Risk Premiums in the U.S. Treasury Futures

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Abstract

We model Treasury futures prices using a no-arbitrage term structure model with GARCH-type volatility factor. We find that model-implied risk premiums are generally positive and exhibit cyclical variations, reflecting investors' dynamic perception of interest rate risk. Notably, heightened risk premiums coincide with an upward-sloping yield curve, attributable to monetary policy easing during economic downturns, and vice versa. We document a significant negative association between Treasury futures risk premiums and the net positions of commercial traders and asset managers, aligning with the hedging pressure hypothesis. Furthermore, we demonstrate that the net positions of market participants are closely related to the shape of the Treasury yield curve, suggesting that investors utilize Treasury futures to manage interest rate risk, especially after the Global Financial Crisis.

JEL Classification: G12, E43, E44

Keywords: Treasury futures; futures risk premium; trader's position; term structure; yield curve factors; GARCH volatility; interest rate risk; monetary policy.

1 Introduction

The U.S. Treasury market, with \$24 trillion in marketable debt outstanding as of December 2022,[1] is widely regarded as the largest and most liquid government securities market in the world, playing a critical role in the global economy and in the Federal Reserve's implementation of monetary policy. Chicago Board of Trade (CBOT) Treasury futures are standardized agreements for the future delivery of U.S. government notes or bonds.[2] These contracts are widely utilized by institutional and individual investors to hedge or assume interest rate risk exposures.[3] Despite the extensive research dedicated to U.S. government securities, there is very limited work on pricing and understanding the Treasury futures market. The existing literature on fixed-income derivatives relies more on caps or swaption.[4] This paper introduces a no-arbitrage model to price the term structure of Treasury futures and investigates the risk premiums embedded in the Treasury futures market.

We use a dynamic term structure model with three latent factors and one GARCH-type volatility factor to price Treasury futures. The model, based on Heston and Nandi (2003), incorporates the GARCH model's capability to precisely capture the time variation in yield volatility, a crucial aspect in derivatives pricing.[5] The model also retains the tractability of affine pricing in bond and bond derivatives. We present a closed-form solution to the pricing of Treasury futures on coupon bonds and estimate the model using monthly futures prices from March 2000 to June 2022 for 5- and 10-year Treasury notes futures, and 30-year Treasury bond futures with maturities ranging from one to nine months. Our model well captures the term structure of futures prices for all underlying Treasury securities.[6]

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[1] `https://www.cmegroup.com/trading/interest-rates/basics-of-us-treasury-futures.html`

[2] For more information on the specifications of these contracts, refer to `https://www.cmegroup.com/trading/interest-rates/us-treasury.html`

[3] See for instance Labuszewski et al. (2013), Morris (1989), and Frankel et al. (1984).

[4] See for instance Longstaff et al. (2001), Collin-Dufresne and Goldstein (2002), Jarrow et al. (2007), Han (2007), Li and Zhao (2006), and Heidari and Wu (2009).

[5] Doshi et al. (2022) propose a similar term structure model with GARCH volatility to investigate the model's potential to fit yield levels and yield volatilities simultaneously, which is a key empirical challenge in term structure modeling.

[6] The in-sample root mean squared error on average is about 0.8% of bond face value for all futures

We find futures risk premiums for all underlying Treasuries are positive on average, and they are marginally larger for longer futures maturities than for shorter maturities. The risk premiums of futures on longer-maturity bonds are on average higher than those on shorter-maturity notes. These results are consistent with the notion that longer-maturity bonds and futures are generally subject to a greater degree of interest rate risk. We also demonstrate substantial cyclical variation in Treasury futures risk premiums over the past two decades. The variation is persistent and related to the macroeconomic conditions, such as the shape of the yield curve, the stance of monetary policy, and the business cycle. More specifically, Treasury futures risk premiums with all maturities tend to be high when the Federal Reserve has an easing monetary policy and the yield curve is upward-sloping, and low when the Federal Reserve has a tightening policy and the yield curve is inverted. The fluctuations in futures risk premiums seem to reflect the market's perception of interest rate risk, shaped by the changes in monetary policy across the business cycle.

We further investigate the relationship between model-implied Treasury futures risk premiums and the trading activities of different types of traders in the Treasury futures market using traders' position data from the Commodity Futures Trading Commission (CFTC) Commitment of Trader (COT) reports. We show a significant level of persistence in the net positions of all trading groups throughout our sample period. We find that the net (long minus short) position of commercial traders, reported in the CFTC legacy COT report, exhibit similar trends to those of asset managers, reported in the CFTC Traders in Financial Futures (TFF) COT report, and are predominately net-long, particularly after 2015. In contrast, noncommercial traders (in the legacy report) and dealers and leveraged funds (in the TFF report) in our sample tend to maintain a net short on average, exhibiting a negative correlation with the net positions of commercial traders.

Regression analyses reveal a negative relationship between our model-implied risk premiums and the net long position among commercial traders, which aligns with the

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contracts in the sample.

hedging pressure hypothesis (See Cootner, 1960; Hirshleifer, 1988; deRoon et al., 2000), as the net long position by commercial traders (hedgers) pay a risk premium to non-commercial traders (speculators), who are net short, for absorbing the hedging demand. To provide additional insights into this finding, we examine the relationship between our model-implied risk premiums and the net trading positions of asset managers, who constitute the primary net public demand within all trading groups. We observe a negative coefficient associated with their net positions in the regression analysis. This aligns with the findings of Barth and Kahn (2021), who highlight a substantial rise in the demand for long Treasury futures positions from traditional asset managers since around 2016. According to the conventional price pressure hypothesis, an increase in the demand for futures contracts is expected to introduce a temporary upward bias to the futures price, subsequently leading to a reversal and a decrease in risk premium (deRoon et al., 2000). On the other hand, leveraged funds and dealers, by taking net short positions to fulfill the long position demands of asset managers, exhibit a significant positive correlation between their net positions and the Treasury futures risk premium. These results hold across various maturities of Treasuries and Treasury futures and remain robust after accounting for the shape of the yield curve summarized by level, slope, and curvature.

Moreover, we document a strong relationship between the net positions of different trader groups and the shape of the yield curve, especially after the Global Financial Crisis. We find that high interest rate level, flattening yield curve, or convex yield curve is commonly linked to commercial traders and asset managers holding more long positions, while dealers and leveraged funds typically favor more short positions. The connection with the yield curve becomes more pronounced after the Global Financial Crisis, considering the changes in the U.S. Treasury market due to unconventional policy and regulatory interventions (Du et al., 2023). These findings suggest that in times of high interest rates, commercial traders who expect the Federal Reserve to cut rates and tighten monetary policy, are inclined to take more long positions in futures to hedge against interest rate risk. Likewise, for a flat or inverted yield curve, commercial traders are more likely to increase their net holdings in futures, expecting the Fed to eventually reduce policy rates. Besides, we note a more convex yield curve makes bond prices more sensitive to interest rate changes than indicated by their duration, leading commercial traders to increase long futures positions to protect against interest rate risk. Our findings confirm that participants in the Treasury futures market utilize futures contracts to manage interest rate risk embedded in the dynamics of the yield curve.

We contribute to the literature on fixed-income derivatives, particularly in the realm of U.S. Treasury derivatives. As previously noted, the literature on pricing Treasury futures and options is notably limited. Instead, much of the prevailing research on fixed-income derivatives relies on caps or swaption data.[7] More recent literature studies other aspects of Treasury futures options including option returns, implied volatility, variance risk premiums, and the use of implied information from Treasury derivatives for forecasting excess bond returns (Bakshi et al., 2022; Bakshi et al., 2023; Beber and Brandt, 2006, Cremers et al., 2021; Choi and Vedolin, 2017; Bauer and Chernov, 2023; Wright and Zhou, 2009). Our work focuses on the valuation of the entire term structure of Treasury futures, utilizing a no-arbitrage dynamic term structure model. This model enables us to analyze the implied risk premium associated with the yield curve, the monetary policy, and the trading activities of different trader groups in this crucial market. Our research fills a gap in the existing literature by offering insights into the pricing and risk premium dynamics in Treasury futures.

Our work is also related to the literature explaining risk premiums and their determinants in various futures markets. The existing literature predominantly concentrates on commodity futures and has identified a set of variables related to commodity futures risk premiums, such as futures basis, return momentum, volatility, hedging pressure, carry factor, inventory level, open interests, macroeconomic factors, and trader's net position (Szymanowska et al., 2014; Bakshi et al., 2019; Moskowitz et al., 2012; Yang, 2013; Fuertes et al., 2010; Gorton et al., 2013; Basu and Miffre, 2013; Asness et al., 2013;

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[7] See also Jagannathan et al. (2003), Almeida et al. (2011), Christoffersen et al. (2014), and Trolle and Schwartz (2009).

Bessembinder, 1992; deRoon et al., 2000; Boons and Prado, 2019; Li, 2018; Kang et al., 2020). Our study extends this strand of literature by examining risk premiums of U.S. Treasury futures and provides evidence that the yield curve dynamic, the monetary policy stance, and the trading activities play a significant role in determining Treasury futures risk premiums across different maturities, enriching our understanding of risk premiums within the broader landscape of futures markets.

As mentioned above, literature in the commodity sector includes studies on hedging pressure using traders' positions (Bessembinder, 1992; deRoon et al., 2000) and research on the relationship between traders' net positions and risk premiums in commodity futures (Li, 2018; Kang et al., 2020). Additional studies document the impact of traders' positions on other variables, such as macroeconomic activities and asset price fluctuations (Hong and Yogo, 2012), traders' profits (Dewally et al., 2013), risk preference in the oil market (Christoffersen et al., 2022), and overall extent of calendar spreading (Robe and Roberts, 2021). Our work broadens the existing literature examining the impact of traders' positions in the realm of financial futures markets. Several studies have examined the influence of traders' positions on VIX futures (Cheng, 2018; Chen and Yang, 2021), foreign currency futures (Chang et al., 2013; Wang, 2002), and equity index futures (Smales, 2016). This paper adds to the literature by examining the trading activities of different trader groups in futures on another significant financial asset, the U.S. government securities. We show that traders' positions in this futures market are significantly related to the yield curve dynamic and also strongly contribute to the movements of futures risk premiums.

The paper proceeds as follows. Section 2 presents the specification of the term structure model. Section 3 provides the data and discusses the estimation method. Section 4 presents model estimation results and discusses the model-implied futures risk premium and its relationship with the yield curve and the monetary policy. Section 5 explains the risk premium with traders' positions and explores the relationship between futures position and the yield curve. Section 6 concludes.

2 The Model

We apply a no-arbitrage term structure model with GARCH volatility factor to investigate the risk premiums of Treasury futures.[8] The model provides analytical solutions to bond prices and bond futures prices and captures the time variation in the conditional variances of yields sufficiently. The model is based on Heston and Nandi (2003), which incorporates ARCH/GARCH volatility into affine term structure models.[9] We focus on a parsimonious model with three latent factors X_t and one time-varying volatility factor.[10] We specify the following dynamics for the state variables under the physical measure P and the risk-neutral measure Q:

$$X_{t+1} = K_0^P + K_1^P X_t + \sqrt{\Sigma_{t+1}}\epsilon_{t+1}, \tag{1}$$

$$X_{t+1} = K_0^Q + K_1^Q X_t + \sqrt{\Sigma_{t+1}}\epsilon_{t+1}, \tag{2}$$

$$r_t = \rho_0 + \rho_1 X_t, \tag{3}$$

where X_{t+1}, K_0^P, and ϵ_{t+1} are 3×1 vectors, and K_1^P is a 3×3 diagonal matrix. r_t denotes the short rate, ρ_0 is a scalar, ρ_1 is a 1×3 vector, and ϵ_{t+1} is assumed to be distributed $N(0, I_3)$. The conditional covariance matrix Σ_{t+1} is a 3×3 diagonal matrix with the first diagonal element $\sigma^2_{1,t+1}$ governed by a GARCH$(1,1)$ dynamic:[11]

$$\sigma^2_{1,t+1} = \omega + \beta\sigma^2_{1,t} + \alpha\epsilon^2_{1,t}, \tag{4}$$

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[8] The no-arbitrage term structure models have been widely used in the literature to study the risk (term) premium in bond yields and commodity futures (Bauer, 2018; Bauer et al., 2012, 2014; Kim and Orphanides, 2012; Backus and Wright, 2007; Joslin et al., 2014; Heath, 2019; Jacobs et al., 2022).

[9] Heston and Nandi (2003) calibrate the model using zero-coupon bond prices for a two-week sample. This limited empirical exercise does not allow them to analyze the pricing and the implied risk premiums of Treasury futures on coupon bonds.

[10] Doshi et al. (2022) show that this model provides an adequate fit for the underlying bond yields and yield volatilities.

[11] There is considerable evidence that ARCH and GARCH modeling effectively characterize interest rate volatility (Koedijk et al., 1997; Brenner et al., 1996; Christiansen, 2005).

where $\epsilon_{1,t}$ is the first element of vector ϵ_t. ω, β, and α are scalars. To ensure that $\sigma^2_{1,t+1}$ is positive, we restrict ω, β, and α to be positive numbers. $\sigma^2_{1,t+1}$ is known as of time t, given the history of the first factor $X_{1,t}$ and the initial variance as follows

$$\sigma^2_{1,t+1} = \omega + \beta\sigma^2_{1,t} + \alpha\frac{(X_{1,t} - K^P_{0(1)} - K^P_{1(1,1)}X_{1,t-1})^2}{\sigma^2_{1,t}}, \tag{5}$$

where $K^P_{0(1)}$ is the first element of K^P_0, and $K^P_{1(1,1)}$ is the first diagonal element of K^P_1. The volatility of the other two state variables is constant over time: σ^2_2 and σ^2_3 are the second and third diagonal elements of Σ_{t+1}.

