The Stock-Bond Correlation: A Tale of Two Days

First Draft: February 3, 2023
This Draft: February 6, 2024

Abstract

Using daily measures of stock-bond correlation, we document two distinctive pricing patterns in global markets. On days with highly negative stock-bond correlations, safety matters the most and the pricing of global assets is determined by their relative safety rather than their own fundamental risk. Within U.S. equity, the value of safety is such that low-beta stocks outperform high-beta stocks with a daily CAPM-alpha of 21 basis points. Absent of safety-first, the CAPM performs well, attributing the presence of betting-against-beta to the value of safety. Examine the pricing of the U.S. Treasury market (UST) under the tale of two days, we find that on safety-first days, the value of safety shrinks the UST term premium, widens the convenience yield of UST, and breaks the link between USD and UST. By contrast, on days with high stock-bond correlation, UST becomes a source of risk with increased volatility, widening term premium, and narrower convenience yield. Overall, the stock-bond correlation can be used to differentiate days of safety from uncertainty in UST and quantify the value of safety in global markets.

Keywords: Flight-to-UST, Global Co-movements, Safe Haven Assets

JEL Classification: G12, G15

1. Introduction

This paper studies the role of the U.S. Treasury bonds in the comovements of global financial markets, both as a destination of safety and as a source of risk. Following the globalization that began in early 1990s, financial markets have become more interconnected, with information, capital, and fear/greed flowing across the global markets. Comovements in global markets have been studied in the context of the influence of U.S. monetary policy by Rey (2015) and the global safety demand for dollar assets by Jiang, Krishnamurthy, and Lustig (2020). In this paper, we anchor the study of global comovements to the interplay between the U.S. stock and Treasury bond markets.

Our focus on the stock-bond correlation is motivated by its overall dominance in the comovement of global markets.[1] At the core of the global markets is the aggregate U.S. stock market, whose pricing reflects the ups and downs of the global risk appetite. This global cycle of risk-on and risk-off, however, does not occur in a vacuum. Accompanying episodes of sudden risk-off in the U.S. equity market are flights to safe assets – a unique comovement best captured by the negative stock-bond correlation (Baele et al. 2019). Conversely, when the U.S. Treasury market is itself mired in concerns over surging inflation (e.g., the 2021-22 inflation surge) or monetary policies (e.g., the FOMC announcements), it becomes a source of risk, contributing toward a positive stock-bond correlation. As the U.S. Treasury market is considered among the safest assets in the global financial market, capturing the moments when it becomes a source of risk is just as important.

Motivated by these observations, we use high-frequency intra-day futures data on U.S. stock and bond to construct a daily safety measure for the U.S. Treasury bond (UST). Specifically, our UST safety measure η_t^{UST} is the negative of the day-t correlation between the five-minute returns on the S&P 500 (SPX) Index futures and the 10-Year T-Note futures, both of which are traded on CME. A higher η_t^{UST} indicates a more negative stock-bond correlation and captures the moment when the safe haven nature of UST is valued the most, while a lower η_t^{UST} captures the moment when UST becomes a source of risk. Leveraging on the high-frequency nature of η_t^{UST}, we identify days of high and low UST safety and document distinctive patterns of risk and return tradeoff under the "tale of two days."

Markets Under High UST Safety – Focusing first on high-η_t^{UST} days, when the safety measure for UST is among the top 20% with an average value of 64%, we find strong evidence of flights-to-safety. Specifically, on high-η_t^{UST} days, 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

[1] Abstracting from the enormity of the global financial markets, Figure A1 focuses on the core building blocks of the global markets – U.S. Equity (SPX), U.S. Treasury (UST), U.S. Dollar, and Commodity, and show the global co-movements to be dominated by the stable relation between SPX and UST.

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 high-η_t^{UST} days, the average daily return of UST becomes significantly negative, indicating the unique importance of such high-η_t^{UST} days in driving the secular decline in UST yield. Consistent with flights-to-safety, option-implied volatilities increase significantly on high-η_t^{UST} days, including 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.

To emphasize on the uniqueness of η_t^{UST} in capturing flights-to-safety, we construct alternative η_t measures using other known safe assets. First, following the insight of Cieslak and Schrimpf (2019), 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 η_t^{2Y} and η_t^{3M} are designed to capture the comovement between short-term interest rates and the SPX returns. Unlike η_t^{UST}, we find that neither η_t^{2Y} nor η_t^{3M} 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 η_t^{UST}. Second, using high-frequency data on the U.S. Dollar (USD) futures and the VIX index, the daily measures of η_t^{USD} and η_t^{VIX} capture the comovement between the SPX returns and those of the USD and changes in the VIX, respectively. Contrary to our findings for η_t^{UST}, days of elevated η_t^{USD} and η_t^{VIX} do not exhibit patterns of flight-to-safety, indicating that it is UST, not USD or VIX, that provides safety in the financial markets amid episodes of global risk-off.

Markets Under Low UST Safety – Focusing next on low-η_t^{UST} days, when the safety measure for UST is among the bottom 20% with an average value of -7%, we find that these are the days when the U.S. Treasury market experiences heightened uncertainty with respect to interest rate risk and worsened liquidity. This is in contrast to the high-η_t^{UST} days, when UST serves as the safe haven asset against the risk emanating from the equity market. On average, UST experiences a negative daily return of 6.05 basis points and an increase in return volatility of 28 basis points. Using the weekly primary dealers data from the New York Fed, we find that primary dealers reduce their Treasury positions significantly during weeks when η_t^{UST} is low.

As further evidence that markets under low UST safety are dominated by heightened interest-rate risk, we focus our attention on the FOMC announcement days, when the markets eagerly await the announcement of the FOMC committee on the monetary policy rate. On such FOMC days, the UST safety measure η_t^{UST} averages to a mere 3%, significantly lower than the sample average of 31%. Moreover, while the low-η_t^{UST} group collects only 20% of the sample, it contains 82 of the 147 pre-scheduled FOMC days in our sample. By contrast, only 13 FOMC days fall under the high-η_t^{UST} group. Outside of the FOMC announcements, the majority of the low-η_t^{UST} days occur during 2004-06, when the fed fund target rates were hiked 17 times from 1.0% to 5.25% to curb inflation and cool off an overheated economy; and after 2021, when the rapid surging inflation dominates the monetary-policy decision. In both cases, instead of serving as a safe-haven asset, UST has turned into a source of risk.

Asset Pricing Under High and Low UST Safety – The high frequency nature of η_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 to the high-η_t^{UST} 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. In other words, on high-η_t^{UST} days, the relative pricing across the global assets is determined by their relative safety rather than their own fundamental risks. Moreover, the same pattern of safety-driven returns can be observed not only across assets, but also cross-sectionally within U.S. equities, Treasury bonds, and global currencies.

First, on U.S. equities, we focus on the ten CAPM-beta sorted portfolios and find that the market price of safety is such that the low beta and relatively safer stocks strongly outperform the high beta stocks on high-η_t^{UST} days. The CAPM-alpha lines up monotonically across the ten beta-sorted portfolios, with the bottom decile (i.e., stocks with the lowest beta and the highest safety) outperforming with a significantly positive daily CAPM-alpha of 7.73 basis points, while the top decile underperforming with a daily CAPM-alpha of -10.59 basis points. Moreover, this rather sharp failure of the CAPM occurs uniquely on high-η_t^{UST} days. Identifying distressed market condition by focusing on days when the S&P 500 underperforms the most or when the VIX index is the highest, we do not find the same safe-driven pattern observed for the high-η_t^{UST} days. Moreover, excluding the high-η_t^{UST} days, the CAPM performs well on other days, attributing the failure of the CAPM uniquely to the presence of flights-to-safety.

Second, 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). Focusing first on the low UST safety days, we find significant increases in both measures of term premium, indicating increased risk premium for long-term bonds. In other words, investors seek higher compensations for bearing the long-term interest 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 days of high UST safety, we observe a significant drop in both measures of term premium.

Third, on global currencies, we find that the safe-haven currencies such as Japanese Yen and Swiss Franc appreciate significantly relative to USD on the high UST safety days, while the risky currencies such as the Australian Dollar and New Zealand Dollar depreciate. Effectively, on high UST safety days, the global risk-off's occur not only from SPX to UST, but also from the risky currencies to the safe currencies. Consistently, the loss to a typical currency-carry trade, which longs the asset currencies and shorts the funding currencies, is on average -14.05 basis points on high UST safety days, while the average daily return of the currency-carry trade is only 0.45 basis points.

The Safety of UST and USD – Given the unique dominance of the U.S. in the global financial system, the safety of its government bond (UST) and its currency (USD) is widely monitored and also closely intertwined. The high frequency nature of the safety measure for UST η_t^{UST} and USD η_t^{USD} allows us to examine the safety demand for dollar assets more closely and further differentiate the safety of UST from that of USD.

The global safety demand for dollar assets is studied by Jiang, Krishnamurthy, and Lustig (2021) via the convenience yield of UST. Measured as the yield difference between a U.S. Treasury bond and a currency-hedged non-U.S. government bond of the same maturity, the Treasury basis captures the financing cost of the U.S. government relative to other developed countries. A negative Treasury basis indicates a relative convenience of UST, often attributed to the safe haven status of UST. Consistently, we find that the convenience yield of the U.S. Treasuries widens substantially on high UST safety days, with Treasury basis decreasing by an average of 1.07 and 0.50 basis points respectively for the three-month and five-year maturities. Moreover, the Treasury basis is on average wider on high-η_t^{UST} days and narrower on low-η_t^{UST} days, connecting the UST convenience directly to the UST safety.[2] To further differentiate whether it is the safe haven status of UST or USD in driving the convenience yield, we use both η_t^{UST} and η_t^{USD} in our analysis and find that the UST convenience is driven mostly by the safety of UST, not that of USD.

Focusing on the safety of UST and USD, we further examine their comovement under the "tale of two days." 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 high UST safety days. In other words, when the decline in UST yields is driven by a

[2] A recent related work by Acharya and Laarits (2023) also 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.

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.[3]

While the UST to USD channel breaks down on high UST safety days, it strengthens on low UST safety 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 low UST safety days are marked by significantly negative UST returns, our result indicates that as UST loses its safe-haven status on low UST safety days, USD appreciates more significantly and replaces UST as the safety destination. Consistently, the USD safety measure η_t^{USD} averages to about 12% on low UST safety days, significantly higher than its full-sample average of 6%. Similarly, the USD safety measure η_t^{USD} increases significantly during the 2022 inflation surge to an average level of 25% when the rapid monetary-policy tightening turns UST into a source of risk.

Related Literature – Our paper is related to the literature on flights-to-safety, including 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), among others. We are mostly related to the recent paper Baele, Bekaert, Inghelbrecht, and Wei (2019), which use the daily returns of international equity and government bonds to infer flight-to-safety episodes based on multiple indicators such as return impact, correlation, and volatility spikes. We differ from their approach by constructing a simple safety measure from the correlation of the U.S. equity and Treasury intraday high-frequency returns, which enables us to identify the flight-to-UST episodes at the daily frequency. We show that the co-movement of global assets, from international bonds and equities to the FX currencies, are largely driven by their relative "safeness" to the U.S. equities on these days, with the U.S. Treasures be the safest one in our sample period.

Our paper also builds on the literature on the stock-bond correlation. Existing work, including Campbell, Pflueger, and Viceira (2020), David and Veronesi (2013), D.E.Shaw (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. Although the specific explanations in these papers differ, there is a consensus that the stock-bond correlation has turned significantly negative since the early 2000s due to the extremely low inflation risk in this period. We build on this observation to construct our safety measure and explore the information contained in the daily variations of the stock-bond correlations.

Our paper also contributes to the large literature on the U.S. Treasury market. We show

[3]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.

that a substantial movement of the U.S. Treasury can be attributed to its unique role as the safe haven asset rather than its own fundamental risk. This safety nature can help to explain the convenience yields of the U.S. Treasuries relative to other risk-free rates, such as the Treasury-Swap spreads (Adrian, Fleming, Shachar, and Vogt 2017), Treasury basis (Du, Im, and Schreger 2018; Jiang, Krishnamurthy, and Lustig 2020), and the Treasury inconvenience yields during the Covid-19 period (He, Nagel, and Song 2022). Our paper also contributes to the literature on the connection between the safety of UST and USD. In particular, we show that the usual negative correlation between returns on UST and USD breaks down under high UST safety. This is related to the work of Kekre and Lenel (2021), who study a business cycle model and show that a flight to safety generates a dollar appreciation and decline in global output in the presence of nominal rigidity.

The rest of our paper is organized as follows. Section 2 describes the construction of the safety measure and the characteristics of the flight-to-UST episodes. Section 3 investigates the asset pricing implications of the equity, Treasury, and FX markets under high and low UST safety. Section 4 discuss the safety of UST and USD. Section 5 concludes the paper. Further details are provided in the appendices.

2. Safety Measures via Stock-Bond Correlations

2.1. *Constructing the Safety Measures* η_t^{UST}

We construct our safety measure η_t^{UST} as the negative of 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:

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

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 (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 safety measure η_t^{UST} on a trading day t. [4]

[4]Considering the limited liquidity during the overnight period, we use the returns within the regular trading hours to construct the safety measures. In appendix C, we construct a safety measure from the

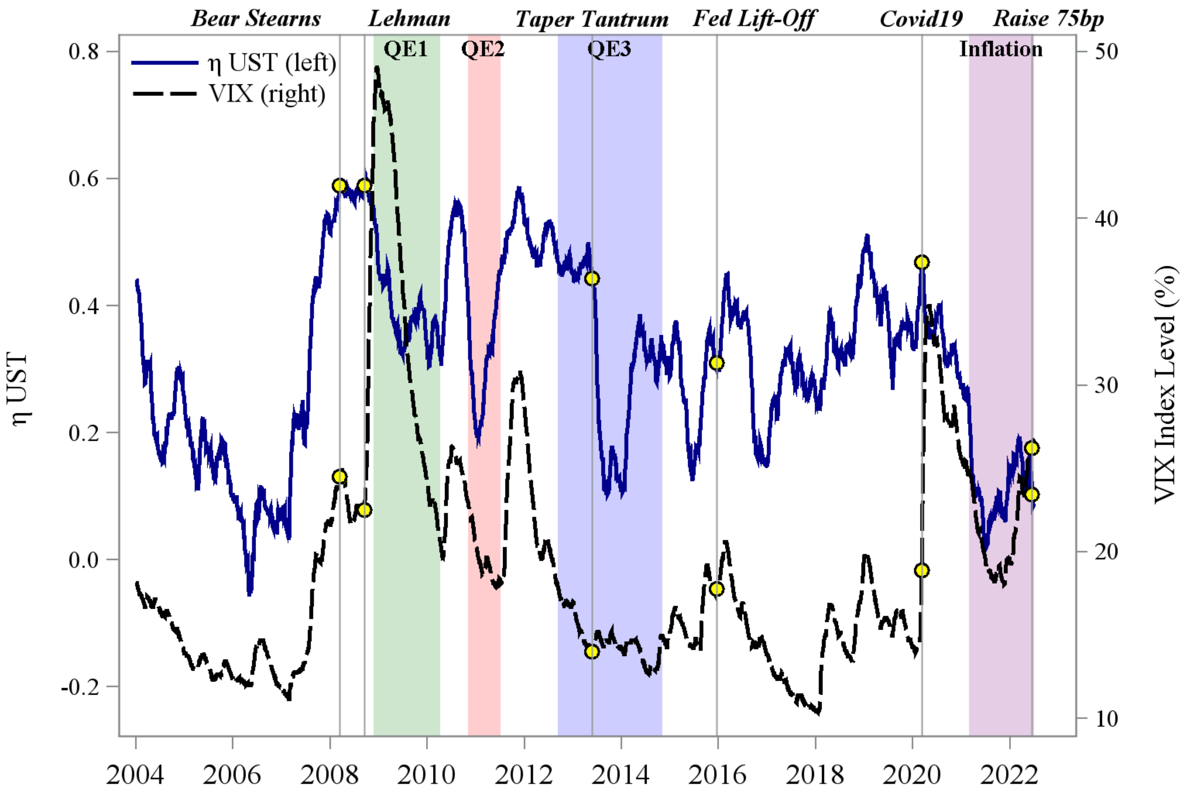
Figure 1 shows the time series of η_t^{UST} from January 2004 to June 2022. To illustrate the overall trend, we plot the exponential weighted moving averages of the time series with a decay factor of 0.98 to reduce noises at the daily frequency. The overall large and positive η_t^{UST} indicates that the U.S. Treasury is often a safe-haven asset in this period. η_t^{UST} peaks to around 0.6 during the 2008 financial crisis, falls sharply after the the Fed announced "tapering" of some of its QE policies in May 2013, then quickly bounces back and stays positive over the following few years. Interestingly, η_t^{UST} has declined significantly to near-zero levels toward the end of the sample period, suggesting that the U.S. Treasuries are no longer safe assets when high inflation becomes a major concern. For comparison, we also plot the time series of the CBOE Volatility Index (VIX, right axis), which is commonly considered as a "fear" gauge of the market. η_t^{UST} tends to co-move with the VIX index. However, with an average correlation of 0.30 between the two, η_t^{UST} clearly contains information that is distinct from the VIX.

We report the summary statistics of the the daily safety measures in Panel A of Table 1. Consistent with the overall pattern shown at Figure 1, η_t^{UST} is mostly positive in the sample period, with an average of 0.31 and a median of 0.33. We also report the summary statistics of the key variables we used in the paper in Panel B of Table 1. For our empirical tests, we consider 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 return of the U.S dollar index provided by the Intercontinental Exchange (ICE); EUR/USD and YEN/USD are the daily percentage 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)

returns of the entire trading day, including both the regular trading hours and the overnight period. Our main results stay quantitatively similar.

Figure 1: **Time Series of the Safety Measure $\eta_t^{\mathbf{UST}}$**



This figure shows the smoothed time series (exponential weighted moving average with a decaying parameter 0.98) of the safety measure η_t^{UST} (solid blue, left axis) and the CBOE VIX Volatility Index (dash black, right axis) from January 2004 to June 2022.

Table 1: **Summary Statistics**

	mean	std	min	Q1	med	Q3	max
Panel A: The main safety measure							
η_t^{UST}	0.31	0.26	-0.75	0.14	0.33	0.51	0.94
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	56.75	-263.9	-31.3	0.8	30.5	392.8
YEN/USD	-0.50	60.75	-349.7	-32.8	-1.1	30.0	488.2
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 safety measures							
η_t^{2Y}	0.16	0.23	-0.74	0.02	0.15	0.30	0.81
η_t^{3M}	0.16	0.24	-0.75	0.00	0.15	0.32	0.84
η_t^{USD}	0.06	0.28	-0.75	-0.14	0.04	0.27	0.77
η_t^{VIX}	0.72	0.18	-0.19	0.63	0.77	0.86	0.98

This table shows summary statistics of the safety measures and major asset performances. Panel A reports summary statistics of key safety measure η_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 return of the U.S dollar index provided by the Intercontinental Exchange (ICE); EUR/USD and YEN/USD are the daily percentage 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 safety measures η_t^{2Y}, η_t^{3M}, η_t^{USD} and η_t^{VIX} as estimated in equation (3) and (14). Returns are in unit of basis point. The sample period is from January 2004 to June 2022.

and 0.036 for Swiss Franc (CHF/USD IV).

