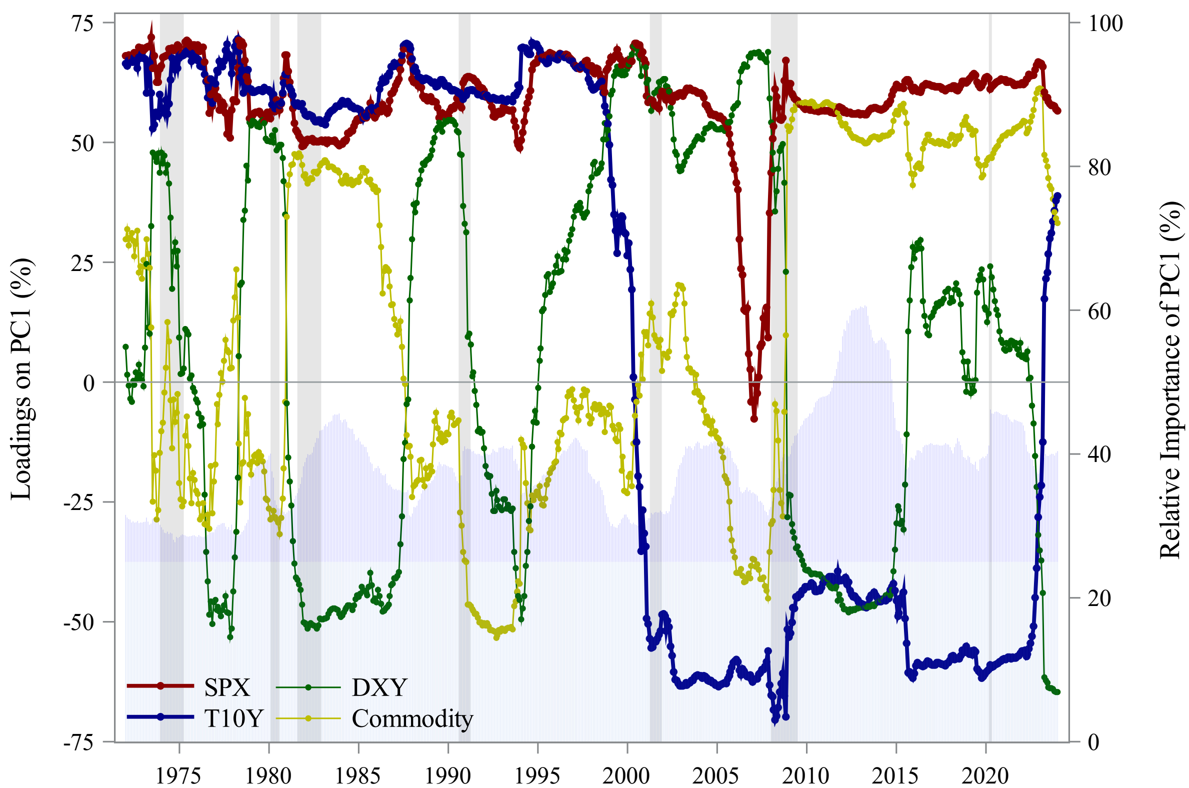




This figure shows the cumulative change of yield (Panel a) and change of realized volatility (Panel b) of 10-Year U.S. Treasury on bond safety days (days with bottom 20% ρ_t^{UST}, in red), bond risky days (days with top 20% ρ_t^{UST}, in blue), and full sample (all day, in gray). The 10-Year Treasury yield is the market yield on U.S. Treasury Securities at 10-Year Constant Maturity from Federal Reserve Bank of St. Louis (FRED). The annualized realized volatility is estimated based on 5-minute intra-day returns and 4pm-9:30am overnight return of the most liquid 10-Year Treasury futures traded on CME following Bollerslev, Tauchen, and Zhou (2009). The sample period is from January 2004 to June 2022.

is the well documented time-varying stock-bond correlation (e.g., Campbell, Pflueger, and Viceira (2020), D.E.Shaw (2019), and Laarits (2022)). By contrast, USD cycles in and out of the riskiness of SPX, peaking rapidly just before recessions and then shifting quickly to the safety side, while the commodity index often cycles in the opposite direction to USD. Throughout our sample period, SPX occupies the center stage of PC1 with a brief retreat from late 2006 to early 2007, just before the 2007-08 financial crisis, when the dramatic increase in GSCI, driven by the surging oil prices, coupled with the rapid decline in USD took over PC1.

Figure 5: **Principal Component Analysis on Global Key Assets**



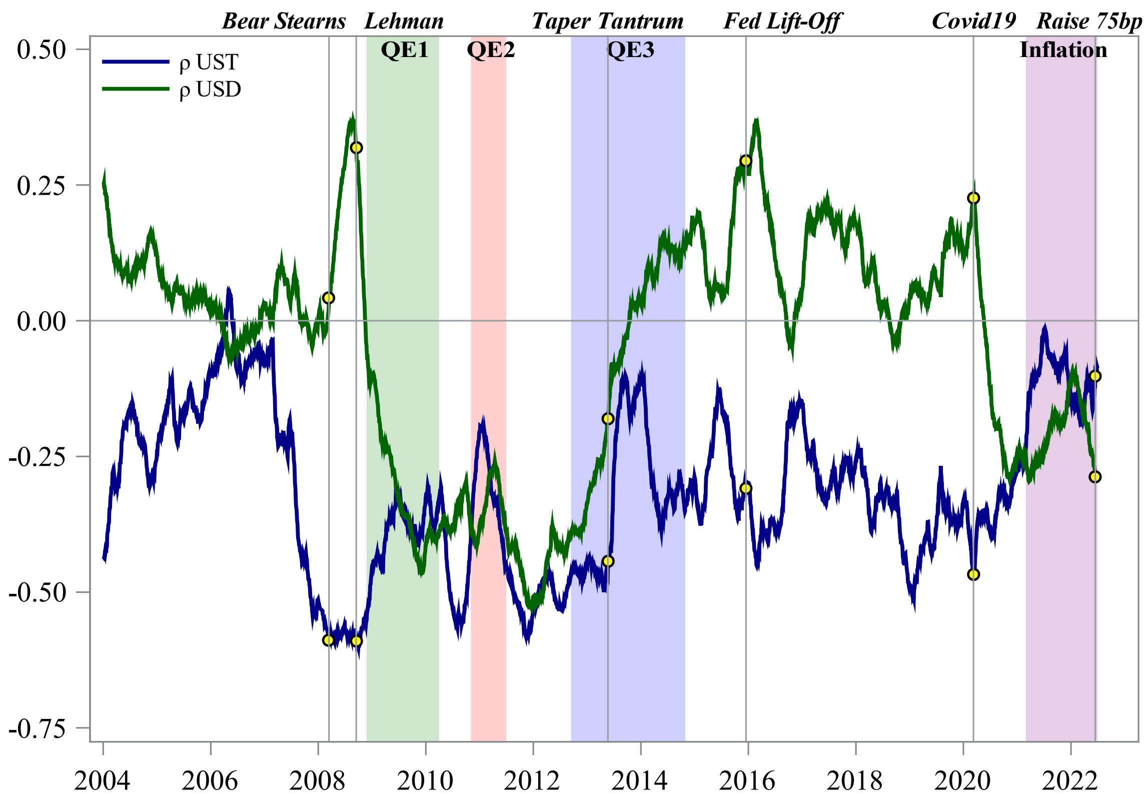
This figure shows the results of a principal component analysis (PCA) performed on the correlation matrix of SPX, UST, USD, and GSCI, estimated using daily returns with a 3-year rolling window. The figure reports the relative loadings on the first principal component (PC1, left axis, lines) and the proportion of variance explained by PC1 (right axis, shaded area). The sample period spans from January, 1969 to December, 2023.

Stock-USD Correlation Measure – We follow the same methodology to construct an alternative stock-USD correlation measure, ρ_t^{USD}:

$$\rho_t^{\text{USD}} = w \times corr(R_t^{\text{SPX}}, R_t^{\text{USD/EUR}}) + (1-w) \times corr(R_t^{\text{SPX}}, R_t^{\text{USD/YEN}}), \tag{2}$$

where $w = \frac{0.576}{0.576+0.136} = 0.81$ is the relative ratio between the index weights of the two most important currencies constituting the U.S. dollar index compiled by ICE (the "DXY" index), 0.576 for the Euro and 0.136 for the Japanese Yen. The 5-minute returns of Euro (EUR/USD) and Japanese Yen (YEN/USD) are based on the intra-day prices of the most liquid Euro/USD and YEN/USD currency futures traded on the CME. Our sample covers the period from January 2004 to June 2022.

Figure 6: **The Time Series of USD and UST Risk Measures**



This figure shows the smoothed time series (exponential weighted moving average with a decaying parameter 0.98) of the UST risk measure ρ_t^{UST} (blue) and the USD risk measure ρ_t^{USD} (green) from January 2004 to June 2022.

Figure 6 compares the time series of dollar risk measure (or USD risk measure) ρ_t^{USD} with our main bond risk measure (or UST risk measure) ρ_t^{UST} in our sample period. To illustrate the overall trend of the two measures, we plot their exponential weighted moving averages with a decay factor of 0.98 to reduce noises at the daily frequency. Compared to the overall negative levels of ρ_t^{UST}, ρ_t^{USD} swings much more notably during our sample period. ρ_t^{USD} is often positive before Lehman's collapse in September 2008, turns negative during the height of the 2008 financial crisis and the subsequent periods of quantitative easing, and reverts back to negative from 2014. Interestingly, ρ_t^{USD} has recently moved to the negative side, coinciding with the Fed's interest rate hikes starts to raise interest rates to battle inflation which causes the U.S. dollar to appreciate significantly against other major global currencies.

We then turn to the dollar safety and risky days identified by ρ_t^{USD}. Similar to our early approach, we define the bottom (top) 20% days with the lowest (highest) dollar risk measures as the dollar safety (risky) days, and report the performance of the key asset classes on the safety and risky days identified by ρ_t^{USD} at Table 3. To highlight the unique information contained in ρ_t^{USD}, we exclude the overlapped days that are also the bond safety or risky days based on ρ_t^{UST}.

The U.S. stock market rallies with a significant positive average daily return of 15.22 bps (t-stat=2.97) on the dollar safety days. Compared to the average decline of -34.58 bps on the bond safety days, it is clear that the U.S. equity market is not under stress on the dollar safety days captured by ρ_t^{USD}. Our analysis also reveals that on the dollar safety days, there are no significant movements in either the U.S. Treasury yields or the U.S. Dollar Index. Furthermore, all of the five implied volatility measures drop slightly, rather than increase, on the dollar safety days. Collectively, these findings suggest that flight-to-USD is not prevalent during our sample period.

Contrast with the relative tranquility observed on the dollar safety days, asset returns and implied volatilities on days characterized by bond safety – specifically excluding those also marked by dollar safety – reveal consistent indications of flight-to-safety behavior. These patterns further confirm the role of U.S. Treasuries as the primary safe-haven assets during our study period.

Other Alternative Correlation Measures – In addition to the stock-USD correlation measure, we examine several alternative correlation metrics, including those based on stock and short-term Treasury returns (Appendix D) and low-frequency stock-bond correlations derived from rolling historical daily returns (Appendix E). Using a method similar to that employed for the long-term Treasury, we construct the short-term Treasury correlation measures as the correlations between the intraday 5-minute returns of the SPX and 2-year Treasury futures (ρ_t^{UST2Y}), as well as 3-month EuroDollar futures (ρ_t^{UST3M}). These short-term Treasury correlation measures are more sensitive to growth shocks (Cieslak and Schrimpf 2019) and are therefore less effective in capturing the risk aversion shocks associated with flight-to-safety days. In Section 4.1, we present evidence that these measures are also less effective in identifying bond risk days, especially those driven by dealer balance sheet constraints. The low-frequency bond risk measure, which can be traced back to earlier periods, exhibits a time-series pattern similar to our bond risk measure. However, its construction method limits its ability to capture the evolving dual roles of bonds on a daily basis. Overall, these alternative measures are less effective at identifying bond safety and risky days. For further details, readers are encouraged to refer to the Appendix.

2.4. Examples of Bond Safety and Bond Risky Days

To illustrate the characteristics of bond safety and bond risky periods, we present four representative episodes of bond safety in Figure 7 and four episodes of bond risk in Figure 8. In both figures, each dot represents a trading day; the x-axis represents the Stock-UST correlation (ρ_t^{UST}), and the y-axis represents the Stock-USD correlation (ρ_t^{USD}). A light pink background marks the trading days within the bond safety zone, where ρ_t^{UST} is in the lowest 20%, while a light blue background identifies days within the bond risky zone, occurring as ρ_t^{UST} enters the top 20% quintile.

The four bond safety periods we examined in Figure 7 include: the peak of the 2008 financial crisis (September to November 2008); the height of the 2011 European debt crisis (June to December 2011); the third round of quantitative easing (QE3, September 13, 2012, to October 31, 2014); and selected market panic events, including the 2010 Flash Crash (May 6, 2010), the false Associated Press tweet about a White House attack (April 23, 2013), and the day when the U.S. government briefly shut down for a few hours overnight due to a delay in passing a budget deal (February 9, 2018).

During the 2008 financial crisis and the 2011 European debt crisis, the majority of trading days fell into the U.S. Treasury (UST) safety regions, highlighting significant flight-to-safety behavior during these two crisis episodes. Interestingly, during the third round of quantitative easing, there was a sharp regime shift on June 19, 2013, when the Federal Reserve Chairman announced plans to gradually reduce the Fed's Treasury purchases – a move that became known as the "Taper Tantrum". Starting from that date, the majority of trading days during the QE3 period shifted from UST safety days to UST risky days, reflecting heightened concerns in the bond market as investors worried that reduced bond purchases would lead to higher and more volatile U.S. interest rates. Notably, the USD also moved into the risky side following the taper announcement.

During all three panic events we examined, the UST risk measures turned significantly negative: -0.85 on the 2010 Flash Crash day, -0.94 on the day of the false tweet about a White House attack, and -0.86 on the government shutdown day. These panic events were extremely short-lived, lasting one day or less, largely unexpected, and not related to economic fundamentals. As investors sharply reduced their risk appetite during these panic events, their strong flight-to-safety behavior triggered significant negative co-movement between stocks and bonds, as evident in the large negative values of ρ_t^{UST}.

In Figure 8, we focus on periods when U.S. Treasuries became a source of risk. The episodes examined include: the 2021 inflation surge (March to July 2021); the 2022 Federal

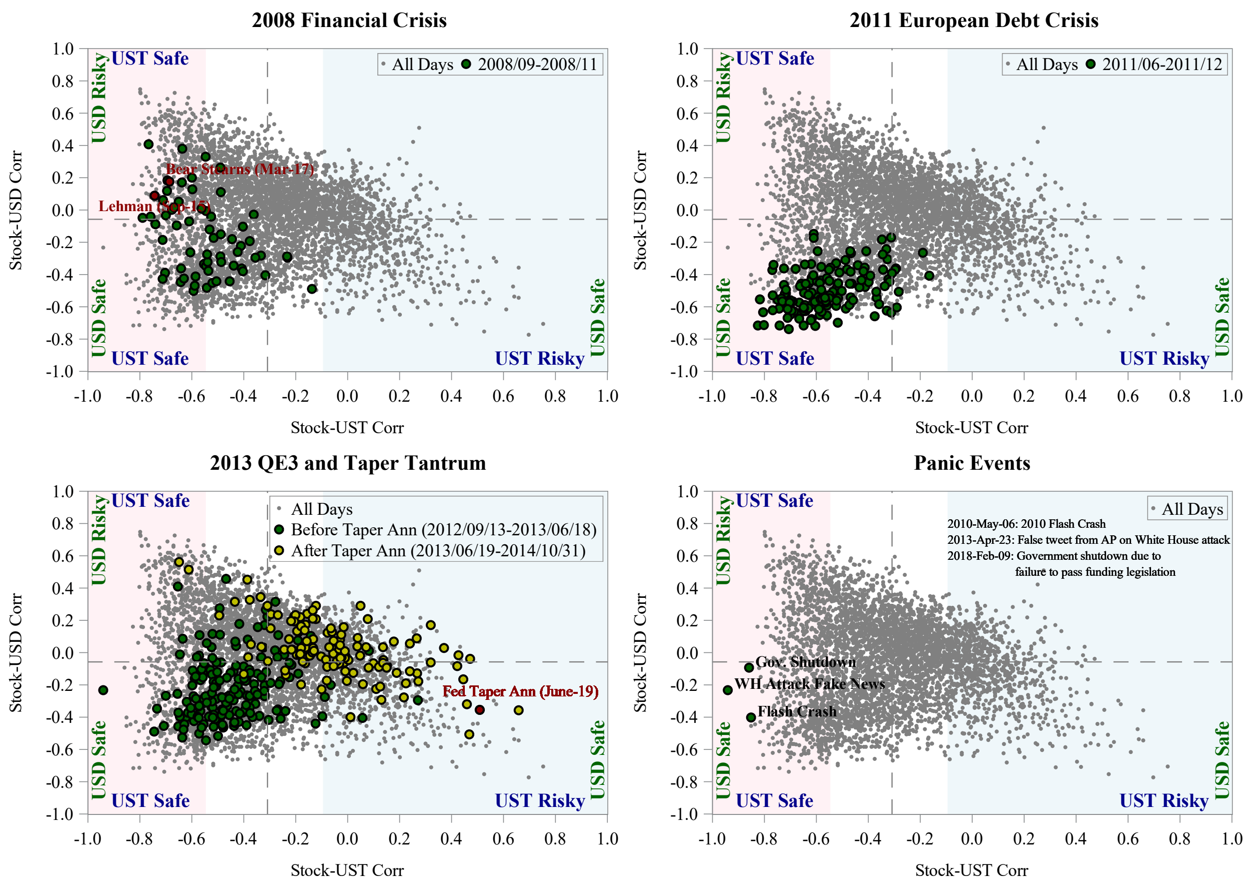
Table 3: **Performance of Key Assets on Dollar Safety and Risky Days**

Panel A: The number of bond and dollar safety and risky days

	Bond Safety	Dollar Safety	Over-lapped				Bond Risky	Dollar Risky	Over-lapped		
# Days	639	641	283			# Days	868	871	52		
Panel B: Asset performance on dollar safety and risky days						***Panel C: Asset Performance on bond safety and risky days***					
(a) Return	SPX	UST	DXY	EUR/USD	YEN/USD	***(a) Return***	SPX	UST	DXY	EUR/USD	YEN/USD
Dollar Safety	15.22***	-2.54	-1.20	1.98	-4.18	Bond Safety	-34.58***	13.18***	-3.72*	4.02	19.54***
(ex. bond safety)	[2.97]	[-1.22]	[-0.54]	[0.76]	[-1.58]	*(ex. dollar safety)*	[-6.91]	[7.95]	[-1.75]	[1.58]	[6.96]
Dollar Risky	-11.92***	8.37***	-4.66***	5.74***	8.67***	Bond Risky	13.89***	-6.38***	2.07	-1.70	-8.54***
(ex. bond risky)	[-3.14]	[6.18]	[-3.27]	[3.41]	[4.27]	*(ex. dollar risky)*	[4.54]	[-3.92]	[1.14]	[-0.81]	[-4.05]
(b) CAPM α	SPX	UST	DXY	EUR/USD	YEN/USD	***(b) CAPM*** α	SPX	UST	DXY	EUR/USD	YEN/USD
Dollar Safety		-1.40	1.85	-2.24	-2.40	Bond Safety		4.78***	-3.64*	3.51	7.97***
(ex. bond safety)		[-0.64]	[0.96]	[-0.96]	[-0.94]	*(ex. dollar safety)*		[3.43]	[-1.66]	[1.38]	[3.21]
Dollar Risky		5.53***	-3.93***	3.93**	4.79***	Bond Risky		-8.28***	3.59**	-4.81**	-10.25***
(ex. bond risky)		[4.54]	[-2.70]	[2.31]	[2.60]	*(ex. dollar risky)*		[-4.86]	[1.99]	[-2.34]	[-4.96]
(c) Δ***Implied Vol***	VIX	MOVE	DXYV	EURV	YENV	***(c)*** Δ***Implied Vol***	VIX	MOVE	DXYV	EURV	YENV
Dollar Safety	-0.19***	-0.30*	-0.06***	-0.06***	-0.06***	Bond Safety	0.50***	0.92***	0.08***	0.07***	0.18***
(ex. bond safety)	[-2.81]	[-1.71]	[-3.83]	[-3.60]	[-2.79]	*(ex. dollar safety)*	[5.83]	[4.67]	[4.27]	[3.85]	[4.86]
Dollar Risky	0.20***	0.17	0.02	0.01	0.04*	Bond Risky	-0.17***	-0.12	-0.03***	-0.03**	-0.04***
(ex. bond risky)	[3.11]	[1.29]	[1.44]	[1.02]	[1.95]	*(ex. dollar risky)*	[-3.98]	[-0.97]	[-2.93]	[-2.25]	[-2.83]

This table compares the performances of major assets on safety and risky days identified by ρ_t^{UST} and ρ_t^{USD}. The safety (risky) days contain the trading days with the bottom (top) 20% ρ_t^{UST} or ρ_t^{USD}. Panel A reports the distribution of safety and risky days identified by two measures. Panel B reports major asset classes' performances on dollar safety and risky days after excluding overlapped bond safety and risky days. Panel C reports major asset classes' performances on bond safety and risky days after excluding overlapped dollar safety and risky days. Definition of market returns and implied volatilities are the same as Table 2. The sample period is from January 2004 to June 2022. The t-statistics are reported in the square brackets and are based on the Newey-West standard errors.