The model-implied time t price of a zero coupon bond $\widehat{P}^n_t$ with maturity n is:[12]

$$\widehat{P}^n_t = \exp\left(A_n(\Theta^Q) + B^{'}_n(\Theta^Q)X_t + C_n(\Theta^Q)\sigma^2_{1,t+1}\right), \tag{6}$$

where $A_n(\Theta^Q)$, $B_n(\Theta^Q)$ and $C_n(\Theta^Q)$ are functions of the parameters $\Theta^Q = \{K^Q_0, K^Q_1, \rho_0, \rho_1, \omega, \beta, \alpha\}$ under the Q-dynamics, satisfying the following recursive relations:

$$A_n = -\rho_0 + A_{n-1} + B^{'}_{n-1}K^Q_0 + \left(C_n\omega - \frac{1}{2}\log(1 - 2\alpha C_{n-1})\right) + \frac{1}{2}B^2_{2,n-1}\sigma^2_2 + \frac{1}{2}B^2_{3,n-1}\sigma^2_3, \tag{7}$$

$$B_n = -\rho^{'}_1 + B^{'}_{n-1}K^Q_1, \tag{8}$$

$$C_n = \frac{B^2_{1,n-1}}{2(1 - 2\alpha C_{n-1})} + \beta C_{n-1}, \tag{9}$$

where A_n and C_n are scalars, and B_n is a 3×1 vector with elements $B_{1,n}$, $B_{2,n}$, and $B_{3,n}$. The initial conditions are $A_1 = -\rho_0$, $B_1 = -\rho^{'}_1$ and $C_1 = 0$.

We use $F(t, T_1, T_2)$ denote the time t price of a futures contract on a discount bond such that the futures contract expires at T_1 and the discount bond expires at T_2, where $T_1 < T_2$. As with the spot bond, we can also write the bond futures prices as exponential

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[12] The pricing kernel takes the standard form, in which an essentially affine specification for the price of risk is used (Duffee, 2002; Dai and Singleton, 2002; Cheridito et al., 2007).

affine in the state variables

$$\widehat{F}(t,T_1,T_2) = \exp\left(A_f(t,T_1,T_2) + B_f^{'}(t,T_1,T_2)X_t + C_f(t,T_1,T_2)\sigma_{1,t+1}^2\right), \tag{10}$$

where

$$\begin{aligned} A_f(t,T_1,T_2) &= A_f(t+1,T_1,T_2) + B_f^{'}(t+1,T_1,T_2)K_0^Q \\ &\quad + \left(C_f(t+1,T_1,T_2)\omega - \frac{1}{2}\log\left(1-2\alpha C_f(t+1,T_1,T_2)\right)\right) \\ &\quad + \frac{1}{2}B_{f,2}^2(t+1,T_1,T_2)\sigma_2^2 + \frac{1}{2}B_{f,3}^2(t+1,T_1,T_2)\sigma_3^2, \end{aligned} \tag{11}$$

$$B_f(t,T_1,T_2) = B_f^{'}(t+1,T_1,T_2)K_1^Q, \tag{12}$$

$$C_f(t,T_1,T_2) = \frac{B_{f,1}^2(t+1,T_1,T_2)}{2(1-2\alpha C_f(t+1,T_1,T_2))} + \beta C_f(t+1,T_1,T_2). \tag{13}$$

A_f and C_f are scalars, and B_f is a 3×1 vector with elements $B_{f,1}$, $B_{f,2}$, and $B_{f,3}$. Note that the futures price equals the spot price at the maturity of the futures contract. Therefore $F(T_1,T_1,T_2) = P(T_1,T_2)$, the price of a (T_2-T_1)-period bond at time T_1. This implies $A_f(T_1,T_1,T_2) = A(T_1,T_2) = A_{T_2-T_1}$, $B_f(T_1,T_1,T_2) = B(T_1,T_2) = B_{T_2-T_1}$, and $C_f(T_1,T_1,T_2) = C(T_1,T_2) = C_{T_2-T_1}$, where $A_{T_2-T_1}$, $B_{T_2-T_1}$, and $C_{T_2-T_1}$ are known from the recursions in equations (7), (8), and (9) to calculate the price of the zero coupon bond. Appendix A provides the derivation of the pricing for bond and bond futures.

3 Data and Estimation Method

3.1 Data

The Treasury futures are traded on the Chicago Board of Trade (CBOT), which was merged with the Chicago Mercantile Exchange (CME) in 2007. We obtain the Treasury futures data from Genesis Financial Technologies. We use end-of-month closing price data for the 5- and 10-year Treasury notes futures and the 30-year Treasury bond futures.[13] The reference coupon rate for the Treasury underlying these futures contracts is fixed at 8% before February 2000 and at 6% after February 2000.[14] In this paper, we focus on the sample after the change of the reference coupon rate: from March 2000 to June 2022.[15] The monthly data on continuously compounded zero coupon bond yields are obtained from the Federal Reserve Economic Data and the Gürkaynak et al. (2007) (GSW 2007) dataset.[16]

We divide the futures data into three groups based on maturity: 1-3 months, 4-6 months, and 7-9 months. Panels A-C of Table 1 present the sample summary statistics for the prices of futures contracts on 5-, 10-, and 30-year Treasuries, respectively. The futures contracts are quoted in terms of percentage of par. The average percentage prices, minima, and maxima are not very different across maturities. The averages and medians exceed one hundred percent, which is because in our sample period, the fixed coupons exceed the prevailing market interest rates. Futures contracts in the first two maturity groups are much more liquid than those in the longer maturity group based on the average daily trading volume and open interest. Also, the most liquid market is the 10-year Treasury notes futures, followed by the 5-year Treasury notes futures, and then the 30-year Treasury bond futures. Figure 1 plots the end-of-month daily trading volume and open interest of the three Treasury futures for all contracts within the three maturity groups. We observe that trading volume and open interest have increased significantly after the financial crisis around 2009, most notably for 10- and 5-year Treasury futures.

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[13] The 30-year Treasury bond futures is the original or classic bond futures contract. After the development of the Ultra bond contract, the delivery window of the original Treasury bond futures contract was amended from 15-30 years to 15-25 years. The contract months for the Treasury futures are the first five (5- and 10-year Treasury futures) or three (30-year Treasury futures) consecutive contracts in the March, June, September, and December quarterly cycle.

[14] Treasury note and bond futures are based upon a 6% coupon security after 2000. But in fact, the contracts permit the delivery of any coupon security, provided that it meets the maturity specification. The conversion factor mechanism aims to standardize delivery prices across the various coupons of the underlying bonds. The normalization relies on a conversion factor for each bond, that is based on a standardized conversion factor yield. This reference yield was 8% since the creation of the Treasury bond futures until it was changed to 6% beginning with March 2000 contracts.

[15] Our conclusions are qualitatively similar if May 1988 is used as the starting date, which is the earliest date with availability of 5-year Treasury note futures.

[16] The GSW dataset is obtained from the Federal Reserve: `http://www.federalreserve.gov/pubs/feds/2006/200628/200628abs.html`. The one- to thirty-year yields are from the GSW 2007 dataset. The three- and six-month yields are from the Federal Reserve Economic Data.

Panel D of Table 1 reports the summary statistics of the yields. On average, the yield curve is upward-sloping, and the volatility of yields is relatively lower for longer maturities. The yields for all maturities are highly persistent, especially for the shorter maturities. Most yields except for 30 years exhibit positive skewness, and yields at shorter (longer) maturities demonstrate positive (negative) excess kurtosis. There is a decrease in both skewness and kurtosis with an increase in yield maturity.

3.2 Estimation Method

The model can be expressed using a state-space representation. The observed futures prices are based on the Treasury notes and bond with 6% coupon rate. The prices of futures contracts on coupon bond are the sum of the prices of futures contracts on a sequence of zero coupon bonds that are specified in equation (10). We assume the measurement errors e_t to be *i.i.d.* normal and the error variance σ_e^2 is the same across contract maturities to ensure that all maturities receive similar weight in the estimation. The state equation is given by equation (1). We apply the Kalman filter to the state-space representation of the model. We estimate the parameters $\Theta = \{K_0^P, K_1^P, K_0^Q, K_1^Q, \rho_0, \rho_1, \omega, \beta, \alpha, \sigma_2^2, \sigma_3^2\}$ and filter the state variables X_t using maximum likelihood. The log-likelihood of the tth observation is

$$\begin{aligned}\log f_t(\Theta) &= const - \frac{N_t}{2}\log(\sigma_e^2) - \frac{1}{2}\frac{\|e_t\|^2}{\sigma_e^2} - \frac{1}{2}\log(\det(\Sigma_t)) \\ &\quad -\frac{1}{2}(X_t - K_0^P - K_1^P X_{t-1})'\Sigma_t^{-1}(X_t - K_0^P - K_1^P X_{t-1}).\end{aligned} \tag{14}$$

N_t denotes the number of available futures contracts at t. $\|e_t\|$ denotes the Euclidean norm of the vector of measurement errors. Appendix B provides more details on the estimation with Kalman filter.[17]

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[17] See Duffee and Stanton (2012) and Christoffersen et al. (2014) for the estimation methods using the Kalman filter.

4 Futures Risk Premium and the Yield Curve

In this section, we first present the estimated parameters of the model along with the model fit. Subsequently, we discuss the model-implied futures risk premium and its connection with the yield curve and the monetary policy.

4.1 Estimation Results of the Model

Table 2 presents the estimated parameters of the model specified in Section 2. The characteristics of the state variables crucially depend on the mean reversion speed in the feedback matrix K_1^P. The first state variable with a time-varying volatility process exhibits strong persistence. Likewise, the second state variable also displays a high level of persistence. However, the third state variable shows less persistence compared to the other two variables. The first state variable demonstrates greater persistence under the Q-measure than under the P-measure, with the estimate under the Q-measure being equal to one. While the other two variables are much less persistent under the Q-measure. The estimated volatility dynamic also shows strong persistence, as indicated by $\beta = 0.9461$. Further, our model with GARCH volatility prices Treasury futures well. The root mean squared error based on the model-implied and observed futures prices is about 0.008 on average across all contracts in our sample. Figure 2 illustrates the model's ability to replicate the time series patterns of futures prices across different Treasury underlyings and maturities.

4.2 Model-Implied Futures Risk Premium

Following Hamilton and Wu (2014), we define the risk premium of a futures contract on a coupon bond, where the coupon bond matures at T_2 and the futures contract expires at T_1 as

$$rp_t^{T_1,T_2} = \log\left(\widetilde{F}_{cpn}(t,T_1,T_2)\right) - \log\left(\widehat{F}_{cpn}(t,T_1,T_2)\right), \tag{15}$$

where $\widehat{F}_{cpn}(t,T_1,T_2)$ is the model-implied prices of futures contracts on coupon bond, which are the sum of the prices of futures contracts on a sequence of zero coupon bonds given by equation (10). $\widetilde{F}_{cpn}(t, T_1, T_2)$ is the model-implied prices of futures contracts on coupon bond when there is no compensation for risk, which can be computed using equation (10), where A_f, B_f, and C_f are obtained from the recursions in equations (11)-(13) with $K_0^Q = K_0^P$ and $K_1^Q = K_1^P$. $rp_t^{T_1,T_2}$ measures the risk premium associated with a futures contract whose underlying is a coupon bond. The premium accounts for compensation for assuming interest rate risk throughout the life of the underlying bond until T_2. Thus, we should anticipate observing a higher implied risk premium on average for longer-maturity bonds and longer-maturity futures.

Figure 3 plots the model-implied risk premiums for the 5- and 10-year Treasury notes futures, and the 30-year Treasury bond futures with different maturities. We observe that futures risk premiums display pronounced counter-cyclical swings throughout our sample. The risk premiums are high during the dot-com recession: March 2001-November 2001, the financial crisis: December 2007-June 2009, and the COVID-19 recession: February 2020-April 2020. After the dot-com recession, the Fed cut its policy rate by 50 basis points in November 2002 and by a modest 25 basis points in Mid-2003 to stimulate the U.S. economy. We observe that futures risk premiums are high during this monetary policy easing cycle. Besides, risk premiums are high during the zero lower bound episodes 2009-2014. In late 2008, the Federal Reserve took an unprecedented step by lowering the policy rate to zero, aiming to mitigate the impact of the 2008 global financial crisis on the U.S. economy. As the economy recovered gradually in the years after, the Fed lifted its policy rate off the zero lower bound in December 2015. Following the onset of the COVID-19 pandemic, the Fed was holding the policy rate at around zero in the first quarter of 2022. But to rein in inflation, it raised the rate by 1.5 percentage points by the end of our sample, June 2022. The futures risk premiums tend to fall at the end of our sample, during this tightening monetary policy cycle. The above conclusions are consistent for futures contracts on 5-, 10-, and 30-year Treasuries with different maturities.