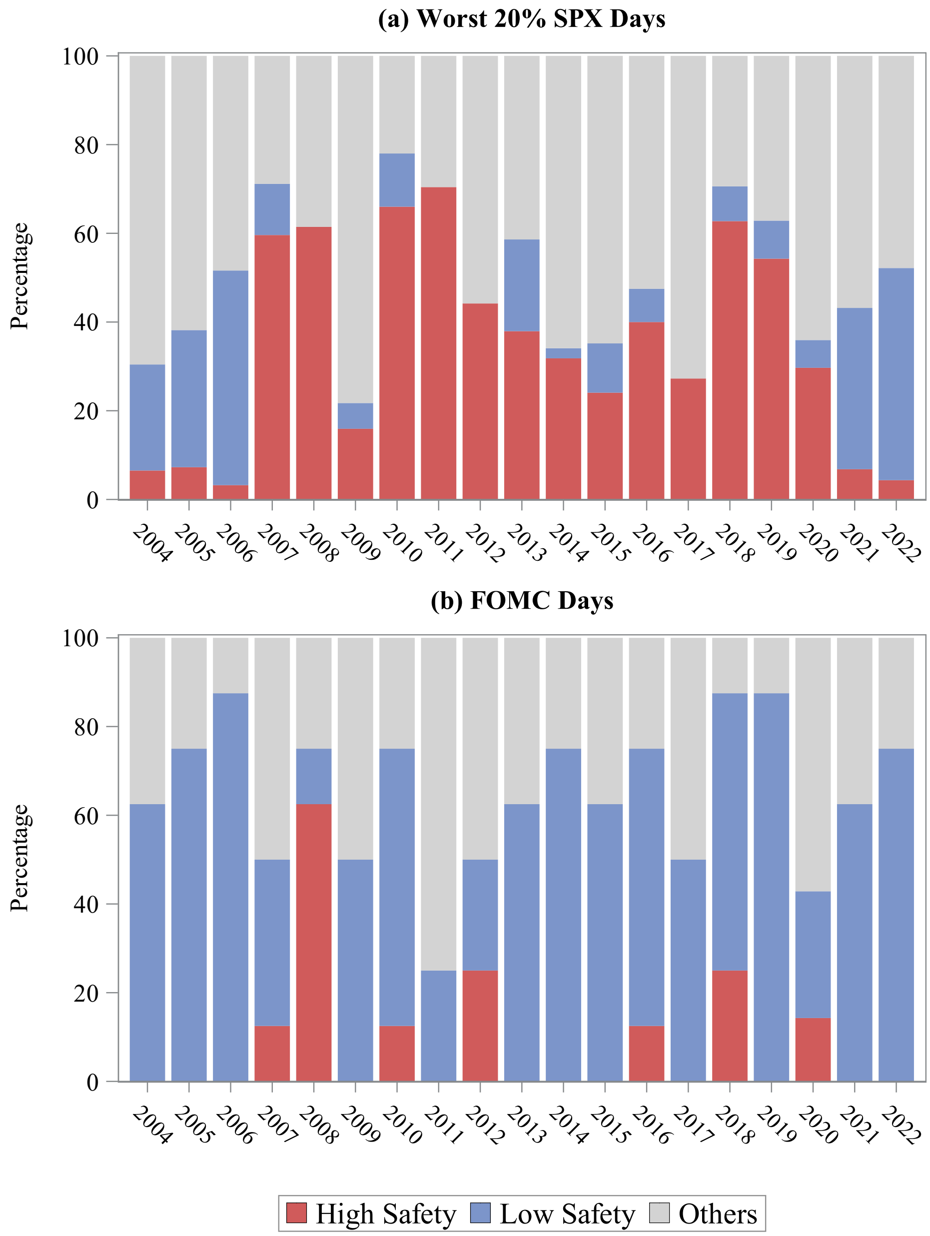
2.2. High and Low Safety Days Captured by the Safety Measure η_t^{UST}

Taking advantage of the daily safety measures, we sort all days into different quintiles, with high UST safety days (also referred as high safety days or high η_t^{UST} days hereafter) containing the top 20% η_t^{UST} days and low UST safety days (also referred as low safety days or low η_t^{UST} days hereafter) containing the bottom 20% η_t^{UST} days. The high UST safety days capture the days when the risk is originated in the U.S. equity market and the U.S. Treasury market is on the receiving end of the flight-to-safety, while the low UST safety days capture the days when the U.S. Treasury market itself becomes the source of risk.

To illustrate the unique information captured by the safety measure, we examine the distribution of the high and low UST safety days among two special types of days. First, we zoom the lens in the 20% trading days with the worst S&P 500 daily returns (daily returns less than -59 basis point) from January 2004 to June 2022. The annual proportion of high (in red) and low (in blue) safety days out of these 20% worst equity performance days are reported in the top panel of Figure 2. Not surprisingly, the UST often serves as a destination of safe haven when the equity market suffers large negative returns in our sample period. The high UST safety days account for more than 20% of the worst SPX performance days for every year from 2007 to 2020, with 2009 being the only exception. For six years within the period from 2007 to 2020, i.e., 2007, 2008, 2010, 2011, 2018, and 2019, the high UST safety days account for more than half of the worst SPX performance days. For the remaining five years outside of this period, i.e., from 2004 to 2006 and 2021 to 2022, the high UST safety days comprise less than 8% of the worst equity performance days while the low UST safety days comprise a majority portion ranging from 24% to 48%. Moreover, given that 22% to 78% of the worst equity performance days are neither high nor low UST safety days, it is also clear that the information captured by η_t^{UST} is not identical to those reflected by the equity returns.

Next, we investigate the composition of the high and low UST safety days on the Federal Open Market Committee (FOMC) announcement days. Considering that interest rate and other monetary policy news are the main drivers of asset returns on the FOMC announcement days, we expect the correlation between the stocks and bonds gets much weaker. At the bottom Panel of Figure 2, we plot the proportion of the high and low UST safety days out of the eight regular FOMC days per year from 2004 to 2022. Indeed, Figure 2 shows that there are substantial more low than high UST safety days on the FOMC announcement days. There are 82 low UST safety days from 2004 to 2022, accounting for 56% of the total 147 FOMC days in this period. In contrast, there are only 13 high UST safety days, representing

Figure 2: **Distribution of High and Low UST Safety Days**



This figure shows the percentage of high UST safety days (top 20% η_t^{UST} days in red), low UST safety days (bottom 20% η_t^{UST} days in blue) and other days (middle 20% to 80% η_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 high and low UST safety 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.

a small 9% of the total FOMC days. The average η_t^{UST} is 0.03 on the FOMC days, not only substantially lower than the average η_t^{UST} on the non-FOMC days (0.32) but also statistically insignificantly from zero.

We then examine the return and volatilities of three key asset classes, i.e., the U.S. equity, the U.S. Treasury, and the FX markets, on the high and low UST safety days from 2004 to 2022. The results, as reported in Table 2, paint a clear picture of flight-to-UST on the high UST safety days. 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). The safe-haven currency Japanese Yen appreciates relative to the USD with an average daily return of 16.48 bps (t-stat=7.07). Controlling for their exposure to the U.S. equity market, the CAPM αs remains significantly positive, 5.03 bps for the UST and 10.27 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 high UST safety days. The volatility across all three markets hike up on the high UST 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.

In contrast to the high UST safety days, the low UST safety 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 8.43 bps. The dollar index and the EUR/USD exchange rates don't move significantly on the low UST safety 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 3.99 bps relative to the dollar. The implied volatilities for the equity and the FX markets drop slightly on the low UST safety 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 low UST safety days.

Lastly, we investigate the impact of the flight-to-UST on the market liquidity of the U.S. equity and Treasury markets. Our main liquidity measures are the realized volatility (Vol) estimated based on the intra-day returns following Bollerslev, Tauchen, and Zhou (2009), the trading volume, and the Noise measure proposed in Hu, Pan, and Wang (2013). 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 daily changes of the liquidity measures are reported separately for the high and low UST safety days at Panel C of Table 2.

On the high UST safety days, both the Treasury and equity markets have significant

Table 2: **Performance of Key Assets on High and Low UST Safety Days**

Panel A: Safety Measures

	η_t^{UST}	# Days		η_t^{UST}	# Days
High η_t^{UST}	0.64***	926	Non-FOMC	0.32***	4509
	[201.95]			[36.74]	
Low η_t^{UST}	-0.07***	926	FOMC	0.03	147
	[-13.03]			[0.83]	

Panel B: Major Market Performance

(a) Excess Return

	SPX	UST	DXY	EUR/USD	YEN/USD
High η_t^{UST}	-36.20***	13.60***	1.20	-1.90	16.48***
	[-8.04]	[9.57]	[0.63]	[-0.82]	[7.07]
Low η_t^{UST}	13.75***	-6.05***	2.14	-1.87	-8.43***
	[4.76]	[-3.92]	[1.22]	[-0.99]	[-4.42]

(b) CAPM α

		UST	DXY	EUR/USD	YEN/USD
High η_t^{UST}		5.03***	-0.89	-0.22	10.27***
		[4.42]	[-0.49]	[-0.10]	[5.10]
Low η_t^{UST}		-7.96***	3.61**	-3.99**	-9.76***
		[-4.92]	[2.06]	[-2.06]	[-5.03]

(c) ΔImplied Vol

	VIX	MOVE	DXYV	EURV	YENV
High η_t^{UST}	0.51***	0.79***	0.07***	0.07***	0.14***
	[6.48]	[4.68]	[3.75]	[3.42]	[4.28]
Low η_t^{UST}	-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	ΔNoise
High η_t^{UST}	1.11***	0.25***	-0.02	0.15***	0.01
	[4.22]	[7.29]	[-0.21]	[5.22]	[1.00]
Low η_t^{UST}	-0.25**	-0.00	0.28***	0.12***	0.01
	[-2.12]	[-0.12]	[3.64]	[3.97]	[1.32]

This table summarizes the performances of major assets on high UST safety (top 20% η_t^{UST}) and low UST safety (bottom 20% η_t^{UST}) days. Panel A reports the average safety measure η_t^{UST} on the high and low η_t^{UST} 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 high and low η_t^{UST} 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 return of the U.S dollar index provided by the Intercontinental Exchange (ICE); EUR/USD and YEN/USD are the daily percentage 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 high and low η_t^{UST} 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). ΔNoise is the daily changes of the Noise measure proposed in Hu, Pan, and Wang (2013) (in unit of basis point). 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.

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.

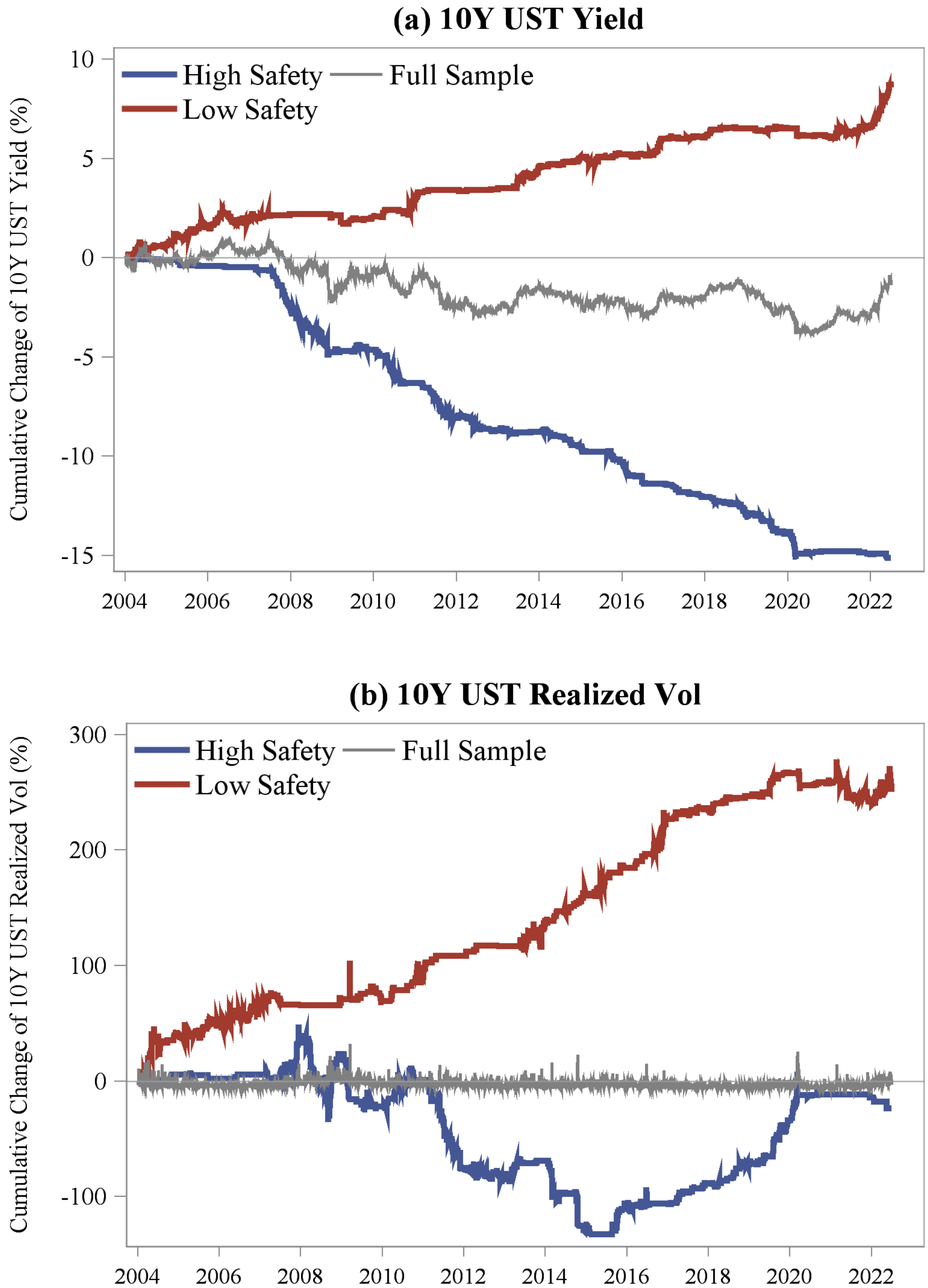
Interestingly, the Treasury market becomes significantly more volatile on the low UST safety days. On average, the volatility of the Treasury market increases by 0.28% (t-stat=3.64). The Treasury market also has higher trading volume on the low UST safety days. In contrast, The equity market has slightly lower volatility and similar trading volume on the low UST safety days. The liquidity pattern is consistent with our previous observations that the Treasury market turns into a source of risk on the low UST safety days.

To emphasize the contrast of high and low UST safety days, we compare the cumulative change of yield and realized volatility of 10-year U.S. Treasury on high and low η_t^{UST} days in Figure 3. In Panel (a), we show the cumulative 10-Year Treasury daily change of yield on high UST safety days (top 20% η_t^{UST} days, in blue), low UST safety days (bottom 20% η_t^{UST} days, in red) and full sample (all day, in gray) through our sample period. 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). In Panel (b), we show the cumulative daily change of the 10-Year Treasury futures' realized volatility on each type of days. 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).

Figure 3 paints a clear picture of divergence in Treasury's performance on the high and low UST safety days. During high η_t^{UST} days, the yield of the 10-year Treasury experiences a significant decline as it functions as the safety destination during periods of flight-to-safety. In fact, the reduction in Treasury yields during our sample period predominantly comes from high UST safety days when Treasuries serve as a safe haven asset. Excluding the high UST safety days, there is actually an upward trend in the 10-year Treasury yields.

Conversely, on low UST safety days, Treasuries no longer serve as the safety destination and instead become a source of risk in their own. This transition is marked by a substantial increase in the realized volatility of Treasuries, coupled with a rise in yields (resulting in a decline in prices) on low η_t^{UST} days. These observations also align with the fact that that low UST safety days often coincide with Federal Open Market Committee (FOMC) meetings, during which the risk in the Treasury market escalates due to the announcements of monetary policy and interest rates.

Figure 3: **10-Year U.S. Treasury Performance on High and Low UST Safety 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 high UST safety days (days with top 20% η_t^{UST}, in blue), low UST safety days (days with bottom 20% η_t^{UST}, in red), 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.

2.3. *Investor Behavior*

Based on the performance of key asset classes, the previous results provide strong evidence that the safety measure η_t^{UST} captures the high UST safety episodes when there is a flight-to-safety from the U.S. equity to the Treasury market, as well as the low UST safety episodes when the U.S. Treasury becomes a source of risk itself. In this section, we turn to the investor behavior on the high and low UST safety days, focusing on publicly available institution 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 Commission (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.[5]. 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 high and low UST safety days identified by the safety measure η_t^{UST},

$$\Delta\text{position}_t = \text{intercept} + b^H \times \text{High}_t^{\text{UST}} + b^L \times \text{Low}_t^{\text{UST}} + c_1 \times \text{VIX}_t + c_2 \times \text{Ted}_t + \epsilon_t, \quad (2)$$

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, $\text{High}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t has top 20% η_t^{UST} , $\text{Low}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t has bottom 20% η_t^{UST}, VIX_t is the level of the VIX index on day t, and Ted_t

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

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, $\text{High}_t^{\text{UST}}$ is a dummy variable that takes value of one if the average of the daily η_t^{UST} within the week t is in the top 20% of the sample, $\text{Low}_t^{\text{UST}}$ is a dummy variable that takes value of one if the average of the daily η_t^{UST} within the week t is in the bottom 20% of the sample, VIX_t and Ted_t are the average VIX and Ted spreads of week t.[6]

The estimation results are reported in Table 3. We find significant ETF flows out of the SPX and into the UST on the high UST 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 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).

In the futures market, we find that asset managers exhibit similar flight behavior on the high UST 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 highest 20% η_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 high UST 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, TIPs, agency bonds and mortgage-backed securities, with t-stat of 2.07, 2.83, 3.44, 4.18, respectively, on weeks with the highest 20% η_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 elevated η_t^{UST}.

Lastly, on the low UST safety 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

[6]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 η_t^{UST}, VIX index and Ted spreads for CFTC futures positions and Wednesday-to-Wednesday averages for primary dealer's fixed income positions.