Figure 7: **Bond as a Safety Destination**



This figure highlights the safe-haven role of U.S. Treasury during four representative periods of market stress. The x-axis shows the stock-UST correlation and the y-axis shows the stock-USD correlation. The stock-UST correlation (ρ_t^{UST}) and stock-USD correlation (ρ_t^{USD}) are estimated following equation (1) and (2). We examine four representative periods: (1) the peak of the 2008 financial crisis (September to November 2008), with major events highlighted in red; (2) the height of the 2011 European debt crisis (June to December 2011); (3) the third round of quantitative easing (QE3), spanning from September 13, 2012, to October 31, 2014; and (4) selected market panic events, including the 2010 Flash Crash (May 6, 2010), the false Associated Press tweet about a White House attack (April 23, 2013), and the government shutdown (February 9, 2018).

Reserve interest rate hike period (March to June 2022); the March 2020 "dash for cash" during the COVID-19 pandemic; and FOMC announcement days from January 2004 to June 2022. Both the 2021 inflation surge and the subsequent period when the Federal Reserve raised interest rates sharply from 0-25 bps to 150-175 bps within three months reflect times when market concerns were dominated by inflation risks and uncertainties in monetary policy. In these periods, movement in U.S. Treasury yields were driven by inflation and monetary policy shocks themselves, rather than merely reacting as the receiving end to risks originating in the equity markets. In fact, we observe many of the largest bond risk values on trading days within these periods, including 0.42 on June 10, 2021, when the CPI rose by 5.0% year-over-year; 0.70 on May 4, 2022, after a 50 bps Fed rate hike; and 0.53 on June 15, 2022, following a 75 bps rate hike.

Lastly, the March 2020 "dash for cash" provides a compelling example of the dual roles taken by U.S. Treasuries, with their status shifting abruptly. Prior to March 12, 2020, Treasuries functioned as typical safe-haven assets, attracting investors amidst the initial economic uncertainty brought on by the COVID-19 pandemic. However, on March 12, this dynamic reversed sharply as panic escalated. Faced with severe liquidity constraints and heightened uncertainty, investors began selling even traditionally safe assets like Treasuries, perceiving them as increasingly risky. This unprecedented sell-off, exacerbated by dealers' balance sheet constraints, led to a brief period of extreme market stress, during which Treasuries temporarily lost their appeal as investors prioritized cash above all else.

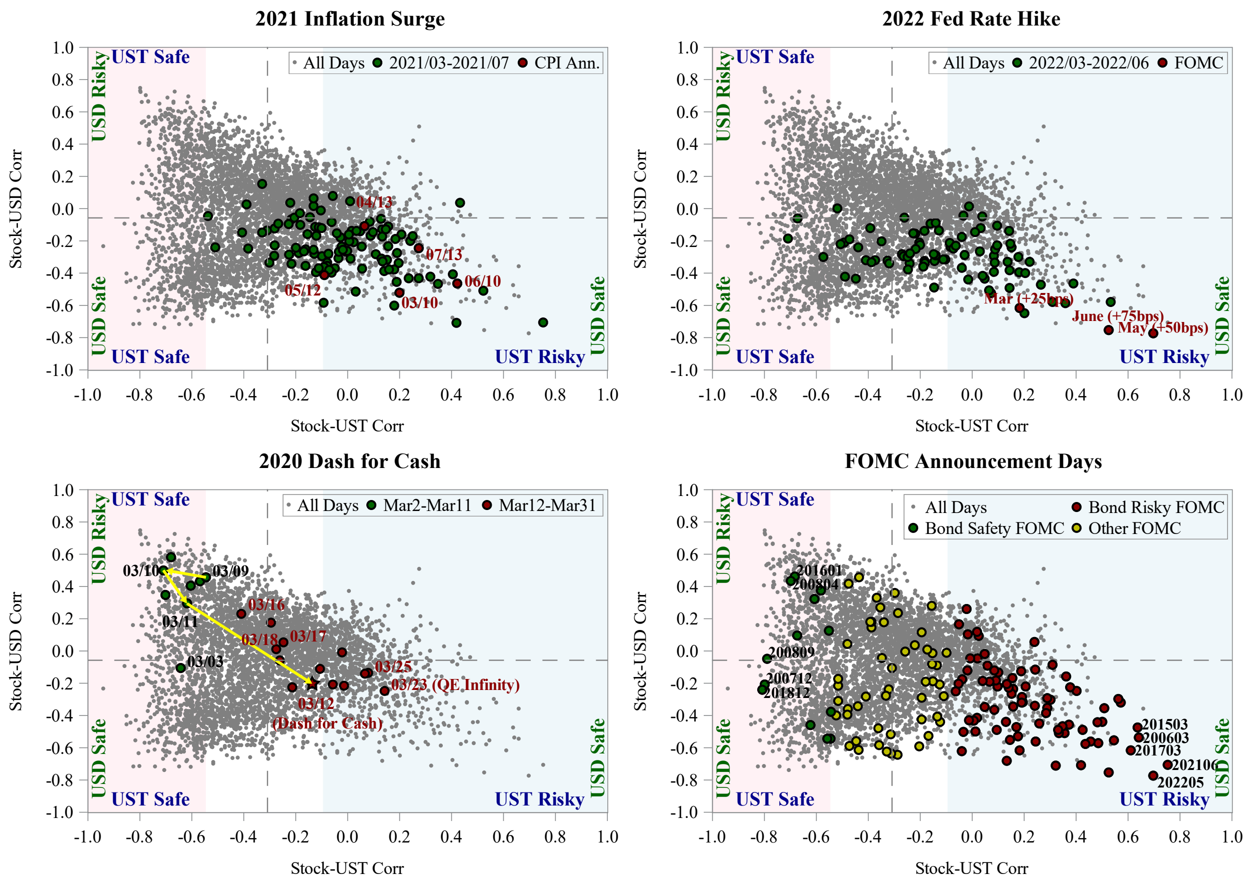
3. U.S. Treasury Bonds – Destination of Safety

In this section, we examine asset pricing dynamics on bond safety day. When U.S. Treasuries function as a flight-to-safety destination, their yield movement primarily reflect their role as safe-haven assets rather than changes in fundamental interest rates. This shift leads to distinctive patterns in global asset performance, the convenience yield of UST, and the relation between U.S. Treasuries and U.S. Dollar.

3.1. Performance of Global Assets

We start by examining the return performance of major global assets on the bond safety days captured by the stock-bond correlation measure ρ_t^{UST}. We consider five major global asset classes: (1) U.S. Treasury and fixed income assets (US Bond), including intermediate and long-term Treasury indexes, Agency, MBS, TIPS, investment-grade corporate bonds, and high-yield corporate bonds; (2) Exchange rates of the G10 currencies relative to the U.S. Dollar (FX); (3) Global bond indexes of the G10 countries (Global Bond) from Bloomberg

Figure 8: **Bond as a Source of Risk**



This figure shows four representative periods when U.S. Treasuries become a source of risk. The x-axis shows the stock-UST correlation and the y-axis shows the stock-USD correlation. The stock-UST correlation (ρ_t^{UST}) and stock-USD correlation (ρ_t^{USD}) are estimated following equation (1) and (2). The four periods analyzed are: (1) the inflation surge of 2021 (March to July 2021), with CPI announcement days highlighted in red; (2) the 2022 Federal Reserve interest rate hike period (March to June 2022), with FOMC meeting days marked in red and rate decisions in brackets; (3) the March 2020 "dash for cash" during the COVID-19 pandemic, with specific event days marked in green before March 12 and in red after March 12; and (4) FOMC announcement days from January 2004 to June 2022, marked in green for bond safety days, red for bond risky days, and yellow for other days.

Global Aggregate Index; (4) Global MSCI equity indexes of the G10 countries (Global Equity) in USD; (5) Major commodity indexes, including the WTI crude oil, gold, and the aggregate S&P GSCI commodity index (Commodity). The notation for the G10 countries is Australia (AU), Canada (CA), Denmark (DE), Germany (GR), Japan (JP), Norway (NO), New Zealand (NZ), Sweden (SW), Switzerland (SZ), and United Kingdom (UK).

In Figure 9, we compare the excess returns of global asset classes against their correlation with the U.S. equity index, which we use as a proxy for their relative safety.[11] Asset classes that exhibit strong positive correlations with the U.S. equity market, such as global equities and commodities, typically move in sync with it and are categorized as "risky". These are generally not considered safe havens during market downturns. Conversely, asset classes like U.S. fixed income and the Japanese Yen, which show negative return correlations with the U.S. equity market, are more likely to act as safe havens during periods of flight-to-safety.[12]

To allow for a fair comparison across asset classes with differing volatilities, we standardize excess returns by dividing them by their respective standard deviations over the full sample. Figure 9 reveals a striking monotonic decline in global assets returns relative to their safety on bond safety days. U.S. fixed income securities fetch the highest standardized returns, ranging from 0.14 to 0.34 standard deviations, while global equities perform the worst, with average excess returns between -0.30 to -0.15 standard deviations.[13] This clear monotonic pattern shows that global asset performance on bond safety days is primarily determined by their relative safety. In contrast, in the full sample, the returns of global asset classes show no significant relationship to their safety.

3.2. The UST Convenience Yield

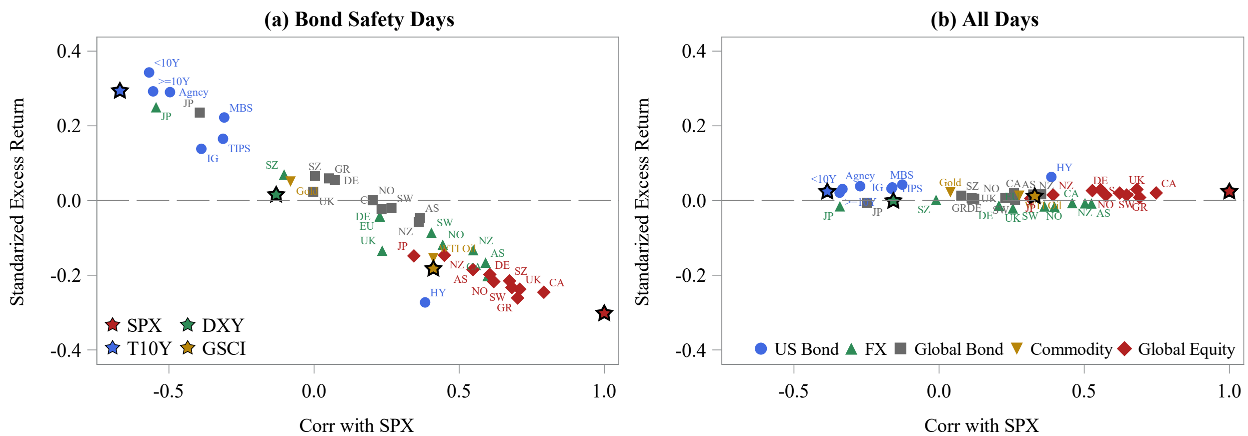
As highlighted in the works of Du, Im, and Schreger (2018) and Jiang, Krishnamurthy, and Lustig (2021), U.S. Treasuries often enjoy a special price premium relative to other risk-free rates, a phenomenon known as the Treasury specialness or "convenience" yield. Following

[11]In the plot, the correlations are estimated based on the daily returns from January 2004 to June 2022. For global equities and bonds, we calculate correlations of two-day cumulative returns (from $t-1$ to t, while the bond safety and risky days are determined by the stock-bond correlation measure ρ_t^{UST} at day t), and estimate the standardized return as the average of the return on day $t-1$ and t divided by the full sample standard deviation, to adjust for the time differences between the hours of the global markets and the U.S. market. As a robustness check, we also estimate the correlations as the single-day return correlation. The results remain similar.

[12]In Appendix F, we provide more detailed analysis on the performance of non-US G10 currencies and carry trades on bond safety days.

[13]The only exception is the high-yield corporate bonds with a standardized return of -0.27. Due to their high credit risk, high-yield corporate bonds have positive return correlation with the equity market and considered to be a risky asset class.

Figure 9: **Performance of Global Assets**



This figure plots the standardized excess returns of each global asset class against its correlation with the U.S. equity index on (a) bond safety days with bottom 20% ρ_t^{UST}; (b) full sample. Global assets include: (1) US Treasury and fixed income assets (US Bond, in blue). In this category, we include intermediate (maturity <10Y) and long-term (maturity >=10Y) Treasury indexes, and other major U.S. fixed income assets, including Bloomberg indexes of Agency, MBS, TIPS, investment-grade aggregate bond, high-yield aggregate bond. (2) Exchange rates of the G10 currencies relative to the U.S. Dollar (FX, in green). (3) Global bond indexes of the G10 countries (Global Bond, in gray) (4) Global MSCI equity indexes of the G10 countries in USD (Global Equity, in red). (5) Major commodity indexes, including the gold, WTI crude oil and the S&P GSCI commodity index (Commodity, in yellow). The notation for the G10 countries is Australia (AU), Canada (CA), Denmark (DE), Germany (GR), Japan (JP), Norway (NO), New Zealand (NZ), Sweden (SW), Switzerland (SZ), and United Kingdom (UK). For each asset class, we standardize the excess returns by their full sample standard deviations. The correlations are estimated based on the daily returns. For global equities and bonds, we calculate the correlations based on cumulative two-day returns from day $t-1$ to day t, and calculate returns as average of the excess returns on the day $t-1$ and t, to adjust for the time differences between the global markets and the U.S. market. The sample period spans from January 2004 to June 2022.

the convention in the literature, we focus on the Treasury basis as the main measure for Treasury convenience yield, which is calculated as the difference between the yield on a cash position in U.S. Treasuries y_t^{UST} and the synthetic FX-hedged dollar yield constructed from a cash position in a foreign government bond y_t^{Govt}:

$$\text{Basis}_t \equiv y_t^{\text{UST}} - y_t^{\text{Synt Govt}} = y_t^{\text{UST}} - (y_t^{\text{Govt}} - (f_t - s_t)), \tag{3}$$

where s_t denotes the log of the nominal exchange rate in units of foreign currency per dollar, f_t denotes the log of the forward exchange rate, $y_t^{\text{Synt Govt}} = y_t^{\text{Govt}} - (f_t - s_t)$ denotes the yield on a synthetic FX-hedged dollar yield constructed from a foreign government bond.[14]

Leveraging the high frequency nature of our safety measures, we examine the underlying drivers of the UST convenience yield through the perspective of the safe haven status of UST and USD. We estimate the following regression:

$$\Delta\text{Basis}_t = \text{intercept} + b_1^{\text{S}} \times \text{Safety}_t^{\text{UST}} + b_1^{\text{R}} \times \text{Risky}_t^{\text{UST}} + b_2^{\text{S}} \times \text{Safety}_t^{\text{USD}} + b_2^{\text{R}} \times \text{Risky}_t^{\text{USD}} + \epsilon_t, \tag{4}$$

where ΔBasis_t is the daily change of Treasury Basis, $\text{Safety}_t^{\text{UST}}$ ($\text{Risky}_t^{\text{UST}}$) is a dummy variable that takes value of one if day t is a bond safety (risky) day with the bottom (top) 20% ρ_t^{UST}. Similarly, $\text{Safety}_t^{\text{USD}}$ and $\text{Risky}_t^{\text{USD}}$ are dummy variables for the bottom and the top 20% USD safety and risky days based on ρ_t^{USD}.

In addition to the Treasury basis, we also consider two other alternative measures of Treasury convenience yields: the Covered-Interest Parity (CIP) adjusted UST Basis and Treasury Libor/Swap spreads.[15] CIP adjusted Treasury Basis is calculated by subtracting the Treasury basis with the CIP basis between the the dollar and the foreign currency; Treasury Libor/Swap spreads is the yield differences between the Treasury yield and Libor/Swap rate with same maturity. For both Treasury basis and CIP adjusted Treasury Basis, we calculate the spreads relative to the Japanese Yen (YEN) which is the most important global funding currency.[16]

Table 4 reports the regression results for the three proxies of Treasury convenience yield. The results indicate a significant negative shift in Treasury convenience yield on bond safety

[14]The U.S. and foreign government yields, as well as the spot and forward exchange rate changes, are sourced from Bloomberg, with Bloomberg tickers following Du and Schreger (2016) and Du, Im, and Schreger (2018), and are obtained from the author's website.

[15]We also examine another four measures of Treasury spreads relative to different risk-free rates: OIS spread, Refcorp spread, and the credit spread between the yields of the Bloomberg AAA bond index and the interpolated constant maturity Treasury yields with matched duration. The results remain similar.

[16]In unreported results, we also examine the average Treasury basis relative to the G10 currencies. The results remain similar, albeit with slightly smaller magnitudes.