The variation of futures risk premium is very persistent: the first-order autocorrelation of monthly 5-, 10-, and 30-year futures risk premiums is on average 0.9511, 0.9633, and 0.9657, respectively, across maturities. The risk premiums of futures on longer-maturity bonds are on average higher than those on shorter-maturity bonds. Because the model-implied measure of risk premium captures the interest rate risk compensation over the life of the underlying bond.[18] A long-term bond is generally subject to more interest rate risk. The risk premiums of Treasury futures with longer maturities are on average slightly larger than those with shorter maturities for all underlying Treasury maturities since longer-maturity contracts are more sensitive to the change in interest rates and are also subject to more liquidity risk. Figure 3 also plots the slope of the yield curve, which is calculated as the second principal component of Treasury yields with 3- and 6-month, 1-5, 10, and 30-year maturities. We find that futures risk premiums tend to increase when the yield curve is steepening, and vice versa. In other words, the slope of the yield curve is positively related to Treasury futures risk premiums. This finding is in line with the literature documenting that yield curve slope affects term premiums in the underlying bond market (Fama and Bliss, 1987; Campbell and Shiller, 1991).

We articulate the findings regarding the correlation between futures risk premiums and macroeconomic conditions through a set of regressions outlined in Table 3. In all specifications, the dependent variable is the futures risk premiums with the nearest maturities: 1-3 months. Panels A-C are for the underlying Treasuries with 5-, 10-, and 30-year maturities, respectively. Our results are robust for the other two maturity groups: 4-6 months and 7-9 months, which are reported in Tables IA1-IA2 in the Appendix. The sample frequency is monthly in these regressions, and Newey and West (1987) standard errors are reported in parentheses. The first column is for a regression on the yield curve factors: level, slope, and curvature which are the first three principal components of Treasury yields with 3- and 6-month, 1- to 5-, 10-, and 30-year maturities, summarizing more

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[18] This also explains why the magnitude of the y-axis in the plot appears to be large, as these values correspond to the overall risk premium throughout the life of the underlying bond. To provide more context, when we calculate the model-implied logarithmic return of a futures contract over just one month, the average return is around 20 basis points for 5-year note, 25 basis points for 10-year note, and 30 basis points for 30-year bond.

than 99% of the variation in the yield curve. All yield curve factors are important for the risk premiums of futures on all underlying Treasury maturities. An upward-sloping yield curve or a positive curvature of the yield curve is associated with high futures risk premiums. While, when the level of yields is high, the futures risk premiums tend to be low. This specification explains as much as 89% of the variation in risk premiums of 5-year Treasury futures.

Monetary policy shifts drive the dynamic of the yield curve (Piazzesi, 2005; Rudebusch and Wu, 2008). We perform regressions incorporating indicator variables for monetary easing and tightening cycles. In column 2, easing and tightening are binary variables denoting whether the Federal Reserve was implementing monetary easing or tightening one year prior, considering observed changes in the policy rate (Bauer and Chernov, 2023). In easing cycles, as the Fed cuts the policy rate, the yield curve typically steepens, resulting in higher futures risk premiums. Intuitively, investors are becoming more concerned about the escalating interest rate risk given the Federal Reserve's rate cuts and the impending initiation of the next monetary tightening cycle. As an example mentioned above, during the monetary easing episode following the dot-com recession, futures risk premiums steadily increased as futures prices reflected a growing risk of an imminent shift in monetary policy. In contrast, in periods of monetary tightening, the fed funds rate increases, accompanied by a decrease in both the slope of the yield curve and futures risk premiums. This is attributed to investors redirecting their attention to the potential downside risks in the interest rate outlook. As an example, in the period since 2015 when the Fed lifted its policy rate off the zero lower bound, futures risk premiums had a tendency to decrease. The regression with monetary policy indicators only, shown in column 2 confirms these intuitions, especially for the risk premiums of 5-year and 10-year Treasury futures. These results that monetary policy influences the risk premiums of Treasury futures align with the study conducted by Hess and Kamara (2005), suggesting notable returns on Treasury bill futures during the monetary policy regime spanning from 1979 to 1982. However, when considering a regression that includes both monetary policy indicators and yield curve factors, the coefficients of the indicators show no statistical significance as reported in column 3. The yield curve effectively conveys information about the monetary policy cycle, displacing the correlation between futures risk premiums and the indicators in the regression.

The course of monetary policy is ultimately influenced by the prevailing macroeconomic conditions. Notably, cyclical indicators such as the unemployment rate often display a significant correlation with the structure of the yield curve (Rudebusch and Wu, 2008). In line with this evidence, Treasury futures risk premiums are also strongly associated with such cyclical indicators. Column 4 of Table 3 shows that the unemployment rate explains more than 50% of the variation in the risk premiums of futures with all underlying maturities. The coefficient on the unemployment rate retains statistical significance for all Treasury futures even after controlling for the yield curve variables, as shown in column 5.

Overall, we find strong contemporaneous correlations with the term structure of the yield curve, the monetary policy stance, and the economic cycle. Specifically, when the yield curve slopes upward due to monetary easing amid economic downturns, futures risk premiums across all underlying maturities generally exhibit high values, and vice versa. The fluctuations in Treasury futures risk premiums seem to reflect investors' views on interest rate risk stemming from changes in monetary policy across the business cycle.

5 Futures Risk Premium and Trader's Position

This section commences with the presentation of the trader's position data in Treasury futures. Following that, we explore the model-implied futures risk premium using the trader's position. Lastly, we explain the trader's position with the yield curve.

5.1 Position Data

To examine the relationship between the model-implied risk premium and trading activities in the Treasury futures market, we sourced trader position data from the Commodity Futures Trading Commission (CFTC) Commitment of Traders (COT) report. The legacy COT report categorizes reportable traders' positions into two main groups: commercial and non-commercial. The commercial category includes traders engaged in managing business risks through futures hedging, often referred to as "hedgers". All other reportable positions fall under the non-commercial category, and the traders are commonly known as "financial traders" or "speculators".[19]

Additionally, the CFTC publishes the Traders in Financial Futures (TFF) reports, which further distinguish participants in financial futures markets into four distinct groups: dealer/intermediary, asset manager/institutional, leveraged funds, and other reportables. Dealers/intermediaries are typically viewed as the "sell side" market participants.

It is important to note that the categories in the TFF report represent distinct segments and do not overlap with the categories in the legacy COT report. The traders classified within the TFF report's four groups can be from either the commercial or non-commercial categories of the legacy COT report.[20]

Figure 4 plots the net positions (the number of contracts in long position minus that in short position) of the commercial traders in the legacy COT report and the net positions of dealer/intermediary, asset manager/institutional, and leveraged fund in the TFF COT report, respectively, for 5-year and 10-year Treasury futures.[21] Commercial traders' net positions are mostly positive, especially after 2015. Table 4 presents that commercial traders on average hold net long positions of 0.0884 million contracts for 5-year Treasury futures and net long positions of 0.1041 million contracts for 10-year

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[19] Note that the distinction between "hedgers" and "speculators", as categorized based on commercial and noncommercial data in the CFTC legacy COT report, is not entirely accurate. This imprecision largely stems from the broad definition of "commercial" and the inclusion of swap dealers in this category. Consequently, it is not always possible to precisely identify all commercial traders as "hedgers". This limitation is an inherent constraint of the publicly available CFTC data

[20] CFTC COT reports lack position data for 30-year futures, and the position data for 5-year and 10-year Treasury futures is aggregated for all maturities. We use the last available weekly position data of each month. The position data in the TFF reports began on June 13, 2006, whereas in the legacy reports, it started on January 26, 1993.

[21] We didn't report positions for noncommercial traders, as they are almost perfectly negatively correlated with those of commercial traders, particularly when unreportable positions are negligible.

Treasury futures. Wang (2003) show that in contrast to the conventional assumption in the commodity (i.e., agricultural, energy) futures markets that hedgers are net short (having more short positions than long positions), in the financial and currency futures markets, hedgers are net long and speculators are net short.[22]

Asset managers' net positions exhibit similar trends to those of commercial traders. Table 5 presents the unconditional correlations of the net positions between commercial traders and the other three trading groups. For asset managers, the correlations are 0.7092 and 0.5830 for 5- and 10-year Treasury futures, respectively. On average, asset managers maintain larger net long positions than commercial traders in both futures contracts. Additionally, 5-year net positions of asset managers fluctuate more than 10-year position levels, with a standard deviation of 0.6414 for 5-year versus 0.4252 for 10-year. Furthermore, Barth and Kahn (2021) note that traditional asset managers, like pension and mutual funds, have increasingly sought long positions in Treasury futures from 2016 to 2020, allowing them to gain cost-effective duration exposure without holding Treasuries on their balance sheets. Figure 4 shows the increase in net long futures positions held by traditional asset managers in 5- and 10-year contracts. From September 23, 2014 to March 3, 2020, long Treasury futures positions held by asset managers grew from 0.32 million contracts to 2.24 million contracts.

On the other hand, the net positions for dealers and leveraged funds are on average negative. Table 4 shows that dealers hold average net short positions of 0.0937 million contracts for 5-year Treasury futures and average net short positions of 0.0187 million contracts for 10-year Treasury futures. Leveraged funds (typically hedge funds and various types of money managers) seem to also have assumed the corresponding short positions. Over the same period, leveraged funds short futures positions grew from 0.29 million contracts to 1.98 million contracts. Dealers' net positions closely resemble those of leveraged funds, especially in the case of 5-year futures. Furthermore, both dealers' and leveraged funds' net positions are negatively correlated with those of commercial

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[22] Wang (2003) show an exception for the T-bill and T-bond futures based on monthly data on futures trader positions from October 1992 to March 2000.

traders as indicated in Table 5. Leveraged funds' net positions are more negative since 2015 for both 5- and 10-year Treasury. Similarly, dealers' net positions in 5-year futures are also more negative since 2015. Nevertheless, in the case of 10-year Treasury futures, dealers initially held significantly more long than short positions, particularly before 2009, the Global Financial Crisis. In the more recent sample period, dealers have maintained relatively balanced long and short positions.

Moreover, we observe a notable degree of persistence in the net positions of all trading groups. According to Naik and Yadav (2003), a mean reversion coefficient below one is seen as evidence that dealers adhere to a fixed inventory target. Fleming et al. (2008) find that Treasury bill spot positions are more strongly mean-reverting than coupon bond spot positions. We show that 5-year Treasury futures positions are more strongly mean-reverting than 10-year Treasury futures positions for all trading groups. Additionally, there is a higher degree of mean reversion in the positions of asset managers and leveraged funds compared to those of commercial traders and dealers.

5.2 Explaining Futures Risk Premium Using Futures Position

Chichernea et al. (2019) discover that the volume of Treasury futures provides insights into future economic and financial market conditions. Our research further shows that Treasury futures net positions are indicative of the expected risk premium in Treasury futures. Table 6 presents the results of univariate regression analyses examining the relationship between futures risk premiums and the net positions of different traders. We perform these regressions using a monthly sample, and present the standard errors in parentheses using the Newey and West (1987) approach. The results are based on the futures with 1-3 months maturities. We find quantitatively and qualitatively similar conclusions when using futures with longer maturities, which are reported in Table IA3 in the Appendix.

In the commodity markets, the relationship between traders' positions and risk premiums varies depending on the conditions of the futures market—specifically, whether the market is in a state of normal backwardation or contango. In a normal backwardation market, where the long-term futures price is lower than the spot price (or short-term futures price), there tends to be a positive risk premium on average. In such a market, a greater number of short positions held by commercial traders (hedgers) correlates with a higher premium. Conversely, in a contango market—where the long-term futures price exceeds the spot price (or short-term futures price), a scenario often observed during periods of financialization—the dynamics differ. Here, an increase in long positions held by noncommercial traders (speculators) corresponds with more short positions by commercial traders (hedgers), leading to a reduction in the risk premium (Hamilton and Wu, 2014).

In the Treasury futures markets, as illustrated in Panel A of Table 6, an increase in net long positions held by commercial traders correlates with a decrease in the premium, which is in line with the theory of normal backwardation in the commodity markets that excessive short commercial positions are associated with higher risk premiums (e.g., Gorton and Rouwenhorst, 2006; Hamilton and Wu, 2014). deRoon et al. (2000) demonstrate a positive relationship between Treasury bond futures returns and their hedging pressure, based on semimonthly data from January 1986 to December 1994. Hedging pressure is defined as the difference between short and long positions, scaled by the total position. Consequently, it is inversely correlated with the net position metric we employed. This finding therefore corroborates the hedging pressure hypothesis that the commercial traders (hedgers) pay a risk premium to noncommercial traders (speculators) for absorbing the net long hedging demand (Cootner, 1960; Hirshleifer, 1988; deRoon et al., 2000).

Asset managers, as institutional investors, encompass a diverse group. This group includes pension funds, endowments, insurance companies, mutual funds, and portfolio or investment managers who primarily serve institutional clients.[23] Their positions represent the predominant net public demand among all trader types in the TFF report,

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[23] https://www.cftc.gov/MarketReports/CommitmentsofTraders/index.htm. CFTC Traders in Financial Futures Explanatory Notes.

as illustrated in Figure 4. Barth and Kahn (2021) illustrate that the demand for off-balance-sheet duration exposure by traditional asset managers leads to futures prices exceeding their no-arbitrage levels. A negative coefficient of futures risk premium on asset managers' net position implies a price reversal effect following increased buying pressure. Under the conventional price pressure hypothesis, an increase in demand (or supply) for futures contracts is posited to impart a transient upward (or downward) bias to the futures price, subsequently leading to a reversal. As depicted in Figure 4 and Table 5, we document a highly positive correlation of net positions between commercial traders and asset managers, suggesting the asset managers or institutional investors may use Treasury futures to hedge their portfolios and are willing to accept a lower premium.