Table 3: **Changes of Positions on High and Low UST Safety Days**

	Daily ETF		Weekly CFTC						Weekly Primary Dealers			
			Asset Mangement		Dealer		Leveraged					
	UST	SPX	UST	SPX	UST	SPX	UST	SPX	Coupons	TIPS	Agency	MBS
High η_t^{UST}	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]
Low η_t^{UST}	-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 Spread	-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 change of institutions' holdings on the high and low UST safety days. The regressions are specified in Equation (2). 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, $\text{High}_t^{\text{UST}}$ ($\text{Low}_t^{\text{UST}}$) is a dummy variable that takes value of one if day t is a high (low) safety UST day, and ted spread is in unit of basis point. For regressions of the weekly changes, $\text{High}_t^{\text{UST}}$ ($\text{Low}_t^{\text{UST}}$)is a dummy variable that takes value of one if the average of the daily η_t^{UST} within the week t is in the top (bottom) 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.

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.

2.4. Alternative Measures

2.4.1. Comovement Between Stocks and Short-term Treasuries

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

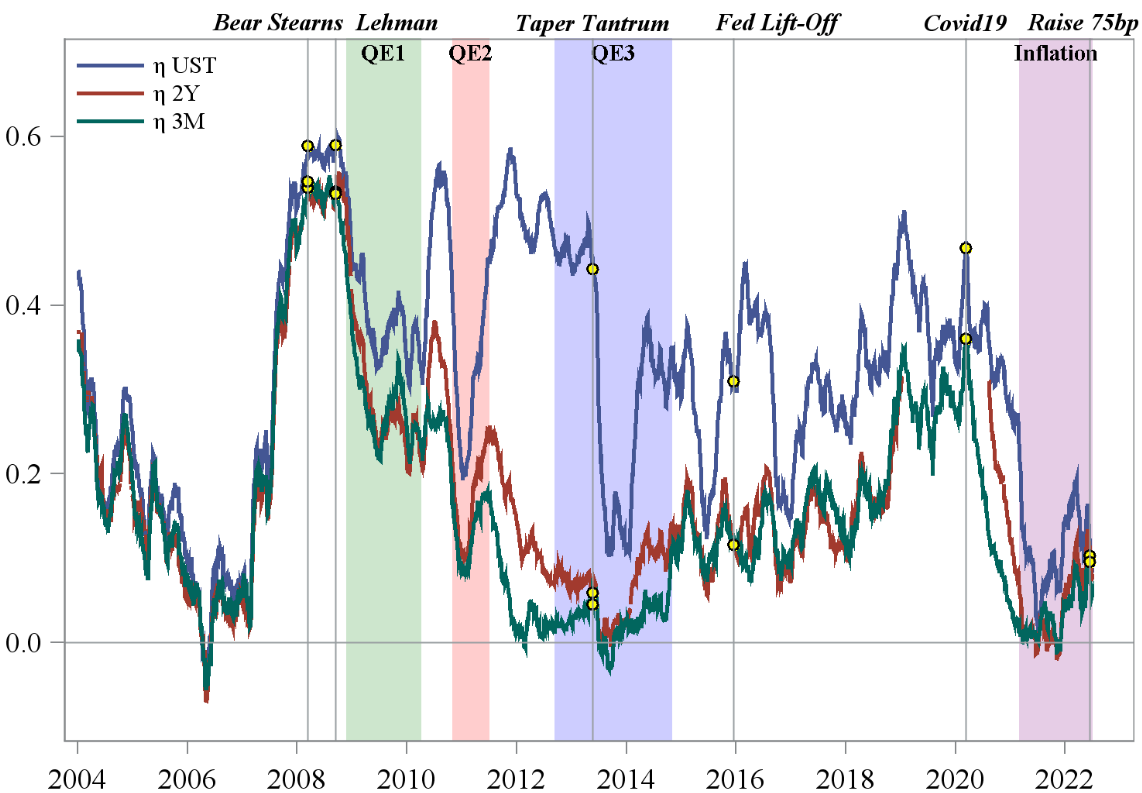
$$\begin{aligned} \eta_t^{\text{2Y}} &= -corr(r_{i,t}^{\text{SPX}}, r_{i,t}^{\text{UST 2Y}})|_{fixed\ t} \\ \eta_t^{\text{3M}} &= -corr(r_{i,t}^{\text{SPX}}, r_{i,t}^{\text{EuroDollar 3M}})|_{fixed\ t} \end{aligned} \tag{3}$$

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[7]. 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 safety measure η_t^{2Y} and η_t^{3M} on a trading day t. The sample period is from Januray 2004 to June 2022[8].

[7]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.

[8]From January 11, 2019 to August 7, 2020, the prices of 2-year futures provided by CME contain data

Figure 4: **3M-, 2Y- and 10Y-Safety Measures**



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

Figure 4 shows the time series of η_t^{UST}, η_t^{2Y}, and η_t^{3M} from January 2004 to June 2022. Notably, the overall trend for η_t^{2Y} and η_t^{3M} remains positive throughout the sample period, albeit that levels considerably lower than those of η_t^{UST}. This divergence confirms that the information content of the long- and short-term safety 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 the three safety measures begin to manifest. Specifically, the 10-Year US Treasury, serving as the 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 lower levels. Between η_t^{2Y} and η_t^{3M}, the two measures consistently show similar magnitudes throughout the majority of our sample period, with η_t^{2Y} being slightly larger 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 high and low UST safety days identified by long- and short-term safety measures, respectively, in Table 4. Considering the similarity between η_t^{2Y} and η_t^{3M} throughout our sample period, we only report the results based on η_t^{3M} for brevity.

Similar to the high- and low-safety days based on the long-term safety measure η_t^{UST}, we identify high- and low-safety days based on the short-term safety measure as the ones with the top 20% and bottom 20% η_t^{3M}. Of the safety days based on long- and short-term safety measures, there is considerable overlap: 479 days with both high η_t^{UST} and high η_t^{3M}. Excluding these overlapped days, we have 382 high η_t^{UST} safety days and 355 high η_t^{3M} safety days. As shown in Table 4, major asset classes show similar flight-to-UST behavior on the 382 days with high η_t^{UST} but not high η_t^{3M} : 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 with high η_t^{3M} but not high η_t^{UST}, 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 safety measure η_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.

errors. We therefore could not calculate η_t^{2Y} for this period.

Table 4: **Performance of Key Assets on High and Low $\eta_t^{\mathbf{UST}}$ and $\eta_t^{\mathbf{3M}}$ Safety Days**

Panel A: High and Low η_t^{UST} and η_t^{3M} Safety Days					
	η_t^{UST} only	η_t^{3M} only	overlapped		
# High	382	355	479		
# Low	389	400	442		
Panel B: High and Low η_t^{UST} Safety Days (excluding overlapped)					
(a) Excess Return					
	SPX	UST	DXY	EUR/USD	YEN/USD
High η_t^{UST}	-28.00***	11.66***	7.24**	-9.32***	10.91***
	[-4.55]	[5.31]	[2.43]	[-2.64]	[3.69]
Low η_t^{UST}	15.14***	-6.25***	2.40	-2.15	-8.03***
	[3.75]	[-2.83]	[0.91]	[-0.74]	[-2.85]
(b) CAPM α					
		UST	DXY	EUR/USD	YEN/USD
High η_t^{UST}		4.73***	3.47	-5.99*	8.58***
		[2.80]	[1.27]	[-1.79]	[2.98]
Low η_t^{UST}		-7.22***	2.75	-4.10	-8.79***
		[-2.94]	[1.04]	[-1.41]	[-2.95]
(c) ΔImplied Vol					
	VIX	MOVE	DXYV	EURV	YENV
High η_t^{UST}	0.36***	0.42**	0.06**	0.06**	0.07**
	[3.09]	[2.25]	[2.49]	[2.24]	[2.45]
Low η_t^{UST}	-0.15**	-0.30	-0.01	-0.01	-0.02
	[-2.56]	[-1.44]	[-0.92]	[-0.68]	[-1.05]
Panel C: High and Low η_t^{3M} Safety Days (excluding overlapped)					
(a) Excess Return					
	SPX	UST	DXY	EUR/USD	YEN/USD
High η_t^{3M}	14.37**	-2.09	-0.97	1.85	-6.41*
	[2.08]	[-0.94]	[-0.40]	[0.69]	[-1.86]
Low η_t^{3M}	2.62	0.15	-0.59	1.15	-1.43
	[0.59]	[0.08]	[-0.25]	[0.41]	[-0.56]
(b) CAPM α					
		UST	DXY	EUR/USD	YEN/USD
High η_t^{3M}		-0.71	-0.74	0.65	-4.85
		[-0.28]	[-0.32]	[0.24]	[-1.50]
Low η_t^{3M}		0.61	-0.30	0.53	-1.16
		[0.40]	[-0.13]	[0.19]	[-0.47]
(c) ΔImplied Vol					
	VIX	MOVE	DXYV	EURV	YENV
High η_t^{3M}	-0.17	-0.48*	-0.02	-0.02	-0.07*
	[-1.48]	[-1.82]	[-1.06]	[-0.74]	[-1.70]
Low η_t^{3M}	0.03	-0.11	0.00	0.00	-0.02
	[0.42]	[-0.87]	[0.04]	[0.12]	[-1.14]

This table compares the performances of major assets on high and low safety days identified by η_t^{UST} and η_t^{3M}. The high (low) safety days contain the trading days with the top (bottom) 20% η_t^{UST} or η_t^{3M}. Panel A reports the distribution of high and low safety days identified by two measures. Panel B reports major asset classes' performances on high or low η_t^{UST} days after excluding high or low η_t^{3M} days, i.e. the η_t^{UST} only days reported in Panel A. Likewise, Panel C reports major asset classes' performances on η_t^{3M} 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.

2.4.2. Low-frequency Safety Measures

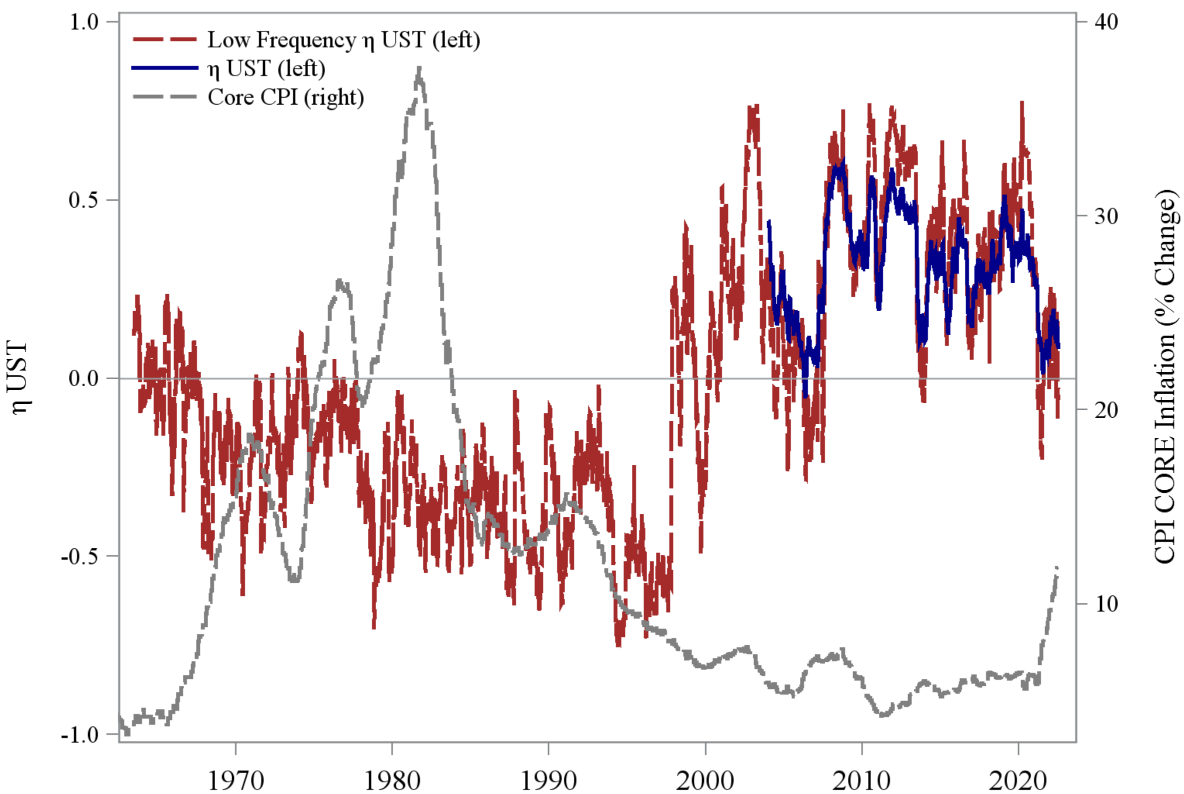
Taking advantage of the intra-day futures returns, our safety measure enables us to capture the flight-to-UST phenomenon at the daily frequency in our sample period. An alternative approach to estimate the stock-bond correlations could be based on the daily stock and bond returns in a rolling historical 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 intra-day stock and bond returns were generally not available.

We compute an alternative low-frequency safety measure as the negative of 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 safety measures back to 1963. We plot the low-frequency safety measure (in red) in Figure 5, against the high-frequency safety 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 5 confirms that our high-frequency safety measure η_t^{UST} is consistent with the overall trend of the low-frequency safety 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 safe measures quickly drop to levels close to zero. Similarly, the low-frequency safety measure was negative for the period from 1967 to 1997 when the inflation in the U.S. was high.

Although the low-frequency safety measure can go back to early times and shares similar time-series pattern as the high-frequency safety measure, its construction method limits its ability to capture flight-to-safety at the daily basis. On the top 20% days with the highest low-frequency safety 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 high UST safety days identified by the high-frequency safety measure η_t^{UST}. On the bottom 20% days with the lowest low-frequency safety 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 safety measure can not capture the variation of market conditions at the daily level.

Figure 5: **Low- and High-frequency Safety Measures**



The smoothed time series (exponential weighted moving average with decaying parameter 0.98) of the safety measure η_t^{UST} (solid blue, left axis), the low-frequency safety measure (dash red, left axis), and the inflation series (gray, right axis) are plotted from January 2004 to June 2022. The low-frequency safety measure is calculated as the negative of 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 change from one year ago of the Consumer Price Index for All Urban Consumers: All Items Less Food and Energy in U.S. City Average.

3. Asset Pricing Under High and Low UST Safety

3.1. Performance of Global Assets under High and Low UST Safety

We start by investigating the return performance of major global assets on the high and low UST safety days captured by the safety measure η_t^{UST}. We consider five major global asset classes: (1) Treasury and fixed income assets (US Fixed Income), 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 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).

For each asset class, we calculate the relative performance on high and low UST safety days as follows:

$$r_{i,t} - r_{f,t} = \text{intercept} + b^{\text{H}} \times \text{High}_t^{\text{UST}} + b^{\text{L}} \times \text{Low}_t^{\text{UST}} + \epsilon_t, \tag{4}$$

Here, $r_{i,t} - r_{f,t}$ is the daily excess return of asset i, $\text{High}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t is a high UST safety day with the top 20% η_t^{UST}, $\text{Low}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t is a low UST safety day with the lowest 20% η_t^{UST}. b^{H}/σ_i, b^{L}/σ_i and intercept$/\sigma_i$ are the estimates of scaled relative returns on high UST safety, low UST safety and normal days, where σ_i is the full sample standard deviations of asset i's returns.

We plot the scaled relative returns of each global asset class against their correlation with the U.S. equity index, which serves as a proxy for the "safeness" of the global asset class, in top panel of Figure 6. [9] Asset classes with large positive correlations with the U.S. equity market, the global equities and commodities, for example, tend to move in the same direction as the U.S. market. These asset classes are considered to be "risky" ones and are unlikely to serve as the safe haven assets when the U.S. equity market suffers a flight-to-safety. By

[9] 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 correlation as the overlapping two-day return correlation, and estimate scaled return as the average of the relative return on the day and next day divided by 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.

comparison, asset classes with negative return correlations with the U.S. equity market, US fixed income assets and Japanese Yen, for example, are more likely to be the safe haven assets at times of flight-to-safety.

Figure 6 paints a clear picture of the relative returns of the global asset classes on the high UST safety days with elevated η_t^{UST}, which declines almost monotonically as one moves from the safest assets to the most riskiest ones. The US fixed-income assets, Treasuries in particular, have the most negative correlations with the U.S. equity market and are the safest asset class, followed by the U.S. dollar index, the gold, the global bonds, FX, and the global equities. For the safest asset class, the US fixed-income assets, their relative returns on the high UST safety days are positive and range from 0.09 to 0.36 of their daily return standard deviations.[10] Conversely, the relative returns of the riskiest asset class, the global equities, are negative and in the range from -0.20 to -0.27 of their daily return standard deviations. That is, the global assets' relative performance on the high UST safety days are closely linked to their safeness relative to the U.S. equity market, consistent with our early observations that the high UST safety days are characterized by a flight-to-safety in global markets whereas the U.S. Treasury market is the main safe haven destination.

By comparison, most of the global asset classes don't show different returns on the low UST safety days, which by definition captures the days when the U.S. Treasury market is the source of risk. For almost all asset classes, with the U.S. Fixed-income assets being the only exception, their relative returns on the low UST safety days are close to zero, suggesting that the risk in the low UST safety days is largely contained within the U.S. fixed-income market and doesn't move global asset classes. Not surprisingly, the U.S. fixed-income assets have negative returns on the low UST safety days, in the range from -0.12 to -0.21 of their daily return standard deviations.[10] Similarly, we don't find the disparity of global asset returns on normal days or days with high VIX level after excluding high UST safety days, implying the special episodes captured by η_t^{UST} when the global financial co-movements are majorly driven by flight-to-safety.