Table 4: **Change of Treasury Convenience Yield on the Bond Safety Days**

	1-Year			5-Year		
	ΔUST Basis	ΔUST Basis (CIP Adj.)	ΔSwap Spreads	ΔUST Basis	ΔUST Basis (CIP Adj.)	ΔSwap Spreads
Bond Safety Days	-0.66***	-0.45***	-0.43***	-0.51***	-0.36***	-0.26***
	[-3.51]	[-3.07]	[-3.01]	[-4.04]	[-3.36]	[-2.76]
Bond Risky Days	0.10	0.03	-0.06	-0.07	-0.05	-0.08
	[0.93]	[0.35]	[-0.80]	[-0.74]	[-0.62]	[-1.26]
Dollar Safety Days	0.23	0.21*	0.14	0.07	0.13	0.14*
	[1.58]	[1.73]	[1.32]	[0.64]	[1.34]	[1.68]
Dollar Risky Days	0.05	0.12	0.14	-0.03	0.05	0.09
	[0.37]	[1.24]	[1.56]	[-0.24]	[0.57]	[1.23]
Intercept	0.07	0.02	0.04	0.11*	0.05	0.03
	[0.85]	[0.38]	[0.71]	[1.87]	[1.10]	[0.87]
NOBS	4423	4423	4423	4428	4428	4428
R2 (%)	0.55	0.37	0.40	0.47	0.29	0.31

This table reports the treasury convenience yield on the bond safety and risky days after controlling for dollar safety and risky days. We examine three UST convenience yield measures: (1) Treasury basis calculated as the difference between the U.S. Treasury yields (y_t^{UST}) and the FX-hedged synthetic dollar yields based on the Japanese government bonds denominated in Yen with the same maturity ($y_t^{\text{Synt Govt}}$) (2) CIP adjusted Treasury basis calculated as the Treasury basis ($y_t^{\text{UST}} - y_t^{\text{Synt Govt}}$) subtracted by the CIP basis between the U.S. dollar and the Japanese Yen ($y_t^{\text{Libor}} - y_t^{\text{Synt Libor}}$) (3) Libor/Swap spreads based on the difference between the Treasury yields (y_t^{UST}) and the Libor/Swap rates with the same maturity (y_t^{Libor}). Spreads are in unit of basis point. The sample period is from January 2004 to December 2021 due to the cessation of Libor at the end of 2021. The t-statistics are reported in the square brackets and are based on the Newey-West standard errors.

days, with average widening of the 1-year and 5-year Treasury convenience yield by 0.66 bps and 0.51 bps for the UST basis, 0.45 bps and 0.36 bps for CIP adjusted UST basis, and 0.43 bps and 0.26 bps for Libor/Swap spreads, respectively – all statistically significant at the 1% level.[17] This shows that on bond safety days, when the Treasury market acts as a safe haven, the unique safety attributes of UST amplify its specialness, resulting in wider spreads compared to other benchmark rates. In contrast, on bond risky days, when the Treasury market itself is perceived as risky, UST convenience yield shows no significant variation. It is also clear that the safety of UST, rather than the safety of USD, is the main driver of the UST convenience yield, as evidenced by the lack of significant movement in UST convenience yield on dollar safety or risky days. [18]

To further understand the key driver of the widening UST basis on bond safety days, we decompose the daily changes in the UST basis into two components: the changes in U.S. Treasury yields Δy^{UST} and the changes in the FX-hedged synthetic dollar yields based on Japanese government bonds $\Delta y^{\text{Synt Govt}} = \Delta y^{\text{FX}} - \Delta(f - s)$. As shown in Table 5, the widening of the UST basis on the bond safety days results from a larger decline in U.S. Treasury yields relative to the change in the synthetic dollar yields. Specifically, for the 1-year (5-year) maturity, U.S. Treasury yields decrease by an average of 1.02 (1.69) basis points, while the synthetic dollar yields drop by an average of 0.51 (1.30) basis points. Consequently, relative to the benchmark movement in the synthetic dollar yields, 1-year (5-year) U.S. Treasury yields experience an additional decrease of 0.51 (0.39) basis points on bond safety days. This additional decline in the U.S. Treasury yields underscores their unique role as a safe haven during times of market stress. In contrast, synthetic dollar bonds do not exhibit these safe haven characteristics on bond safety days.

To highlight the unique safe haven nature of U.S. Treasuries, we compare bond safety days with non-safety days that showed similar changes in Treasury yields. On non-safety days, where movements in Treasury yields are not driven by safe haven demand, synthetic dollar yields closely mirror those of U.S. Treasuries, resulting in insignificant changes in the Treasury basis. For example, on non-safety days, synthetic bond yields decline by an average of 0.88 (1.67) basis points for the 1-year (5-year) maturity, close to the 1.02 (1.69) basis drop in the U.S. Treasury yields, which lead to negligible variations in Treasury basis. Similarly, no significant changes in the Treasury basis are observed on non-safety days matched by the

[17] Although the widening of the UST basis is less than 1 bps on bond safety days, its economic magnitude is substantial. For comparison, the standard deviation of the daily changes in the 1-year and 5-year UST basis are 3.80 and 2.95 bps in our sample from 2004 to 2021.

[18] In our main results, we use Libor-based interest rate swaps and currency swaps, limiting the sample period to December 2021 due to the end of Libor usage at the end of that year. Our results remain robust whether we supplement the post-2021 period with SOFR-based rates or begin using SOFR starting from 2020.

Table 5: **Decomposition of Treasury Convenience Yield**

Panel A. Decomposition of 1-year ΔBasis		Decomposition #1		Decomposition #2	
	ΔUST Basis	Δy^{UST}	$\Delta y^{\text{FX}} - \Delta(f-s)$	$\Delta(y^{\text{UST}} - y^{\text{FX}})$	$\Delta(f-s)$
Bond Safety Days	-0.51***	-1.02***	-0.51***	-0.95***	0.44**
	[-3.16]	[-5.97]	[-2.62]	[-5.77]	[2.33]
Matched Days (without bond safety features)					
(1) by $\Delta y^{\text{UST(1y)}}$	-0.14	-1.02***	-0.88***	-0.95***	0.81***
	[-0.93]	[-6.17]	[-4.75]	[-6.07]	[4.69]
(2) by $R^{\text{UST(10y)}}$	0.23*	-0.09	-0.33**	-0.11	0.34**
	[1.81]	[-0.88]	[-2.37]	[-0.97]	[2.53]
(3) by R^{SPX}	-0.08	-0.34**	-0.25*	-0.29**	0.21
	[-0.59]	[-2.57]	[-1.87]	[-2.20]	[1.55]
(4) by ΔVIX	-0.07	-0.04	0.03	-0.06	-0.01
	[-0.57]	[-0.40]	[0.22]	[-0.55]	[-0.09]

Panel B. Decomposition of 5-year ΔBasis		Decomposition #1		Decomposition #2	
	ΔUST Basis	Δy^{UST}	$\Delta y^{\text{FX}} - \Delta(f-s)$	$\Delta(y^{\text{UST}} - y^{\text{FX}})$	$\Delta(f-s)$
Bond Safety Days	-0.39***	-1.69***	-1.30***	-1.40***	1.00***
	[-3.69]	[-9.13]	[-6.75]	[-7.74]	[5.47]
Matched Days (without bond safety features)					
(1) by $\Delta y^{\text{UST(5y)}}$	-0.02	-1.69***	-1.67***	-1.78***	1.76***
	[-0.21]	[-9.13]	[-9.08]	[-9.31]	[9.46]
(2) by $R^{\text{UST(10y)}}$	0.11	-1.08***	-1.19***	-1.10***	1.21***
	[1.13]	[-5.68]	[-6.25]	[-5.43]	[6.25]
(3) by R^{SPX}	-0.21*	-0.59***	-0.38**	-0.64***	0.43**
	[-1.91]	[-3.37]	[-2.27]	[-3.46]	[2.50]
(4) by ΔVIX	0.05	0.22	0.17	0.11	-0.05
	[0.50]	[1.04]	[0.79]	[0.49]	[-0.25]

This table presents the average daily changes in the 1-year and 5-year Treasury basis and their decomposed components on bond safety days and matched non-safety days. Daily changes in the Treasury basis, denoted as ΔUST Basis and calculated following Equation (3), are broken down into two parts: changes in the U.S. Treasury yield Δy^{UST} and changes in FX-hedged synthetic dollar yields based on Japanese government bonds $\Delta y^{\text{Synt Govt}} = \Delta y^{\text{FX}} - \Delta(f-s)$. Alternatively, it can be decomposed into the yield differential between U.S. Treasuries and Japanese government bonds $\Delta(y^{\text{UST}} - y^{\text{FX}})$ and changes in the hedging cost $\Delta(f-s)$. Additional statistics are provided for non-safety days, matched based on four market indicators: changes in U.S. Treasury yields $\Delta y^{\text{UST(1y)}}$ or $\Delta y^{\text{UST(5y)}}$, returns of the CRSP 10-year maturity index bonds $R^{\text{UST(10y)}}$, returns of the S&P 500 index R^{SPX}, and changes in the VIX index ΔVIX. All values are reported in basis points. The period covered is from January 2004 to December 2021, due to the end of Libor usage at the end of 2021. The t-statistics are reported in the square brackets and are based on the Newey-West standard errors.

daily return of the 10-year UST, the S&P 500 index, and changes in the VIX index.

Alternatively, the Treasury basis can be decomposed into the yield differential between U.S. Treasuries and Japanese government bonds, represented as $\Delta(y^{\text{UST}} - y^{\text{FX}})$, and changes in the hedging cost $\Delta(f - s)$. Table 5 shows that the widening of the Treasury basis is primarily due to a larger drop in the yield differential relative to the hedging costs. On bond safety days, the average drop in the yield differential between 1-year (5-year) U.S. Treasuries and Japanese government bonds is 0.95 (1.40) bps, while the hedging cost increases only 0.44 (1.00) bps. This larger drop in yield differentials is unique to bond safety days. On matched non-safety days, the yield differentials tend to move closely with hedging costs, leading to insignificant changes in Treasury basis.

Overall, our findings align with those of Du, Im, and Schreger (2018) and Jiang, Krishnamurthy, and Lustig (2021), both of which document a significant Treasury convenience yield. Our results, however, add an additional layer by showing that Treasury convenience yield widens significantly on bond safety days when Treasures act as the destination of flight-to-safety. In unreported results, we also examine the dynamics of the CIP basis on bond safety days. Consistent with the observation that safety demand for UST is the key driver of Treasury convenience yield on such days, we find that CIP basis, which doesn't have a Treasury component, shows insignificant changes.

3.3. *The Transmission of UST to USD*

In this subsection, we investigate the co-movement between the U.S. Treasury bonds and the U.S. dollar, focusing on how this co-movement varies in response to changes in the safety status of UST. During normal times, the yields of the UST tend to move in the same direction with the USD. Decreases (increases) in U.S. interest rates tend to drive global capital out of (into) the U.S., leading to a weakening (strengthening) of the USD. We examine how this strong UST-to-USD link changes under different UST safety status by estimating the following regression:

$$\begin{aligned} R_t^{\text{USD}} = {} & \text{intercept} + b^{\text{S}} \times \Delta y_t^{\text{UST}} \times \text{Safety}_t^{\text{UST}} + c^{\text{S}} \times R_t^{\text{SPX}} \times \text{Safety}_t^{\text{UST}} \\ & + b^{\text{R}} \times \Delta y_t^{\text{UST}} \times \text{Risky}_t^{\text{UST}} + c^{\text{R}} \times R_t^{\text{SPX}} \times \text{Risky}_t^{\text{UST}} \\ & + d^{\text{S}} \times \text{Safety}_t^{\text{UST}} + d^{\text{R}} \times \text{Risky}_t^{\text{UST}} + d^{\text{UST}} \times \Delta y_t^{\text{UST}} + d^{\text{SPX}} \times R_t^{\text{SPX}} + \epsilon_t, \end{aligned} \tag{5}$$

where R_t^{USD} is the return of the U.S. dollar index (DXY) on day t, $\text{Safety}_t^{\text{UST}}$ ($\text{Risky}_t^{\text{UST}}$) is a dummy variable that takes value of one if ρ_t^{UST} is in the bottom (top) 20% of the sample from January 2004 to June 2022, Δy_t^{UST} is the change of the 10-year U.S. Treasury constant maturity rate on day t, R_t^{SPX} is the daily return of the S&P 500 index on day t. The estimation results are reported at the left panel of Table 6.[19]

As expected, the relation between the change of the 10-year Treasury yields ($\Delta y_t^{\mathrm{UST}}$) and the USD return ($R_t^{\mathrm{USD}}$) is positive at normal times. The coefficient d^{UST} is estimated to be 1.52, positive and statistically significant with a t-stat of 6.96. The relation, however, changes on bond safety days when the UST is on the receiving end of a flight-to-safety in the equity market. The coefficient b^{S} for the interaction term of $\mathrm{Safety}_t^{\mathrm{UST}} \times \Delta y_t^{\mathrm{UST}}$ is estimated to be -1.39, negative and statistically significant with a t-stat of -2.79. This makes the contemporaneous relation between the U.S. Treasury bond yields and the U.S. dollar to be $-1.39 + 1.16 = -0.23$, which is close to zero and statistically insignificant. That is, the U.S. Treasury bonds do not move in tandem with the U.S. dollar anymore on the bond safety days with low ρ_t^{UST}, when the safe-haven nature of the U.S. Treasury bonds offset their normal co-movement due to the common interest rate exposure.

After establishing the above results for the U.S. dollar index, we move on to examine the relation between the U.S. Treasuries and the exchange rates of the U.S. dollar relative to individual currencies. We estimate the following panel regressions on the daily exchange rates of the USD relative to the G10 currencies,

$$\begin{aligned} R_t^{\mathrm{USD/i}} &= \text{intercept} + b^{\mathrm{S}} \times \Delta y_t^{\mathrm{UST}} \times \mathrm{Safety}_t^{\mathrm{UST}} + c^{\mathrm{S}} \times R_t^{\mathrm{SPX}} \times \mathrm{Safety}_t^{\mathrm{UST}} \\ &+ b^{\mathrm{R}} \times \Delta y_t^{\mathrm{UST}} \times \mathrm{Risky}_t^{\mathrm{UST}} + c^{\mathrm{R}} \times R_t^{\mathrm{SPX}} \times \mathrm{Risky}_t^{\mathrm{UST}} \\ &+ d^{\mathrm{S}} \times \mathrm{Safety}_t^{\mathrm{UST}} + d^{\mathrm{R}} \times \mathrm{Risky}_t^{\mathrm{UST}} + d^{\mathrm{UST}} \times \Delta y_t^{\mathrm{UST}} + d^{\mathrm{SPX}} \times R_t^{\mathrm{SPX}} + \epsilon_t, \end{aligned} \tag{6}$$

where $R_t^{\mathrm{USD/i}}$ is the return of the U.S. dollar relative to a G10 currency i on day t, and all other variables are defined in the same ways as Equation (5). The estimation results are reported at the middle panel of Table 6. The coefficient b^{S} for the interaction term of $\mathrm{Safety}_t^{\mathrm{UST}} \times \Delta y_t^{UST}$ is estimated to be -1.52, negative and statistically significant with a t-stat of -2.99. The magnitudes are also similar to those obtained in the time-series regression on the returns of the U.S. dollar index as specified by Equation (5).

Next, we examine how the UST safety affect the relation between foreign sovereign bond yields and exchange rates for non-US currencies. We estimate the following panel regression by replacing the U.S. Treasury and Equity indexes in Equation (6) with the local sovereign

[19] In Appendix G, we consider the regression model which further controls of USD safety. The results remain robust.

Table 6: **The Transmission of UST and USD**

yvar=	R_t^{USD} (1)	R_t^{USD} (2)	$R_t^{USD/Foreign}$ (3)	$R_t^{USD/Foreign}$ (4)		$R_t^{Foreign/USD}$ (5)	$R_t^{Foreign/USD}$ (6)
$\Delta y^{UST} \times$ Bond Safety		-1.39***		-1.52***	$\Delta y^{Local\ Bond} \times$ Bond Safety		1.71**
		[-2.79]		[-2.99]			[2.49]
$\Delta y^{UST} \times$ Bond Risky		1.89***		1.92***	$\Delta y^{Local\ Bond} \times$ Bond Risky		-2.18***
		[4.36]		[4.27]			[-4.80]
Δy^{UST}	1.52***	1.16***	1.62***	1.32***	$\Delta y^{Local\ Bond}$	1.66***	1.80***
	[6.96]	[4.43]	[3.97]	[3.06]		[8.15]	[6.65]
$R^{SPX} \times$ Bond Safety		0.04*		0.04*	$R^{Local\ Equity} \times$ Bond Safety		-0.05***
		[1.68]		[1.72]			[-2.76]
$R^{SPX} \times$ Bond Risky		-0.04		-0.02	$R^{Local\ Equity} \times$ Bond Risky		-0.01
		[-1.57]		[-0.88]			[-0.46]
R^{SPX}	-0.09***	-0.08***	-0.18***	-0.17***	$R^{Local\ Equity}$	0.06	0.06*
	[-7.65]	[-5.26]	[-3.97]	[-3.68]		[1.50]	[1.75]
Bond Safety	-0.11	-0.83	-1.01	-1.96	Bond Safety	-0.90	-0.38
	[-0.06]	[-0.41]	[-0.53]	[-1.08]		[-0.33]	[-0.14]
Bond Risky	1.63	0.75	1.23	0.08	Bond Risky	-3.33*	-2.24
	[0.85]	[0.38]	[0.73]	[0.04]		[-1.72]	[-1.15]
Intercept	0.36	0.27	-	-	Intercept	-	-
	[0.42]	[0.31]					
Currency FE	No	No	Yes	Yes	Currency FE	Yes	Yes
NOBS	4604	4604	46034	46034	NOBS	43890	43890
R2 (%)	4.97	6.46	8.48	9.24	R2 (%)	2.63	3.25

This table reports the additional comovement between the UST and the USD on the bond safety and risky days as specified by Equation (5), (6) and (7). The dependent variables are the daily returns of the dollar index (DXY) for the first two columns; the FX exchange rates quoted as the units of dollar per one foreign currency for the middle two columns; and the FX exchange rates quoted as the units of foreign currencies per one U.S. dollar for the last two columns. Major currencies of the G10 countries include Euro (EUR), Japanese Yen (YEN), British Pound (GBP), Canadian Dollar (CAD), Australian Dollar (AUD), New Zealand Dollar (NZD), Swiss Franc (CHF), Norwegian Krone (NOK), Swedish Krona (SEK) and Danish Krone (DKK). The detailed description of the local equity and treasury indexes for the G10 countries are listed in Appendix table H1. The sample period is from January 2004 to June 2022. The t-statistics are reported in the square brackets. For the time-series regressions reported in the first two columns, the t-statistics are based on the Newey-West standard errors. For the panel regressions reported in the last four columns, the t-statistics are based on double-clustered standard errors in currency and time dimensions.

bond and equity market indexes:

$$
\begin{aligned}
R_t^{\text{i/USD}} &= \text{intercept}_i + b^{\text{S}} \times \Delta y_t^{\text{Local Bond},i} \times \text{Safety}_t^{\text{UST}} + c^{\text{S}} \times R_t^{\text{Local Equity},i} \times \text{Safety}_t^{\text{UST}} \\
&+ b^{\text{R}} \times \Delta y_t^{\text{Local Bond},i} \times \text{Risky}_t^{\text{UST}} + c^{\text{R}} \times R_t^{\text{Local Equity},i} \times \text{Risky}_t^{\text{UST}} \\
&+ d^{\text{S}} \times \text{Safety}_t^{\text{UST}} + d^{\text{R}} \times \text{Risky}_t^{\text{UST}} + d^{\text{Bond}} \times \Delta y_t^{\text{Local Bond},i} \\
&+ d^{\text{Equity}} \times R_t^{\text{Local Equity},i} + \epsilon_{i,t},
\end{aligned} \tag{7}
$$

where $R_t^{\text{i/USD}}$ is the return of a G10 currency i relative to the U.S. dollar on day t, $\Delta y_t^{\text{Local Bond},i}$ is the change of the 10-year local sovereign bond yields of the country i on day t, $R_t^{\text{Local Equity},i}$ is the return of the local equity market index of the country i on day t, and all other variables are defined in the same ways as Equation (5). The full list of the local sovereign bond and equity indexes for the G10 countries are reported in the Appendix H.

The estimation results are reported at the right panel of Table 6. Different from the U.S. Treasuries, foreign countries' local sovereign bond yields co-move more strongly with their exchange rates on the bond safety days. The coefficient b^{S} for the interaction term of $\Delta y_t^{\text{Local Bond},i} \times \text{Safety}_t^{\text{UST}}$ is estimated to be 1.71, positive and statistically significant with a t-stat of 2.49. That is, on bond safety days, flight-to-UST pushes the exchange rates of the foreign currencies co-move more with their local sovereign bond yields. Interestingly, when the US Treasury market is perceived as risky on bond risky days, the exchange rates of foreign currencies no longer comove with their local bond yields, mirroring the dynamics of dollar and UST on bond safety days.