Leveraged funds, which predominantly consist of hedge funds and various money managers, employ strategies that often include taking outright positions or engaging in arbitrage. These activities span both within and across markets, primarily serving the interests of speculative clients. Barth and Kahn (2021) show that hedge funds met asset managers' demand by going short on Treasury futures and purchasing the cash notes from 2017 to 2019.[24] Consequently, a surge in the demand for futures contracts tends to correlate with decreased premiums, due to the eventual price reversal. The greater the short position of leveraged funds (and the larger the long position of asset managers), the lower the Treasury futures risk premium, as the overpricing driven by asset managers reverses. From the perspective of hedging and speculation, leveraged funds absorb the hedging demand from asset managers or commercial traders, thereby getting compensated for their positions.

Dealers, acting as intermediaries or market-makers, provide liquidity to end-users by taking the opposite side of the net demand from other traders (Garleanu et al., 2009). Fleming et al. (2008) show that while dealers use futures to hedge their Treasury spot position, they only hedge to a limited extent and the shares are much smaller than they

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[24] Barth and Kahn (2020) document the size and extent of Treasury futures basis trading by the hedge funds and evaluate the possibility that the trade's vulnerability to financing and liquidity risks played a role in the illiquidity observed in the Treasury market in March 2020.

do of other position changes due to Treasury issuance. Naik and Yadav (2003) find that U.K. government bond dealers utilize futures for directional speculation and selectively hedge changes in spot positions. Therefore, dealers and leveraged funds share certain speculative properties to an extent. Dealers, by taking net short positions that exceed what leveraged funds can absorb from net long asset managers, get compensated through risk premiums, particularly in the sample period after 2015.

We also report the results of a multivariate regression analysis, which examines the Treasury futures risk premium in relation to the yield curve dynamics (level, slope, and curvature), along with the net positions of different traders, as shown in Table 7. Recall that we use the first three principal components of Treasury yields with 3- and 6-month, 1-5, 10, and 30-year maturities as proxies for the level, slope, and curvature of the yield curve respectively. The signs of the multivariate regression coefficients, corresponding to the net positions of various traders, align with those observed in the univariate regression in Table 6. It is important to note that the significance of some coefficients has changed after accounting for yield curve factors. The position data is aggregated for all futures maturities, which could account for occasional instances where the results are not statistically significant. Nevertheless, the majority of the regression outcomes remain both statistically significant and robust across various combinations of futures contracts and trader's groups. The results based on longer maturities are available in Tables IA4 and IA5 in the Appendix.

In sum, the positions of asset managers are highly correlated with those of commercials, and the positions of leveraged funds are highly correlated with those of dealers. The regression results in Table 6 reflect this relationship. Asset managers, as the dominating traders in the Treasury futures market, have shifted towards increasing long positions since 2015. This shift has introduced buying pressure, leading to a price reversal. Consequently, there is a negative coefficient between the net position of asset managers and the Treasury futures risk premium. Leveraged funds and dealers, by taking net short positions to meet the long position demands of asset managers, exhibit a positive relationship between their net positions and the Treasury futures risk premium—the more they take short positions, the lower the premium. Additionally, commercial traders in the COT legacy report, overlapping with asset managers, predominantly take more long positions than short ones to hedge their portfolio's risk exposure in the underlying market, necessitating lower compensation.

5.3 Futures Position and the Yield Curve

We have investigated how the yield curve and the trader's position help to explain the risk premium in the Treasury futures markets. Additionally, it's worth noting that there may be a potential link between the yield curve information and the trader's futures positions. In this section, we explore the relationship between Treasury futures trading position and the shape of the yield curve. Figures 5a-5c summarize the relationship between the 5-year Treasury futures net position and the three yield curve factors: level, slope, and curvature, which are the first three principal components of Treasury yields with 3- and 6-month, 1- to 5-, 10-, and 30-year maturities. The results for the 10-year Treasury futures are qualitatively similar and are reported in Figures IA1a-IA1c in the Appendix.

In the first column of each figure, the four panels display the net position of 5-year futures (solid line in blue, left y-axis, in millions) held by different market participants: commercial traders, dealers, asset managers, and leveraged funds in our full sample: March 2000 to January 2022 for the commercial traders and June 2006 to January 2022 for the other three groups of participants. The yield curve factors (dashed line in red, right y-axis) are the same in the left four panels in each figure, although they pertain to different sample periods. We observe that the two time series in these four panels of each figure appear to exhibit a stronger correlation with each other after the Global Financial Crisis (GFC), especially for Figure 5a: level of the yield curve. This finding is consistent with the literature documenting the regime change in the U.S. Treasury market post-GFC given the unconventional policy and regulatory policy interventions (Du et al., 2023).

The four panels in the second column of each figure present the scatter plots that illustrate the relationship between the trader's net position in millions (on the y-axis) and the yield curve factor (on the x-axis) for the post-2009 period. We find that the shape of the yield curve is highly correlated with the net position of all four groups of market participants. Figure 5a shows that on average, a high interest rate level corresponds to a net long position for commercial traders and asset managers and a net short position for dealers and leveraged funds. The unconditional correlations between the interest rate level and the net position of the aforementioned four trader groups are 0.51, 0.52, -0.44, and -0.41, respectively. Traders who prioritize monitoring high-level interest rates tend to favor short positions in the futures market. Conversely, those who anticipate that the Federal Reserve is on the verge of reducing interest rates and initiating a monetary tightening phase are inclined to assume long positions in the futures market.

After 2009, a flat or inverted yield curve (small or negative slope factor) is typically associated with commercial traders and asset managers holding net long positions, while dealers and leveraged funds tend to maintain net short positions as indicated in Figure 5b. The unconditional correlation between the net position of commercial traders (dealers) and the slope factor reaches as high as -0.39 (0.59). When the yield curve flattens, commercial traders tend to long more futures to protect against interest rate risk, driven by the expectation that the Federal Reserve will eventually lower policy rates. On the other hand, dealers tend to reduce (increase) their net holdings in futures when the anticipated excess returns on Treasury bonds are low (high), as proxied by a flat (steep) yield curve.

The results for the curvature of the yield curve indicate that a more convex yield curve (smaller curvature factor) is generally linked with an augment in net holdings by commercial traders and asset managers, while dealers and leveraged funds tend to reduce their net holdings. When the yield curve becomes more convex (concave), long-term interest rates rise less (more) quickly than short-term rates and bond prices are more (less) sensitive to changes in interest rates than indicated by their duration. The correlations displayed in Figures 5c seem to suggest that traders adjust their futures holdings to manage the curvature risk, especially for commercial traders with a correlation of -0.70. In the presence of a more convex yield curve, which heightens the sensitivity of bond prices to interest rate shifts, commercial traders tend to augment their net holdings in futures as a safeguard against interest rate risk.

Furthermore, we formalize the empirical findings regarding the connection between futures positions and the yield curve through regression analyses using post-2009 data, and the results are presented in Table 8. These regressions are conducted at a monthly sample frequency, and we report the Newey and West (1987) standard errors in parentheses. The regression coefficients exhibit signs that align with the unconditional correlation findings mentioned earlier. We find that the level factor is significantly and positively (negatively) related to commercial traders' and asset managers' (dealers and leveraged funds) net positions for both 5- and 10-year Treasury futures. The slope factor significantly accounts for the net positions in 5-year futures across all trader groups. However, its significant explanatory power is limited to asset managers and leveraged funds when it comes to 10-year futures. The curvature factor remains statistically significant even after accounting for the level and slope factors in particular for the commercial traders' net positions in both 5- and 10-year Treasury futures. The adjusted R-squares are relatively higher for the net positions of the asset managers and the leveraged funds than for the other two groups. For example, the yield curve factors explain as much as 79% (53%) of the variation in asset managers' (dealers') net position in 5-year futures. Additionally, the explanatory power of the three yield curve factors is stronger for the net positions in 5-year futures than 10-year futures for all trading groups. To illustrate, the three factors account for up to 53% (12%) of the variation in dealers' net position in 5-year (10-year) Treasury futures.

6 Conclusion

We model the term structure of Treasury futures prices using a no-arbitrage model with three latent factors and one GARCH-type volatility factor. We conduct model estimation utilizing monthly futures prices covering the period from March 2000 to June 2022 for 5- and 10-year Treasury notes futures, along with 30-year Treasury bond futures with maturities ranging from one to nine months. The model adeptly captures the term structure of futures prices across all underlying Treasuries. Our paper is among the few studies focusing on Treasury derivatives. We not only present a model to effectively capture the term structure of futures prices but also explore the explanations for the dynamics of risk premiums in the futures market. The futures risk premiums implied by the model are on average positive across different combinations of underlying Treasuries and futures maturities.

The futures risk premiums closely respond to the term structure of the yield curve, the monetary policy stance, and the economic cycle. During economic downturns accompanied by monetary easing, leading to an upward-sloping yield curve, futures risk premiums for all underlying maturities tend to be high, and the opposite also holds. These findings suggest that the fluctuations in futures risk premiums reflect investors' view of interest rate risk in response to changes in monetary policy throughout the business cycle.

Furthermore, there is a notable correlation between the futures risk premiums and the net positions held by various traders in the futures market. Regression analyses show that the more long positions taken by commercial traders (using data in the CFTC legacy COT report), who are primarily hedgers, result in a reduction in the futures risk premium, in line with the hedging pressure theory and theory of normal backwardation. From the traders categories in the CFTC TFF report, asset managers who are dominating traders in the market have increased long positions substantially around 2015-2016, leading to a price reversal due to heightened buying pressure. As a result, we find a negative relation between the net positions of asset managers and Treasury futures risk premium at all maturities. Leveraged funds and dealers who generally take the opposite position of asset managers demonstrate a positive association with the futures risk premium. These findings remain robust across various bonds and maturities in the Treasury futures market and after accounting for the yield curve factors.

Additionally, traders' positions are significantly related to the yield curve factors, especially after the Global Financial Crisis. We find that commercial traders and asset managers appear to take more long positions when the interest rate level is high, the yield curve is flat or convex, whereas dealers and leveraged funds exhibit the opposite trend. These results indicate that participants in Treasury futures markets adapt their trading positions to mitigate interest rate risk inherent in the yield curve dynamics, which in turn moves the risk premium in the futures market.

Appendix A. Bond and Bond Futures Pricing

This appendix summarizes the calculations of bond and bond futures prices under the model specified in Section 2. To derive the recursions in equations (7), (8) and (9), we first note that the price of a one-period bond, $n = 1$, can be written as

$$\begin{aligned} P(t, t+1) &= E_t^Q \left[\exp(-r_t)\right] \\ &= \exp(-\rho_0 - \rho_1 X_t). \end{aligned} \tag{A.1}$$

Suppose that the price of a n-period bond is given by $P_t^n = \exp\left(A_n + B_n^{'} X_t + C_n \sigma_{1,t+1}^2\right)$. Matching coefficients gives $A_1 = -\rho_0$, $B_1 = -\rho_1^{'}$ and $C_1 = 0$. In order to solve for A_n, B_n and C_n we derive the bond price under the risk-neutral probability measure

$$\begin{aligned} P_t^n &= E_t^Q[\exp(-r_t) P_{t+1}^{n-1}] \\ &= E_t^Q \left[\exp\left(-\rho_0 - \rho_1 X_t\right) \exp\left(A_{n-1} + B_{n-1}^{'} X_{t+1} + C_{n-1}\sigma_{1,t+2}^2\right)\right] \\ &= \exp\left(-\rho_0 - \rho_1 X_t + A_{n-1} + B_{n-1}^{'}(K_0^Q + K_1^Q X_t) + C_{n-1}\omega + C_{n-1}\beta\sigma_{1,t+1}^2\right) \\ &\times E_t^Q \left[\exp\left(B_{2,n-1}\sigma_2\epsilon_{2,t+1} + B_{3,n-1}\sigma_3\epsilon_{3,t+1}\right)\right] \times E_t^Q \left[\exp\left(B_{1,n-1}\sigma_{1,t+1}\epsilon_{1,t+1} + C_{n-1}\alpha\epsilon_{1,t+1}^2\right)\right]. \end{aligned} \tag{A.2}$$

$\epsilon_{2,t}$ and $\epsilon_{3,t}$ are the second and third elements of vector ϵ_t. To Finalize the last square in the portion to which the expectation applies, we employ the property valid for a standard normal distribution z, $E\left(a(z+b)^2\right) = \exp\left(-\frac{1}{2}\log(1-2a) + \frac{ab^2}{1-2a}\right)$, and match the coefficients resulting in the recursive relations in equations (7), (8), and (9).

Futures prices are martingales under the risk-neutral probability measure (Cox et al., 1981). To derive the recursions in equations (11), (12) and (13), we thus express bond futures prices as

$$
\begin{aligned}
F(t,T_1,T_2) &= E_t^Q\left[F(t+1,T_1,T_2)\right] \qquad \text{(A.3)}\\
&= E_t^Q\left[\exp\left(A_f(t+1,T_1,T_2) + B_f^{'}(t+1,T_1,T_2)X_{t+1} + C_f(t+1,T_1,T_2)\sigma_{1,t+2}^2\right)\right]\\
&= \exp\left(A_f(t+1,T_1,T_2) + B_f^{'}(t+1,T_1,T_2)(K_0^Q + K_1^Q X_t) + C_f(t+1,T_1,T_2)(\omega + \beta\sigma_{1,t+1}^2)\right)\\
&\times E_t^Q\left[\exp\left(B_{f,2}(t+1,T_1,T_2)\sigma_2\epsilon_{2,t+1} + B_{f,3}(t+1,T_1,T_2)\sigma_3\epsilon_{3,t+1}\right)\right]\\
&\times E_t^Q\left[\exp\left(B_{f,1}(t+1,T_1,T_2)\sigma_{1,t+1}\epsilon_{1,t+1} + C_f(t+1,T_1,T_2)\alpha\epsilon_{1,t+1}^2\right)\right].
\end{aligned}
$$

We complete the last two squares in the portion to which the expectations apply using the same property and match the coefficients resulting in the recursive relations in equations (11), (12), and (13).