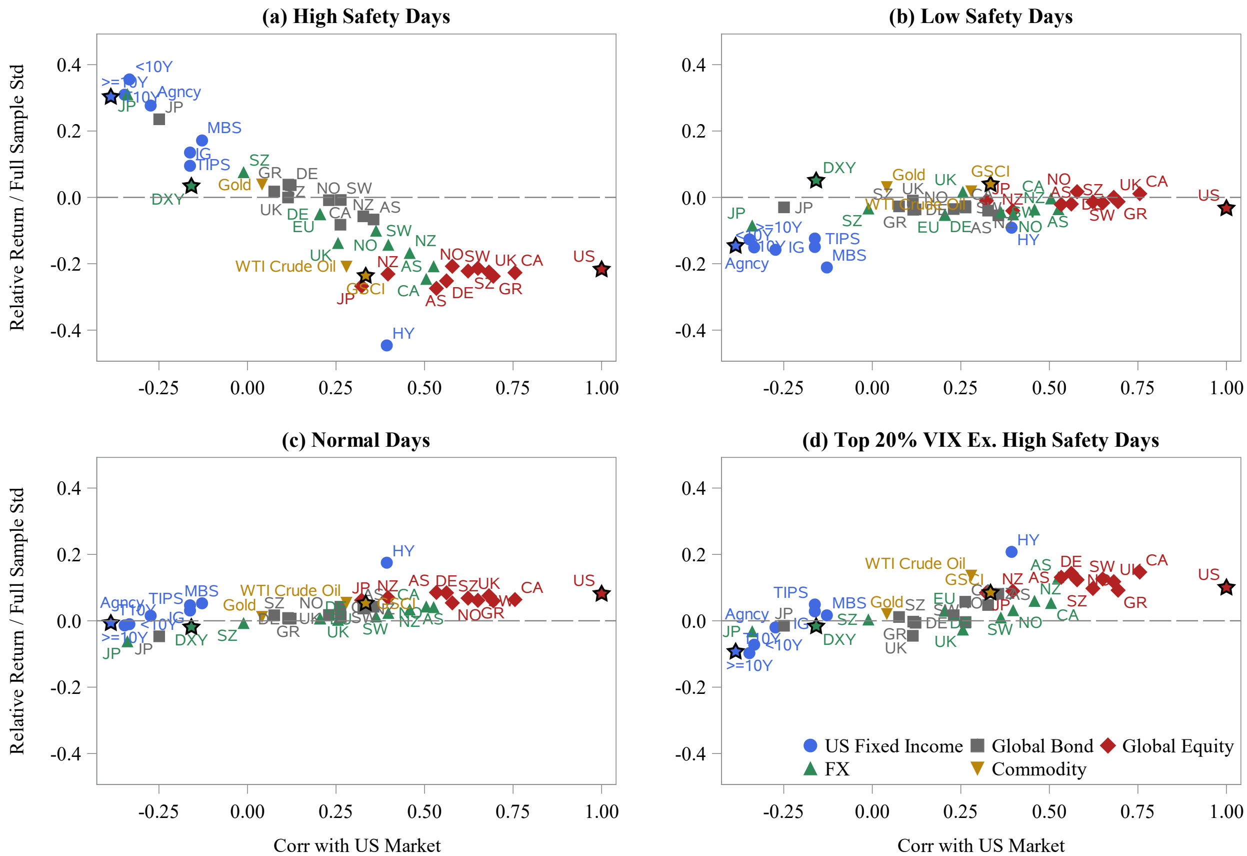
3.2. Tests of the CAPM under High and Low UST Safety

In this subsection, we examine the CAPM model on high and low UST safety days in the equity market. We obtain the returns of 10 beta-sorted portfolios of stocks from the q-factor library. [11] Specifically, at the beginning of each month t, stocks are sorted into deciles

[10] The only exception is the High-yield corporate bonds. 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.

[11] The q-factor library is at https://global-q.org/testingportfolios.html. We have replicated the tests using 10 beta-sorted portfolios we constructed. The findings are similar. We report results based on

Figure 6: **Performance of Global Assets**



This figure plots the scaled relative returns of each global asset class against its correlation with the U.S. equity index on (a) high safety days with top 20% η_t^{UST}; (b) low safety days with bottom 20% η_t^{UST}; (c) normal days with η_t^{UST} in the middle of 20% to 80% percentile; (d) top 20% VIX level days excluding high safety days. Global assets include: (1) US Treasury and fixed income assets (US Fixed Income, 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 calculate the scaled relative returns on the specified group of daysfollowing equantion (4), which equals to subtracting the average returns by their counterparts on the rest of the days and divivded by the standard deviation of full sample returns (for high or low η_t^{UST}, the rest of days are days with middle 20% to 80% η_t^{UST}; for top 20% VIX days, the rest of days are days with middle 20% to 80% VIX index days). The correlations are estimated based on the daily returns from January 2004 to June 2022. For global equities and bonds, we calculate the correlations based on overlapping two-day returns, and calculate scaled relative returns as average of relative returns on the day and next, to adjust for the time differences between the global markets and the U.S. market.

Table 5: **Performance of Beta-Sorted Portfolios on High and Low UST Safety Days**

Portfolio	Excess Return	CAPM α	CAPM β	CAPM R2	CAPM α High η_t^{UST}	CAPM α Low η_t^{UST}	CAPM α Normal	Fama-French 3-Factor α High η_t^{UST}	Fama-French 3-Factor α Low η_t^{UST}	Fama-French 3-Factor α Normal
1 (low beta)	3.22***	0.94	0.60***	69.99	7.73***	-3.73**	0.54	7.00***	-3.21**	0.38
	[2.99]	[1.40]			[4.79]	[-2.13]	[0.57]	[4.63]	[-2.00]	[0.42]
2	3.62***	0.82	0.74***	85.55	5.85***	-0.22	-0.46	5.51***	0.34	-0.57
	[2.92]	[1.48]			[4.07]	[-0.17]	[-0.64]	[4.28]	[0.28]	[-0.80]
3	4.55***	1.07**	0.92***	90.7	1.52	0.43	0.79	1.25	0.91	0.57
	[3.08]	[2.30]			[1.12]	[0.39]	[1.23]	[1.01]	[0.86]	[0.94]
4	4.66***	0.93*	0.99***	91.31	-1.52	0.56	1.58**	-1.48	1.29	1.38**
	[2.84]	[1.71]			[-1.20]	[0.41]	[2.25]	[-1.24]	[0.98]	[2.13]
5	5.11***	1.08*	1.07***	91.28	0.04	0.46	1.23	0.30	0.82	1.09
	[2.86]	[1.94]			[0.02]	[0.39]	[1.62]	[0.22]	[0.71]	[1.45]
6	4.82**	0.54	1.13***	91.05	-1.70	-0.66	0.72	-0.83	-1.00	0.8
	[2.54]	[0.90]			[-1.02]	[-0.53]	[0.89]	[-0.55]	[-0.81]	[1.04]
7	5.01**	0.6	1.17***	88.56	-2.63	-0.06	1.68	-1.81	-0.61	1.86*
	[2.48]	[0.79]			[-1.53]	[-0.04]	[1.51]	[-1.11]	[-0.40]	[1.72]
8	4.94**	0.13	1.27***	86.71	-5.10**	2.41	0.73	-3.50*	1.89	1.00
	[2.15]	[0.15]			[-2.52]	[1.13]	[0.59]	[-1.92]	[0.98]	[0.88]
9	4.75*	-0.46	1.38***	82.75	-7.87***	4.04	0.18	-5.68***	2.89	0.47
	[1.84]	[-0.43]			[-3.22]	[1.56]	[0.12]	[-2.66]	[1.26]	[0.35]
10 (high beta)	5.23*	-0.53	1.52***	79.27	-10.59***	2.10	0.69	-7.57***	-0.36	1.23
	[1.75]	[-0.38]			[-3.61]	[0.65]	[0.37]	[-3.17]	[-0.13]	[0.78]
BAB	2.79	2.79	0.00		20.65***	-6.27	1.19	17.46***	-3.79	0.57
	[1.61]	[1.61]			[5.08]	[-1.40]	[0.49]	[4.95]	[-0.98]	[0.26]

This table shows the performance of the beta-sorted portfolios and betting-against-beta strategies on the high and low UST safety days. Beta-sorted portfolios are downloaded from q-factor library. Specifically, at the beginning of each month t, stocks are sorted into deciles on their market beta, β, which is estimated with monthly returns from month t-60 to t-1 (minimum of 24 monthly returns are required). Decile returns are calculated for the current month t and the deciles are rebalanced at the beginning of month t+1. Stock sample includes all NYSE, Amex, and Nasdaq common stocks with a CRSP share code of 10 or 11. Financial firms (SIC between 6000 and 6999) and firms with negative book equity are excluded. Stock returns are adjusted for delisting. BAB portfolio is the long-short portfolio based on lowest and highest deciles. The low beta and high beta portfolios are leveraged so that the BAB portfolio has zero full sample CAPM beta. The first column report portfolios' excess returns. The following three columns report CAPM α, β and R2 of each portfolio. The fifth to seventh columns report full sample α decomposition on high UST safety (top 20% η_t^{UST}), low UST safety (bottom 20% η_t^{UST}) and other days (middle 20% to 80% η_t^{UST}). The last three columns report replace CAPM α with Fama-French 3-factor α and report its decomposition on high UST safety, low UST safety and normal days. 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.

on their market βs, which are estimated from the monthly returns from month t-60 to t-1 (a minimum of 24 monthly returns are required). Decile returns are calculated for the current month t and the deciles are rebalanced at the beginning of month t+1. The stock sample includes all NYSE, Amex, and Nasdaq common stocks with a CRSP share code of 10 or 11. Financial firms (SIC between 6000 and 6999) and firms with negative book equity are excluded. Stock returns are adjusted for delisting. We report the average daily excess returns, market betas, and alphas of the 10-sorted portfolios in Table 5.

Consistent with the literature, high-beta stocks tend to under-perform low-beta stocks on average. A beta-neutral betting against beta (BAB) factor, i.e., a portfolio that longs leveraged low-beta stocks and that shortsells de-leveraged high-beta stocks, earns an average excess daily return of 2.79 bps in our sample from January 2004 to June 2022, positive but not statistically significant with a marginal t-stats of 1.61. Compared with Frazzini and Pedersen (2014) which finds significant returns for their sample period from 1926 to 2012, the BAB factor returns are indeed much smaller in our sample period. For beta deciles, only one of them have significant CAPM αs, suggesting that the CAPM generally holds for the beta-sorted portfolios in our sample period.

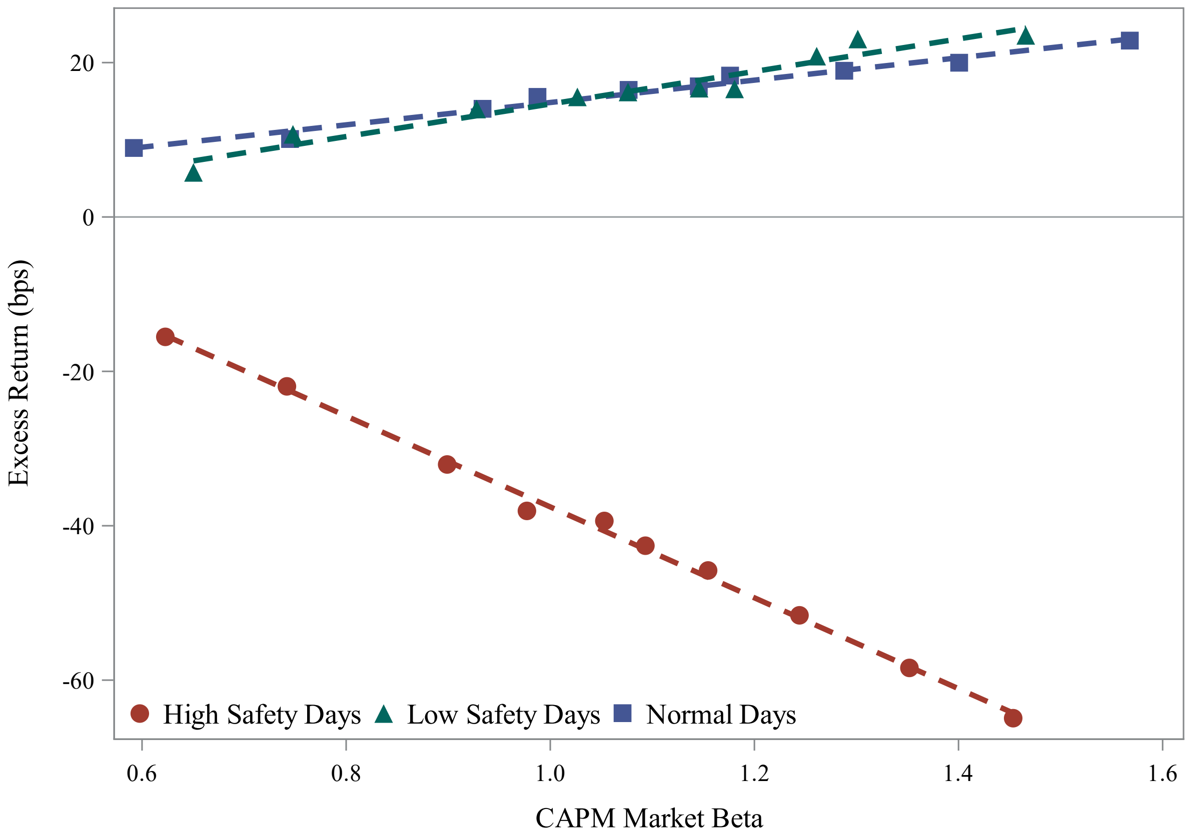
However, we find that low beta and high beta stocks have very different performance after zooming the lens into individual trading days. On the high UST safety days with elevated η_t^{UST}, the average α decreases from 7.73 bps (t-stat=4.79) to -10.59 bps (t-stat=-3.61) when moving from the low-beta portfolio 1 to the high-beta portfolio 10. CAPM model is severely violated with 5 out of 10 deciles-portfolios having significant CAPM αs. As a result, the BAB factor has a large and significant CAPM α of 20.65 bps on the high UST safety days. In other words, flight-to-safety strongly impacts the equity market on high UST safety days, resulting a flight from risky stocks (high β portfolios) to safe ones (low β portfolios). The safety driven co-movements lead to the phenomena that high β stocks under perform and low β stocks outperform relative to their exposure to the market, indicating a strong violation of CAPM. Similar results are obtained for the Fama-French 3-factor model (referred also as "FF3"). On high UST safety days, five out of ten beta-sorted portfolios have significant FF3 α and the BAB strategy earns significant positive FF3 α of 17.46 bps.

In contrast, CAPM αs are small and mostly insignificant on low UST safety days and the normal days. On low UST safety days with small η_t^{UST}, only the lowest beta decile portfolio has negative significant α, potentially driven by the market risk-on and outflow from safe equities. CAPM works well for all other decile portfolios, leading to insignificant αs. The BAB factor has slightly negative return of -6.27 bps which is not statistically significant from zero (t stat=-1.40). On normal day with moderate η_t^{UST}, the returns of both high and low β

portfolio returns from the q-factor library for ease of replication by readers.

portfolios are fully explained by CAPM model, leading to small (1.19 bps) and insignificant (t stat=0.49) BAB portfolio returns.

Figure 7: **Security Market Lines on High and Low UST Safety Days**



This figure shows the average daily excess returns against market βs of 10 beta-sorted portfolios separately for high UST safety days (days with top 20% η_t^{UST}, red circle-shaped points and line), low UST safety days (days with bottom 20% η_t^{UST}, green triangle-shaped points and line) and normal days (days with middle 20% to 80% η_t^{UST}, blue square-shaped points and line). The implied securities market line by ordinary least squares are also plotted. The sample period is from January 2004 to June 2022.

The drastic different performance of the CAPM model can also be seen in Figure 7, where we plot the excess returns of the 10 beta-sorted portfolios against their respective market βs for high UST safety days, low UST safety days, and the rest normal days, along with the implied ordinary least squares estimates of the securities market lines. On high UST safety days, the excess returns of the 10 beta-sorted portfolios are negatively related with market betas, leading to a downward-sloping securities market line. Most importantly, this securities market line has a large and significant intercept of 21 bps, which suggests that the strong flight-to-safety effect on high UST safety days causes portfolio returns to diverge substantially from those predicted by the CAPM model. In contrast, on low UST safety and normal days, the actual portfolio performance align better with the CAPM model, indicating its efficacy in the absence of heightened safety concerns.

To further highlight the impact of flight-to-safety on stock returns, we implement the classic two-stage Fama-Macbeth regression analysis on different groups of days in our sample period. For each day, we estimate the following cross-sectional regressions:

$$r_{i,t} - r_{f,t} = \gamma_{0,t} + \gamma_{1,t}\beta_i + \epsilon_{i,t} \tag{5}$$

where $r_{i,t} - r_{f,t}$ is the daily excess return of portfolio i, β_i is the portfolio i's market beta estimated on days of interest (for example, on high UST safety or low UST safety days). We then use the sample average of regression coefficients as the estimates for the intercept and the daily market risk premium: $\overline{\gamma_0} = \sum_{t=1}^{T} \gamma_{0,t}$ and $\overline{\gamma_1} = \sum_{t=1}^{T} \gamma_{1,t}$. If the CAPM holds, the excess returns of the testing portfolios will be fully explained by their market βs, and we should expect an insignificant $\overline{\gamma_0}$ that is close to zero.

Table 6 reports the regression results. Consistent with previous discussions, the CAPM can be easily rejected on high UST safety days – the intercept coefficient $\overline{\gamma_0}$ is estimated to be 21.32 bps (t-stats=4.82) which is large in magnitudes and statistically significant. The estimated $\overline{\gamma_1}$ equals -58.88 bps (t-stats = -8.19), close to the average of market excess returns, implying a negative risk premium on high UST safety days. On low UST safety and normal days, the CAPM model works well as $\overline{\gamma_0}$ is insignificant and small while $\overline{\gamma_1}$ is large and significantly positive on both days.

For comparison, we also examine the performance of the CAPM model on other alternative days. Baele, Bekaert, Inghelbrecht, and Wei (2019) propose an alternative safety measure (flight-to-safety measure, hereafter referred as "FTS") based on a bivariate regime-switching model for bond and equity returns. There are 115 FTS days in our sample period, constituting only 2.5% of the total trading days. On these FTS days, the equity market faces significantly more stress, with an average market excess return of -203.2 bps, over five times greater than that on high UST safety days. The estimated $\overline{\gamma_0}$ is 26.13 bps, large in magnitudes but however, not statistically significant (t-stat=1.76). We then examine whether the CAPM model consistently fails on market stress days, such as the bottom 20% of trading days with the worst S&P 500 returns and the top 20% with the highest VIX levels. Here, the estimated $\overline{\gamma_0}$ are 11.87 bps and -3.80 bps, respectively, but again, neither is statistically significant. We also examine the CAPM model for a matched sample of non-high UST safety days with market returns similar to high UST safety days, the estimated $\overline{\gamma_0}$ is -1.43 basis points with a small t-stats of -0.31. Combining these findings, it is clear that stressed equity market along does not necessarily lead to the CAPM model's failure.