4. U.S. Treasury Bonds – Source of Risk

In this section, we explore the risky side of U.S. Treasuries by focusing on bond risky days. We begin by demonstrating that our bond risk measure effectively identifies bond stress days driven by interest rate risk or market illiquidity – a capability not shared by other existing market measures. Next, we examine the dynamics of the term premium, the comovement between U.S. Treasuries and the U.S. Dollar, and global asset returns. Lastly, we show a unique intraday lead-lag relation between the UST and the SPX, further confirming that the UST market is the source of risk on bond risky days.

4.1. Bond Market Stress Captured by Elevated ρ_t^{UST}

To assess whether our bond risk measure ρ_t^{UST} captures the riskiness of the UST market, we focus on days when the market is known to experience stress due to heightened interest rate risks or tightened constraints on dealers' balance sheet capacity. To analyze heightened interest rate risk days, we consider FOMC announcement days and the release days of FOMC meeting minutes, which provide details on the committee's discussion process. These days are further categorized into three groups based on the Fed's interest rate decisions: rate hikes, no change in rates, or rate cuts.[20] To analyze bond stressed days due to constrains on dealers' capacity, we focus on quarter-end and month-end dates, when dealers face balance-sheet reporting regulatory constraints (Duffie et al. 2023; Cochran et al. 2024). We also investigate Treasury auction days, particularly those with large offering size, which impose significant capacity challenges for dealers due to their obligations to intermediate in the primary market (Lou et al. 2013).[21]

Table 7 presents the changes in our bond risk measure on these bond stress days, using three metrics to capture abnormal levels: (1) the difference relative to the previous day's level, $\Delta\rho_t^{\text{UST}}$, (2) the difference relative to the 60-day moving average, $\rho_t^{\text{UST}} - \rho_{t-1}^{avg}$, and (3) the difference relative to the exponentially weighted moving average (EWMA) with a decay parameter of 0.94, $\rho_t^{\text{UST}} - \rho_{t-1}^{ewma}$. As shown in Table 7, our stock-bond correlation measure effectively captures the heightened risk in the UST market. On FOMC announcement days, the bond risk measure increases significantly by 0.30, 0.28, and 0.28 when compared to the previous day, the 60-day average, and the EWMA average, respectively. These increases are more pronounced for FOMC announcement days associated with rate hikes or unchanged rate decisions and are smaller, with marginal significance, for accommodative announcements involving rate cuts. Similarly, ρ_t^{UST} also rises on days when detailed FOMC meeting minutes are released, though the increases are more modest, ranging from 0.08 to 0.10. Interestingly, most of the increase in ρ_t^{UST} occurs on minutes release days for FOMC meetings with no rate changes, likely because these minutes are more informative compared to those associated with rate changes.

We observe similar increases in our bond risk measure on bond stress days driven by tightened constraints on dealers' capacity. On average, ρ_t^{UST} increases significantly by 0.04 to 0.09 on quarter-ends and by 0.03 to 0.05 on month-ends. We do not observe significant increases in the bond risk measure across all 10-year Treasury auction dates. However, for auctions with larger issuance sizes compared to the previous auction, the increase in ρ_t^{UST} turns large and statistically significant, ranging from 0.09 to 0.13.[22] These increases in

[20]During our sample period, there are 147 FOMC announcement days and 146 FOMC minutes release days. The FOMC meeting held on June 15, 2022, released its minutes on July 6, 2022, which falls outside our sample period.

[21]The dates and details of Treasury auctions are obtained from Treasury Direct. We include only auction days for regular 10-year Notes issuance (February, May, August, and November) and exclude the reopening ones that are usually with smaller issuance size (January and July).

[22]We observe a similar pattern of increased bond riskiness, albeit with smaller magnitudes, for 5-year Treasury auction days.

the bond risk measure become even more pronounced following the implementation of the Volcker Rule, which imposes stricter regulations on dealers' trading activities and balance sheet capacity. Post-Volcker, the increases in the bond risk measure are generally larger – often doubling – on bond stress days driven by constraints on dealers' capacity.

In contrast, we find that other existing measures could not capture the increased riskiness in the UST market on these bond stress days. We consider the following alternative measures of risk: (1) VIX, the implied volatility of the S&P 500 index; (2) MOVE, a yield curve-weighted average of Treasury implied volatility; (3) Noise, a funding liquidity measure based on Treasury market price deviations (Hu, Pan, and Wang 2013); (4) UST volatility, the realized volatility of 10-year Treasury futures based on 5-minute intraday returns; (5) SPX volatility, the realized volatility of E-mini S&P 500 index futures based on 5-minute intraday returns; and (6) alternative correlation measures based on the returns of SPX and 3-month EuroDollar futures (ρ_t^{UST3M}), SPX and 2-year Treasury futures (ρ_t^{UST2Y}), and SPX and USD (ρ_t^{USD}).

Compared to the significant increases observed in ρ_t^{UST}, none of the alternative measures consistently capture heightened bond market risk during stress days. The commonly used VIX and MOVE indexes, which are derived from the implied volatilities of traded options, often decrease rather than increase on FOMC announcement days due to the resolution of interest rate uncertainty. While the realized volatilities of UST ($\mathrm{Vol}_t^{\mathrm{UST}}$) and SPX ($\mathrm{Vol}_t^{\mathrm{SPX}}$), along with the illiquidity measure (Noise), spike on FOMC announcement days, these increases are primarily driven by market reactions to the news component of the announcements. Consequently, they fail to differentiate between FOMC announcements involving tightening rate decisions, which pose higher risks to the UST market, and those with accommodative rate decisions. Furthermore, most of these measures fail to capture more subtle increases in bond market risk on FOMC minutes release days, with the only exception being $\mathrm{Vol}_t^{\mathrm{UST}}$. These variables are also ineffective at detecting bond market risk on stress days driven by dealers' limited capacity. Although they often exhibit increases at month-ends, none show significant changes on quarter-ends or Treasury auction days.

Turning to other alternative correlation measures, we observe that the short-term Treasury correlation measures (ρ_t^{UST3M} and ρ_t^{UST2Y}) spike on FOMC announcement days and FOMC minutes release days but fail to capture elevated stress in the Treasury bond market on month-ends, quarter-ends, and Treasury auction days. In contrast, the correlation measures based on the USD (ρ_t^{USD}) typically decrease on these stress days, underscoring its inability in capturing bond market risk.

Table 7: **Increased Stock-Bond Correlation on Bond Market Stress Days**

		Bond risk measure ρ_t^{UST}			Other market variables					Alternative corr. measures		
	N	$\Delta\rho_t^{UST}$	$\rho_t^{UST} - \rho_{t-1}^{avg}$	$\rho_t^{UST} - \rho_{t-1}^{ewma}$	ΔVIX_t	$\Delta MOVE_t$	$\Delta Noise_t$	ΔVol_t^{UST}	ΔVol_t^{SPX}	$\Delta\rho_t^{UST3M}$	$\Delta\rho_t^{UST2Y}$	$\Delta\rho_t^{USD}$
Panel A. Days with heightened interest rate risks												
FOMC Announcement Days	147	0.30***	0.28***	0.28***	-0.52***	-2.30***	0.07***	2.19***	2.66**	0.23***	0.19***	-0.21***
		[10.18]	[10.20]	[10.71]	[-3.26]	[-6.63]	[2.92]	[6.53]	[5.60]	[7.08]	[7.28]	[-8.42]
rate hike	29	0.30***	0.32***	0.32***	-0.66**	-2.26***	0.10*	2.43***	2.94***	0.19***	0.24***	-0.24***
		[5.63]	[5.81]	[6.09]	[-2.13]	[-3.83]	[1.72]	[6.75]	[2.72]	[3.15]	[3.15]	[-5.15]
rate unchanged	107	0.31***	0.27***	0.28***	-0.42**	-1.83***	0.06**	2.09***	2.17***	0.24***	0.18***	-0.19***
		[9.64]	[9.04]	[9.57]	[-2.28]	[-5.35]	[2.26]	[5.01]	[3.95]	[6.65]	[6.83]	[-6.82]
rate cut	11	0.18*	0.23*	0.22*	-1.19	-6.91***	0.11**	2.57***	6.66***	0.30***	0.14	-0.28***
		[1.74]	[1.85]	[1.87]	[-1.31]	[-2.89]	[2.16]	[5.08]	[4.15]	[2.96]	[1.09]	[-3.25]
FOMC Minutes Release	146	0.10***	0.08***	0.08***	-0.09	0.18	-0.03	0.44**	0.07	0.07**	0.07***	-0.06***
		[3.39]	[3.46]	[3.60]	[-0.99]	[0.78]	[-1.34]	[2.24]	[0.15]	[2.17]	[2.68]	[-2.92]
rate hike	28	0.06	0.05	0.05	-0.17	0.45	-0.06	0.79**	0.33	0.05	0.07	-0.04
		[1.14]	[1.05]	[1.19]	[-1.33]	[0.90]	[-0.94]	[2.25]	[0.38]	[0.99]	[1.12]	[-1.01]
rate unchanged	107	0.13***	0.11***	0.11***	-0.09	0.18	-0.02	0.42*	-0.14	0.10***	0.08***	-0.08***
		[3.90]	[3.76]	[3.96]	[-0.86]	[0.75]	[-1.07]	[1.76]	[-0.21]	[2.78]	[2.68]	[-3.28]
rate cut	11	-0.12***	-0.08	-0.08*	0.06	-0.42	0.00	-0.27	1.55	-0.14***	-0.01	0.07
		[-4.68]	[-1.55]	[-1.83]	[0.08]	[-0.25]	[0.09]	[-0.25]	[1.40]	[-2.95]	[-0.15]	[1.52]
Panel B. Days with tightened constraints on dealers' balance-sheet capacity												
Quarter End	74	0.04**	0.09***	0.07***	-0.17	0.27	0.04	0.10	-0.96	0.02	0.01	0.00
		[1.97]	[3.65]	[3.19]	[-0.83]	[1.11]	[0.98]	[0.30]	[-1.10]	[0.74]	[0.31]	[0.18]
post Volcker Rule	28	0.09***	0.10***	0.08***	-0.50**	-0.09	0.08	-0.08	0.49	0.09**	0.02	-0.01
		[2.98]	[3.02]	[2.61]	[-1.98]	[-0.19]	[1.13]	[-0.28]	[0.56]	[1.99]	[0.43]	[-0.39]
Month End (ex. Qtr End)	148	0.03*	0.04**	0.05***	0.40***	0.59**	0.05**	1.92***	0.42	0.00	-0.02	-0.03*
		[1.84]	[2.38]	[3.21]	[3.77]	[2.28]	[2.46]	[3.63]	[0.64]	[0.05]	[-0.99]	[-1.75]
post Volcker Rule	56	0.06*	0.08***	0.09***	0.50***	0.87**	0.03	0.15	0.60	-0.03	0.00	-0.05*
		[1.89]	[3.42]	[4.32]	[2.68]	[2.12]	[1.23]	[0.22]	[0.93]	[-0.77]	[0.12]	[-1.68]
10Y UST Auctions	74	0.00	-0.01	0.00	0.32	-0.12	-0.03	0.32	-0.53	-0.02	0.01	-0.01
		[0.22]	[-0.44]	[-0.13]	[1.19]	[-0.27]	[-0.88]	[1.05]	[-0.58]	[-0.98]	[0.35]	[-0.25]
with Increased Off. Amt.	14	0.13***	0.09***	0.09**	0.06	-1.37	-0.16	-0.75	-6.18*	0.04	0.10**	-0.07*
		[2.64]	[2.88]	[2.57]	[0.11]	[-1.09]	[-1.62]	[-1.40]	[-1.86]	[0.71]	[2.38]	[-1.73]
post Volcker Rule	7	0.22**	0.13***	0.12***	-0.13	-0.69	0.02	-0.87	-9.59	0.05	0.19***	-0.07
		[2.56]	[2.91]	[2.77]	[-0.14]	[-1.27]	[0.88]	[-1.00]	[-1.60]	[0.34]	[3.20]	[-1.15]

This table reports changes in the bond risk measure, ρ_t^{UST}, on bond stress days. Panel A focuses on days with heightened interest rate risks, while Panel B examines days with tightened constraints on dealers' balance sheet capacity. Days with heightened interest rate risks include: (1) FOMC announcement days, further categorized into three groups based on the Federal Reserve's decisions (rate hikes, no changes, or rate cuts); and (2) FOMC minutes release days. Days with tightened constraints on dealers' balance sheet capacity include: (1) quarter-ends, the final trading day of each calendar quarter; (2) month-ends, the final trading day of each month, excluding those that are also quarter-ends; and (3) 10-year Treasury auction days, with a focus on those featuring larger offering sizes than the previous auction. For bond stress days driven by constrained dealer intermediation, we also report results for the period after the Volcker Rule became fully effective on July 21, 2015. The variables ρ_{t-1}^{avg} and ρ_{t-1}^{ewma} represent, respectively, the 60-day simple moving average and the exponentially weighted moving average (with a decay parameter of 0.94) of ρ_t^{UST} as of day $t-1$. The sample period spans from January 2004 to June 2022. T-statistics, reported in square brackets, are computed using Newey-West standard errors.

4.2. The UST Term Premium

Next, we examine the pricing in the Treasury market on bond safety and risky days. Our focus is on the Treasury term premium, which is the risk premium compensating investors for bearing the risk of long-term bonds. Since the term premium cannot be directly observed, we rely on the daily term premium estimated based on two different models: Adrian, Crump, and Moench (2013) (hereafter referred as ACM) and Kim and Wright (2005) (hereafter referred as KW). [23]

To understand the dynamics of the term premium on bond safety and risky days, we estimate the following regression:

$$\Delta \text{Term Premium}_t = \text{intercept} + b^{\text{S}} \times \text{Safety}_t^{\text{UST}} + b^{\text{R}} \times \text{Risky}_t^{\text{UST}} + \text{controls}_t + \epsilon_t, \quad (8)$$

Here, $\Delta\text{Term Premium}_t$ is the daily change of ACM or KW term premiums, $\text{Safety}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t is a bond safety day with the bottom 20% ρ_t^{UST}, $\text{Risky}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t is a bond risky day with the top 20% ρ_t^{UST}. To highlight the unique impact of ρ_t^{UST} on term premiums, we add several controls in the regression model, including flight-to-safety dummy days proposed by Baele, Bekaert, Inghelbrecht, and Wei (2019), Federal Open Market Committee (FOMC) announcement days, SPX worst and best 20% performance days, VIX top and bottom 20% days, change of the Treasury market illiquidity measure (Noise) proposed by Hu, Pan, and Wang (2013), and change of realized volatility of most liquid 10-year Treasury futures.

Table 8 shows drastically different dynamics of the term premium on bond safety and risky days. On bond risky days with elevated ρ_t^{UST}, with the Treasury market itself becoming a source of risk, the term premium rises as investors demand higher returns for taking on future interest rate uncertainties. This leads to an increase of 0.45 basis points (t-stat=2.31) in the ACM term premium and 0.37 basis points (t-stat=3.40) in the KW term premium. In contrast, on normal days, the term premium shows near zero change (0.06 or 0.07 basis points). By comparison, on bond safety days with low ρ_t^{UST}, the U.S. Treasury's role as a safe haven offsets the term premium, resulting in a significant reduction of 0.99 basis points (t-stat=4.71) in the ACM term premium and 0.84 basis points (t-stat=8.06) in the KW term premium.

The impact of ρ_t^{UST} on Treasury term premium remains robust when accounting for other factors. The FTS dummy, an alternative flight-to-safety measure proposed by Baele,

[23]Daily ACM term premium based on Adrian, Crump, and Moench (2013) is from the website of Federal Reserve Bank of New York. Daily KW term premium based on Kim and Wright (2005) is from the website of Board of Governors of the Federal Reserve.

Table 8: **10-Year Treasury Term Premiums on Bond Safety and Risky Days**

	Panel A: Adrian, Crump, and Moench (2013)					***Panel B: Kim and Wright (2005)***				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Bond Safety Days	-0.99***	-0.82***	-0.99***	-0.59***	-0.63***	-0.84***	-0.63***	-0.84***	-0.58***	-0.51***
	[-4.71]	[-3.78]	[-4.72]	[-2.91]	[-2.94]	[-8.06]	[-5.52]	[-8.05]	[-5.64]	[-4.74]
Bond Risky Days	0.45**	0.44**	0.50**	0.45**	0.53***	0.37***	0.35***	0.41***	0.36***	0.42***
	[2.31]	[2.22]	[2.55]	[2.28]	[2.74]	[3.40]	[3.20]	[3.74]	[3.17]	[3.79]
FTS by Baele et al. (2019)		-1.97*			-0.81		-2.38***			-1.64***
		[-1.82]			[-0.82]		[-7.52]			[-5.18]
FOMC			-0.61		-0.90*			-0.46		-0.51*
			[-1.11]		[-1.67]			[-1.53]		[-1.74]
SPX Worst 20%				-1.60***	-1.70***				-1.13***	-1.05***
				[-5.60]	[-6.50]				[-8.90]	[-8.46]
SPX Best 20%				1.97***	1.88***				0.86***	0.80***
				[8.57]	[8.11]				[8.02]	[7.73]
VIX Top 20%					0.32					0.14
					[1.11]					[0.89]
VIX Bottom 20%					-0.30**					-0.21**
					[-2.03]					[-2.33]
ΔNoise					1.63***					0.14
					[2.99]					[0.59]
ΔTYF Vol					0.00					-0.01
					[0.09]					[-0.48]
Intercept	0.06	0.08	0.07	-0.10	-0.02	0.07	0.09	0.07	0.07	0.11
	[0.60]	[0.77]	[0.71]	[-1.00]	[-0.19]	[1.22]	[1.59]	[1.38]	[1.26]	[1.64]
NOBS	4570	4570	4570	4570	4557	4570	4570	4570	4570	4557
R2 (%)	0.81	1.13	0.86	5.3	5.99	2.42	4.36	2.51	8.23	9.23

This table shows the change of term premiums on bond safety (bottom 20% ρ_t^{UST}) and bond risky (top 20% ρ_t^{UST}) days following regression (8). Panel A shows the results of term premium measures estimated by Adrian, Crump, and Moench (2013), and Panel B shows results of term premium measures estimated Kim and Wright (2005). Control variables include (1) flight-to-safety dummy days proposed by Baele, Bekaert, Inghelbrecht, and Wei (2019) (2) Federal Open Market Committee (FOMC) announcement days (3) days with worst and best 20% performance of S&P 500 index returns (4) days with top and bottom 20% VIX index (5) daily changes of the Noise measure proposed in Hu, Pan, and Wang (2013) (in unit of basis point) (6) daily change of the annualized realized volatility estimated based on the 5-minute intra-day returns and 4pm-9:30am overnight return of most liquid 10-year Treasury futures traded on CME following Bollerslev, Tauchen, and Zhou (2009) (in unit of percent). The daily change of term premium is in unit of basis points. The sample period is from January 2004 to June 2022. The t-statistics are reported in the square brackets and are based on the Newey-West standard errors.

Bekaert, Inghelbrecht, and Wei (2019), also indicates a term premium decrease (-1.97 bps for ACM and -2.38 bps for KW) but does not subsume the impact of our bond risk measure ρ_t^{UST}. Equity market returns have a notable impact on the term premium, with a significant drop (-1.60 bps for ACM and -1.13 bps for KW) during market crashes and a significant increase (1.97 bps for ACM and 0.86 bps for KW) during market recoveries. After adjusting for equity market returns and other factors, the impact of ρ_t^{UST} persists, showing an increase of 0.53 bps (ACM) and 0.42 bps (KW) on bond risky days and an decrease of -0.63 bps (ACM) and -0.51 bps (KW) on bond safety days.