Appendix B. Estimation with the Kalman Filter

This appendix describes the Kalman Filter Algorithm used in the model estimation. The contemporaneous prediction of the state vector and its corresponding covariance matrix are denoted by $X_{t|t}$ and $P_{t|t}$. At any given time t, the algorithm follows these steps:

1. Compute the one-period ahead forecast of the state vector and its corresponding covariance matrix using $X_{t|t}$ and $P_{t|t}$[25]

$$X_{t+1|t} = K_0^P + K_1^P X_{t|t}, \qquad \text{(B.1)}$$

and

$$P_{t+1|t} = K_1^{P'} P_{t|t} K_1^P + \Sigma_{t+1|t}. \qquad \text{(B.2)}$$

---

[25] The first two unconditional moments are used in the first step of the recursion.

The volatility factor can be computed based on equation (5)

$$\begin{aligned}\sigma^2_{1,t+2|t} &= \omega + \beta\sigma^2_{1,t+1|t} + \alpha\frac{E^P_t(X_{1,t+1} - K^P_{0(1)} - K^P_{1(1,1)}X_{1,t})^2}{\sigma^2_{1,t+1|t}} \\ &= \omega + \beta\sigma^2_{1,t+1|t} + \alpha.\end{aligned} \tag{B.3}$$

2. Compute the one-period ahead forecast of prices for futures on zero coupon bond $\widehat{F}(t+1, T_1, T_2)$

$$\widehat{F}(t+1, T_1, T_2) = \exp\Big(A_f(t+1, T_1, T_2) + B^{'}_f(t+1, T_1, T_2)X_{t+1|t} + C_f(t+1, T_1, T_2)\sigma^2_{1,t+2|t}\Big) \tag{B.4}$$

$$\begin{aligned}&= \exp\Big(A_f(t+1, T_1, T_2) + B^{'}_f(t+1, T_1, T_2)X_{t+1|t}\Big) \\ &\times \exp\big(C_f(t+1, T_1, T_2)\left(\omega + \beta\sigma^2_{1,t+1|t} + \alpha\right)\big).\end{aligned}$$

The one-period ahead forecast of prices for futures on coupon bond $\widehat{F}_{cpn}(t+1, T_1, T_2)$ is the sum of the prices for futures on a sequence of zero coupon bonds. We thus write

$$\begin{aligned}\widehat{F}_{cpn}(t+1, T_1, T_2) = \exp&\left(\overbrace{A_f}(t+1, T_1, T_2) + \overbrace{B^{'}_f}(t+1, T_1, T_2)X_{t+1|t}\right) \\ \times \exp&\left(\overbrace{C_f}(t+1, T_1, T_2)\left(\omega + \beta\sigma^2_{1,t+1|t} + \alpha\right)\right),\end{aligned} \tag{B.5}$$

where $\overbrace{A_f}$, $\overbrace{B^{'}_f}$, and $\overbrace{C_f}$ are the sum of A_f, B_f, and C_f for a sequence of zero coupon bonds, as specified in equations (11)-(13), respectively. The corresponding covariance matrix is

$$V_{t+1|t} = \overbrace{B^{'}_f}P_{t+1|t}\overbrace{B_f} + R_t, \tag{B.6}$$

where R_t is an $N_t \times N_t$ diagonal matrix. N_t denotes the number of available futures contracts at t. We assume that the variance of the pricing errors σ^2_e on the diagonal is the same across contracts.

3. Compute the forecast error $e_{t+1|t} = F_{cpn}(t+1, T_1, T_2) - \widehat{F}_{cpn}(t+1, T_1, T_2)$.

4. Update the contemporaneous forecast of the state vector and its corresponding covariance matrix

$$X_{t+1|t+1} = X_{t+1|t} + P_{t+1|t} \overbrace{B_f} V_{t+1|t}^{-1} e_{t+1|t}, \tag{B.7}$$

$$P_{t+1|t+1} = P_{t+1|t} - P_{t+1|t} \overbrace{B_f} V_{t+1|t}^{-1} \overbrace{B_f^{'}} P_{t+1|t}, \tag{B.8}$$

and compute the smoothed volatility factor

$$\sigma^2_{1,t+2|t+1} = \omega + \beta\sigma^2_{1,t+1} + \alpha\frac{(X_{1,t+1} - K^P_{0(1)} - K^P_{1(1,1)}X_{1,t})^2}{\sigma^2_{1,t+1}}. \tag{B.9}$$

5. Return to the first step.

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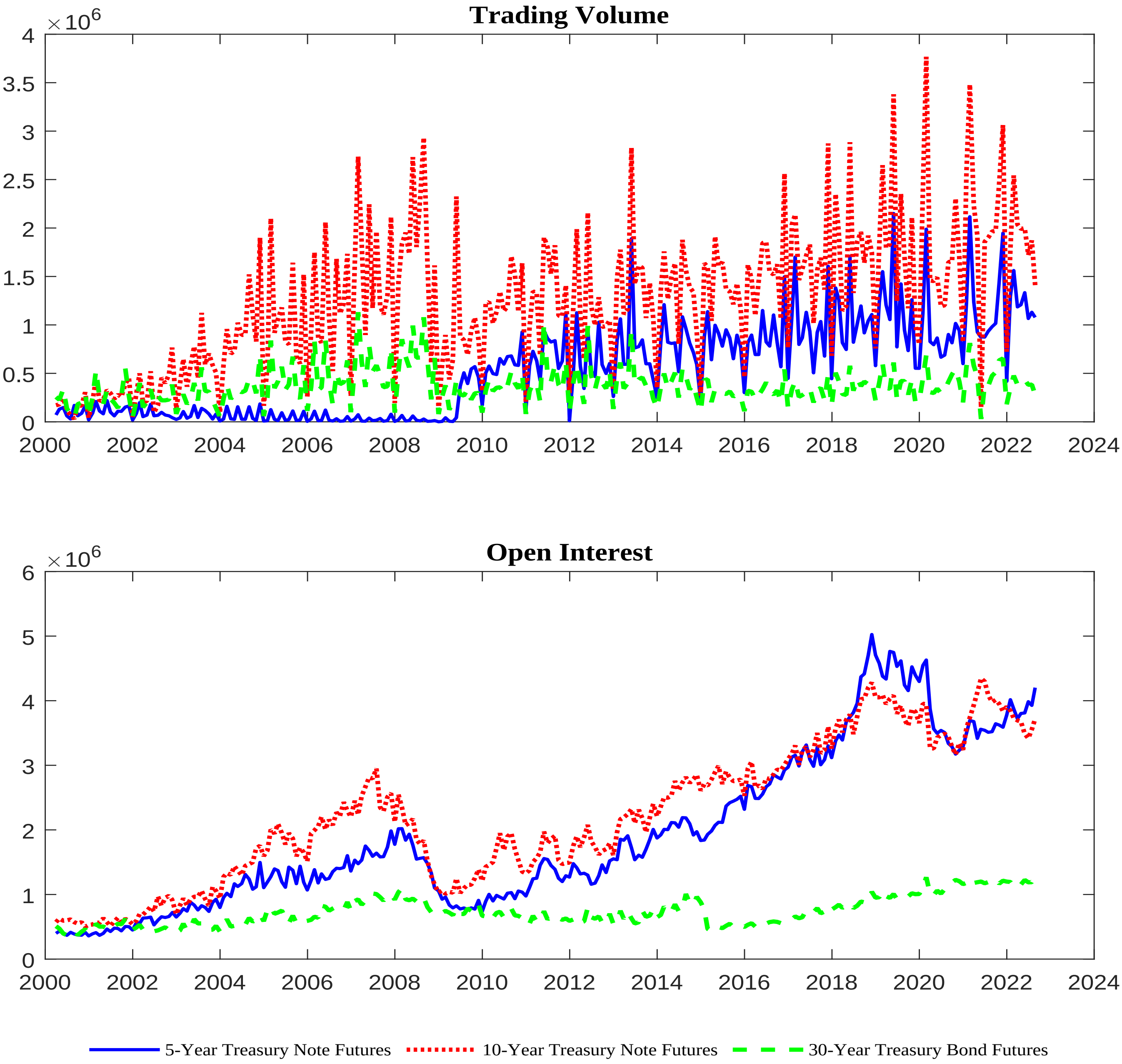
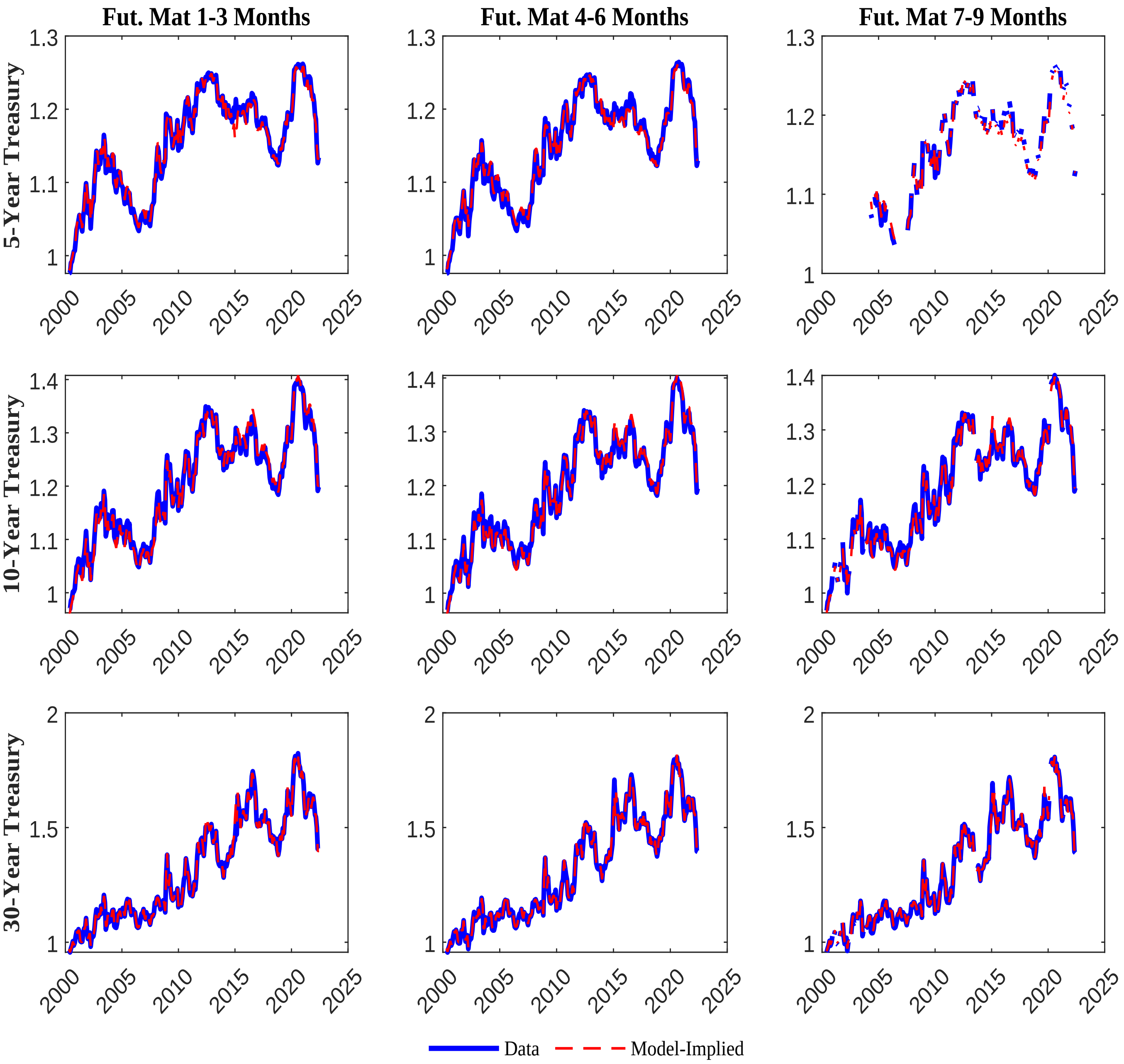
Figure 1: Trading Volume and Open Interest