Drawing on the findings of Savor and Wilson (2014), which document the effectiveness of the CAPM model on macroeconomic announcement days, we investigate the potential

Table 6: **Fama-Macbeth CAPM Test on High and Low UST Safety Days**

Type of day	Fama-Macbeth Test $\overline{\gamma_0}$	$\overline{\gamma_1}$	Avg. R2	Nobs	Avg. Market Excess Return
Panel A: High and Low UST Safety Days					
High η_t^{UST}	21.32***	-58.88	49.42	926	-37.40
	[4.82]	[-8.19]			[-8.10]
Low η_t^{UST}	-6.44	21.07	35.94	926	14.61
	[-1.51]	[3.96]			[4.92]
Normal	0.36	14.47	43.35	2779	14.10
	[0.15]	[4.33]			[7.01]
Full sample	2.42	2.01	43.12	4656	3.78
	[1.33]	[0.74]			[2.41]
Panel B: Other Stress Days					
FTS-day Baele et al. (2019)	26.13*	-228.5	50.16	115	-203.2
	[1.76]	[-7.26]			[-8.28]
Matched safety days	-1.43	-34.61	47.41	926	-37.32
	[-0.31]	[-5.00]			[-8.08]
SPX worst 20%	11.87*	-167.4	53.29	931	-156.2
	[1.76]	[-19.0]			[-24.4]
VIX top 20%	-3.80	-10.68	53.98	931	-16.57
	[-0.60]	[-1.01]			[-2.55]
Panel C: FOMC Days					
FOMC	-14.64	51.13	42.22	147	35.26
	[-1.36]	[3.01]			[3.25]
Full sample ex. FOMC	3.04	0.38	43.15	4509	2.75
	[1.63]	[0.14]			[1.70]
High η_t^{UST} ex. FOMC	20.88***	-59.03	49.62	913	-38.27
	[4.69]	[-8.17]			[-8.24]
Non-FOMC ex. High η_t^{UST}	-0.36	14.27	41.55	3572	13.36
	[-0.17]	[4.92]			[7.76]

This table reports the Fama-Macbeth two-stage test of CAPM on various types of days following equation (5). Testing assets are 10 beta-sorted portfolios rebalanced every month. Panel A reports the results on high UST safety (top 20% η_t^{UST}), low UST safety (bottom 20% η_t^{UST}), normal days (middle 20% tom 80% η_t^{UST}) and full sample (all days in the sample period). Panel B reports other days of interest. FTS-day is the US flight-to-safety days identified by Baele, Bekaert, Inghelbrecht, and Wei (2019). Matched safety days are selected non high safety days whose market excess returns are closest to those on high safety days. SPX worst 20% are days with lowest S&P 500 index daily returns. VIX top 20% are days with highest 20% VIX index level. Panel C reports results related to FOMC days. FOMC are the Federal Open Market Committee interest rate decisions announcement days. Full sample ex. FOMC are non-FOMC announcement dates. High UST safety ex. FOMC are high safety days that are not FOMC days. Non-FOMC ex. High η_t^{UST} are days that are neither FOMC announcement days nor high UST safety days. The last column reports average market excess returns on different types of days, respectively. 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.

influence of such announcements on our results. We particularly focus on FOMC announcements, the most important macroeconomic announcements with substantial market impact. As shown in Table 6, even after excluding FOMC days from the high UST safety days, the estimated coefficient $\overline{\gamma_0}$ remains significant at 20.88 basis points. This aligns with the observation that most FOMC days fall under low UST safety days, rather than high. Echoing Savor and Wilson (2014), we also observe the failure of the CAPM model on non-FOMC days. Notably, our analysis reveals that this failure is predominantly attributed to the flight-to-safety effect on high UST safety days. When further excluding these high UST safety days from the non-FOMC days, the CAPM holds as the estimated $\overline{\gamma_0}$ drops to -0.36 basis points and loses statistical significance, while the the estimated $\overline{\gamma_1}$ becomes to a significant 14.27 bps.

3.3. The UST Term Premium under High and Low UST Safety

Next, we examine the pricing in the Treasury market on high and low UST safety 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). [12]

To understand the dynamics of the term premium on high and low UST safety days, we estimate the following regression:

$$\Delta \text{Term Premium}_t = \text{intercept} + b^{\text{H}} \times \text{High}_t^{\text{UST}} + b^{\text{L}} \times \text{Low}_t^{\text{UST}} + \text{controls}_t + \epsilon_t, \tag{6}$$

Here, $\Delta\text{Term Premium}_t$ is the daily change of ACM or KW term premiums, $\text{High}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t is a high UST safety day with the top 20% η_t^{UST}, $\text{Low}_t^{\text{UST}}$ is a dummy variable that takes value of one if day t is a low UST safety day with the lowest 20% η_t^{UST}. To highlight the unique impact of η_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

[12]Daily ACM term premium based on Adrian, Crump, and Moench (2013) is from the website of Federal Reserve Bank of New York `https://www.newyorkfed.org/research/data_indicators/term-premia-tabs#/interactive`. Daily KW term premium based on Kim and Wright (2005) is from the website of Board of Governors of the Federal Reserve`https://www.federalreserve.gov/data/yield-curve-tables/feds200533_1.html`.

Table 7: **10-Year Treasury Term Premium on High and Low UST Safety Days**

	Panel A: Adrian, Crump, and Moench (2013)					Panel B: Kim and Wright (2005)				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
High η_t^{UST}	-0.99***		-0.82***		-0.70***	-0.84***		-0.63***		-0.61***
	[-4.71]		[-3.78]		[-3.25]	[-8.06]		[-5.52]		[-5.69]
Low η_t^{UST}	0.45**		0.44**		0.38**	0.37***		0.35***		0.35***
	[2.31]		[2.22]		[2.05]	[3.40]		[3.20]		[3.14]
FTS by Baele et al. (2019)		-2.70**	-1.97*				-2.87***	-2.38***		
		[-2.47]	[-1.82]				[-9.12]	[-7.52]		
FOMC					-0.85					-0.43
					[-1.54]					[-1.47]
SPX worst 20%				-1.78***	-1.82***				-1.30***	-1.25***
				[-6.32]	[-6.66]				[-10.40]	[-10.01]
SPX best 20%				1.93***	1.96***				0.84***	0.86***
				[8.56]	[8.26]				[8.03]	[8.33]
VIX top 20%					0.33					0.12
					[1.07]					[0.77]
VIX bottom 20%					-0.28*					-0.19**
					[-1.87]					[-2.17]
ΔNoise					1.67***					0.08
					[2.89]					[0.31]
ΔTYF Vol					0.01					-0.01
					[0.17]					[-0.54]
Intercept	0.06	0.02	0.08	-0.08	0.00	0.07	0.04	0.09	0.06	0.12*
	[0.60]	[0.20]	[0.77]	[-1.03]	[0.01]	[1.22]	[0.90]	[1.59]	[1.38]	[1.85]
NOBS	4570	4588	4570	4588	4433	4570	4588	4570	4588	4433
R2 (%)	0.81	0.63	1.13	4.94	6.22	2.42	3.00	4.36	7.05	8.95

This table shows the change of term premiums on high UST safety (top 20% η_t^{UST}) and low UST safety (bottom 20% η_t^{UST}) days following regression (6). 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.

Wang (2013), and change of realized volatility of most liquid 10-year Treasury futures.

Table 7 shows drastically different dynamics of the term premium on high and low UST safety days. On high UST safety days with elevated η_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. Conversely, on low UST safety days, 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).

The impact of η_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, Bekaert, Inghelbrecht, and Wei (2019), also indicates a term premium decrease (-2.70 bps for ACM and -2.87 bps for KW) but does not subsume the impact of our safety measure η_t^{UST}. Equity market returns have a notable impact on the term premium, with a significant drop (-1.78 bps for ACM and -1.30 bps for KW) during market crashes and a significant increase (1.93 bps for ACM and 0.84 bps for KW) during market recoveries. After adjusting for equity market returns and other factors, the impact of η_t^{UST} persists, showing an decrease of -0.70 bps (ACM) and -0.61 bps (KW) on high η_t^{UST} days and an increase of 0.38 bps (ACM) and 0.35 bps (KW) on low η_t^{UST} days.

3.4. Currency Carry Trade under High and Low UST Safety

Last, we move to the FX markets and examine the returns of major currencies and carry trade portfolios on the high and low UST safety 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 (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 flight-to-UST days:

$$\text{currency}_t = \text{intercept} + b_1^{\text{H}} \times \text{High}_t^{\text{UST}} + b_1^{\text{L}} \times \text{Low}_t^{\text{UST}} + b_2^{\text{H}} \times \text{High}_t^{\text{USD}} + b_2^{\text{L}} \times \text{Low}_t^{\text{USD}} + \text{controls}_t + \epsilon_t \quad (7)$$

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

The estimation results at Table 8 show a clear appreciation of major funding currencies, YEN and CHF in particular, during episodes of flight-to-UST. During the high safety days with elevated η_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 high UST 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 high safety days.

The above results suggest that, similar to a flight-to-safety in the equity market, there is also a flight from the risky to the safe currencies in the FX market on the high UST safety days with heightened η_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, which is statically significant with a t-stats of -5.47. On low UST safety days, currencies and carry trade portfolios don't perform differently relative to the normal days, consistent with the observation that low UST safety 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 high safety days identified by the safety measure η_t^{UST}. Even though η_t^{USD}

Table 8: **Currency Returns on High and Low Safety 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
High η_t^{UST}	-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]
Low η_t^{UST}	-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]
High η_t^{USD}	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]
Low η_t^{USD}	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 Spread	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	EUR	DKK
High η_t^{UST}	-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]
Low η_t^{UST}	-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]
High η_t^{USD}	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]
Low η_t^{USD}	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 Spread	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 high and low UST safety days identified by η_t^{UST} with control of high and low USD sfaety days identified by η_t^{USD} following equantion (7). 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 USD per foreign currency. Carry trades formed with G10 currencies are constructed through the procedures describe in Section(3.4). 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 Spread (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.

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 high USD safety days and a negative return of 4.43 basis points on low USD safety days. Both the economic magnitudes and statistical significance of these returns are, however, considerably smaller than those observed on high UST safety days. Similarly, the Japanese Yen, the safest currency in our sample period, appreciates by only 7.43 basis points on low USD safety days when the U.S. dollar is perceived as risky, an appreciation that is only half of its size on high UST 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 η_t^{UST}.

4. The Safety of UST and USD

4.1. 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. The Treasury convenience yield measures 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}:

$$\text{UST Basis}_t = y_t^{\text{UST}} - y_t^{\text{Synt Govt}} = y_t^{\text{UST}} - (y_t^{\text{Govt}} + (s_t - f_t)). \tag{8}$$

Here 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, $y_t^{\text{Synt Govt}} = y_t^{\text{Govt}} + (s_t - f_t)$ denotes the yield on a synthetic FX-hedged dollar yield constructed from a foreign government bond.

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:

$$\text{spreads}_t = \text{intercept} + b_1^{\text{H}} \times \text{High}_t^{\text{UST}} + b_1^{\text{L}} \times \text{Low}_t^{\text{UST}} + b_2^{\text{H}} \times \text{High}_t^{\text{USD}} + b_2^{\text{L}} \times \text{Low}_t^{\text{USD}} + \epsilon_t, \tag{9}$$

or

$$\Delta\text{spreads}_t = \text{intercept} + b_1^{\text{H}} \times \text{High}_t^{\text{UST}} + b_1^{\text{L}} \times \text{Low}_t^{\text{UST}} + b_2^{\text{H}} \times \text{High}_t^{\text{USD}} + b_2^{\text{L}} \times \text{Low}_t^{\text{USD}} + \epsilon_t, \tag{10}$$

Where spreads_t is the Treasury basis at day t, $\Delta\text{spreads}_t$ is the change of the spreads_t from spreads$_{t-1}$.[13] $\text{High}_t^{\text{UST}}$ ($\text{Low}_t^{\text{UST}}$) is a dummy variable that takes value of one if day t is a high (low) UST safety day with the top (bottom) 20% η_t^{UST}. Similarly, $\text{High}_t^{\text{USD}}$ and $\text{Low}_t^{\text{USD}}$ are dummy variables for the top and the bottom 20% USD safety days based on η_t^{USD}. In addition to the Treasury basis, we also consider two other additional measures of Treasury convenience yields: the Covered-Interest Parity (CIP) adjusted Treasury Basis and Treasury Libor/Swap spreads. The CIP adjusted Treasury Basis is calculated by subtracting the Treasury basis with the CIP basis between the the dollar and the foreign currency, while the 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.[14]

Table 9 reports the regression results for the three measures of Treasury convenience yield. We focus first on the variations of the daily changes of the convenience yield, reported in Panel A of Table 9. It is clear that Treasury convenience yield becomes significantly more negative on high η_t^{UST} days. On average, the 3-month and 5-year Treasury convenience yield widens by 1.07 bps and 0.50 bps for Treasury basis, 1.02 bps and 0.34 bps for CIP adjusted Treasury basis, and 1.42 bps and 0.25 bps for Libor/Swap spreads, all statistically significant at the 1% or 5% level. This shows that on high η_t^{UST} days, when the Treasury market serves as the destination of safe haven, its unique safety attributes further intensify its specialness, leading to wider spreads relative to other benchmark rates. In contrast, on low η_t^{UST} days, when the Treasury market itself is perceived as risky, UST convenience yield does not change significantly. It is also clear that the safety of UST, not that of USD, is the main driver of the UST convenience yield, as evidenced by the lack of significant movement in UST convenience yield on high and low USD safety days.

In our final analysis, as detailed in Panel B of Table 9, we investigate the factors influencing the levels of UST convenience yield. Generally, U.S. Treasury yields are lower than both FX-hedged foreign government yield and Libor/swap rates, indicated by the negative intercepts in all regression analyses across the three measures of Treasury convenience yield. The average spreads for 3-month and 5-year U.S. Treasuries are -41.76 bps and -51.91 bps for the Treasury basis, -20.77 bps and -12.40 bps for CIP-adjusted Treasury basis, and -40.78 bps and -23.12 bps for Libor/Swap spreads. Notably, on high UST safety days, all Treasury convenience measures significantly decrease, with magnitudes ranging from 6.34

[13] 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.

[14] 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 9: **Treasury Specialness on the High and Low UST Safety Days**

	Treasuries Basis		Treasury Basis (CIP Adjusted)		Libor/Swap Spreads	
	3M	5Y	3M	5Y	3M	5Y
Panel A: Changes ($y = \Delta$***spreads***$_t$)						
High η_t^{UST}	-1.07**	-0.50***	-1.02***	-0.34***	-1.42***	-0.25***
	[-2.35]	[-3.94]	[-3.24]	[-3.18]	[-3.81]	[-2.65]
Low η_t^{UST}	0.04	-0.08	-0.11	-0.05	-0.26*	0.05
	[0.13]	[-0.82]	[-0.85]	[-0.61]	[-1.94]	[0.71]
High η_t^{USD}	-0.05	0.09	0.19	0.14	0.26	0.20**
	[-0.17]	[0.74]	[1.07]	[1.40]	[1.22]	[2.19]
Low η_t^{USD}	0.08	-0.01	0.19	0.07	0.27	0.11
	[0.27]	[-0.07]	[0.97]	[0.74]	[1.24]	[1.27]
Intercept	0.2	0.08	0.14	0.03	0.21	-0.01
	[1.04]	[1.43]	[1.12]	[0.64]	[1.57]	[-0.29]
NOBS	4476	4427	4291	4427	4420	4420
R2 (%)	0.23	0.43	0.64	0.26	1.23	0.28
Panel B: Level ($y =$ ***spreads***$_t$)						
High η_t^{UST}	-15.01***	-6.34***	-14.06***	-11.89***	-20.78***	-12.53***
	[-4.20]	[-4.34]	[-4.51]	[-5.67]	[-5.28]	[-5.47]
Low η_t^{UST}	8.63***	9.75***	3.96**	-1.85	6.60***	-2.92**
	[3.90]	[7.40]	[2.06]	[-1.40]	[2.97]	[-2.13]
High η_t^{USD}	2.68	-21.81***	4.90*	-7.36***	9.91***	-0.63
	[0.88]	[-11.13]	[1.83]	[-4.66]	[3.14]	[-0.39]
Low η_t^{USD}	-0.96	-0.59	5.77**	5.75**	2.11	2.81
	[-0.38]	[-0.45]	[2.41]	[2.55]	[0.69]	[1.18]
Intercept	-41.76***	-51.91***	-20.77***	-12.40***	-40.78***	-23.12***
	[-18.43]	[-52.57]	[-10.03]	[-10.41]	[-17.20]	[-19.47]
NOBS	4479	4453	4401	4453	4454	4454
R2 (%)	3.94	22.2	3.22	6.91	5.11	4.12

This table reports the treasury convenience yield on the high and low UST safety days after controlling for USD Safety proxied by η_t^{USD}, as specified by Equation (9) and (10). We examine three yield spreads respectively: (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}) . Panel A reports results based on change of these spreads. Panel B reports the results of level of spreads. All 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.

bps to 20.78 bps, and strongly statistically significant. Conversely, on low UST safety days, Treasury convenience measures, particularly in the short-term, tend to increase and become less negative as the Treasury market turns into a source of risk. In comparison to the clear trends observed on high and low UST safety days, the patterns on high and low USD safety days are less clear across the three Treasury convenience measures.

Overall, our results are consistent with the findings in 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 and show that the Treasury convenience yield widens on the high UST safety days when the Treasures serve as the destination of flight-to-safety. In addition, we show that the daily movement of Treasury convenience yield is mainly driven by variations in the Treasury market, as opposed to variations in the FX market.

4.2. The co-movement between the UST and 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 the 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:

$$\begin{aligned} r_t^{\text{USD}} = {} & \text{intercept} + b^{\text{H}} \times \Delta y_t^{\text{UST}} \times \text{High}_t^{\text{UST}} + c^{\text{H}} \times r_t^{\text{SPX}} \times \text{High}_t^{\text{UST}} \\ & + b^{\text{L}} \times \Delta y_t^{\text{UST}} \times \text{Low}_t^{\text{UST}} + c^{\text{L}} \times r_t^{\text{SPX}} \times \text{Low}_t^{\text{UST}} \\ & + d^{\text{H}} \times \text{High}_t^{\text{UST}} + d^{\text{L}} \times \text{Low}_t^{\text{UST}} + d^{\text{UST}} \times \Delta y_t^{\text{UST}} + d^{\text{SPX}} \times r_t^{\text{SPX}} + \epsilon_t, \end{aligned} \tag{11}$$

Where r_t^{USD} is the return of the U.S. dollar index (DXY) on day t, $\text{High}_t^{\text{UST}}$ ($\text{Low}_t^{\text{UST}}$) is a dummy variable that takes value of one if η_t^{UST} is in the top (bottom) 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 10.[15]

As expected, the relation between the change of the 10-year Treasury yields (Δy_t^{UST}) and the USD return (r_t^{USD}) is positive at normal times. The coefficient d^{UST} is estimated to be 1.10, positive and statistically significant with a t-stat of 4.14. The relation, however,

[15] In Appendix D, we consider the regression model which further controls the impact of high and low USD safety days. The results remain consistent and and robust.