4.3. Amplified Transmission from UST to USD

On the bond risky days featured by heightened interest-rate risk, the transmission from UST to USD further strengthened. As shown in Table 6, the coefficient for the interaction term of $\text{Risky}_t^{\text{UST}} \times \Delta y_t^{\text{UST}}$ is estimated to be 1.89, positive and statistically significant with a t-stat of 4.36. This implies that the sensitivity of USD to UST reaches $1.89 + 1.16 = 3.05$ on bond risky days, which is almost three times of its normal level. This strengthened linkage between UST and USD stands in sharp contrast to bond safety days, when their comovement breaks down due to flight-to-UST.

Since bond risky days are marked by significantly negative UST returns (increase in UST yields), our results suggest that USD appreciates relatively more significantly and replaces UST as the safe assets on these days. Indeed, the average USD safety measure ρ_t^{USD} is around -0.12 on bond risky days, significantly lower than its full-sample average of -0.06. An example of this shift in safety asset occurs during the 2021-2022 inflation surge, when the rapid monetary-policy tightening turns UST into a source of risk. The stock-USD correlation measure ρ_t^{USD} drops quickly to an average level of -0.21 during March 2021 to June 2022. In Appendix G, we provide further discussions on the relation between ρ_t^{UST} and ρ_t^{USD} with additional controls of market conditions.

4.4. A Two-Factor Model of Stock and Bond

On bond risky days, when U.S. Treasuries themselves become a source of risk, we expect that the bond market factor will play a significant role in explaining global asset returns. To test this, we compare the explanatory power of a two-factor model (market and bond) against the one-factor CAPM model (market only) based on the following regressions:

$$\begin{aligned} R_{i,t} - R_{f,t} &= \text{intercept}_i + b_{1,i} \times (R_t^M - R_{f,t}) + b_{2,i} \times (R_t^{\text{UST}} - R_{f,t}) + \epsilon_{i,t}, \\ R_{i,t} - R_{f,t} &= \text{intercept}_i + b_{1,i} \times (R_t^M - R_{f,t}) + \epsilon_{i,t} \end{aligned} \tag{9}$$

Here, $R_{i,t}$ represents the return of asset i on day t, and $R_{f,t}$ is the risk-free rate. The market factor, R_t^M, is the CRSP value-weighted U.S. equity market return, while the bond factor, R_t^{UST}, is the return of the CRSP Fixed Term index at the 10-year maturity. The global assets analyzed include major currencies, global equities, global bonds and major commodity indices discussed in Section 3.1, excluding U.S. fixed-income assets due to their obvious improvement under the two-factor model. The R-squared differences between the two-factor model and the one-factor CAPM model are plotted in Figure 10, shown separately for bond risky days and bond safety days.[24]

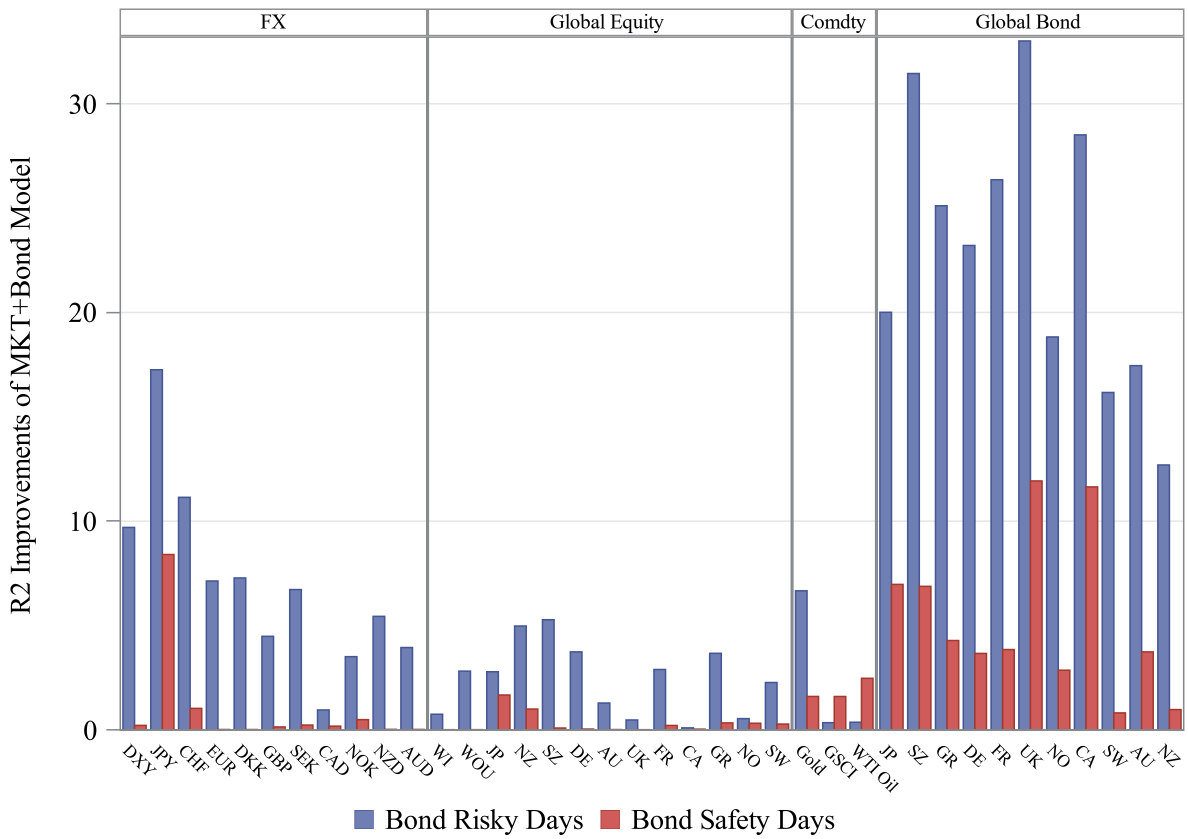
Our analysis reveals that the two-factor model significantly outperform the CAPM model on bond risky days, especially for currencies, global equities and commodities. Among non-U.S. G10 currencies, the R-squared improvement provided by the two-factor model exhibits a monotonic relationship with interest rate differentials, ranging from 17.25% for low-yield funding currencies like the Japanese Yen to 3.94% for high-yield asset currencies such as the Australian Dollar. For the Dollar Index (DXY), the two-factor model achieves a substantial R-squared increase of 9.70% compared to the CAPM model. Similarly, the tow-factor model improves explanatory power for global equities, with R-squared gains between 0.08% and 5.27%, and for commodities, with improvements ranging from 0.34% to 6.66%. These results indicate that on bond risky days, when U.S. Treasuries themselves become a source of market uncertainty, they emerge as a key driver of global asset returns.

Interestingly, on bond safety days, where UST movements are largely driven by safety demand in response to equity market risks, incorporating a bond factor adds only marginal explanatory power. For most assets, the R-squared improvement remains below 2.47%. The notable exception is the Japanese Yen, which, as a prominent safe-haven currency for global investors, stands out as an outlier and exhibits a 8.40% increase in R-squared on bond safety days.

Lastly, we also observe a sharp increase in the explanatory power of the two-factor model for global bonds, which is not surprising, given their fixed income characteristics. More interestingly, the improvement of R-squared is significantly higher on bond risky days, ranging from 12.69% to 33.01%, compared with those on bond safety days, in the range from 0.81% to 11.93%. The disproportionally higher increase in the R-squared further confirm the dominance of interest rate risks on bond risky days.

[24]To account for time zone differences between global markets and the U.S. market and to maintain consistency across asset classes, we preform all tests using three-day cumulative returns (from $t-1$ to $t+1$) while the bond safety and risky days are determined by the stock-bond correlation measure ρ_t^{UST} at day t.

Figure 10: **Improvement in R2 of Two-Factor Model on Bond Risky Days**



This figure shows the improvements in explanatory power of a two-factor model (market + bond) over a one-factor model (market only) for global assets on bond safety and risky days. The two-factor model includes both the CRSP U.S. equity value-weighted market return and the U.S. 10-year Treasury return, while the one-factor model includes only U.S. equity market returns. The improvement in bond explanatory power is represented by the R-squared difference between the two-factor and one-factor models. Global assets considered include: (1) FX: the Dollar Index (DXY) and exchange rates of the G10 currencies relative to the U.S. Dollar; (2) MSCI global equity indexes of the G10 countries in USD, plus the World Index (WI) and World ex-U.S. Index (WOU); (3) major commodity indexes, including gold, WTI crude oil, and the S&P GSCI Commodity Index; and (4) Global bond indexes of the G10 countries. The G10 countries are designated as Australia (AU), Canada (CA), Denmark (DE), Germany (GR), Japan (JP), Norway (NO), New Zealand (NZ), Sweden (SW), Switzerland (SZ), and the United Kingdom (UK). To account for time zone differences between global markets and the U.S. market and to maintain consistency across asset classes, we preform all tests using three-day cumulative returns (from $t-1$ to $t+1$) while the bond safety and risky days are determined by the stock-bond correlation measure ρ_t^{UST} at day t.

4.5. UST as the Source of Risk: UST Leading SPX in Intraday Pricing

By exploring the intraday lead-lag relation between SPX and UST, we provide further evidence that the UST market becomes the source of risk on bond risky days. In particular, we perform the following regression to estimate the intraday lead-lag relation between UST and SPX:

$$R_{i+1,t}^{\text{SPX/UST}} = \text{intercept} + b_1 \times R_{i,t}^{\text{SPX}} + b_2 \times R_{i,t}^{\text{UST}} + \epsilon_{i,t}, \tag{10}$$

Where $R_{i,t}^{\text{SPX}}$ and $R_{i,t}^{\text{UST}}$ are the i^{th} 5-minute returns of the most liquid E-mini S&P 500 index futures and the 10-year Treasury futures on day t. The dependent variable $R_{i+1,t}^{\text{SPX/UST}}$ is the next 5-minute $(i + 1^{th})$ returns of either SPX or UST. We include only intraday 5-minute returns during the regular trading hours from 9:30 AM to 4:00 PM Eastern Time.

Table 9: **Intrady Lead-lag Relation Between SPX and UST Returns**

	Bond Risky Days		**Non-Bond Risky**		**Full Sample**	
	$R_{i+1,t}^{\text{SPX}}$	$R_{i+1,t}^{\text{UST}}$	$R_{i+1,t}^{\text{SPX}}$	$R_{i+1,t}^{\text{UST}}$	$R_{i+1,t}^{\text{SPX}}$	$R_{i+1,t}^{\text{UST}}$
$R_{i,t}^{\text{SPX}}$	-0.03**	0.01	-0.02**	-0.01***	-0.02**	-0.01***
	[-2.58]	[1.63]	[-2.29]	[-7.91]	[-2.38]	[-4.26]
$R_{i,t}^{\text{UST}}$	0.15***	-0.03**	-0.01	-0.08***	0.03	-0.06***
	[2.65]	[-2.05]	[-0.40]	[-11.54]	[1.46]	[-7.56]
Intercept	0.08**	-0.03**	-0.01	0.02***	0.01	0.01*
	[2.51]	[-2.33]	[-0.42]	[2.87]	[0.29]	[1.84]
NOBS	70,147	69,992	283,174	282,891	353,331	352,893
R2 (%)	0.39	0.11	0.04	0.50	0.05	0.34

This table reports the lead-lag relations between intraday 5-min returns of SPX and UST. $R_{i,t}^{\text{SPX}}$ and $R_{i,t}^{\text{UST}}$ are the i^{th} 5-minute returns of the most liquid E-mini S&P 500 index futures and the 10-year Treasury futures on day t. $R_{i+1,t}^{\text{SPX/UST}}$ is the next 5-minute $(i+1^{th})$ returns of SPX or UST. We only consider intraday 5-minute returns during the regular trading hours from 9:30 AM to 4:00 PM Eastern Time. Bond risky days are days with top 20% bond risk measure ρ_t^{UST}. The sample period spans from January 2004 to June 2022. The t-statistics are reported in the square brackets and are based on the standard errors clustered by calendar time.

Table 9 reports the intraday lead-lag relationship between UST and SPX returns across bond risky days, non-bond risky days, and the full sample. The results support the hypothesis that U.S. Treasuries act as a primary source of risk on bond risky days. Specifically, only on bond risky days do UST returns lead SPX returns, while the reverse relationship is absent. A one basis point increase in UST returns significantly predicts a 0.15 basis point increase in SPX returns (t-stat = 2.65). Conversely, SPX returns show no significant predictive power over UST returns, with an estimated impact of just 0.01 basis points and an insignificant t-stat of 1.63. These findings suggest that on bond risky days, the UST market drives risk dynamics, playing a leading role over the equity market.

Outside of bond risky days, the relationship shifts. SPX returns negatively predict UST returns, while UST returns have no significant predictive power over SPX. This suggests that the equity market dominates on non-bonds risky days. However, this leading effect of SPX over UST is quite small in magnitude, with an estimated impact of just -0.01. These observations further underscore the unique risk dynamics on bond risky days, as captured by our stock-bond correlation measure.

5. Conclusions

Using intraday high-frequency returns of the S&P 500 Index and 10-year U.S. Treasury futures, we construct a daily UST risk measure based on the stock-bond correlation ρ_t^{UST}. This measure effectively captures the dual roles of U.S. Treasuries: as a safe-haven destination and as a source of risk. Our findings reveal strong evidence of flight-to-safety on the bottom 20% of trading days with highly negative ρ_t^{UST} (bond safety days). These days are marked by significant declines in SPX returns and UST yields, appreciation of the Japanese Yen against the USD, increased volatility in equities and major currencies, and a pronounced shift in investor holdings from SPX to UST. Conversely, on the top 20% of days with highly positive ρ_t^{UST}, the Treasury market itself becomes a source of risk, characterized by increased uncertainty and deteriorating liquidity (bond risky days). Our bond risk measure effectively identifies stress in the bond market arising from heightened interest rate risk, inflation risk, or dealer capacity constraints – an advantage not shared by other existing market measures.

The distinct nature of risks results in very different asset pricing dynamics on bond safety and risky days. On bond safety days, safety dominates, and global asset pricing is driven by relative safety rather than fundamental risks. Within the UST market, flight-to-safety widens the convenience yield of Treasuries and disrupts the usual correlation between the USD and UST. On bond risky days, however, we observe a sharp increase in the term premium, a strengthening of the link between UST and USD, and a unique pattern where UST leads SPX in intraday returns. As bond risk becomes the dominant factor on these days, a two-factor model incorporating both stocks and bonds significantly outperforms the traditional one-factor CAPM model for global asset returns.

Going forward, amid increased concern over the resilience of the U.S. Treasury market, both the market participants and regulators need better surveillance tools for this extremely important market. Compared with the existing measures designed to gauge the liquidity and uncertainty of the U.S Treasury market, our high-frequency measure of stock-bond correlation is unique in that it can capture both UST safety and, more importantly, UST riskiness, and with opposite signals. As such, our measure is well suited to capture the moments when UST abruptly relinquishes its safety role to become a source of risk. Having a timely measure to capture such crucial shifts in market condition is of the first order importance, as such abrupt shifts indicate dangerous moments for both the U.S. Treasury market and the global markets, moments when the regulators should take swift action, as they did in March 2020 amid the dash for cash.

Appendices

Appendix A: High-Frequency Correlation with Overnight Returns

The bond risk measures constructed in this paper use 5-minute interval returns within the regular trading hours (9:30 AM to 4 PM, U.S. Eastern Time). In this section, we show that measures using entire trading day (6 PM in the day before to 5 PM) returns are very similar except slightly less accurate than the measure based on the day time returns.

The trading hours of futures traded on CME (E-mini S&P 500, 10-year Treasury, EUR/USD, and YEN/USD) are nearly 24 hours a day. For E-mini S&P 500 index futures, trading is continuous with short breaks every day between 4:15 PM and 4:30 PM, and then between 5 PM and 6 PM for any scheduled maintenance. For 10-year Treasury futures, and EUR/USD or YEN/USD futures, trading hours are quite similar to E-mini S&P 500 index futures, except that there are no breaks between 4:15 PM and 4:30 PM. To calculate bond risk measure based on entire day returns (hereafter reffered as all-day measures), we use data from 6 PM on day $t-1$ to 5 PM on day t as the all-day bond risk measure on day t.

We compare the measures using intraday returns (9:30 AM to 4 PM, i.e. Intraday measures) and entire day returns (6 PM to 4 PM, i.e. All-day measures). Table A1 shows the summary statistics of two measures and their differences. There are not many differences between the two measures. The daily basis correlations are 0.91 and 0.94 for ρ_t^{UST} and ρ_t^{USD} between intraday and all-day measures. The average differences are quite small compared to the magnitudes and standard deviations.

Table A1: **Summary Statistics of Intraday and All-day Risk Measures**

		Mean	Std	Min	Q1	Med	Q3	Max	Corr
ρ_t^{UST}	Intraday	-0.31	0.26	-0.94	-0.51	-0.33	-0.14	0.75	0.91
	All-day	-0.27	0.23	-0.88	-0.44	-0.29	-0.12	0.70	
	Diff	-0.04	0.11	-0.69	-0.10	-0.04	0.02	0.69	
ρ_t^{USD}	Intraday	-0.06	0.28	-0.77	-0.27	-0.04	0.14	0.75	0.94
	All-day	-0.06	0.23	-0.77	-0.23	-0.04	0.10	0.80	
	Diff	0.00	0.10	-0.76	-0.06	0.00	0.07	0.58	

This table shows summary statistics of bond and dollar risk measures using intraday (9:30AM-4PM ET) and entire-day (6PM-5PM ET) 5-min high frequency returns. ρ_t^{UST} and ρ_t^{USD} are calculated in the same way as described in equation (1) and (2) except the time span is either from 9:30AM to 4PM or from 6PM one day before to 5PM today, in US Eastern Time. Column corr is the correlation between the same measure using intraday and all-day returns. Row Diff reports the difference between the same measure using intraday and all-day returns. The sample period is from January 2004 to June 2022.

Figure A1 compares the time series (exponential weighted moving average with a decaying parameter of 0.98) of intraday and all-day ρ_t^{UST} and ρ_t^{USD}. The time trends of the two measures closely mimic each other for the bond and dollar risk measures. However, there does exist some differences. During the 2008 financial crisis, intraday ρ_t^{UST} is lower than all-day $\rho_t^{\text{UST-All}}$, indicating a more intense flight-to-safety degree captured by intraday measures. Similarly, during 2011 European debt crisis periods, where USD also serves as safety assets, intraday ρ_t^{USD} is lower than all-day $\rho_t^{\text{USD-All}}$. These are evidence implying measures are more accurate based on intraday high-frequency returns.

Moreover, the ρ_t^{UST} can more accurately capture bond safety and bond risky episodes than the all-day measure. In Table A2, we present the performance of SPX and UST on bond safety and risky days identified by ρ_t^{UST} or $\rho_t^{\text{UST-All}}$. In Panel A, we show the averages of SPX and UST daily returns on bond safety days, where ρ_t^{UST} or $\rho_t^{\text{UST-All}}$ is lower than its full sample 10% or 20% percentiles. On both days, SPX drops, and UST rallies, but the magnitudes are larger on low ρ_t^{UST} days than low $\rho_t^{\text{UST-All}}$ days. Specifically, SPX drops by -39.27 and -36.20 bps on the bottom 10% and 20% ρ_t^{UST} days, which are larger in magnitudes than the -31.87 and -23.83 bps on bottom $\rho_t^{\text{UST-All}}$ days. Similarly, UST increases by 14.28 and 13.60 bps on the bottom 10% and 20% days of ρ_t^{UST}, which is larger than the 11.06 and 10.56 bps on bond safety days identified by $\rho_t^{\text{UST-All}}$. In Panel B, the rise in SPX and drops in UST are also in larger magnitudes on days identified by ρ_t^{UST} than those by $\rho_t^{\text{UST-All}}$. SPX increases by 6.33 ($= 11.47 - 5.14$) and 4.13 ($= 13.75 - 9.62$) bps more, and UST decreases by 1.54 and 1.79 bps more on top ρ_t^{UST} days than top $\rho_t^{\text{UST-All}}$ days, respectively. The results support our choice of ρ_t^{UST}, which use only regular trading hours data, as the main measures in this paper.