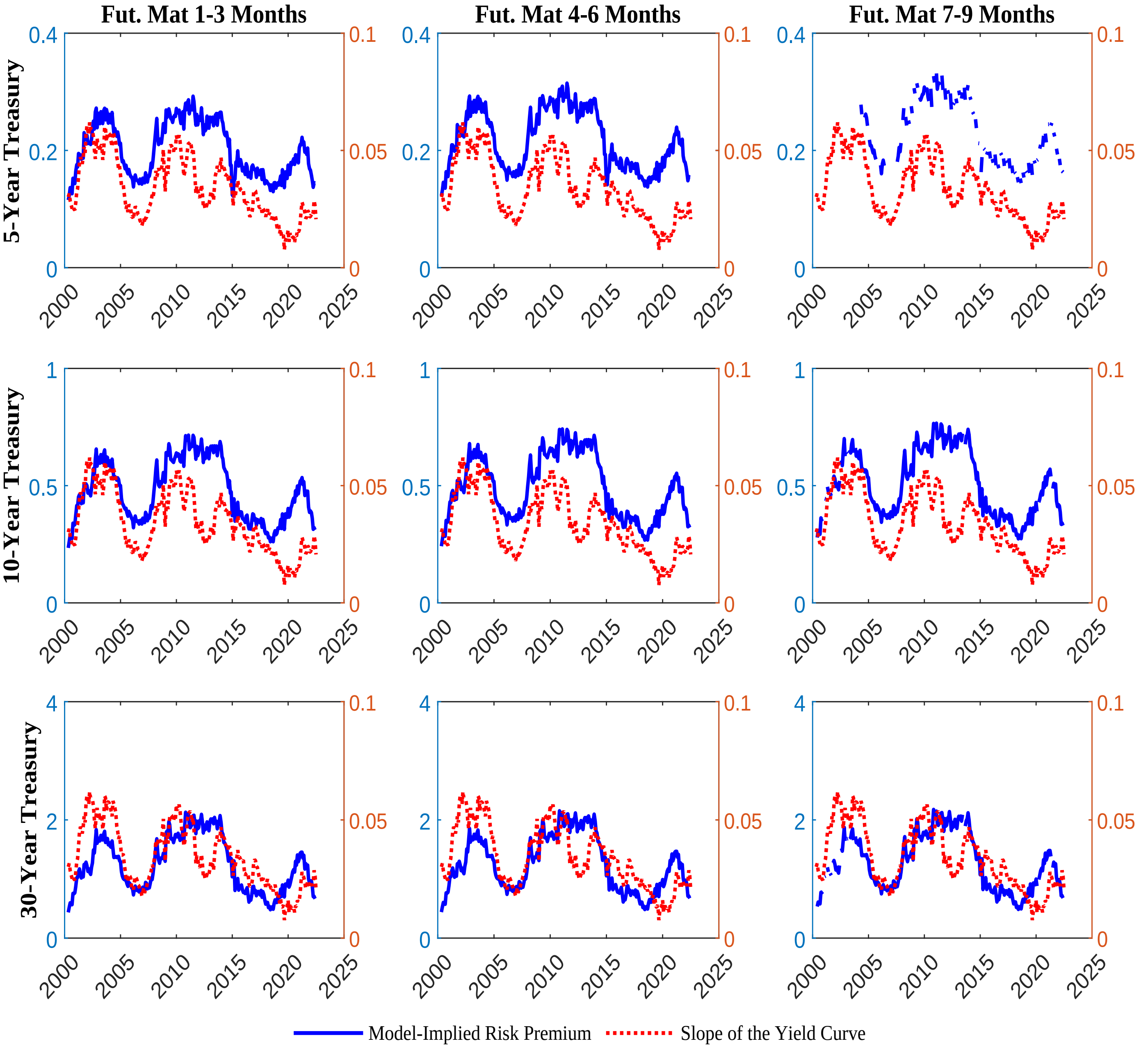
Notes: This figure plots the end-of-month daily trading volume and open interest of 5-year Treasury note futures (solid line in blue), 10-year Treasury note futures (dotted line in red), and 30-year Treasury bond futures (dashed line in green), respectively. The trading volume and open interest are for the contracts with 1-9 months maturities. The sample period is from 2000:03 to 2022:06.

Figure 2: Term Structure of Treasury Futures Prices



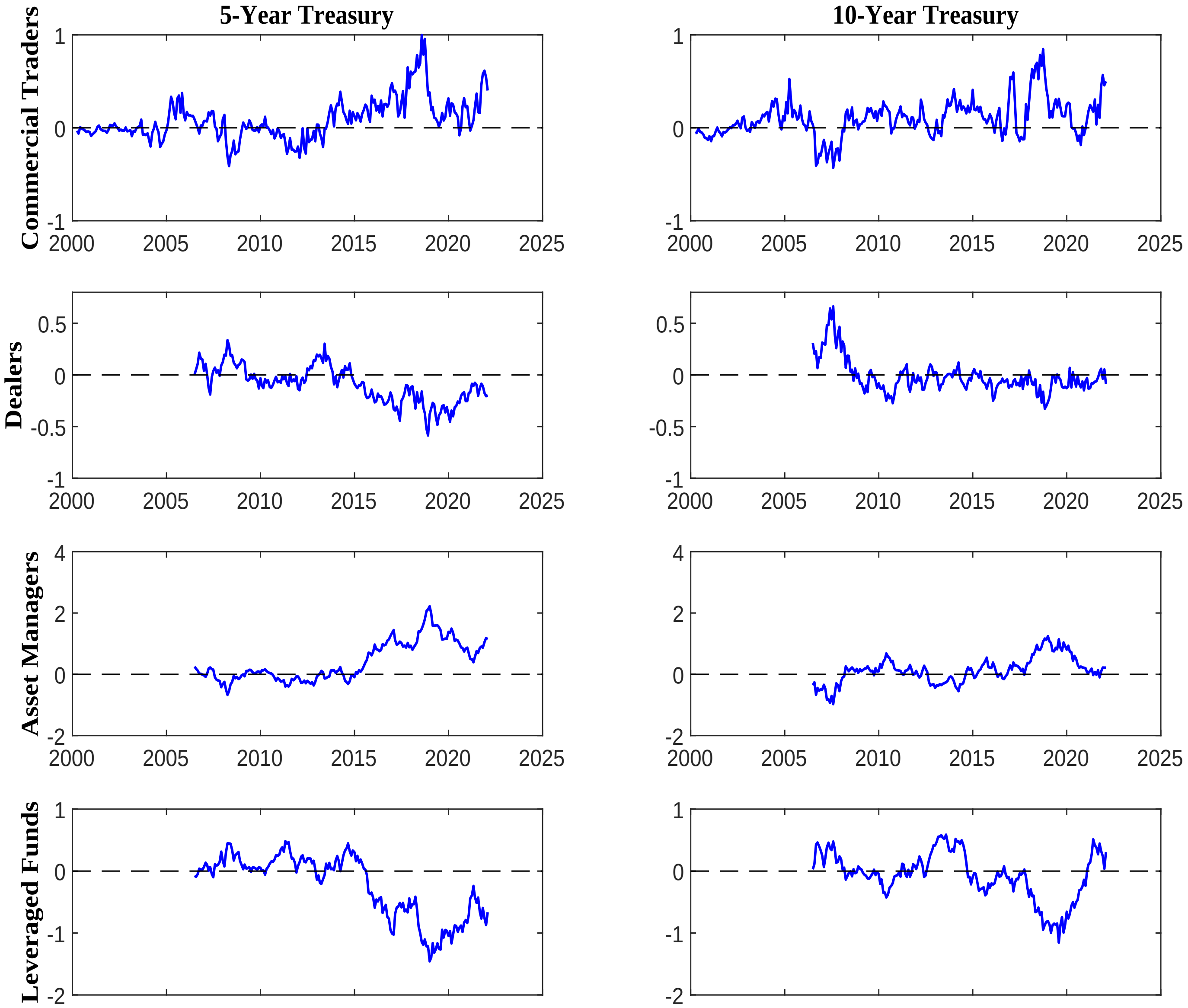
Notes: This figure plots the monthly model-implied Treasury futures prices (dashed line in red) and the data (solid line in blue) from 2000:03 to 2022:06. The panels in the first, second, and third row are for the 5-year Treasury note futures, 10-year Treasury note futures, and 30-year Treasury bond futures, respectively. The panels in the first, second and third column are for the futures with 1-3 months, 4-6 months, 7-9 months maturities, respectively. The futures prices are expressed as percentage of par.

Figure 3: Model-Implied Futures Risk Premiums



Notes: This figure plots the model-implied futures risk premiums (solid line in blue, left y-axis) and the slope of the yield curve (dashed line in red, right y-axis) from 2000:03 to 2022:06. The panels in the first, second, and third row are for the 5-year Treasury note futures, 10-year Treasury note futures, and 30-year Treasury bond futures, respectively. The panels in the first, second and third column are for the futures with 1-3 months, 4-6 months, 7-9 months maturities, respectively. The slope is the second principal component of Treasury yields with 3- and 6-month, 1-5, 10, and 30-year maturities, and are the same across all panels.

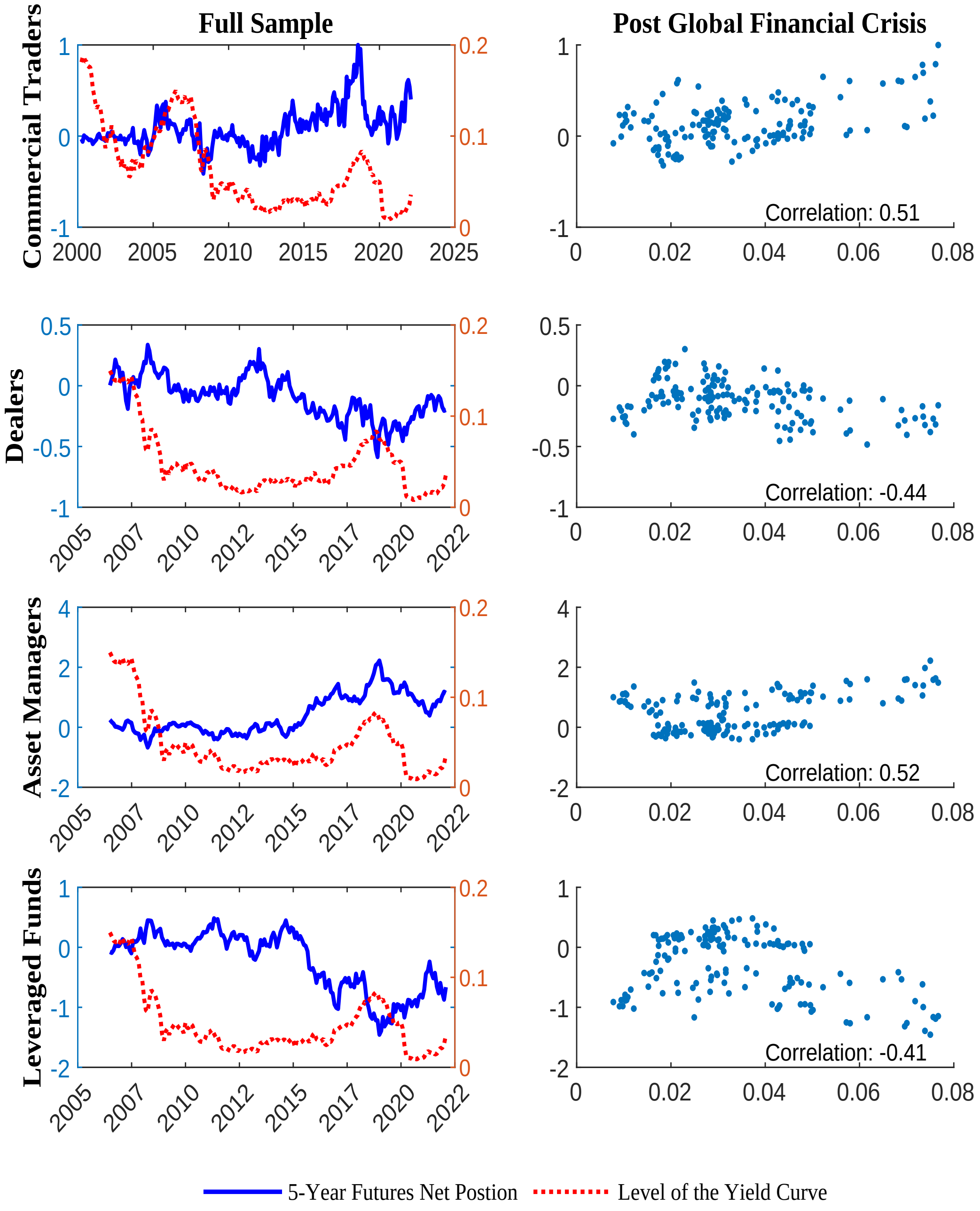
Figure 4: Traders' Net Position in Treasury Futures