Table 10: **The Comovement of UST and USD**

yvar=	r_t^{USD} (1)	r_t^{USD} (2)	$r_t^{\text{USD/Foreign}}$ (3)	$r_t^{\text{USD/Foreign}}$ (4)	yvar=	$r_t^{\text{Foreign/USD}}$ (5)	$r_t^{\text{Foreign/USD}}$ (6)
$\Delta y^{\text{UST}} \times$ High η_t^{UST}		-1.33***		-1.45***	$\Delta y^{\text{Local Bond}} \times$ High η_t^{UST}		1.79***
		[-2.67]		[-2.84]			[2.75]
$\Delta y^{\text{UST}} \times$ Low η_t^{UST}		1.95***		1.98***	$\Delta y^{\text{Local Bond}} \times$ Low η_t^{UST}		-2.05***
		[4.47]		[4.44]			[-4.70]
Δy^{UST}	1.49***	1.10***	1.58***	1.25***	$\Delta y^{\text{Local Bond}}$	1.57***	1.66***
	[6.73]	[4.14]	[3.93]	[2.97]		[7.93]	[6.80]
$r^{\text{SPX}} \times$ High η_t^{UST}		-0.04*		-0.04*	$r^{\text{Local Equity}} \times$ High η_t^{UST}		-0.05***
		[1.69]		[1.77]			[-2.59]
$r^{\text{SPX}} \times$ Low η_t^{UST}		-0.04		-0.02	$r^{\text{Local Equity}} \times$ Low η_t^{UST}		-0.01
		[-1.56]		[-0.85]			[-0.34]
r^{SPX}	-0.09***	-0.08***	-0.18***	-0.17***	$r^{\text{Local Equity}}$	0.05	0.06*
	[-7.66]	[-5.28]	[-3.98]	[-3.70]		[1.55]	[1.79]
High η_t^{UST}	-0.25	-0.91	-1.10	-1.99	High η_t^{UST}	-0.44	0.10
	[-0.12]	[-0.45]	[-0.58]	[-1.09]		[-0.15]	[0.04]
Low η_t^{UST}	1.59	0.67	1.25	0.05	Low η_t^{UST}	-2.81	-1.76
	[0.83]	[0.34]	[0.74]	[0.03]		[-1.48]	[-0.92]
Intercept	0.44	0.35			Intercept		
	[0.51]	[0.40]					
Currency FE	No	No	Yes	Yes	Currency FE	Yes	Yes
NOBS	4622	4622	46220	46220	NOBS	46220	46220
R2 (%)	4.90	6.41	8.51	9.27	R2 (%)	2.43	3.02

This table reports the additional comovement between the UST and the USD on the high and low safety days as specified by Equation (11), (12) and (13). 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 E1. For the control variables, VIX is in unit of 1 (VIX=VIX/100) and Ted Spread is in unit of percent. 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.

changes on the high UST safety days when the UST is on the receiving end of a flight-to-safety in the equity market. The coefficient b^{H} for the interaction term of $\mathrm{High}_t^{\mathrm{UST}} \times \Delta y_t^{\mathrm{UST}}$ is estimated to be -1.33, negative and statistically significant with a t-stat of -2.67. This makes the contemporaneous relation between the U.S. Treasury bond yields and the U.S. dollar to be $-1.33 + 1.10 = -0.23$, 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 high safety days with elevated η_t^{UST}, when the safe-haven nature of the U.S. Treasury bonds offset their normal comovement due to the common interest rate exposure.

By comparison, on the low UST safety days featured by heightened interest-rate risk, the co-movement between UST and USD further strengthened. The coefficient b^{L} for the interaction term of $\mathrm{Low}_t^{\mathrm{UST}} \times \Delta y_t^{\mathrm{UST}}$ is estimated to be 1.95, negative and statistically significant with a t-stat of 4.47. The implies that the sensitivity of USD to UST reaches $1.95 + 1.10 = 3.05$ on low UST safety days, which is almost three times of its normal level.

Since low UST safety 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 η_t^{USD} is around 12% on low UST safety days, significantly higher than its full-sample average of 6%. An example of this shift in safety asset occurs during the 2022 inflation surge, when the rapid monetary-policy tightening turns UST into a source of risk. The USD safety measure η_t^{USD} rises quickly to an average level of 25% during the first six months of 2022. Further discussions on the relation between η_t^{UST} and η_t^{USD} can be found in Appendix B.

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,

$$\begin{aligned} r_t^{\mathrm{USD/i}} &= \text{intercept} + b^{\mathrm{H}} \times \Delta y_t^{\mathrm{UST}} \times \mathrm{High}_t^{\mathrm{UST}} + c^{\mathrm{H}} \times r_t^{\mathrm{SPX}} \times \mathrm{High}_t^{\mathrm{UST}} \\ &+ b^{\mathrm{L}} \times \Delta y_t^{\mathrm{UST}} \times \mathrm{Low}_t^{\mathrm{UST}} + c^{\mathrm{L}} \times r_t^{\mathrm{SPX}} \times \mathrm{Low}_t^{\mathrm{UST}} \\ &+ d^{\mathrm{H}} \times \mathrm{High}_t^{\mathrm{UST}} + d^{\mathrm{L}} \times \mathrm{Low}_t^{\mathrm{UST}} + d^{\mathrm{UST}} \times \Delta y_t^{\mathrm{UST}} + d^{\mathrm{SPX}} \times r_t^{\mathrm{SPX}} + \epsilon_t, \end{aligned} \tag{12}$$

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 (11). The estimation results are reported at the middle panel of Table 10. The coefficient b^{H} for the interaction term of $\mathrm{High}_t^{\mathrm{UST}} \times \Delta y_t^{UST}$ is estimated to be -1.45, negative and statistically significant with a t-stat of -2.84. 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 (11).

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 (12) with the local sovereign bond and equity market indexes:

$$
\begin{aligned}
r_t^{\text{i/USD}} = &\ \text{intercept}_i + b^{\text{H}} \times \Delta y_t^{\text{Local Bond},i} \times \text{High}_t^{\text{UST}} + c^{\text{H}} \times r_t^{\text{Local Equity},i} \times \text{High}_t^{\text{UST}} \\
&+ b^{\text{L}} \times \Delta y_t^{\text{Local Bond},i} \times \text{Low}_t^{\text{UST}} + c^{\text{L}} \times r_t^{\text{Local Equity},i} \times \text{Low}_t^{\text{UST}} \\
&+ d^{\text{H}} \times \text{High}_t^{\text{UST}} + d^{\text{L}} \times \text{Low}_t^{\text{UST}} + d^{\text{Bond}} \times \Delta y_t^{\text{Local Bond},i} + d^{\text{Equity}} \times r_t^{\text{Local Equity},i} + \epsilon_{i,t},
\end{aligned} \tag{13}
$$

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 (11). The full list of the local sovereign bond and equity indexes for the G10 countries are reported in the Appendix.

The estimation results are reported at the right panel of Table 10. Different from the U.S. Treasuries, foreign countries' local sovereign bond yields co-move more strongly with their exchange rates on the high UST safety days. The coefficient b^{H} for the interaction term of $\Delta y_t^{\text{Local Bond},i} \times \text{High}_t^{\text{UST}}$ is estimated to be 1.79, positive and statistically significant with a t-stat of 2.75. That is, on the high UST 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 low UST safety days, the exchange rates of foreign currencies no longer comove with their local bond yields, mirroring the dynamics of dollar and UST on high safety days.

5. Conclusion

Based on the intraday high-frequency returns of the S&P 500 Index (SPX) and 10-year U.S. Treasury futures, we construct a daily measure of UST safety, η_t^{UST}, as the negative correlation between stocks and bonds. We find strong evidence of flight-to-safety on the top 20% trading days with elevated η_t^{UST}. Such high UST safety days are characterized with significant drops in SPX returns and UST yields, appreciation of the Japanese Yen against the USD, increased volatility in equities and major currencies, and a notable shift in investor holdings from SPX to UST. On these high-UST safety days, safety matters the most and the pricing of global assets is determined by their relative safety rather than their own fundamental risks. Conversely, on the bottom 20% days with low η_t^{UST}, the Treasury market becomes a source of risk with heightened uncertainty and worsened liquidity.

The distinct nature of risks results in markedly different asset pricing dynamics on high and low UST safety days. Within the U.S. equity market, the preference for safety leads to low-beta stocks outperforming high-beta stocks with a daily CAPM alpha of 21 basis points on high UST safety days. In the absence of a safety-first approach, the CAPM model performs effectively, suggesting that the excess returns of the "betting against beta" strategy primarily stem from the premium placed on safety. When examining the U.S. Treasury market, we find that flight-to-UST shrinks the Treasury term premium, increases the convenience yield of UST, and disrupts the usual correlation between the USD and UST. Among global currencies, safe-haven (funding) currencies appreciate relative to risky (asset) currencies, resulting in substantial losses for a typical currency-carry trade strategy on high UST safety days. In comparison to other commonly mentioned safe assets such as short-term U.S. Treasuries, the U.S. Dollar, and the VIX index, we find that only long-term U.S. Treasuries effectively capture the flight-to-safety episodes in our sample period.

Appendix

Appendix A: Global Comovement: A PCA Approach

Abstracting from the enormity of the global financial markets, Figure A1 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.

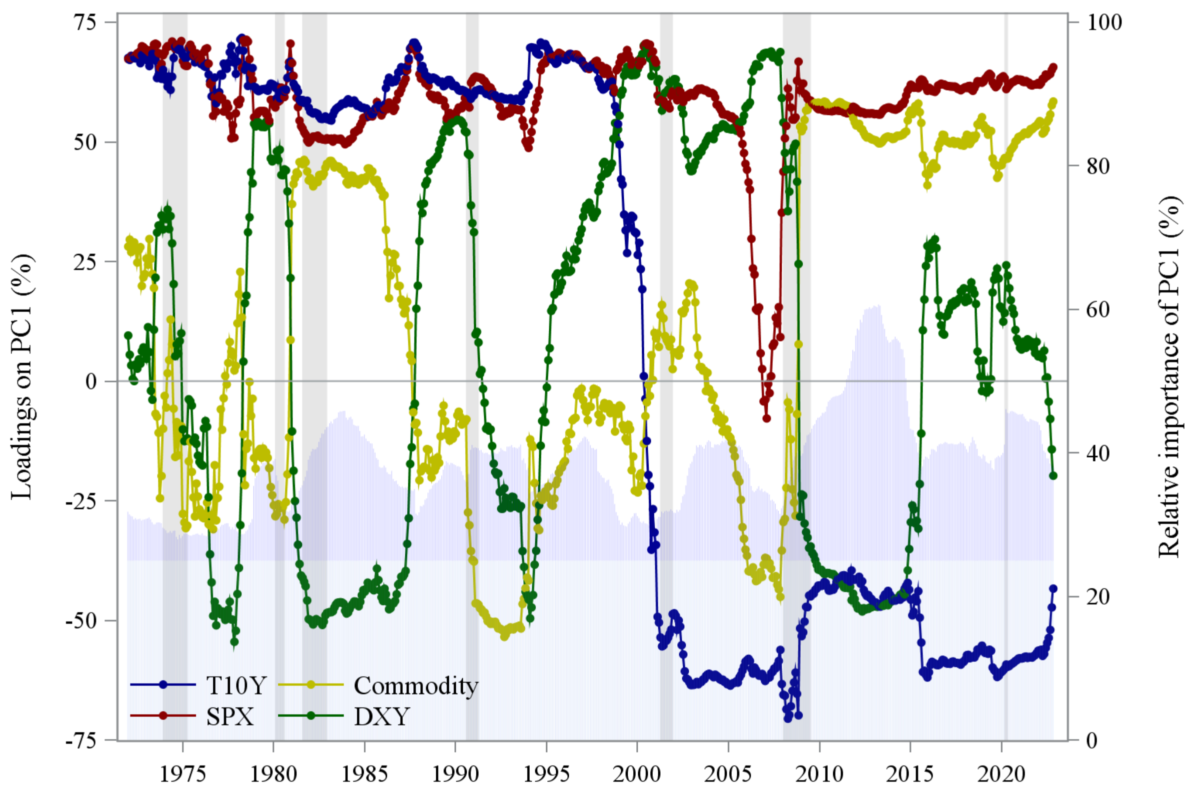
Each month, the principal component analysis is performed on the correlation matrix, estimated using daily returns on SPX, UST, USD, and GSCI over a three-month rolling window. Under the assumption of zero comovements across all four asset returns, one single factor accounts for 25%. As shown in Figure A1, 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 A1 is the stable relation between the SPX and UST pair, whose alliance switches sides only once around 2000 and behind this shift 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.

Appendix B: Alternative Dollar ($\eta_t^{\mathbf{USD}}$) and VIX ($\eta_t^{\mathbf{VIX}}$) Safety Measures

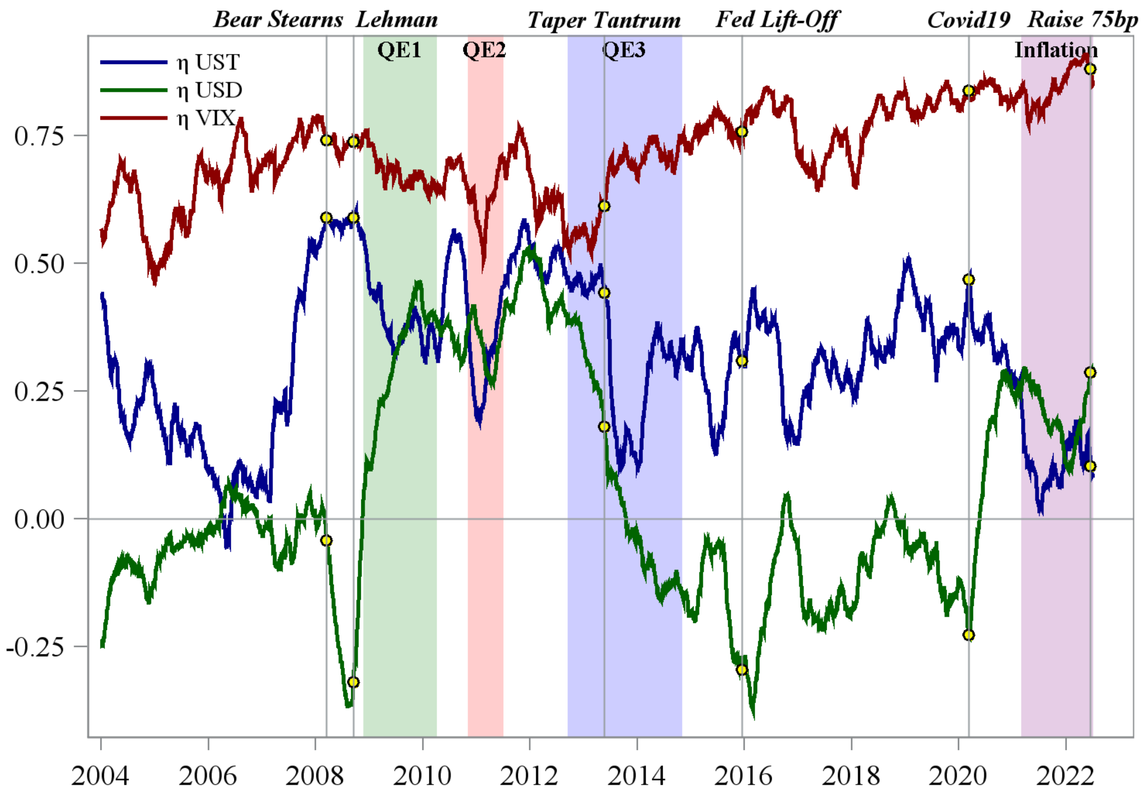
Considering that the U.S. Dollar (USD) and the option implied VIX index (VIX) are often referred as safe-haven assets, we follow the same methodology to construct two alternative

Figure A1: **Principal Component Analysis on Global Key Assets**



This figure shows principal component analysis on the correlation matrix of SPX, UST, USD, and GSCI, estimated using daily returns with a 3-year rolling window. Reported are the relative loadings on the first pricincipal component (PC1) and the relative importance of PC1.

Figure B1: **Comparing the Three Safety Measures: $\eta_t^{\mathbf{UST}}$, $\eta_t^{\mathbf{USD}}$ and $\eta_t^{\mathbf{VIX}}$**



This figure shows the smoothed time series (exponential weighted moving average with decaying parameter 0.98) of the three safety measures, η_t^{UST} (blue), η_t^{USD} (green) and η_t^{VIX} (red) from January 2004 to June 2022.

safety measures, η_t^{USD} and η_t^{VIX}:

$$\eta_t^{\text{USD}} = w \times corr(r_t^{\text{SPX}}, r_t^{\text{EUR/USD}}) + (1-w) \times corr(r_t^{\text{SPX}}, r_t^{\text{YEN/USD}}),$$
$$\eta_t^{\text{VIX}} = -corr(r_t^{\text{SPX}}, \Delta\text{VIX}_t), \tag{14}$$

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 intraday prices of the most liquid Euro/USD and YEN/USD currency futures traded on the CME, and the 5-minute change of VIX (ΔVIX) are based on the intra-day tick data obtained from the Chicago Board of Options Exchanges (CBOE). Our sample covers the period from January 2004 to June 2022, during which the S&P 500 E-mini futures, 10-year Treasury futures, Euro/USD and YEN/USD currency futures are traded with high liquidity and have reliable minute-end prices.[16]

Figure B1 compares the time series of η_t^{USD} and η_t^{VIX} with our main safety measure η_t^{UST} in our sample period. To illustrate the overall trend of the three safety 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 positive η_t^{UST}, η_t^{USD} swings much more notably during our sample period. η_t^{USD} is often negative before Lehman's collapse in September 2008, turns positive during the height of the 2008 financial crisis and the subsequent periods of quantitative easing, and reverts back to negative from 2014. Interestingly, η_t^{USD} has recently moved to the positive 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. Unlike η_t^{UST} and η_t^{USD}, η_t^{VIX} has remained at a very high level throughout the sample period, ranging mostly between 0.5 to 0.8. The high levels of η_t^{VIX} reflect the fact that VIX, which is often regarded as a "fear" gauge, tends to rise (drop) when the equity market goes down (up). η_t^{VIX} also exhibits a slow upward trend over time, suggesting a stronger connection between the stock market and the VIX index at the latter half of the sample period.

[16] 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; EUR/USD and YEN/USD futures data starts from January 1990. 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.