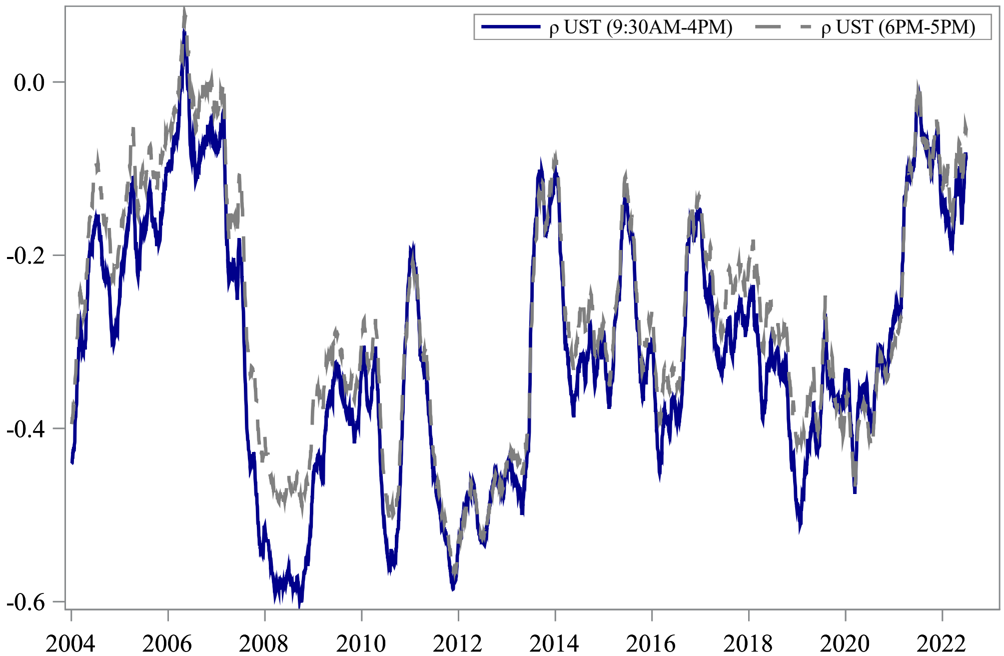
Appendix B: Investor Behavior on Bond Safety and Risky Days

Based on the performance of key asset classes, the previous results provide strong evidence that the bond risk measure ρ_t^{UST} captures the bond safety episodes when there is a flight-to-safety from the U.S. equity to the Treasury market, as well as the bond risky episodes when the U.S. Treasury becomes a source of risk itself. In this section, we turn to the investor behavior on the bond safety and risky days, focusing on publicly available institutional holdings data such as the ETFs flows, investor positions on futures and options, and primary dealers' holdings of Treasuries.

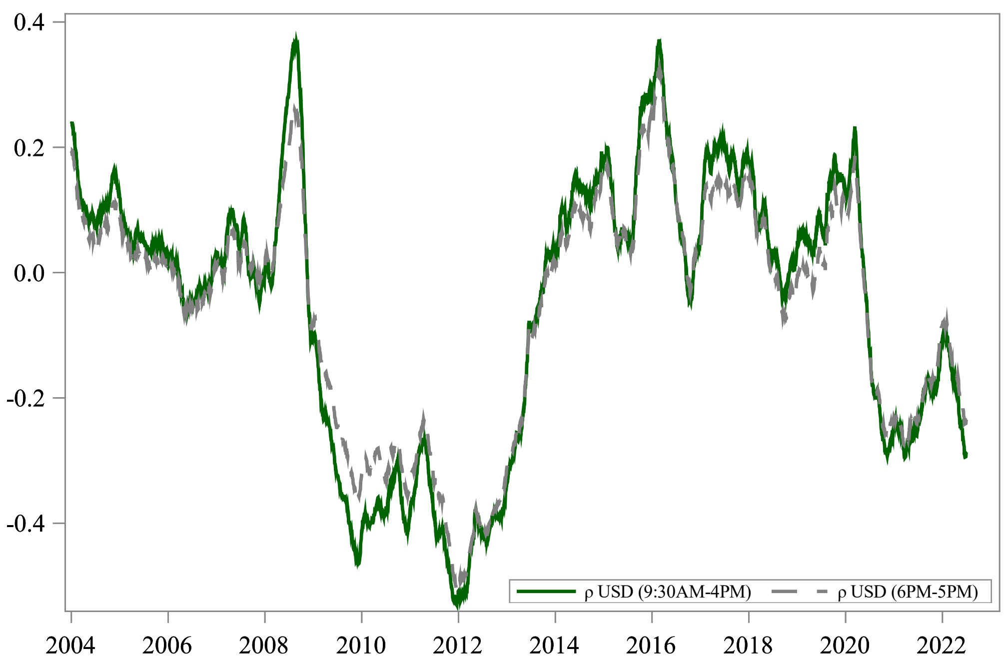
We obtain the daily ETF net fund flow data from Morningstar. We focus on the two largest Treasury and Equity ETFs in the U.S., the iShares 7-10 Year Treasury Bond ETF (IEF) and the SPDR S&P 500 ETF (SPY). We collect traders' net futures position from the Commitment of Traders (CoT) reports released by the Commodity Futures Trading Com-

Figure A1: **Time Series of Intraday and All-day Risk Measures**

(a) ρ UST



(b) ρ USD



This figure shows the time-series of bond and dollar risk measures using intraday or all-day returns. Panel (a) shows smoothed time series (exponential weighted moving average with decaying parameter 0.98) of ρ_t^{UST} using intraday 5-min returns from 9:30AM to 4PM (blue solid line) and from 6PM one day before to 5PM today (gray dash line), in US Eastern Time. Panel (b) shows smoothed time series of ρ_t^{USD} using intraday 5-min returns from 9:30AM to 4PM (green solid line) and from 6PM one day before to 5PM today (gray dash line) in US Eastern Time.

Table A2: **Market Performance under Different $\rho_t^{\mathbf{UST}}$ Measure**

Panel A: Bond safety days				
	Bottom 10% Days		Bottom 20% Days	
	ρ_t^{UST}	$\rho_t^{\text{UST-All}}$	ρ_t^{UST}	$\rho_t^{\text{UST-All}}$
SPX	-39.27	-31.87	-36.20	-23.83
UST	14.28	11.06	13.60	10.56
Panel B: Bond risky days				
	Top 10% Days		Top 20% Days	
	ρ_t^{UST}	$\rho_t^{\text{UST-All}}$	ρ_t^{UST}	$\rho_t^{\text{UST-All}}$
SPX	11.47	5.14	13.75	9.62
UST	-7.52	-5.98	-6.05	-4.26

This table shows performance of SPX and UST on bond safety and risky days based on ρ_t^{UST} and $\rho_t^{\text{UST-All}}$. The two measures are calculated in the same way as described in equation (1) except the time span is either from 9:30AM to 4PM (ρ_t^{UST}) or from 6PM one day before to 5PM today ($\rho_t^{\text{UST-All}}$), in US Eastern Time. Panel A reports the average daily returns of S&P 500 Index (SPX) and 10-year U.S. constant maturity Treasury (UST) on bond safety days, i.e. days with lowest (bottom 10% or 20%) ρ_t^{UST} or $\rho_t^{\text{UST-All}}$. Similarly, panel B reports the daily returns of SPX and UST on bond risky days, i.e. days with highest (top 10% or 20%) ρ_t^{UST} or $\rho_t^{\text{UST-All}}$. The returns are in unit of basis point. The sample period is from January 2004 to June 2022.

mission (CFTC). The aggregated weekly positions of financial futures are reported under the "Current Traders in Financial Futures Reports" of the CoT. The reports classify traders into four types: dealers and intermediaries, asset managers, leveraged funds and other reportables.[25]. For traders' net futures positions on Treasuries, we use the sum of the net positions of the 10-year Treasury note futures and the Ultra 10-year Treasury note futures. For traders' net futures positions on equities, we combine the net positions of the S&P 500 Index futures and the E-mini S&P 500 Index futures. Lastly, we obtain primary dealers' weekly net positions from the website of the New York Fed. Considering the strong time persistence in the net positions of both CFTC traders and primary dealers, we normalize the weekly net positions by their mean and standard deviations in the past one-year window.

We estimate the following regression to capture investor behavior on the bond safety and risky days identified by the bond risk measure ρ_t^{UST},

$$\Delta\text{position}_t = \text{intercept} + b^S \times \text{Safety}_t^{\text{UST}} + b^R \times \text{Risky}_t^{\text{UST}} + c_1 \times \text{VIX}_t + c_2 \times \text{Ted}_t + \epsilon_t, \quad (11)$$

Where the $\Delta\text{position}_t$ is the daily net flow of ETFs, the weekly change of the traders' net positions of equity and Treasury futures, or the weekly change of the primary dealers' net positions of fixed-income securities. To calculate the weekly change of net positions, we subtract the weekly position with its mean and then scale the difference by its standard deviation, where the mean and standard deviation are estimated from a rolling 1-year window. When $\Delta\text{position}_t$ measures the daily net flow of ETFs, $\text{Safety}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t has bottom 20% ρ_t^{UST} , $\text{Risky}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t has top 20% ρ_t^{UST}, VIX_t is the level of the VIX index on day t, and Ted_t is the Ted spreads on day t, measured as the difference between the 3-month LIBOR rates and the 3-month constant maturity Treasury rates. When $\Delta\text{position}_t$ measures the change in traders' net futures positions or primary dealers' net positions at week t, $\text{Safety}_t^{\text{UST}}$ is a dummy variable that takes value of one if the average of the daily ρ_t^{UST} within the week t is in the bottom 20% of the sample, $\text{Risky}_t^{\text{UST}}$ is a dummy variable that takes value of one if the average of the daily ρ_t^{UST} within the week t is in the top 20% of the sample, VIX_t and Ted_t are the average VIX and Ted spreads of week t.[26]

The estimation results are reported in Table B1. We find significant ETF flows out of the SPX and into the UST on the bond safety days. On average, there is a significant daily outflow of 162.85 million (t-stat=-2.04) from the equity ETF and a significant daily inflow

[25]The detailed description of the four types of investors can be found in CFTC webpage.

[26]CFTC reports weekly holdings from Tuesday to Tuesday, while New York Fed keeps the records every Wednesday. Thus we calculate the Tuesday-to-Tuesday averages of ρ_t^{UST}, VIX index and Ted spreads for CFTC futures positions and Wednesday-to-Wednesday averages for primary dealer's fixed income positions.

Table B1: **Changes of Positions on Bond Safety and Risky Days**

	Daily ETF		Weekly CFTC						Weekly Primary Dealers			
			Asset Mangement		Dealer		Leveraged					
	UST	SPX	UST	SPX	UST	SPX	UST	SPX	Coupons	TIPS	Agency	MBS
Bond Safety	13.09***	-162.85**	0.65***	-0.38**	-0.45**	0.39*	-0.52***	-0.37**	0.40**	0.45***	0.58***	0.74***
	[2.61]	[-2.04]	[3.67]	[-2.36]	[-2.31]	[1.93]	[-2.88]	[-2.29]	[2.07]	[2.83]	[3.44]	[4.18]
Bond Risky	-6.26	10.02	-0.05	0.01	0.06	-0.36*	0.41**	0.58***	-0.60***	0.00	-0.22	-0.11
	[-1.03]	[0.11]	[-0.22]	[0.07]	[0.36]	[-1.77]	[1.98]	[3.53]	[-3.88]	[0.00]	[-1.34]	[-0.71]
VIX	0.27	-11.16**	-0.01	-0.09***	-0.03***	0.04***	0.02*	0.01	0.01	-0.02	-0.04***	-0.01
	[0.76]	[-2.20]	[-1.00]	[-7.60]	[-2.73]	[2.72]	[1.96]	[1.40]	[0.85]	[-1.60]	[-3.49]	[-0.79]
Ted Spreads	-0.09	3.60***	0.52**	0.38*	-0.31	-1.02***	-0.43**	0.47	0.80***	0.08	0.65***	0.22
	[-1.61]	[2.89]	[2.39]	[1.85]	[-1.56]	[-2.94]	[-2.06]	[1.63]	[2.86]	[0.41]	[3.54]	[1.19]
Intercept	0.87	147.79*	-0.04	1.41***	0.68***	-0.21	-0.28	-0.39**	-0.42*	0.26	0.32	0.10
	[0.15]	[1.85]	[-0.15]	[5.65]	[3.20]	[-0.70]	[-1.18]	[-2.05]	[-1.84]	[1.59]	[1.53]	[0.47]
NOBS	4601	3479	835	835	835	835	835	835	963	963	963	963
R2 (%)	0.25	0.51	6.27	30.62	11.45	10.86	5.62	8.52	16.56	2.30	9.93	6.10

This table summarizes the fund flows and changes of institutions' holdings on the bond safety and risky days. The regressions are specified in Equation (11). ETF daily fund flow data are obtained from Morningstar, where UST represents the daily flow of iShares 7-10 Year Treasury Bond ETF (symbol:IEF), and SPX represents the daily flow of SPDR S&P 500 ETF Trust (symbol:SPY). Traders' weekly net futures position data are collected from the Commitment of Traders (CoT) reports released by the Commodity Futures Trading Commission (CFTC). For traders' net futures positions on Treasuries (UST), we use the sum of the net positions of the 10-year Treasury note futures and the Ultra 10-year Treasury note futures. For traders' net futures positions on equities (SPX), we combine the net positions of the S&P 500 Index futures and the E-mini S&P 500 Index futures. Primary dealers' weekly net positions of Treasury coupons, TIPS, Agency and MBS are from the website of the New York Fed. The daily change of ETF flows is in unit of $millions. The weekly change of net positions are calculated by first subtracting the weekly position with its mean and then scaling the difference by its standard deviation, where the mean and standard deviation are estimated from a rolling 1-year window. For regressions of the daily net flow of ETFs, $\text{Safety}_t^{\text{UST}}$ ($\text{Risky}_t^{\text{UST}}$) is a dummy variable that takes value of one if day t is a bond safety (risky) day, and ted spread is in unit of basis point. For regressions of the weekly changes, $\text{Safety}_t^{\text{UST}}$ ($\text{Risky}_t^{\text{UST}}$) is a dummy variable that takes value of one if the average of the daily ρ_t^{UST} within the week t is in the bottom (top) 20% of the sample, and ted spread is in unit of percent. VIX index is in unit of percent. The sample period is from January 2004 to June 2022. The t-statistics are reported in the square brackets and are based on the Newey-West standard errors.

of 13.09 million (t-stat= 2.61) into the Treasury ETF, after controlling the impact of the VIX index and the Ted spreads. The outflow from the equity ETF accounts for 8.6% of the daily ETF flow standard deviation (1,892 million) in our sample period, comparable to the magnitudes of the inflow to the Treasury ETF which accounts for 9.3% of its standard deviation (141 million).[27]

In the futures market, we find that asset managers exhibit similar flight behavior on the bond safety days. Asset managers increase their net positions of Treasury futures by 0.65 standard deviation (t-stat=3.67), and reduces their net positions of equity futures by 0.38 standard deviation (t-stat=-2.36) on weeks with the lowest 20% ρ_t^{UST}. Dealers, who function as liquidity providers in the market, trade in the opposite direction as the asset managers. Dealers net positions of Treasury futures decrease by 0.45 standard deviation (t-stat=2.31), and their net positions of equity futures increase by 0.39 standard deviations (t-stat=1.93). Leveraged investors, mostly hedge funds, decrease the holdings of both UST and SPX, with 0.52 standard deviation (t-stat=2.88) and 0.37 standard deviation (t-stat=2.29) respectively.

Primary dealers increase their net positions of Treasuries and other fixed-income securities on the bond safety days. The primary dealers' net positions of fixed-income securities increase by 0.40, 0.45, 0.58, 0.74 standard deviations for Treasury bonds and notes (coupons), TIPs, agency bonds and mortgage-backed securities, with t-stat of 2.07, 2.83, 3.44, 4.18, respectively, on weeks with the lowest 20% ρ_t^{UST}. Of course, we can't argue for sure that primary dealers exhibit flight-to-UST in the absence of information on their net equity positions. However, the evidence does point out a fact that primary dealers tend to hold more fixed-income securities during the times with low ρ_t^{UST}.

Lastly, on the bond risky days when the U.S. Treasury market becomes a source of risk, primary dealers reduce their Treasury positions by 0.60 standard deviation with a t-stat of 3.88. Primary dealers also reduce their positions in other fixed-income securities, but the reduction is not statistically significant. There is no significant change in the flow of Treasury and equity ETFs. In the futures market, leveraged investors increase their net positions of both Treasury and equity futures by a significant 0.41 (t stat = 1.98) and 0.58 (t stat = 3.53) standard deviation.

[27]In unreported results, we extend our analysis to another widely recognized equity ETF, the Vanguard S&P 500 ETF (VOO). Our findings indicate a consistent pattern in daily flows. The Vanguard S&P 500 ETF has significantly lower trading volume and tends to attract more activity from retail investors compared to the SPDR S&P 500 ETF (SPY). Given this context, we have opted to focus our reported results on SPY, as it offers a broader perspective on market behavior.

Appendix C: Interest Rates and Volatilities

We estimate the following regression to capture the interest rate yield and volatility performance on the bond safety and risky days identified by the bond risk measure ρ_t^{UST},

$$\Delta y_t = \text{intercept} + b^H \times \text{Safety}_t^{\text{UST}} + b^L \times \text{Risky}_t^{\text{UST}} + c_1 \times \text{VIX}_t + c_2 \times \text{Ted}_t + \epsilon_t, \quad (12)$$

Where the Δy_t is the daily change in yield of zero-coupon Treasuries or the Treasury Inflation-Protected Securities (TIPS), or the daily change in realized volatility of the 3-month EuroDollar, 2-Year and 10-Year Treasury futures. $\text{Safety}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t has bottom 20% ρ_t^{UST} , $\text{Risky}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t has top 20% ρ_t^{UST}. VIX_t is the level of the VIX index on day t, and Ted_t is the Ted spreads on day t, measured as the difference between the 3-month LIBOR rates and the 3-month constant maturity Treasury rates.

Table C1 shows the performance of interest rates and realized short- and long-term interest rate volatilities on bond safety and bond risky days. Complementing our main findings in Table 2, the zero-coupon rates for both short-term (2-year) and long-term (10-year) bonds decrease significantly on bond safety days, with daily yield changes of -1.41 bps and -1.80 bps, and corresponding t-statistics of -7.60 and -7.93. Real rates, proxied by yields of Treasury Inflation-Protected Securities (TIPS), also decline markedly by -0.70 bps and -1.23 bps. There are no significant movements in the realized volatilities of either short- or long-term interest rates. These results for bond safety days align with the flight-to-safety phenomenon, wherein yields drop while volatilities remain largely unchanged, reflecting the role of UST as a passive recipient of capital flows fleeing from equity markets.