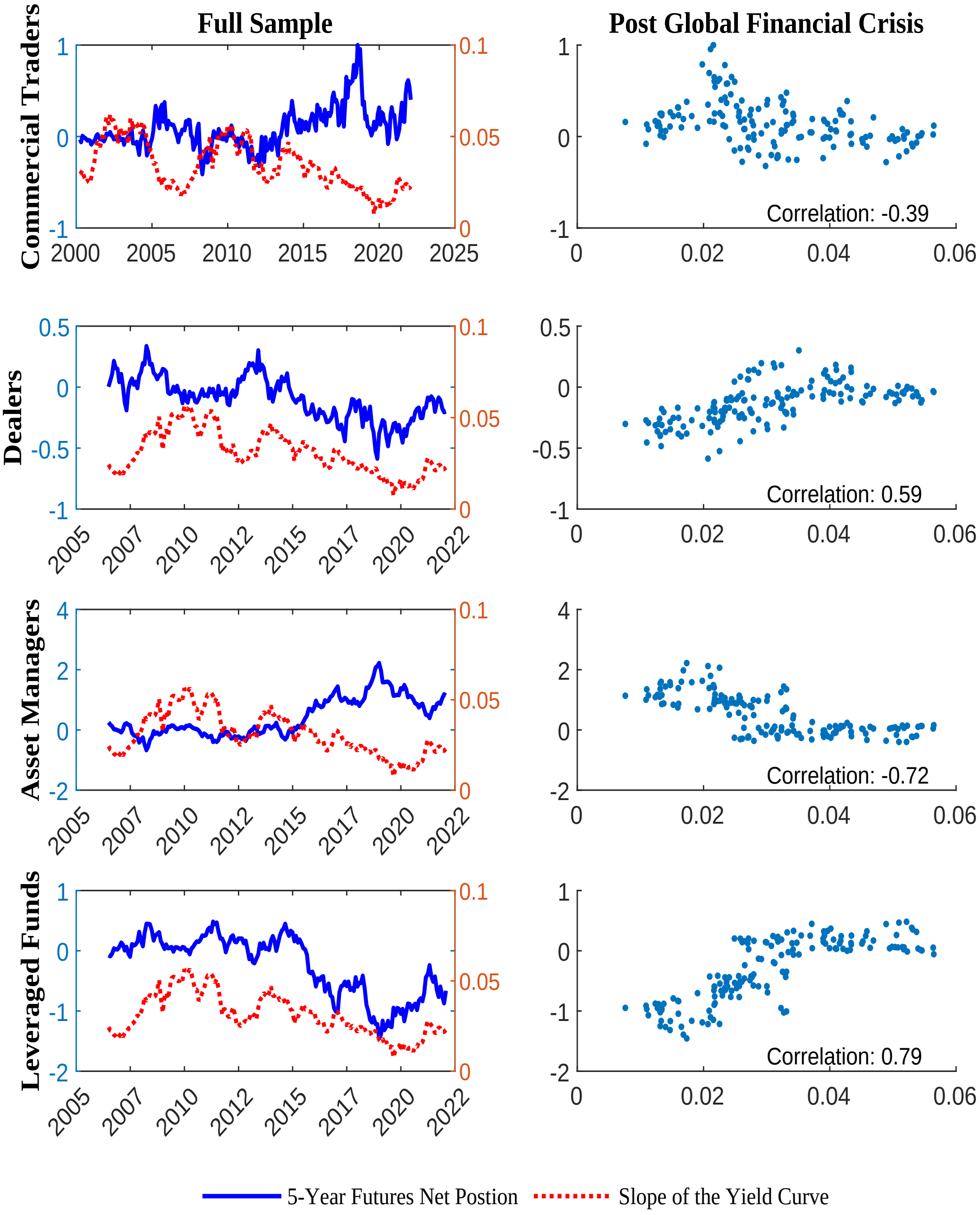
Notes: This figure plots the net position (long minus short, in millions of number of contracts) in 5-year (left panels) and 10-year (right panels) Treasury futures for four trading groups: commercial traders in the CFTC COT legacy report, dealers, asset managers, and leveraged funds in the CFTC COT FTT report. The sample period for commercial traders is 2000:03 to 2022:01. The sample period for the other three groups of traders is 2006:06 to 2022:01.

Figure 5: Five-Year Treasury Futures Net Position and the Yield Curve Factors

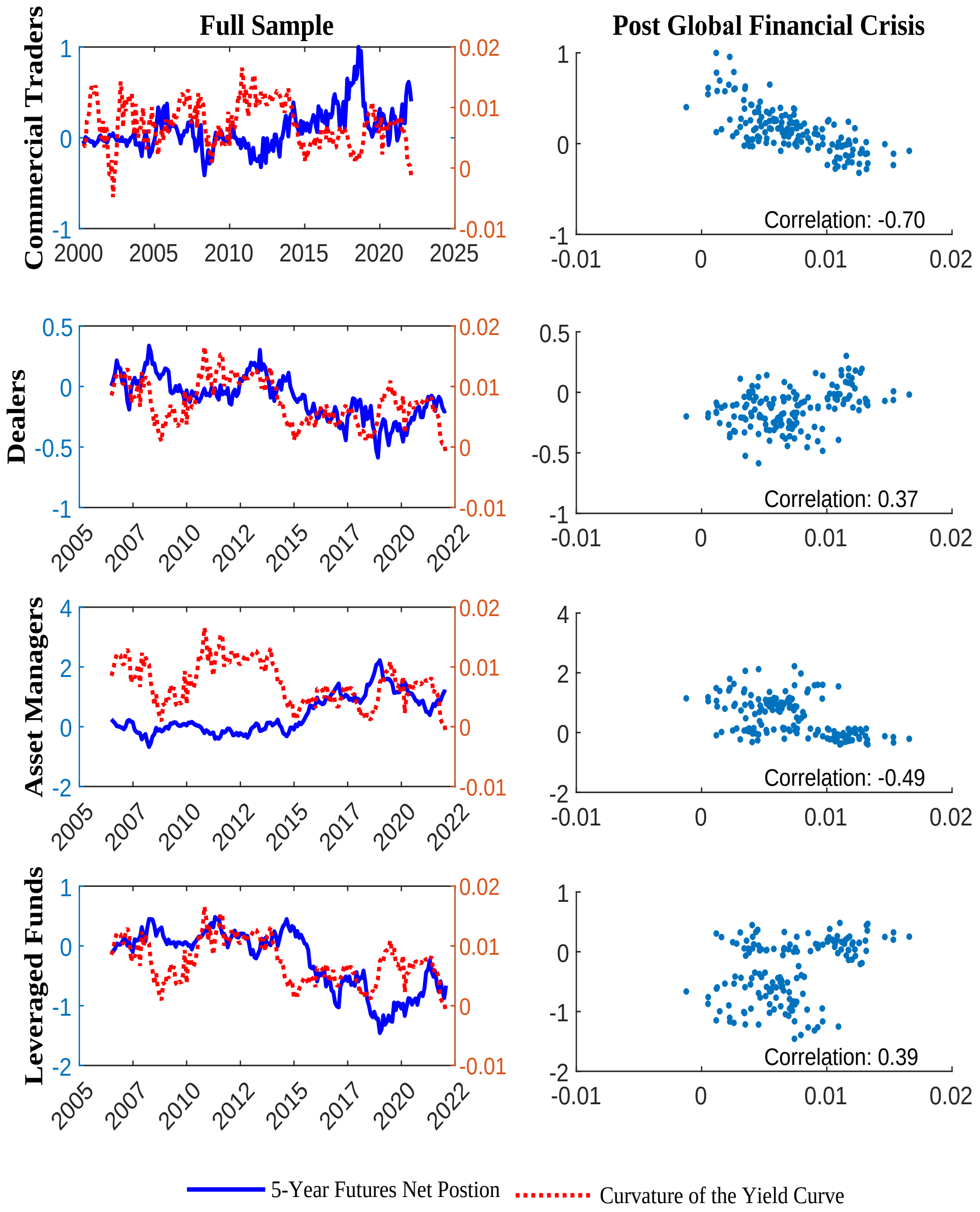
(a) Level of the Yield Curve



(b) Slope of the Yield Curve



(c) Curvature of the Yield Curve



Notes: This figure plots the relationship between the 5-year Treasury futures net position and the level (a), slope (b), and curvature (c) of the yield curve. We use the first three principal components of Treasury yields with 3- and 6-month, 1-5, 10, and 30-year maturities as proxies for the level, slope, and curvature of the yield curve respectively. The four panels in the first column of each figure plot the net position of 5-year futures held by different market participants (solid line in blue, left y-axis, in millions): commercial traders, dealers, asset managers, and leveraged funds in our full sample: 2000:03 to 2022:01 for the commercial traders and 2006:06 to 2022:01 for the other three groups of traders. The yield curve factors are plotted as a dashed line in red, right y-axis in all figures. The four panels in the second column of each figure plot the relationship between the two time series in the corresponding first column panels post-2009 in a scatter plot. The y-axis is the trader's net position in millions. The x-axis is the yield curve factor.

Table 1: Summary Statistics

Panel A: 5-Year Treasury Futures

Maturity	Mean	Median	Min	Max	Volume	Open Interest	Obs.
1-3 months	115%	116%	98%	126%	344413	1338927	268
4-6 months	115%	116%	98%	126%	183185	593169	268
7-9 months	116%	117%	100%	126%	185	110	155

Panel B: 10-Year Treasury Futures

Maturity	Mean	Median	Min	Max	Volume	Open Interest	Obs.
1-3 months	120%	121%	97%	140%	836973	1540524	268
4-6 months	120%	120%	97%	140%	416383	671926	268
7-9 months	119%	120%	97%	140%	1975	1001	254

Panel C: 30-Year Treasury Futures

Maturity	Mean	Median	Min	Max	Volume	Open Interest	Obs.
1-3 months	132%	130%	96%	182%	249268	512967	268
4-6 months	132%	129%	96%	181%	125044	216961	268
7-9 months	131%	127%	96%	181%	906	2347	265

Panel D: Yields

	Central Moments				Autocorrelation		
Maturity	Mean (%)	St. Dev (%)	Skewness	Kurtosis	Lag 1	Lag 12	Lag 30
3 month	1.4400	1.6846	1.2097	3.3968	0.9815	0.5635	-0.0031
6 month	1.5333	1.6840	1.1486	3.2590	0.9810	0.5770	0.0143
1 year	1.7026	1.7156	1.1123	3.2604	0.9779	0.5854	0.0374
2 year	1.8985	1.6417	0.9462	2.9579	0.9748	0.6213	0.1216
3 year	2.1216	1.5618	0.8078	2.7445	0.9730	0.6481	0.1955
4 year	2.3430	1.4952	0.6825	2.5982	0.9720	0.6692	0.2578
5 year	2.5515	1.4467	0.5620	2.4766	0.9717	0.6872	0.3112
10 year	3.3201	1.3857	0.1156	1.9947	0.9744	0.7542	0.4875
30 year	3.9231	1.1874	-0.0195	1.9754	0.9771	0.7482	0.5224

This table presents the summary statistics for the prices of futures contracts on 5-, 10-, and 30-year Treasuries (Panels A-C). We use the end-of-month closing prices of futures with 1- to 9-month maturities. We present the sample mean, median, minimum and maximum prices for three maturity groups: 1-3 months, 4-6 months, and 7-9 months. The futures prices are quoted as percentage of par. We also report the average trading volume, the average open interest, and the number of observations for each maturity group. Panel D reports the sample mean, standard deviation, skewness, kurtosis, and autocorrelations for the continuously compounded zero coupon bond yields with 3-month to 30-year maturities. The sample period is from 2000:03 to 2022:06.

Table 2: Parameter Estimates

K_0^P	K_1^P			K_0^Q	K_1^Q		
0.0021	0.9898			0.0009	1.0000		
-0.0003		0.9999		-0.0050		0.9785	
0.0007			0.9306	0.0116			0.8660

ρ_0	ρ_1		
-0.0020	0.0014	-0.1331	0.4246

$\omega \times 1e2$	α	β	$\sigma_2^2 \times 1e4$	$\sigma_3^2 \times 1e4$
0.0001	0.1105	0.9461	0.0035	0.0278

This table presents the estimated model parameters using the futures prices of 5-, 10-, and 30-year Treasuries with the nearest three maturities on each month from 2000:03 to 2022:06.

Table 3: Explaining Futures Risk Premiums: 1-3 Months Maturity

Panel A: 5-Year Treasury Futures

	(1)	(2)	(3)	(4)	(5)
Level	-0.46***		-0.48***		-0.35***
	(0.04)		(0.04)		(0.05)
Slope	2.63***		2.63***		2.35***
	(0.11)		(0.10)		(0.10)
Curvature	4.65***		4.74***		3.94***
	(0.51)		(0.53)		(0.48)
Easing		0.02**	0.0049		
		(0.01)	(0.0031)		
Tightening		-0.06***	0.01		
		(0.01)	(0.0031)		
Unemployment Rate				0.02***	0.0049***
				(0.0036)	(0.0014)
Constant	0.11***	0.21***	0.11***	0.10***	0.09***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Adj Rsquare	0.89	0.18	0.89	0.52	0.91

Panel B: 10-Year Treasury Futures

	(1)	(2)	(3)	(4)	(5)
Level	-1.36***		-1.38***		-0.98***
	(0.14)		(0.13)		(0.17)
Slope	6.50***		6.51***		5.53***
	(0.38)		(0.37)		(0.43)
Curvature	14.95***		15.09***		12.51***
	(1.69)		(1.71)		(1.62)
Easing		0.05*	0.0077		
		(0.03)	(0.0072)		
Tightening		-0.15***	0.01		
		(0.02)	(0.0113)		
Unemployment Rate				0.05***	0.02***
				(0.01)	(0.01)
Constant	0.24***	0.50***	0.23***	0.18***	0.16***
	(0.03)	(0.02)	(0.03)	(0.06)	(0.04)
Adj Rsquare	0.85	0.15	0.85	0.55	0.88

Panel C: 30-Year Treasury Futures

	(1)	(2)	(3)	(4)	(5)
Level	-5.04***		-5.08***		-3.58***
	(0.54)		(0.52)		(0.69)
Slope	21.02***		21.07***		17.27***
	(1.49)		(1.45)		(1.87)
Curvature	56.80***		57.13***		47.36***
	(6.87)		(6.89)		(6.71)
Easing		0.12	0.0056		
		(0.10)	(0.0256)		
Tightening		-0.50***	0.0204		
		(0.08)	(0.0438)		
Unemployment Rate				0.18***	0.07***
				(0.04)	(0.02)
Constant	0.45***	1.31***	0.44***	0.20	0.16
	(0.11)	(0.08)	(0.11)	(0.21)	(0.15)
Adj Rsquare	0.81	0.13	0.81	0.56	0.85