Table B1: **Key Asset Performance on the High and Low Safety Days Captured by $\eta_t^{\mathbf{USD}}$ and $\eta_t^{\mathbf{VIX}}$**

Panel A: Summary Statistics

	High	Low		High	Low
η_t^{USD}	0.45***	-0.30***	η_t^{VIX}	0.91***	0.43***
	[92.72]	[-55.92]		[617.79]	[73.15]
# Days	642	626	# Days	680	826

Panel B: Market Performance

	High-USD			High-VIX		
	Return	CAPM α	ΔImp. Vol	Return	CAPM α	ΔImp. Vol
SPX	14.81***		-0.18***	-7.24*		0.05
	[2.98]		[-2.78]	[-1.74]		[0.71]
UST	-2.29	-1.13	-0.30*	-1.86	-2.52	0.17
	[-1.12]	[-0.52]	[-1.71]	[-1.07]	[-1.48]	[1.25]
DXY	-0.97	2.04	-0.05***	3.41**	2.59	0.00
	[-0.45]	[1.07]	[-3.87]	[2.00]	[1.57]	[0.29]
EUR/USD	0.63	-2.21	-0.06***	-4.20**	-4.28**	-0.00
	[0.27]	[-1.00]	[-3.65]	[-2.19]	[-2.25]	[-0.19]
YEN/USD	-4.69**	-3.63	-0.06***	-3.41*	-4.23**	0.01
	[-1.98]	[-1.49]	[-2.76]	[-1.71]	[-2.11]	[0.57]

This table reports the performance of major asset classes on the high safety days with the top 20% safety measure η_t^{USD} (High-USD) and η_t^{VIX} (High-VIX), where the overlapped High-UST (the top 20% days by η_t^{USD}) days are excluded. Panel A reports the average of the safety measures η_t^{USD} and η_t^{VIX}; Panel B reports the average return, CAPM α, and the daily change of the implied volatilities of major asset classes on the respective high safety days, respectively. 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 return of the U.S dollar index provided by the Intercontinental Exchange (ICE); EUR/USD and YEN/USD are the daily percentage 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. ΔImp. Vol is the daily change of the implied volatility of major assets, as listed in Table 1: VIX index for SPX; MOVE index for UST; DXY IV for DXY; EUR/USD IV for EUR/USD; YEN/USD IV for YEN/USD. 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.

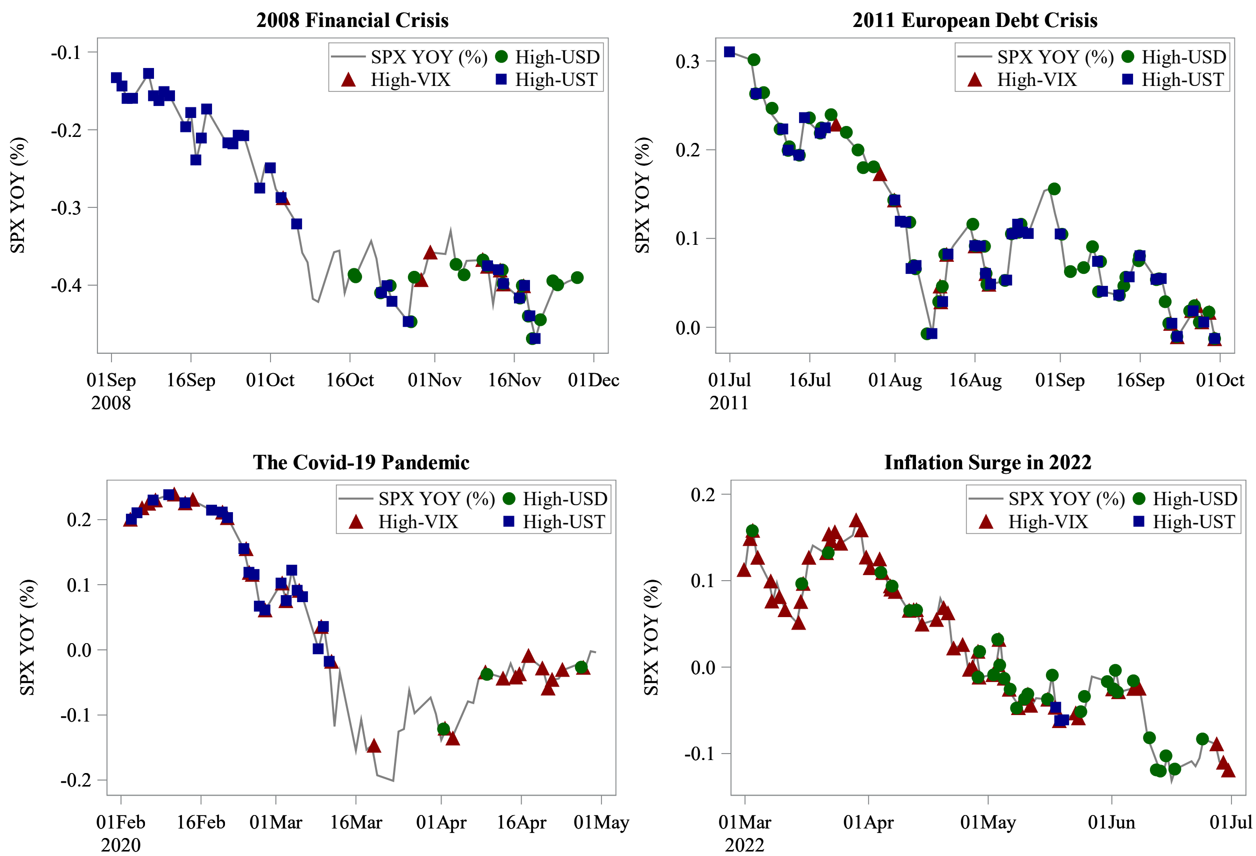
We then turn to the high safety days identified by η_t^{USD} (High-USD) and η_t^{VIX} (High-VIX). Similar to our early approach, we define the top 20% days with the highest safety measures as the high safety days, and report the performance of the three key assets, i.e., the U.S. equity, the 10-year U.S. Treasury, and the U.S. dollar, on the high safety days identified by η_t^{USD} and η_t^{VIX} at Table B1. To highlight the unique information contained in η_t^{USD} and η_t^{VIX}, we exclude the overlapping days that are also the high safety days based on η_t^{UST} (top 20% days with highest η_t^{UST}, hereafter referred as High-UST days).

Table B1 shows that the U.S. stock market rallies with a significant positive average daily return of 14.81 bps (t-stat=2.98) on the High-USD days. On the High-VIX days, the U.S. stock market drops with an average return of -7.24 bps, but only marginally significant with a t-stat of 1.74. Compared to the average decline of 36.20 bps on the High-UST days, it is clear that the U.S. equity market is much less stressed on the high safety days captured by η_t^{USD} and η_t^{VIX}. The U.S. Treasury doesn't move significantly on either the High-USD or High-VIX days. The U.S. dollar index doesn't move significantly on the High-USD days and appreciate slightly by 3.41 bps on the High-VIX days. The implied volatilities drop slightly on the High-USD days, but don't change significantly on the High-VIX days. Overall, these results show that flight-to-USD and flight-to-VIX are not prevalent during our sample period.

We then zoom the lens in the dynamics of the safety measures at different market crisis. Figure B2 zoom into the Year-to-Year (YoY) returns of the S&P 500 index during four representative crises in our sample period – the 2008 financial crisis, the 2011 European debt crisis, the Covid-19 pandemic, and the inflation surge in 2022. We mark the High-UST days in blue rectangles, the High-USD days in green dots, and the High-VIX days in red triangles for all four crises. Clearly, the presence of High-USD, High-UST, and High-VIX days varies substantially across crises, implying that the safe-haven assets in these crises are very different from one to another. For example, the 2008 financial crisis, especially during the time leading up to Lehman's bankruptcy on September 15, 2008, is largely dominated by High-UST days. The 2011 European debt crisis, on the other hand, has relatively more High-USD days. During the Covid-19 pandemic period, High-UST days frequently appear in the period before March 16, 2020, but disappears afterward. During the most recent inflation surge, the High-VIX and High-USD days dominate the first half year of 2022 while the High-UST days have largely disappeared because the U.S. Treasuries are no longer safe haven assets when inflation picks up.

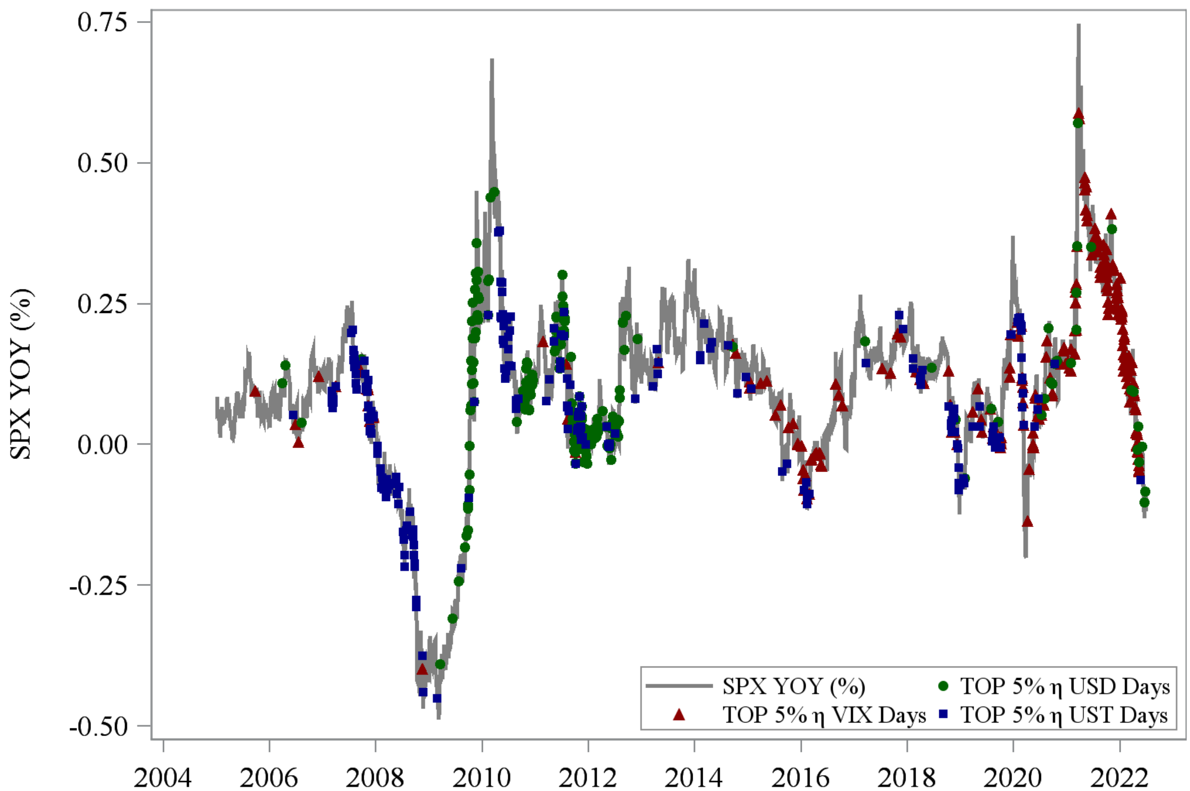
To further illustrate the variations of the safe-haven assets in our sample period, we plot the year-to-year return of the S&P 500 index from 2004 to 2022 and mark the high safety days identified by η_t^{UST}, η_t^{USD}, and η_t^{VIX} with different colors in Figure B3. For illustration purpose, we only mark the extremely risky days when the safety measures fall into the top 5%

Figure B2: **High Safety Days at Different Market Crisis**



This figure shows high safety (top 20%) days captured by η_t^{UST} (High-UST), η_t^{USD} (High-USD), η_t^{VIX} (High-VIX) and the time-series of the Year-to-Year (YoY) return of the S&P 500 index during four representative market crisis periods. The selected periods of market downturns are: (1) the 2008 financial crisis from September 1, 2008 to November 30, 2008 (2) the 2011 European debt crisis from July 1, 2011 to September 30, 2011 (3) the Covid-19 pandemic from February 1, 2020 to April 30, 2020 and (4) the inflation surge in 2022 from March 1, 2022 to June 30, 2022. We mark High-UST days in blue squares, High-USD days in green dots, and High-VIX days in red triangles, respectively.

Figure B3: **High Safety Days and SPX YoY Returns**



This figure shows the trading days with the top 5% η_t^{UST}, η_t^{USD}, η_t^{VIX} and the year-to-year return of the S&P 500 index. We mark the top 5% η_t^{UST} days in blue squares, the top 5% η_t^{USD}days in green dots, and the top 5% η_t^{VIX} days in red triangles, respectively.

band. Focusing on the crisis periods in our sample period, i.e, the various troughs when the S&P 500 index year-to-year return reaches its bottom, we find that the UST is the leading safe haven asset in our sample period, except for the post Covid-19 period when inflation becomes the major concern. The USD is the safe-heaven asset from 2009 to 2012, as well as the most recent period when inflation surges. In the latter sample period, the VIX is often the safe-haven asset.

Figure B4 shows the relative returns of global assets on safety days identified by alternative measures η_t^{USD}, η_t^{VIX} as well as short-term measures η_t^{2Y} and η_t^{3M}. Different from strong comovement of the global asset classes on the high safety days as shown in figure 6, there are no such flight-to-safety driven comovements on either of the alternative safety days. From panel (a) to panel (d) show the global asset's relative performance on high η_t^{USD}, high η_t^{VIX}, high η_t^{2Y} and high η_t^{3M} days, after excluding high η_t^{UST} days. It's obvious that the relative returns of global assets are close to zero, suggesting that global markets barely move with their global safeness (correlation with U.S. Equity SPX) on alternative safety days. The results further emphasizing the uniqueness and specialness of U.S. Treasury as the global safe haven destination and the sign of global flight-to-safety.

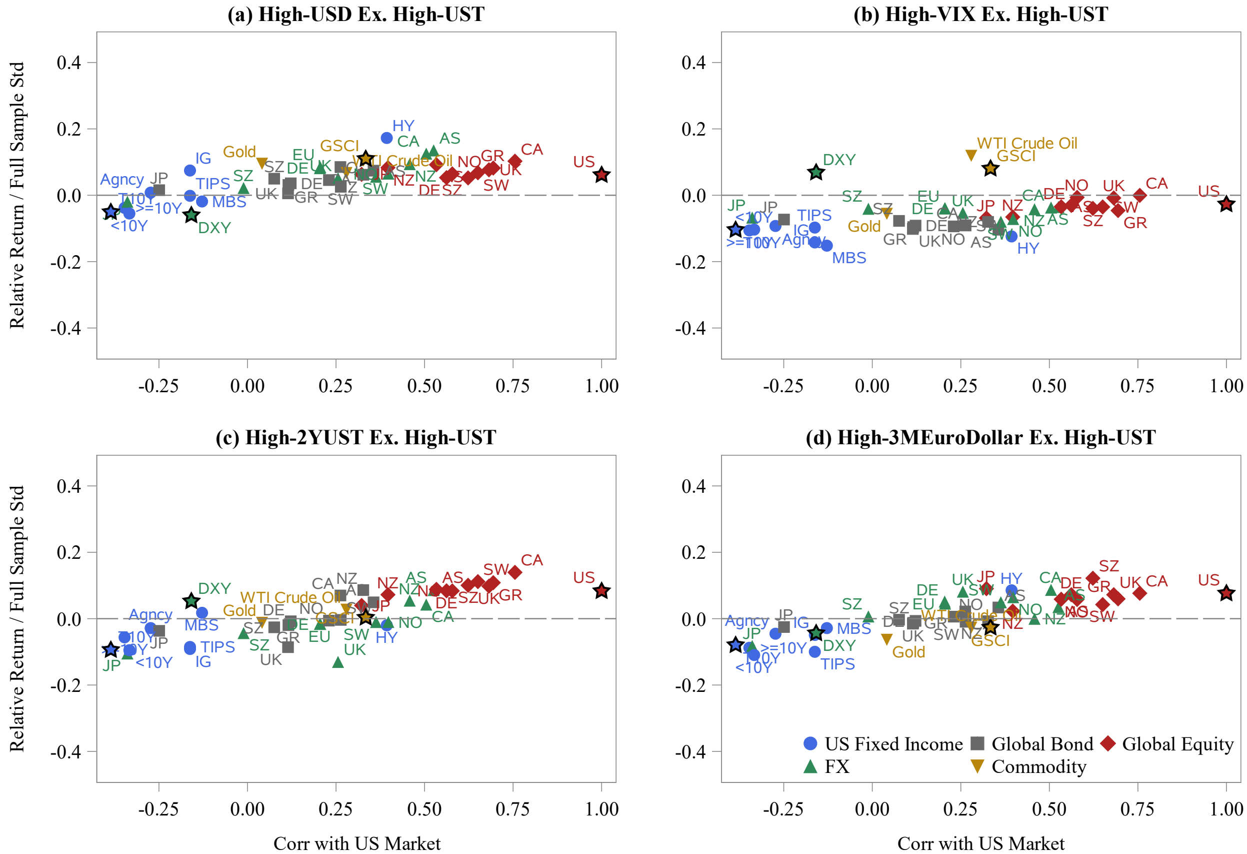
Appendix C: Safety measures with overnight returns

The safety 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 to capture flight-to-safety patterns 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. The VIX tick from CBOE is calculated between 3:15 AM and 9:15 AM and between 9:30 AM and 4:15 PM. To calculate safety measures 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 safety measures on day t.

We compare safety 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 C1 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, 0.94, and 0.95 for η_t^{UST},

Figure B4: **Performance of Global Assets on Alternative Safety Days**



This figure plots the scaled relative returns of each global asset class against its correlation with the U.S. equity index on (a) top 20% η_t^{USD} days excluding top 20% η_t^{UST} days; (b) top 20% η_t^{VIX} days excluding top 20% η_t^{UST} days; (c) top 20% η_t^{2Y} days excluding top 20% η_t^{UST} days; (d) top 20% η_t^{3M} days excluding top 20% η_t^{UST} days. Global assets include: (1) US Treasury and fixed income assets (US Fixed Income, 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 calculate the scaled relative returns on the specified group of days following equantion (4) by replacing high and low UST safety days with high and low USD/VIX/2Y/3M safety days excluding high UST safety days. The correlations are estimated based on the daily returns from January 2004 to June 2022. For global equities and bonds, we calculate the correlations based on overlapping two-day returns, and calculate scaled relative returns as average of relative returns on the day and next, to adjust for the time differences between the global markets and the U.S. market.

η_t^{USD}, and η_t^{VIX} between intraday and all-day measures. The average differences are quite small compared to the magnitudes and standard deviations.