In contrast, both interest rates and volatilities rise significantly on bond risky days, highlighting the U.S. Treasury as a source of risk. Specifically, daily changes in zero-coupon Treasury yields increase by 0.57 bps for the 2-year and 0.74 bps for the 10-year bonds. Real rates also exhibit significant increases, with short-term TIPS rising by 0.87 bps and long-term TIPS by 0.82 bps, both statistically significant. Moreover, realized interest rate volatilities, proxied by the intraday volatilities of the most liquid futures for the 3-month Eurodollar, 2-year, and 10-year U.S. Treasuries, also show notable increases. These volatilities rise by 0.10, 0.12, and 0.37 bps, respectively, underscoring the heightened riskiness of U.S. Treasuries on such days.

In summary, on bond safety days, Treasury yields drop significantly without notable changes in realized volatilities, reflecting their role as a safe haven. Conversely, on bond risky days, both yields and realized volatilities increase sharply, indicating that U.S. Treasuries themselves become a source of market risk.

Table C1: **Interest Rates and Volatilities**

	Panel A. Interest rate (Δyield)				*Panel B. Interest rate vol (ΔVol)*		
	(1)	(2)	(3)	(4)	(1)	(2)	(3)
	Zero-Coupon Treas.		TIPS		ΔIntraday Realized Vol		
	2Y	10Y	<5Y	5-10Y	EurDol 3M	UST 2Y	UST 10Y
Bond Safety Days	-1.41***	-1.80***	-0.70	-1.23**	0.04	0.00	0.02
	[-7.60]	[-7.93]	[-1.52]	[-2.52]	[1.58]	[0.07]	[0.16]
Bond Risky Days	0.57***	0.74***	0.87**	0.82**	0.10***	0.12***	0.37***
	[3.13]	[3.34]	[2.25]	[2.00]	[4.04]	[3.73]	[3.78]
VIX	-0.01	-0.02	-0.01	-0.06**	0.00	0.00	0.00
	[-1.20]	[-1.14]	[-0.54]	[-2.07]	[1.14]	[-0.14]	[0.68]
Ted Spreads	-0.44	0.42	0.38	0.78	0.01	0.03	0.02
	[-1.49]	[1.22]	[0.52]	[1.37]	[0.33]	[1.11]	[0.21]
Intercept	0.62***	0.39	0.13	0.87*	-0.04***	-0.03	-0.12
	[3.76]	[1.23]	[0.36]	[1.66]	[-2.68]	[-1.29]	[-1.63]
NOBS	4603	4603	3012	4603	3066	3678	4584
R2 (%)	2.85	2.40	0.27	0.51	0.55	0.28	0.22

This table reports daily changes in interest rate yields and realized interest rate volatility on bond safety and risky days. We present the regression coefficients from equation (12). The 2-year and 10-year zero-coupon Treasury yields are estimated from a fitted nominal yield curve following Gürkaynak, Sack, and Wright (2007), obtained from the Federal Reserve's website. Treasury Inflation-Protected Securities (TIPS) yields correspond to the Bloomberg 0-5 Year TIPS index (ticker: LTP5TRUU) and the 5-10 Year TIPS index (ticker: I05876US). Realized volatility for the 3-month Eurodollar, 2-year, and 5-year U.S. Treasury rates is annualized and estimated from 5-minute intraday returns and 4:00 pm to 9:30 am overnight returns of the most liquid contracts on the Chicago Mercantile Exchange (CME), following the method of Bollerslev, Tauchen, and Zhou (2009). For the 3-month Eurodollar futures, we use the fourth-nearest quarter contract to calculate intraday returns. VIX is the level of the VIX index, and Ted spreads are the differences between the 3-month LIBOR and 3-month constant maturity Treasury rates. Changes in yield and volatility are measured in basis points. VIX and Ted Spreads are measured in percent. The sample period spans from January 2004 to June 2022. The t-statistics are reported in the square brackets and are based on the Newey-West standard errors.

Appendix D: Short-Term Treasuries Risk Measures

In addition to the flight-to-safety channel we focus in this paper, the negative stock-bond correlation can also be driven by the cash flow channel. Positive growth shocks could lead to positive stock returns and negative bond returns, leading to a negative stock-bond correlation. We follow Cieslak and Schrimpf (2019) to differentiate risk aversion and growth shocks by comparing the comovements between stocks and either long- or short-term bonds. Growth shocks have a more pronounced effect on short-term yields compared to long-term yields. Risk aversion shocks, on the other hand, have a greater impact on long-term yields than short-term yields.

Similar to ρ_t^{UST}, we construct alternative measures as the correlation between the intraday 5-minute returns of SPX and 2-year Treasury futures (ρ_t^{UST2Y}) or 3-month EuroDollar futures (ρ_t^{UST3M}) on a trading day t:

$$\begin{aligned} \rho_t^{\text{UST2Y}} &= corr(R_{i,t}^{\text{SPX}}, R_{i,t}^{\text{UST 2Y}})|_{fixed\ t} \\ \rho_t^{\text{UST3M}} &= corr(R_{i,t}^{\text{SPX}}, R_{i,t}^{\text{EuroDollar 3M}})|_{fixed\ t} \end{aligned} \tag{13}$$

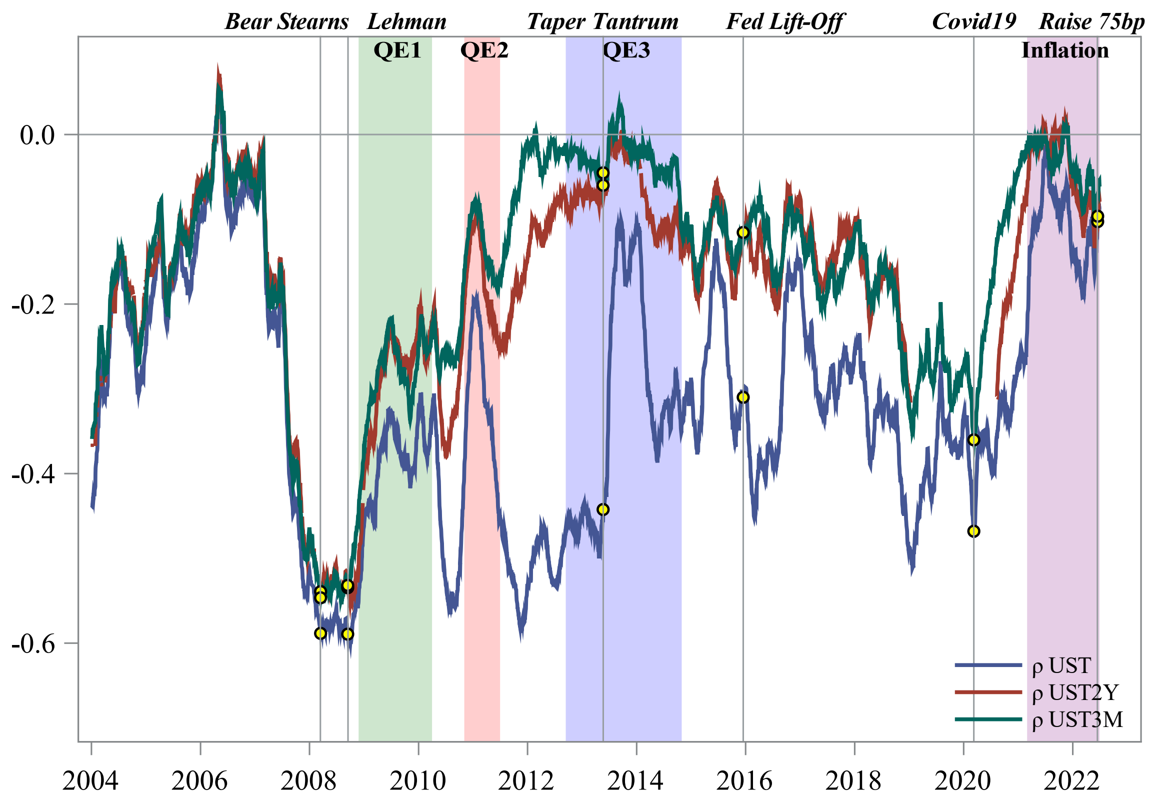
where $R_{i,t}^{\text{UST 2Y}}$ is the 5-minute return of the most liquid 2-year Treasury futures contracts; $R_{i,t}^{\text{EuroDollar 3M}}$ is the 5-minute return of 3-month EuroDollar futures contract expiring one year later. [28] Both returns are calculated for the 5-minute intervals within the regular trading hours (9:30 AM to 4:00 PM Eastern Time) of day t. We require a minimum N_t of 30 for the estimation of the bond risk measure ρ_t^{UST2Y} and ρ_t^{UST3M} on a trading day t. The sample period is from Januray 2004 to June 2022. [29]

Figure D1 shows the time series of ρ_t^{UST}, ρ_t^{UST2Y}, and ρ_t^{UST3M} from January 2004 to June 2022. Notably, the overall trend for ρ_t^{UST2Y} and ρ_t^{UST3M} remains negative throughout the sample period, albeit that levels considerably higher than those of ρ_t^{UST}. This divergence confirms that the information content of the long- and short-term bond risk measures are indeed different. Before the 2008 financial crisis, all three measures move closely with no clear differences. However, following the collapse of Lehman Brothers, the spreads between

[28] Both 2-year Treasury futures and 3-month EuroDollar futures are traded on the Chicago Mercantile Exchange (CME). Unlike 2-year or 10-year Treasury futures that have only one or two active traded contracts at one time, 3-month EuroDollar futures usually have 10-40 active contracts expiring in 1 month to 5 years traded simultaneously, with the most liquid contract changing frequently. Considering the trade-off between liquidity (to ensure enough number of returns) and shorter maturity (to ensure we measure close-to-date 3-month rate), we use the 4th nearest quarter contract, which expire approximately in one year, to calculate the intraday returns.

[29] From January 11, 2019 to August 7, 2020, the prices of 2-year futures provided by CME contain data errors. We therefore could not calculate ρ_t^{UST2Y} for this period.

Figure D1: **3M-, 2Y- and 10Y-Bond Risk Measures**



This figure shows the smoothed time series (exponential weighted moving average with a decaying parameter 0.98) of the bond risk measure ρ_t^{UST} (blue), 2-year measure ρ_t^{UST2Y} (red) and 3-month measure ρ_t^{UST3M} (green) from January 2004 to June 2022.

the three measures begin to manifest. Specifically, the 10-Year US Treasury, serving as a preferred safe-haven asset, exhibits a more pronounced negative comovement with the SPX in the post-2008 period when compared to the 2-year Treasury or 3-month EuroDollar. During recent periods marked by rising concerns about inflation, the three measures converge again, collectively receding to higher levels. Between ρ_t^{UST2Y} and ρ_t^{UST3M}, the two measures consistently show similar magnitudes throughout the majority of our sample period, with ρ_t^{UST2Y} being slightly more negative during the periods from 2010 to 2014 and again in 2021.

To illustrate the distinct effects of risk premium and growth shocks on the overall market, we compare the performance of key asset classes during bond safety and risky days identified by long- and short-term bond risk measures, respectively, in Table D1. Considering the similarity between ρ_t^{UST2Y} and ρ_t^{UST3M} throughout our sample period, we only report the results based on ρ_t^{UST3M} for brevity.

Similar to the bond safety and risky days based on the long-term bond risk measure ρ_t^{UST}, we identify bond safety and risky days based on the short-term bond risk measure as the ones with the bottom 20% and top 20% ρ_t^{UST3M}. Of the safety days based on long- and short-term bond risk measures, there is considerable overlap: 479 days with both low ρ_t^{UST} and low ρ_t^{UST3M}. Excluding these overlapped days, we have 382 10-year safety days and 355 3-month safety days. As shown in Table D1, major asset classes show similar flight-to-UST behavior on the 382 days of 10-year bond safety days after excluding the overlapped 3-month safety days: SPX has a large negative return of -28.00 basis points, UST gains a large positive return of 11.66 basis points, the Dollar index appreciate by 7.24 basis points, and the implied volatilities of major asset classes increase substantially. By comparison, on the 355 days of 3-month safety but not 10-year safety days, there is no longer pattern of flight-to-safety: SPX has a positive return of 14.27 basis points, while other asset classes don't show significant movement in either returns or implied volatilities. Combining these evidences, it is clear that only the long-term bond risk measure ρ_t^{UST} contains the right information to identify the "flight-to-safety" days, when the equity market is the source of risk and the long-term Treasury market is the destination of safety.

Appendix E: Low-Frequency Bond Risk Measures

Taking advantage of the intraday futures returns, our bond risk measure enables us to capture the flight-to-UST and bond riskiness phenomenon at the daily frequency in our sample period. An alternative approach to estimate the stock-bond correlations could be based on the daily stock and bond returns in a rolling historical window. This alternative low-frequency measure is less precise at the daily level, but could offer a long-term perspective on the variations of the stock-bond correlations, especially for the early period when reliable

Table D1: **Performance of Key Assets on 3-Month Bond Safety and Risky Days**

Panel A: 10-year and 3-month bond safety and risky days					
	ρ_t^{UST} Only	ρ_t^{UST3M} Only	Overlapped		
# Safety	382	355	479		
# Risky	389	400	442		
Panel B: 3-month bond safety and risky days (excluding overlapped)					
(a) Return					
	SPX	UST	DXY	EUR/USD	YEN/USD
3-Month Safety	14.37**	-2.09	-0.97	1.71	-4.93
	[2.08]	[-0.94]	[-0.40]	[0.64]	[-1.49]
3-Month Risky	2.62	0.15	-0.59	0.89	-1.38
	[0.59]	[0.08]	[-0.25]	[0.31]	[-0.54]
(b) CAPM α					
		UST	DXY	EUR/USD	YEN/USD
3-Month Safety		-0.71	-0.74	0.07	-2.41
		[-0.28]	[-0.32]	[0.03]	[-0.78]
3-Month Risky		0.61	-0.30	0.04	-1.11
		[0.40]	[-0.13]	[0.02]	[-0.46]
(c) Δ***Implied Vol***					
	VIX	MOVE	DXYV	EURV	YENV
3-Month Safety	-0.17	-0.48*	-0.02	-0.02	-0.07*
	[-1.48]	[-1.82]	[-1.06]	[-0.74]	[-1.70]
3-Month Risky	0.03	-0.11	0.00	0.00	-0.02
	[0.42]	[-0.87]	[0.04]	[0.12]	[-1.14]
Panel C: 10-year bond safety and risky days (excluding overlapped)					
(a) Return					
	SPX	UST	DXY	EUR/USD	YEN/USD
10-Year Safety	-28.00***	11.66***	7.24**	-9.40***	9.80***
	[-4.55]	[5.31]	[2.43]	[-2.64]	[3.28]
10-Year Risky	15.14***	-6.25***	2.40	-2.77	-7.77***
	[3.75]	[-2.83]	[0.91]	[-0.95]	[-2.78]
(b) CAPM α					
		UST	DXY	EUR/USD	YEN/USD
10-Year Safety		4.73***	3.47	-4.40	5.86**
		[2.80]	[1.27]	[-1.36]	[2.18]
10-Year Risky		-7.22***	2.75	-4.93*	-8.31***
		[-2.94]	[1.04]	[-1.67]	[-2.89]
(c) Δ***Implied Vol***					
	VIX	MOVE	DXYV	EURV	YENV
10-Year Safety	0.36***	0.42**	0.06**	0.06**	0.07**
	[3.09]	[2.25]	[2.49]	[2.24]	[2.45]
10-Year Risky	-0.15**	-0.30	-0.01	-0.01	-0.02
	[-2.56]	[-1.44]	[-0.92]	[-0.68]	[-1.05]

This table compares the performances of major assets on bond safety and risky days identified by ρ_t^{UST} and ρ_t^{UST3M}. The bond safety (risky) days contain the trading days with the bottom (top) 20% ρ_t^{UST} or ρ_t^{UST3M}. Panel A reports the distribution of bond safety and risky days identified by two measures. Panel B reports major asset classes' performances on 3-month bond safety or risky days after excluding 10-year bond safety or risky days, i.e. the ρ_t^{UST3M} only days reported in Panel A. Likewise, Panel C reports major asset classes' performances on 10-year bond safety or risky only days. Definition of market returns and implied volatilities are the same as Table 2. The sample period is from January 2004 to June 2022. The t-statistics are reported in the square brackets and are based on the Newey-West standard errors.

intraday stock and bond returns were generally not available.

We compute an alternative low-frequency bond risk measure as the exponentially weighted moving average (EWMA) correlations of the daily returns of the S&P 500 and the CRSP 10-year Treasury indexes, with a decay parameter of 0.98. We are able to estimate the low-frequency bond risk measures back to 1963. We plot the low-frequency bond risk measure (in red) in Figure E1, against the high-frequency bond risk measure (in blue) as well as the inflation level measured by the percentage change of the core CPI from one year ago (in gray, right axis).

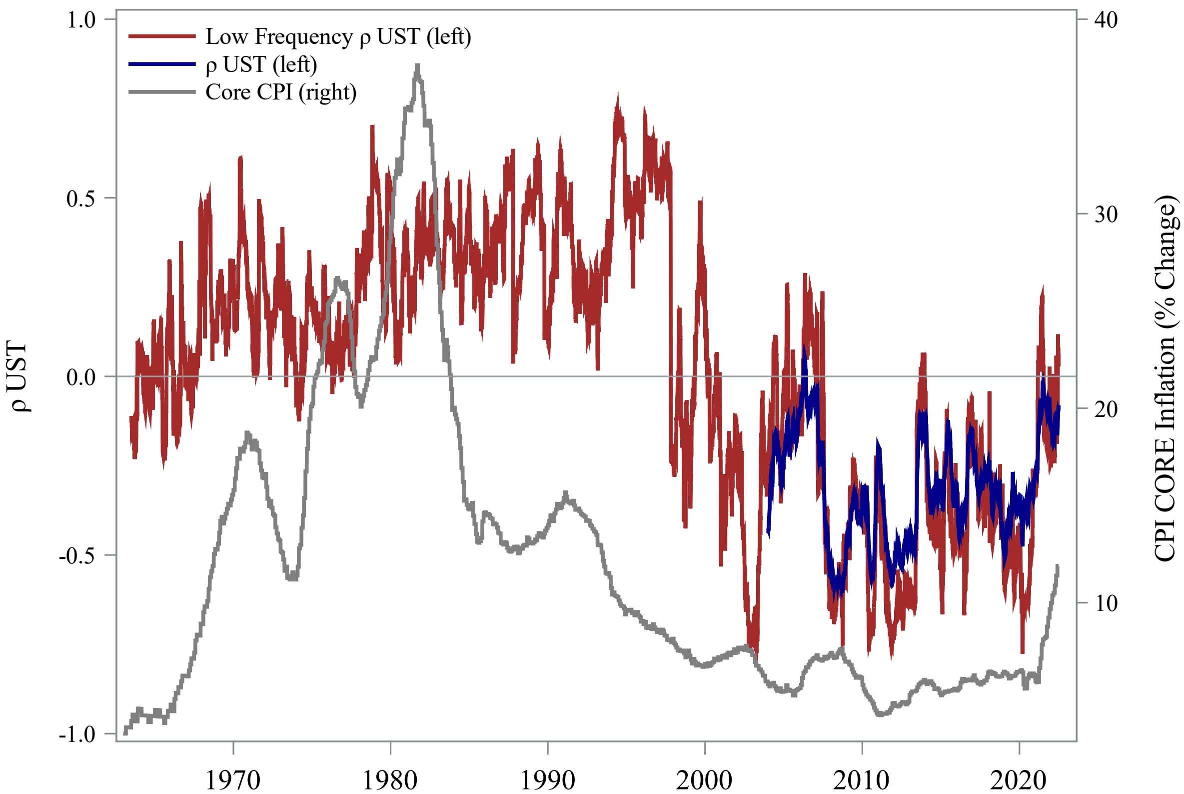
Figure E1 confirms that our high-frequency bond risk measure ρ_t^{UST} is consistent with the overall trend of the low-frequency bond risk measures estimated from the daily stock bond returns from 2004 to 2022. Moreover, it is clear that the overall negative stock-bond correlations during our sample period is related to the general low inflation risk in this period. The average annual percentage change of the U.S. core CPI is 6.13% from 2004 to 2022, significantly lower than its levels back in the 1970s and 1980s. Indeed, when inflation quickly hikes up at the end of our sample period, from 5.94% at March 2021 to 11.95% at June 2022, both the low- and high-frequency correlations quickly drop to levels close to zero. Similarly, the low-frequency bond risk measure was positive for the period from 1967 to 1997 when the inflation in the U.S. was high.