Table C1: **Summary Statistics of Intraday and All-day Safety Measures**

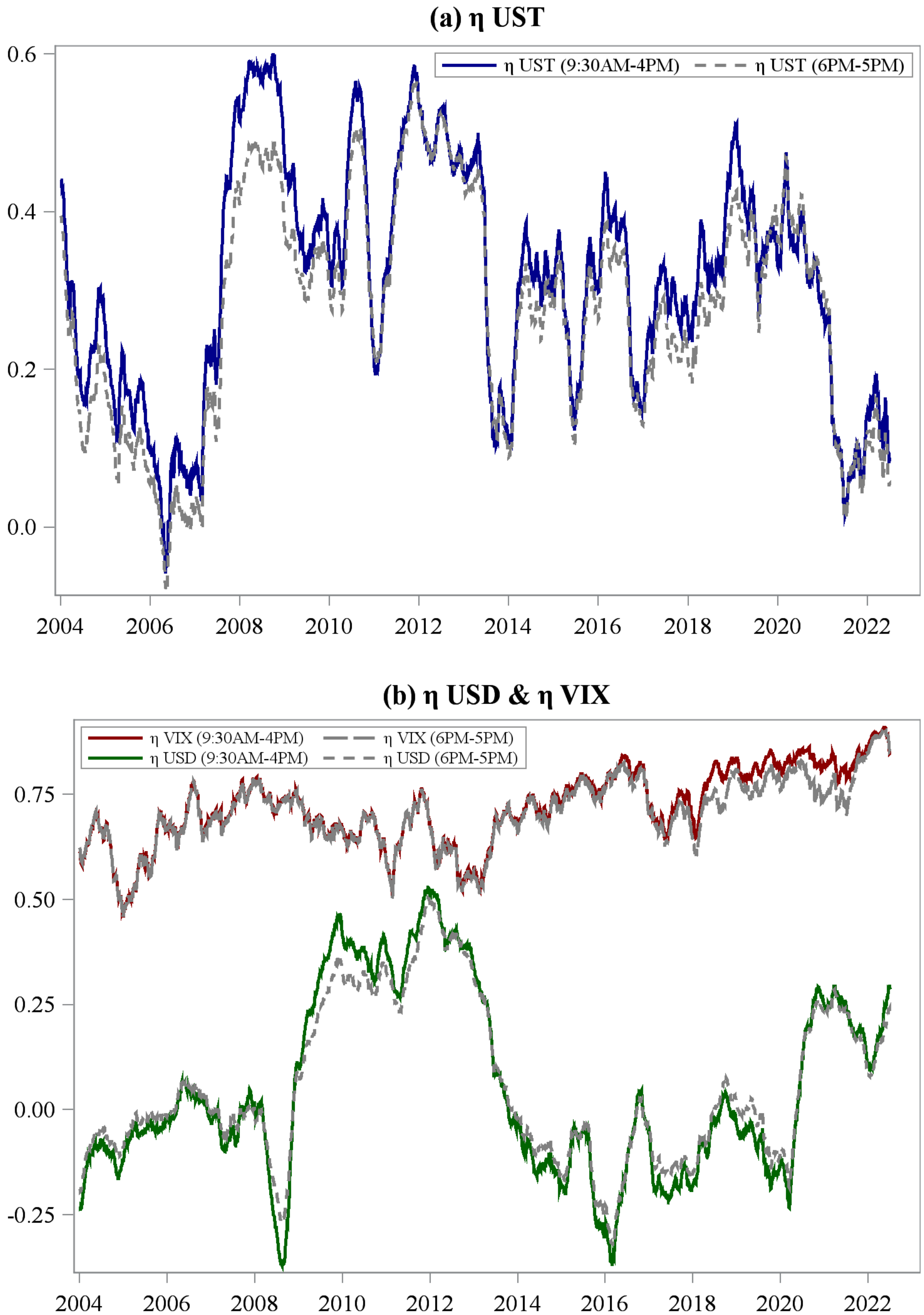
		mean	std	min	Q1	med	Q3	max	corr
η_t^{UST}	Intraday	0.31	0.26	-0.75	0.14	0.33	0.51	0.94	0.91
	All-day	0.27	0.23	-0.70	0.12	0.29	0.44	0.88	
	Diff	0.04	0.11	-0.69	-0.02	0.04	0.10	0.69	
η_t^{USD}	Intraday	0.06	0.28	-0.75	-0.14	0.04	0.27	0.77	0.94
	All-day	0.06	0.23	-0.80	-0.10	0.04	0.23	0.77	
	Diff	0.00	0.10	-0.58	-0.07	0.00	0.06	0.76	
η_t^{VIX}	Intraday	0.72	0.18	-0.19	0.63	0.77	0.86	0.98	0.95
	All-day	0.71	0.18	-0.16	0.61	0.75	0.84	0.98	
	Diff	0.01	0.06	-0.38	0.00	0.00	0.01	0.78	

This table shows summary statistics of safety measures using intraday (9:30AM-4PM ET) and entire-day (6PM-5PM ET) 5-min high frequency returns. η_t^{UST}, η_t^{USD} and η_t^{VIX} are calculated in the same way as described in equation (1) and (14) 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 safety measure using intraday and all-day returns. Row Diff reports the difference between the same safety measure using intraday and all-day returns. The sample period is from January 2004 to June 2022.

Figure C1 compares the time series (exponential weighted moving average with a decaying parameter of 0.98) of intraday and all-day η_t^{UST}, η_t^{USD}, and η_t^{VIX}. The time trends of the two measures closely mimic each other for the three safety measures. However, there does exist some differences. During the 2008 financial crisis, intraday η_t^{UST} is higher than all-day η_t^{UST}, indicating a more intense flight-to-safety degree captured by intraday measures. Similarly, during QE1 periods after the 2008 financial crisis, where USD serves as safety assets, intraday η_t^{USD} is higher than all-day η_t^{USD}. For η_t^{VIX}, since the extended hour from 2:15 AM to 8:15 AM started in 2016, observable differences between intraday and all-day measures have emerged after 2016, with the intraday measure also being higher than the all-day measure. These are evidence implying measures are more accurate based on intraday high-frequency returns.

Moreover, the η_t^{UST} can more accurately capture flight-to-safety episodes than the all-day measure, hereafter referred as $\eta_t^{\text{UST-All}}$. In Table C2, we present the performance of SPX and UST on high and low safety days identified by η_t^{UST} or $\eta_t^{\text{UST-All}}$. In Panel A, we show the averages of SPX and UST daily returns on high safety days, where η_t^{UST} or $\eta_t^{\text{UST-All}}$ is higher than its full sample 90% or 80% percentiles. On both days, SPX drops, and UST rallies, but the magnitudes are larger on high η_t^{UST} days than $\eta_t^{\text{UST-All}}$. Specifically, SPX drops by -39.27

Figure C1: **Time Series of Intraday and All-day $\eta_t^{\mathbf{UST}}$, $\eta_t^{\mathbf{USD}}$ and $\eta_t^{\mathbf{VIX}}$**



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

and -36.20 bps on the top 10% and 20% η_t^{UST} days, which are larger than the -31.87 and -23.83 bps on high $\eta_t^{\text{UST-All}}$ days. Similarly, UST increases by 14.28 and 13.60 bps on the top 10% and 20% days of η_t^{UST}, which is larger than the 11.06 and 10.56 bps of $\eta_t^{\text{UST-All}}$. In Panel B, the rise in SPX and drops in UST are also in larger magnitudes on days identified by η_t^{UST} than those by $\eta_t^{\text{UST-All}}$. SPX increases by 6.33 and 4.13 bps more, and UST decreases by 1.54 and 1.79 bps more on bottom η_t^{UST} days than bottom $\eta_t^{\text{UST-All}}$ days, respectively. The results support our choice η_t^{UST}, which use only regular trading hours data, as the main measures in this paper.

Table C2: **Market Performance under Different η_t^{UST} Measure**

Panel A: High safety days				
	Top 10% Days		Top 20% Days	
	η_t^{UST}	$\eta_t^{\text{UST-All}}$	η_t^{UST}	$\eta_t^{\text{UST-All}}$
SPX	-39.27	-31.87	-36.20	-23.83
UST	14.28	11.06	13.60	10.56
Panel B:Low safety days				
	Bottom 10% Days		Bottom 20% Days	
	η_t^{UST}	$\eta_t^{\text{UST-All}}$	η_t^{UST}	$\eta_t^{\text{UST-All}}$
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 returns on high or low safety days based on η_t^{UST} and $\eta_t^{\text{UST-All}}$. 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 (η_t^{UST}) or from 6PM one day before to 5PM today ($\eta_t^{\text{UST-All}}$), 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 high safety days, i.e. days with highest (top 10% or 20%) η_t^{UST} or $\eta_t^{\text{UST-All}}$. Similarly, panel B reports the daily returns of SPX and UST on low safety days, i.e. days with lowest (bottom 10% or 20%) η_t^{UST} or $\eta_t^{\text{UST-All}}$. The returns are in unit of basis point. The sample period is from January 2004 to June 2022.

Appendix D: UST-USD Relations on high and low safety days with controls of η_t^{USD}

In this section, we supplement the results of comovements between UST and USD by considering the safety measure η_t^{USD}. In section 4.2, we find the original postive relation of UST and USD are offset by the safe-heaven nature of UST. Since the safety measure η_t^{USD} directly measures the safeness of USD, we further control the effect from η_t^{USD} and examine the impact of η_t^{UST} on foreign exchange markets.

Table D1: **The Comovement of UST and USD**

yvar=	r_t^{USD}		$r_t^{\text{USD/Foreign}}$			$r_t^{\text{Foreign/USD}}$	
	(1)	(2)	(3)	(4)		(5)	(6)
$\Delta y^{\text{UST}} \times \text{High}\eta_t^{\text{UST}}$		-1.61***		-1.63***	$\Delta y^{\text{Local Bond}} \times \text{High}\eta_t^{\text{UST}}$		1.96***
		[-2.99]		[-2.93]			[2.76]
$\Delta y^{\text{UST}} \times \text{High}\eta_t^{\text{USD}}$		-1.36***		-1.19***	$\Delta y^{\text{Local Bond}} \times \text{High}\eta_t^{\text{USD}}$		0.59
		[-2.99]		[-2.79]			[1.23]
$\Delta y^{\text{UST}} \times \text{Low}\eta_t^{\text{UST}}$		1.90***		1.95***	$\Delta y^{\text{Local Bond}} \times \text{Low}\eta_t^{\text{UST}}$		-1.97***
		[4.35]		[4.38]			[-4.44]
$\Delta y^{\text{UST}} \times \text{Low}\eta_t^{\text{USD}}$		0.35		0.71	$\Delta y^{\text{Local Bond}} \times \text{Low}\eta_t^{\text{UST}}$		-0.08
		[0.53]		[1.24]			[-0.16]
Δy^{UST}	1.48***	1.38***	1.58***	1.43***	$\Delta y^{\text{Local Bond}}$	1.57***	1.48***
	[6.71]	[4.51]	[3.93]	[3.26]		[7.91]	[4.67]
$r^{\text{SPX}} \times \text{High}\eta_t^{\text{UST}}$		0.03		0.03	$r^{\text{Local Equity}} \times \text{High}\eta_t^{\text{UST}}$		-0.05**
		[1.36]		[1.17]			[-2.37]
$r^{\text{SPX}} \times \text{High}\eta_t^{\text{USD}}$		-0.10***		-0.12***	$r^{\text{Local Equity}} \times \text{High}\eta_t^{\text{USD}}$		0.09***
		[-3.47]		[-4.32]			[2.78]
$r^{\text{SPX}} \times \text{Low}\eta_t^{\text{UST}}$		-0.02		-0.00	$r^{\text{Local Equity}} \times \text{Low}\eta_t^{\text{UST}}$		-0.02
		[-0.97]		[-0.16]			[-1.00]
$r^{\text{SPX}} \times \text{Low}\eta_t^{\text{USD}}$		0.14***		0.15***	$r^{\text{Local Equity}} \times \text{Low}\eta_t^{\text{USD}}$		-0.15***
		[3.92]		[4.26]			[-5.36]
r^{SPX}	-0.09***	-0.07***	-0.18***	-0.16***	$r^{\text{Local Equity}}$	0.06	0.06*
	[-7.67]	[-4.80]	[-3.99]	[-3.54]		[1.55]	[1.86]
High η_t^{UST}	-0.84	-1.44	-1.74	-2.58	High η_t^{UST}	0.24	0.86
	[-0.41]	[-0.69]	[-0.88]	[-1.34]		[0.08]	[0.30]
Low η_t^{UST}	1.35	0.08	1.04	-0.65	Low η_t^{UST}	-2.57	-1.24
	[0.69]	[0.04]	[-0.60]	[-0.37]		[-1.32]	[-0.64]
High η_t^{USD}	-1.44	0.04	-1.95	-0.20	High η_t^{USD}	1.97	1.09
	[-0.69]	[0.02]	[-0.94]	[-0.10]		[0.83]	[0.47]
Low η_t^{UST}	-1.63	-2.14	-1.44	-1.90	Low η_t^{USD}	1.64	2.16
	[-0.76]	[-1.04]	[-0.73]	[-1.00]		[0.83]	[1.10]
Intercept	1.02	0.89			Intercept		
	[0.97]	[0.83]					
Currency FE	No	No	Yes	Yes	Currency FE	Yes	Yes
NOBS	4622	4622	46220	46220	NOBS	46220	46220
R2 (%)	4.92	9.31	8.52	11.05	R2 (%)	2.44	4.13

This table shows relation between equity/10-year treasury and exchange rates conditional on high and low safety days identified by η_t^{UST} and η_t^{USD}. The regressions are the same as reported in Table 10 except that high or low η_t^{USD} days after excluding high η_t^{UST} days and their interactions with bond and equity are added in regression as additional controls. The detailed description of equity and treasury data for G10 countries are listed in Appendix table E1. 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.

Table D1 follows the same format as Table 10 except that it includes controls for high and low η_t^{USD} days and their interactions with equity and bonds. Focusing on the effects of high (low) η_t^{UST} 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, a one-standard-deviation increase in bond yield will lead to 1.61 bps less (1.90 bps more) returns of USD on high (low) η_t^{UST} days. For G10 countries, a one-standard-deviation increase in bond yield will result in 1.96 bps more (1.97 bps less) returns of the local currency on high (low) η_t^{UST} days.

For η_t^{USD}, it affects the dynamics between USD and UST with three distinct characteristics. First, the positive UST/USD relations are offset on high η_t^{USD} days when USD exhibits its safe-haven nature, albeit with less magnitude. The relations are slightly enhanced on low η_t^{USD} days but are not statistically significant. This suggests that UST-USD relations can be influenced bilaterally by the safe-haven nature of both UST and USD, but UST has relatively larger impacts. Second, unlike on high η_t^{UST} days, the relations with foreign bonds and currencies do not change significantly on high η_t^{USD} 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 UST is enhanced on high η_t^{USD} days and weakened on low η_t^{USD} days, in the opposite direction compared to high or low η_t^{UST} and is much more significant. A one-standard-deviation increase in SPX will generate 0.10 bps less (0.14 bps more) returns of USD on high (low) η_t^{USD} days.

The results suggest a robust impact of η_t^{UST} on UST-USD relations even after controlling for η_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 E: 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 10 and D1 are listed in Table E1. The data is obtained from Bloomberg.

Table E1: List of G10 Country T10Y, Equity and Currency

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

References

Acharya, V. V. and T. Laarits (2023). When do Treasuries Earn the Convenience Yield? — A Hedging Perspective. Working Paper 31863, National Bureau of Economic Research.

Adrian, T., R. K. Crump, and E. Moench (2013). Pricing the Term Structure with Linear Regressions. Journal of Financial Economics 110(1), 110–138.

Adrian, T., M. Fleming, O. Shachar, and E. Vogt (2017). Market Liquidity after the Financial Crisis. Annual Review of Financial Economics *9*, 43–83.

Baele, L., G. Bekaert, and K. Inghelbrecht (2010). The Determinants of Stock and Bond Return Comovements. Review of Financial Studies 23(6), 2374–2428.

Baele, L., G. Bekaert, K. Inghelbrecht, and M. Wei (2019). Flights to Safety. The Review of Financial Studies 33(2), 689–746.

Bansal, N., R. A. Connolly, and C. Stivers (2010). Regime-switching in Stock Index and Treasury Futures Returns and Measures of Stock Market Stress. Journal of Futures Markets: Futures, Options, and Other Derivative Products 30(8), 753–779.

Baur, D. G. and B. M. Lucey (2009). Flights and Contagion—An Empirical Analysis of Stock–Bond Correlations. Journal of Financial Stability 5(4), 339–352.

Beber, A., M. W. Brandt, and J. Cen (2014). Switching Risk Off: FX Correlations and Risk Premia. Available at SSRN 2508651.

Bollerslev, T., G. Tauchen, and H. Zhou (2009). Expected Stock Returns and Variance Risk Premia. Review of Financial Studies 22(11), 4463–4492.

Campbell, J. Y., C. Pflueger, and L. M. Viceira (2020). Macroeconomic Drivers of Bond and Equity Risks. Journal of Political Economy 128(8), 3148–3185.

Cieslak, A. and A. Schrimpf (2019). Non-monetary News in Central Bank Communication. Journal of International Economics *118*, 293–315.

Connolly, R., C. Stivers, and L. Sun (2005). Stock Market Uncertainty and the Stock-Bond Return Relation. Journal of Financial and Quantitative Analysis 40(1), 161–194.

David, A. and P. Veronesi (2013). What Ties Return Volatilities to Price Valuations and Fundamentals? Journal of Political Economy 121(4), 682–746.

D.E.Shaw (2019). Positively Negative: Stock-Bond Correlation and Its Implications for Investors. DEShaw Report.

Du, W., J. Im, and J. Schreger (2018). The US Treasury Premium. Journal of International Economics *112*, 167–181.

Ermolov, A. (2022). Time-varying Risk of Nominal Bonds: How Important are Macroeconomic Shocks? Journal of Financial Economics 145(1), 1–28.

Frazzini, A. and L. H. Pedersen (2014). Betting against Beta. Journal of Financial Economics 111(1), 1–25.

Goyenko, R. and S. Sarkissian (2014). Treasury Bond Illiquidity and Global Equity Returns. Journal of Financial and Quantitative Analysis 49(5-6), 1227–1253.

He, Z., S. Nagel, and Z. Song (2022). Treasury Inconvenience Yields during the Covid-19 Crisis. Journal of Financial Economics 143(1), 57–79.

Hu, G. X., J. Pan, and J. Wang (2013). Noise as Information for Illiquidity. Journal of Finance 68(6), 2341–2382.

Jiang, Z., A. Krishnamurthy, and H. Lustig (2020). Dollar Safety and the Global Financial Cycle. NBER Working Paper (27682).

Jiang, Z., A. Krishnamurthy, and H. Lustig (2021). Foreign Safe Asset Demand and the Dollar Exchange Rate. The Journal of Finance 76(3), 1049–1089.

Kekre, R. and M. Lenel (2021, September). The Flight to Safety and International Risk Sharing. Working Paper 29238, National Bureau of Economic Research.

Kim, D. H. and J. H. Wright (2005). An Arbitrage-Free Three-Factor Term Structure Model and the Recent Behavior of Long-Term Yields and Distant-Horizon Forward Rates.

Laarits, T. (2022). Precautionary Savings and the Stock-Bond Covariance. Working Paper.

Li, E. X., T. Zha, J. Zhang, and H. Zhou (2022). Does Fiscal Policy Matter for Stock-Bond Return Correlation? Journal of Monetary Economics *128*, 20–34.

Rey, H. (2015). Dilemma not Trilemma: The Global Financial Cycle and Monetary Policy Independence. NBER Working Paper.

Savor, P. and M. Wilson (2014). Asset Pricing: A Tale of Two Days. Journal of Financial Economics 113(2), 171–201.