Although the low-frequency bond risk measure can go back to early times and shares similar time-series pattern as the high-frequency bond risk measure, its construction method limits its ability to capture the changing of bond dual roles at the daily basis. On the bottom 20% days with the lowest low-frequency bond risk measure, the average daily SPX and UST returns are 2.71 bps (t-stat=0.49) and 3.58 bps (t-stat=2.03), respectively. This is in sharp contrast to the large negative SPX (-36.2 bps) and positive UST (13.6 bps) returns on the bond safety days identified by the high-frequency bond risk measure ρ_t^{UST}. On the top 20% days with the highest low-frequency bond risk measure, the average daily SPX and UST returns are 0.19 bps and 0.38 bps, both are small and insignificant. In other words, the low-frequency bond risk measure can not capture the variation of market conditions at the daily level.

Appendix F: Currency Carry Trade Returns

In this section, we examine the returns of major currencies and carry trade portfolios on the bond safety and risky days. Our main variable is the U.S. dollar index (DXY), which is maintained by the Intercontinental Exchange (ICE) and measures the value of the U.S. dollar relative to a basket of foreign currencies. In addition to the dollar index, we also consider the ten major currencies of the G10 countries, i.e., the British Pound (GBP), Euro

Figure E1: **Low- and High-Frequency Bond Risk Measures**



The smoothed time series (exponential weighted moving average with decaying parameter 0.98) of the bond risk measure ρ_t^{UST} (blue line, left axis), the low-frequency measure (red line, left axis), and the inflation series (gray line, right axis) are plotted from January 1963 to June 2022. The low-frequency bond risk measure is calculated as the exponential weighted moving average correlation (with decaying parameter 0.98) between the daily returns of the SPX and the UST. The inflation is based on the year-to-year percentage changes of the Consumer Price Index for All Urban Consumers: All Items Less Food and Energy in U.S. City Average.

(EUR), Japanese Yen (YEN), Swiss Franc (CHF), Canadian Dollar (CAD), New Zealand Dollar (NZD), Australian Dollar (AUD), Danish Krone (DKK), Norwegian Krone (NOK) and Swedish Krona (SEK). We obtained the daily exchange rates of these currencies relative to the U.S. dollar from Bloomberg. Following the literature, we form three daily-rebalanced carry trade portfolios based on the forward premium of the G10 currencies (the log overnight forward rate f_t minus the log spot rate s_t), with the Carry 1 portfolio contains the top three currencies with the highest forward premium (asset currencies) , the Carry 2 portfolio contains the four currencies with forward premium in the middle, and the Carry 3 portfolio contains the bottom three currencies with the lowest forward premium (funding currencies).

We estimate the following regression to examine the returns of different currency portfolios on the bond safety and risky days:

$$\begin{aligned} \text{currency}_t = \text{intercept} + b_1^{\text{S}} \times \text{Safety}_t^{\text{UST}} + b_1^{\text{R}} \times \text{Risky}_t^{\text{UST}} + b_2^{\text{S}} \times \text{Safety}_t^{\text{USD}} \\ + b_2^{\text{R}} \times \text{Risky}_t^{\text{USD}} + \text{controls}_t + \epsilon_t \end{aligned} \tag{14}$$

Where currency_t is the return of different currencies or currency portfolios on day t, $\text{Safety}_t^{\text{UST}}$ ($\text{Risky}_t^{\text{UST}}$) is a dummy variable that takes value of one if ρ_t^{UST} is the bottom (top) 20% of the sample from January 2004 to June 2022, and $\text{Safety}_t^{\text{USD}}$ ($\text{Risky}_t^{\text{USD}}$) is a dummy variable that takes value of one if ρ_t^{USD} is the bottom (top) 20% of sample periods. We include the Ted spreads and the VIX index as the control variables.

The estimation results at Table F1 show a clear appreciation of major funding currencies, YEN and CHF in particular, during episodes of flight-to-UST. During the bond safety days with low ρ_t^{UST}, the safest funding currency YEN strengthens against the USD by 17.28 bps (t-stat = 6.50) on average, followed by the CHF with an appreciation of 6.25 bps (t-stat= 1.64). In contrast, the asset currencies, which are the relatively riskier currencies, weaken substantially relative to the USD. For NZD, AUD, NOK, i.e., the three major asset currencies in our sample period, the depreciation with respective to the USD is 10.50 bps, 13.43 bps, and 7.74 bps, respectively, and all statistically significant at the 5% level. The dollar index, which measures the value of the U.S. dollar to a basket of currencies, doesn't have significant returns on the bond safety days. This is probably due to the fact that the dollar index weights heavily on the Euro (57.6%) which doesn't move significantly relative to the USD on the bond safety days.

The above results suggest that there is a flight from the risky to the safe currencies in the FX market on the bond safety days with low ρ_t^{UST}. Due to this flight among the currencies, a typical carry trade portfolio that longs the asset currencies (Carry 1) and shorts the funding currencies (Carry 3) experiences an average loss of -15.01 bps relative to the normal days,

Table F1: **Currency Returns on Bond Safety and Risky Days**

	Panel A: Carry trade portfolio returns				***Panel B: DXY and major funding-currencies (YEN and CHF)***		
	Carry 1	Carry 2	Carry 3	Carry 1−3	DXY	YEN	CHF
Bond Safety	-10.83***	-4.61*	4.17*	-15.01***	0.87	17.28***	6.25
	[-3.27]	[-1.70]	[1.75]	[-5.47]	[0.37]	[6.50]	[1.64]
Bond Risky	-4.38*	-2.48	-2.00	-2.38	2.69	-2.52	-1.82
	[-1.73]	[-1.19]	[-0.88]	[-1.38]	[1.30]	[-1.07]	[-0.74]
Dollar Safety	4.78	0.43	-1.21	5.99**	0.61	-4.00	-3.51
	[1.41]	[0.17]	[-0.51]	[2.33]	[0.27]	[-1.41]	[-1.16]
Dollar Risky	0.56	3.75**	4.99**	-4.43**	-4.52***	7.43***	3.69
	[0.26]	[2.10]	[2.52]	[-2.32]	[-2.59]	[3.22]	[1.44]
VIX	-0.71**	-0.31*	-0.02	-0.69***	0.19	0.43**	-0.03
	[-2.52]	[-1.65]	[-0.12]	[-3.40]	[1.19]	[2.30]	[-0.16]
Ted Spreads	0.02	0.00	-0.00	0.02	0.00	-0.02	-0.02
	[0.36]	[0.04]	[-0.03]	[0.41]	[0.04]	[-0.71]	[-0.59]
Intercept	14.80***	5.97*	-1.05	15.84***	-3.25	-11.51***	1.03
	[3.17]	[1.81]	[-0.42]	[4.30]	[-1.17]	[-3.70]	[0.34]
NOBS	4577	4576	4577	4577	4577	4577	4577
R2 (%)	1.27	0.52	0.39	2.53	0.38	2.32	0.28

	Panel C.Other G10 currencies (ex. YEN, CHF)							
	NZD	AUD	NOK	GBP	CAD	SEK	DKK	EUR
Bond Safety	-10.50***	-13.43***	-7.74**	-6.00**	-11.61***	-4.95	-1.98	-2.09
	[-2.67]	[-3.22]	[-2.09]	[-1.98]	[-3.91]	[-1.42]	[-0.70]	[-0.74]
Bond Risky	-4.09	-3.94	-5.97*	0.25	-1.38	-4.08	-2.41	-2.37
	[-1.36]	[-1.41]	[-1.82]	[0.11]	[-0.69]	[-1.42]	[-1.00]	[-0.98]
Dollar Safety	4.18	6.26	1.98	3.33	3.40	1.18	-0.86	-0.69
	[1.08]	[1.55]	[0.47]	[1.05]	[1.30]	[0.34]	[-0.32]	[-0.26]
Dollar Risky	1.42	1.40	-1.21	2.00	-1.66	2.87	5.71***	5.87***
	[0.53]	[0.54]	[-0.45]	[0.92]	[-0.80]	[1.18]	[2.74]	[2.80]
VIX	-0.81***	-0.72**	-0.73*	-0.55**	-0.58***	-0.54**	-0.19	-0.20
	[-2.87]	[-2.39]	[-1.88]	[-2.21]	[-3.18]	[-2.29]	[-1.11]	[-1.13]
Ted Spreads	0.04	0.01	0.04	0.01	0.03	0.02	0.00	0.00
	[0.68]	[0.13]	[0.56]	[0.34]	[0.47]	[0.32]	[0.05]	[0.05]
Intercept	15.28***	14.88***	14.34**	9.29**	12.11***	9.83***	3.20	3.23
	[3.23]	[2.78]	[2.41]	[2.42]	[3.39]	[2.59]	[1.01]	[1.01]
NOBS	4577	4577	4575	4577	4577	4575	4575	4577
R2 (%)	0.95	1.13	0.75	0.86	1.44	0.49	0.34	0.35

This table reports returns of major currencies and carry trade portfolios on bond safety and risky days identified by ρ_t^{UST} with control of dollar safety and risky days identified by ρ_t^{USD} following equantion (14). Major currencies of the G10 countries include Euro (EUR), Japanese Yen (YEN), British Pound (GBP), Canadian Dollar (CAD), Australian Dollar (AUD), New Zealand Dollar (NZD), Swiss Franc (CHF), Norwegian Krone (NOK), Swedish Krona (SEK) and Danish Krone (DKK). For G10 countries, currency price is in unit of foreign currency per USD. Carry trades formed with G10 currencies are constructed through the procedures describe in Appendix F. Panel A exhibits the carry trade returns. Panel B shows results for US Dollar and major funding currencies YEN and CHF. Panel C shows results of other individual currency returns. VIX index level (in unit of percent) and Ted Spreads (in unit of basis point) are used as control variables in these regressions. The sample period is from January 2004 to June 2022. The t-statistics are reported in the square brackets and are based on the Newey-West standard errors.

which is statically significant with a t-stats of -5.47. On bond risky days, currencies and carry trade portfolios don't perform differently relative to the normal days, consistent with the observation that bond risky days capture the episodes when the risk is largely contained within the Treasury market.

It's worth emphasizing that the above flight-to-safety movements in the FX market is unique to the bond safety days identified by the bond risk measure ρ_t^{UST}. Even though ρ_t^{USD} directly measures the safeness of USD, a typical carry trade portfolio – long on asset currencies (Carry 1) and short on funding currencies (Carry 3) – yields a positive return of 5.99 basis points on dollar safety days and a negative return of -4.43 basis points on dollar risky days. Both the economic magnitudes and statistical significance of these returns are, however, considerably smaller than those observed on bond safety days. Similarly, the Japanese Yen, the safest currency in our sample period, appreciates by only 7.43 basis points on dollar safety days when the U.S. dollar is perceived as risky, an appreciation that is only half of its size on bond safety days. These findings underscores the substantial impact of the flight-to-UST on the foreign exchange market, an unique phenomenon captured by our stock-bond comovement measure ρ_t^{UST}.

Appendix G: UST-USD Transmission with Controls of Dollar Risk

In this section, we supplement the results of comovements between UST and USD by considering the dollar risk measure ρ_t^{USD}. In section 3.3, we find the original positive relation of UST and USD are offset by the safe-heaven nature of UST. Since the dollar risk measure ρ_t^{USD} directly measures the safeness of USD, we further control the effect from ρ_t^{USD} and examine the impact of ρ_t^{UST} on UST-USD transmissions.

Table G1 follows the same format as Table 6 except that it includes controls for dollar safety and risky days and their interactions with equity and bonds. Focusing on the effects of bond safety (risky) days, the negative (positive) impacts on the original positive UST/USD relations remain robust after incorporating additional controls. Similarly, opposite effects on foreign bonds and currencies are robustly observed. Specifically, 1 bps increase in bond yield daily changes will lead to 1.34 bps less (1.90 bps more) returns of USD on bond safety (risky) days. For G10 countries, 1 bps increase in bond yield daily changes will result in 1.47 bps more (2.20 bps less) returns of the local currency on bond safety (risky) days.

For ρ_t^{USD}, it affects the dynamics between USD and UST with three distinct characteristics. First, the positive UST/USD relations are offset on dollar safety days when USD exhibits its safe-haven nature, albeit with less magnitude. The relations are slightly enhanced on dollar risky days but are only marginally statistically significant. This suggests that UST-USD relations can be influenced bilaterally by the safe-haven nature of both UST

Table G1: **The Transmission of UST and USD with Dollar Risk Control**

yvar=	R_t^{USD}		$R_t^{\text{USD/Foreign}}$			$R_t^{\text{Foreign/USD}}$	
	(1)	(2)	(3)	(4)		(5)	(6)
$\Delta y^{\text{UST}} \times$ Bond Safety		-1.34***		-1.47***	$\Delta y^{\text{Local Bond}} \times$ Bond Safety		1.47**
		[-2.87]		[-3.05]			[2.34]
$\Delta y^{\text{UST}} \times$ Dollar Safety		-1.14***		-1.01***	$\Delta y^{\text{Local Bond}} \times$ Dollar Safety		0.30
		[-2.81]		[-2.74]			[0.64]
$\Delta y^{\text{UST}} \times$ Bond Risky		1.90***		1.89***	$\Delta y^{\text{Local Bond}} \times$ Bond Risky		-2.20***
		[4.42]		[4.15]			[-4.70]
$\Delta y^{\text{UST}} \times$ Dollar Risky		0.91*		0.91*	$\Delta y^{\text{Local Bond}} \times$ Dollar Risky		-0.63
		[1.65]		[1.93]			[-1.40]
Δy^{UST}	1.49***	1.27***	1.60***	1.40***	$\Delta y^{\text{Local Bond}}$	1.66***	1.78***
	[6.79]	[4.38]	[3.91]	[3.03]		[8.11]	[5.03]
$R^{\text{SPX}} \times$ Bond Safety		0.03		0.03	$R^{\text{Local Equity}} \times$ Bond Safety		-0.04**
		[1.14]		[1.27]			[-2.05]
$R^{\text{SPX}} \times$ Dollar Safety		-0.09***		-0.11***	$R^{\text{Local Equity}} \times$ Dollar Safety		0.09***
		[-3.98]		[-5.47]			[3.07]
$R^{\text{SPX}} \times$ Bond Risky		-0.03		-0.00	$R^{\text{Local Equity}} \times$ Bond Risky		-0.02
		[-1.02]		[-0.15]			[-0.98]
$R^{\text{SPX}} \times$ Dollar Risky		0.12***		0.14***	$R^{\text{Local Equity}} \times$ Dollar Risky		-0.12***
		[4.71]		[4.87]			[-4.59]
R^{SPX}	-0.09***	-0.07***	-0.18***	-0.16***	Local Equity	0.06	0.06*
	[-7.66]	[-4.95]	[-3.97]	[-3.43]		[1.53]	[1.69]
Bond Safety	0.09	-0.14	-0.81	-1.23	Bond Safety	-1.01	-0.81
	[0.04]	[-0.07]	[-0.42]	[-0.70]		[-0.37]	[-0.30]
Bond Risky	1.05	0.06	0.54	-0.8	Bond Risky	-2.7	-1.54
	[0.54]	[0.03]	[0.31]	[-0.45]		[-1.37]	[-0.78]
Dollar Safety	1.76	0.93	1.05	0.26	Dollar Safety	-1.34	-0.71
	[0.96]	[0.53]	[0.59]	[0.15]		[-0.66]	[-0.37]
Dollar Risky	-4.97***	-3.07*	-4.58***	-2.45	Dollar Risky	4.62***	3.23*
	[-2.85]	[-1.80]	[-2.58]	[-1.50]		[2.65]	[1.94]
Intercept	1.08	0.9			Intercept		
	[1.06]	[0.87]					
Currency FE	No	No	Yes	Yes	Currency FE	Yes	Yes
NOBS	4578	4578	45774	45774	NOBS	43657	43657
R2 (%)	5.10	11.68	8.53	12.6	R2 (%)	2.73	4.87

This table shows relation between equity/10-year treasury and exchange rates conditional on bond safety and risky days identified by ρ_t^{UST} and dollar safety and risky days identified by ρ_t^{USD}. The regressions are the same as reported in Table 6 except that dollar safety and risky days based on ρ_t^{USD} are added in regression as additional controls. The detailed description of equity and treasury data for G10 countries are listed in Appendix table H1. The sample period is from January 2004 to June 2022. The reported t-stat's for the first two regressions use Newey-West standard errors, and the reported t-stat's for the rest use two-way clustered standard errors.

and USD, but UST has relatively larger impacts. Second, unlike on bond safety days, the relations with foreign bonds and currencies do not change significantly on dollar safety or risky days. This suggests UST plays a more special role of safe-haven asset in global financial markets compared to USD. Third, the negative relation between SPX and USD is enhanced on dollar safety days and weakened on dollar risky days, in the opposite direction compared to bond safety or risky days and is much more significant. 1 bps increase in SPX return will generate 0.09 bps less (0.12 bps more) returns of USD on dollar safety (risky) days.

The results suggest a robust impact of ρ_t^{UST} on UST-USD relations even after controlling for ρ_t^{USD}. Additionally, the UST-USD relationship is influenced bilaterally by both UST and USD. UST exhibits unique impacts in global financial markets, while USD can also have additional effects on SPX-USD relations.

Appendix H: List of Sovereign Bond and Equity Indexes for the G10 Countries

The details of the bond and equity indexes of G10 countries used in Table 6 and Table G1 are listed in Table H1. The data is obtained from Bloomberg.

Table H1: **List of G10 Currency, 10-Year Treasury and Equity Index**

Country	Currency	10-Year Treasury		Equity Index	
		Ticker	Full Name	Ticker	Full Name
Eurozone	EUR	GECU10YR Index	Euro Generic Govt Bond 10 Year	SX5E Index	EURO STOXX 50 Price EUR
Japan	YEN	GJGB10 Index	Japan Govt 10 Yr	NKY Index	Nikkei 225
Britain	GBP	GUKG10 Index	UK Gilts 10 Yr	UKX Index	FTSE 100 Index
Canada	CAD	GCAN10YR Index	Canadian Govt Bonds 10 Year	SPTSX Index	S&P/TSX Composite Index
Australia	AUD	GACGB10 Index	Australia Govt 10 Yr	AS51 Index	S&P/ASX 200
New Zealand	NZD	GNZGB10 Index	New Zealand Govt Bond 10 Year	NZSE50FG Index	S&P/NZX 50 Gross Index
Switzerland	CHF	GSWISS10 Index	Switzerland Govt Bonds 10 Year	SMI Index	Swiss Market Index
Norway	NOK	GNOR10YR Index	Norway Government Bonds 10 Year	OSEAX Index	Oslo Stock Exchange All Share
Sweden	SEK	GSGB10YR Index	Swedish Government Bond 10 Yr	OMX Index	OMX Stockholm 30 Index
Denmark	DKK	GDGB10YR Index	Denmark Government Bonds 10 Year	KFX Index	OMX Copenhagen 20

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