This table presents the regressions for the risk premiums of futures with 1-3 month maturity using monthly data from 2000:03 to 2022:06. Panels A-C are for the futures contracts on 5-, 10-, and 30-year Treasuries, respectively. Level, slope, and curvature are the first three principal components of Treasury yields with 3- and 6-month, 1- to 5-, 10-, and 30-year maturities. Easing and tightening are dummy variables indicating whether the Federal Reserve was easing or tightening monetary policy one year ago based on observed changes in the target rate, which is obtained from the Federal Reserve Economic Data (FRED). Unemployment rate is also from FRED. The Newey-West standard errors with automatic bandwidth selection are reported in parentheses. $*$, $**$, and $***$ indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table 4: Summary Statistics of Futures Net Positions

Panel A: Commercial Traders			
	Mean	St.Dev	Autocorrelation
5-Year Treasury Futures	0.0884	0.2216	0.8818
10-Year Treasury Futures	0.1041	0.2016	0.8376
Panel B: Dealers			
	Mean	St.Dev	Autocorrelation
5-Year Treasury Futures	-0.0937	0.1741	0.9176
10-Year Treasury Futures	-0.0187	0.1614	0.8574
Panel C: Asset Managers			
	Mean	St.Dev	Autocorrelation
5-Year Treasury Futures	0.4124	0.6414	0.9799
10-Year Treasury Futures	0.1391	0.4252	0.9420
Panel D: Leveraged Funds			
	Mean	St.Dev	Autocorrelation
5-Year Treasury Futures	-0.2400	0.5052	0.9737
10-Year Treasury Futures	-0.0722	0.3822	0.9547

This table presents the summary statistics for the Treasury futures net positions for four trading groups: commercial traders (Panel A), dealers (Panel B), asset managers (Panel C), and leveraged funds (Panel D). We present the sample mean, standard deviation, and first-order autocorrelation for the futures on 5- and 10-year Treasuries. Net position is long position minus short position, expressed in millions of number of contracts. Commercial traders' net positions are from the CFTC COT legacy report. The net positions of the other three trading groups are from the CFTC COT FTT report. The sample period in Panel A is 2000:03 to 2022:01. The sample period in Panels B-D is 2006:06 to 2022:01.

Table 5: Futures Net Position Correlations: Commercial Traders vs. Other Traders

	5-Year Treasury Futures	10-Year Treasury Futures
Dealers	-0.5174	-0.4936
Asset Managers	0.7092	0.5830
Leveraged Funds	-0.6325	-0.3950

This table presents the unconditional correlations of futures net positions between different financial traders in the CFTC COT TFF report with commercial traders in the CFTC COT legacy report. Net position is defined as the number of traders' long positions minus that of the short positions. The sample period is 2006:06 to 2022:01.

Table 6: Explaining Futures Risk Premium Using Trader's Position: 1-3 Months Maturity

Panel A: Commercial Traders		
	5-Year Treasury Futures	10-Year Treasury Futures
Commercial Net Position	-0.1141***	-0.0332
	(0.0147)	(0.0968)
Constant	0.2127***	0.4830***
	(0.0063)	(0.0217)
Adj Rsquare	0.30	0.00
Panel B: Dealers		
	5-Year Treasury Futures	10-Year Treasury Futures
Dealer Net Position	0.1435***	-0.0790
	(0.0253)	(0.1035)
Constant	0.2152***	0.4803***
	(0.0082)	(0.0229)
Adj Rsquare	0.28	0.01
Panel C: Asset Managers		
	5-Year Treasury Futures	10-Year Treasury Futures
Asset Manager Net Position	-0.0497***	-0.0963*
	(0.0066)	(0.0528)
Constant	0.2223***	0.4951***
	(0.0080)	(0.0253)
Adj Rsquare	0.46	0.09
Panel D: Leveraged Funds		
	5-Year Treasury Futures	10-Year Treasury Futures
Leveraged Fund Net Position	0.0590***	0.1629***
	(0.0090)	(0.0382)
Constant	0.2159***	0.4935***
	(0.0077)	(0.0217)
Adj Rsquare	0.40	0.21

This table presents the regressions for the risk premiums of futures with 1-3 months maturity using monthly data from 2000:03 to 2022:01 (Panel A) and from 2006:06 to 2022:01 (Panels B-D). Panels A-D are for the net positions of commercial traders, dealers, asset managers, and leveraged funds, respectively. Commercial traders' net positions are from the CFTC COT legacy report. The net positions of the other three trading groups are from the CFTC COT FTT report. The Newey-West standard errors with automatic bandwidth selection are reported in parentheses. $*$, $**$, and $***$ indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table 7: Explaining Futures Risk Premium Using Trader's Position and the Yield Curve: 1-3 Months Maturity

	Panel A: Commercial Traders			**Panel B: Dealers**	
	5-Year Treasury Futures	10-Year Treasury Futures		5-Year Treasury Futures	10-Year Treasury Futures
Level	-0.4701***	-1.3683***	Level	-0.5327***	-1.7684***
	(0.0419)	(0.1638)		(0.0478)	(0.2005)
Slope	2.4739***	6.5694***	Slope	2.3426***	6.8596***
	(0.1135)	(0.3792)		(0.1795)	(0.5866)
Curvature	4.2247***	15.7514***	Curvature	4.9243***	17.5571***
	(0.6457)	(1.8830)		(0.7488)	(2.0002)
Commercial Net Position	-0.0225**	-0.0100	Dealer Net Position	0.0456***	0.1016***
	(0.0096)	(0.0308)		(0.0129)	(0.0340)
Constant	0.1189***	0.2279***	Constant	0.1222***	0.2247***
	(0.0114)	(0.0342)		(0.0109)	(0.0285)
Adj Rsquare	0.89	0.85	Adj Rsquare	0.88	0.85

	Panel C: Asset Managers			**Panel D: Leveraged Funds**	
	5-Year Treasury Futures	10-Year Treasury Futures		5-Year Treasury Futures	10-Year Treasury Futures
Level	-0.5013***	-1.5537***	Level	-0.4925***	-1.4897***
	(0.0501)	(0.1739)		(0.0568)	(0.1523)
Slope	2.3506***	6.6503***	Slope	2.5722***	6.4544***
	(0.2624)	(0.6371)		(0.3291)	(0.6347)
Curvature	4.8573***	17.3241***	Curvature	5.3761***	17.0613***
	(1.0635)	(2.0982)		(0.9772)	(1.8843)
Asset Manager Net Position	-0.0097	-0.0274**	Leveraged Fund Net Position	0.0035	0.0419***
	(0.0068)	(0.0130)		(0.0098)	(0.0125)
Constant	0.1207***	0.2247***	Constant	0.1064***	0.2289***
	(0.0195)	(0.0348)		(0.0207)	(0.0298)
Adj Rsquare	0.87	0.85	Adj Rsquare	0.87	0.86

This table presents the regressions for the risk premiums of futures with 1-3 months maturity using monthly data from 2000:03 to 2022:01 (Panel A) and from 2006:06 to 2022:01 (Panels B-D). Panels A-D are for the net positions of commercial traders, dealers, asset managers, and leveraged funds, respectively. Commercial traders' net positions are from the CFTC COT legacy report. The net positions of the other three trading groups are from the CFTC COT FTT report. Level, slope, and curvature are the first three principal components of Treasury yields with 3- and 6-month, 1- to 5-, 10-, and 30-year maturities. The Newey-West standard errors with automatic bandwidth selection are reported in parentheses. $*$, $**$, and $***$ indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table 8: Explaining Futures Net Positions Using the Term Structure of Yields Factors

Panel A: 5-Year Treasury Futures

	Commercial Traders	Dealers	Asset Managers	Leveraged Funds
Level	4.4062***	-3.4469***	15.9599***	-10.1495***
	(1.5304)	(0.7905)	(3.0134)	(2.443)
Slope	-4.9133**	7.2952***	-35.1047***	32.1799***
	(2.0349)	(1.1411)	(3.1542)	(3.1956)
Curvature	-36.3517***	4.5427	-31.4318**	11.5503
	(7.1395)	(4.8927)	(15.1344)	(13.2395)
Constant	0.4084***	-0.2684***	1.2685***	-1.0397***
	(0.073)	(0.0568)	(0.1956)	(0.1839)
Adj Rsquare	0.63	0.53	0.79	0.77

Panel B: 10-Year Treasury Futures

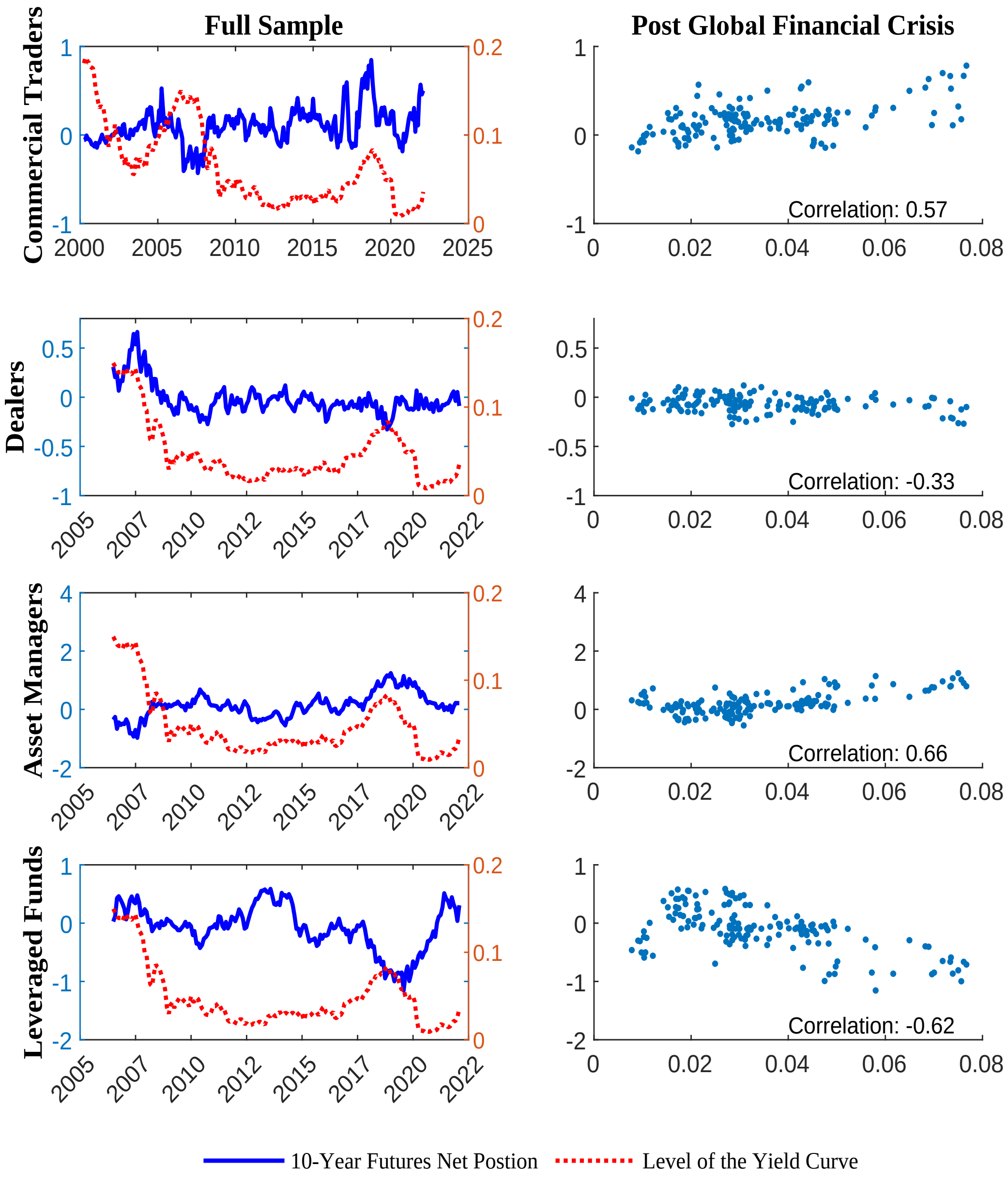
	Commercial Traders	Dealers	Asset Managers	Leveraged Funds
Level	5.1263***	-1.6862**	14.1724***	-13.5868***
	(1.3986)	(0.7012)	(1.7795)	(2.4604)
Slope	1.6355	0.6503	-12.9231***	13.7144***
	(1.4918)	(0.9285)	(3.4441)	(3.9692)
Curvature	-17.796***	-2.2411	3.5261	-2.1640
	(5.9092)	(3.0821)	(9.0604)	(11.992)
Constant	0.0666	-0.0156	0.1003	-0.0511
	(0.0813)	(0.0395)	(0.1674)	(0.2200)
Adj Rsquare	0.42	0.12	0.60	0.56

This table presents the regressions for the net positions (long minus short, in millions) in 5-year Treasury futures (Panel A) and 10-year Treasury futures (Panel B) for commercial traders, dealers, asset managers, and leveraged funds using monthly data from 2009:01 to 2022:01, after the GFC. Commercial traders' net positions are from the CFTC COT legacy report. The net positions of the other three trading groups are from the CFTC COT FTT report. Level, slope, and curvature are the first three principal components of Treasury yields with 3- and 6-month, 1- to 5-, 10-, and 30-year maturities. The Newey-West standard errors with automatic bandwidth selection are reported in parentheses. $*$, $**$, and $***$ indicate statistical significance at 10%, 5% and 1% levels, respectively.

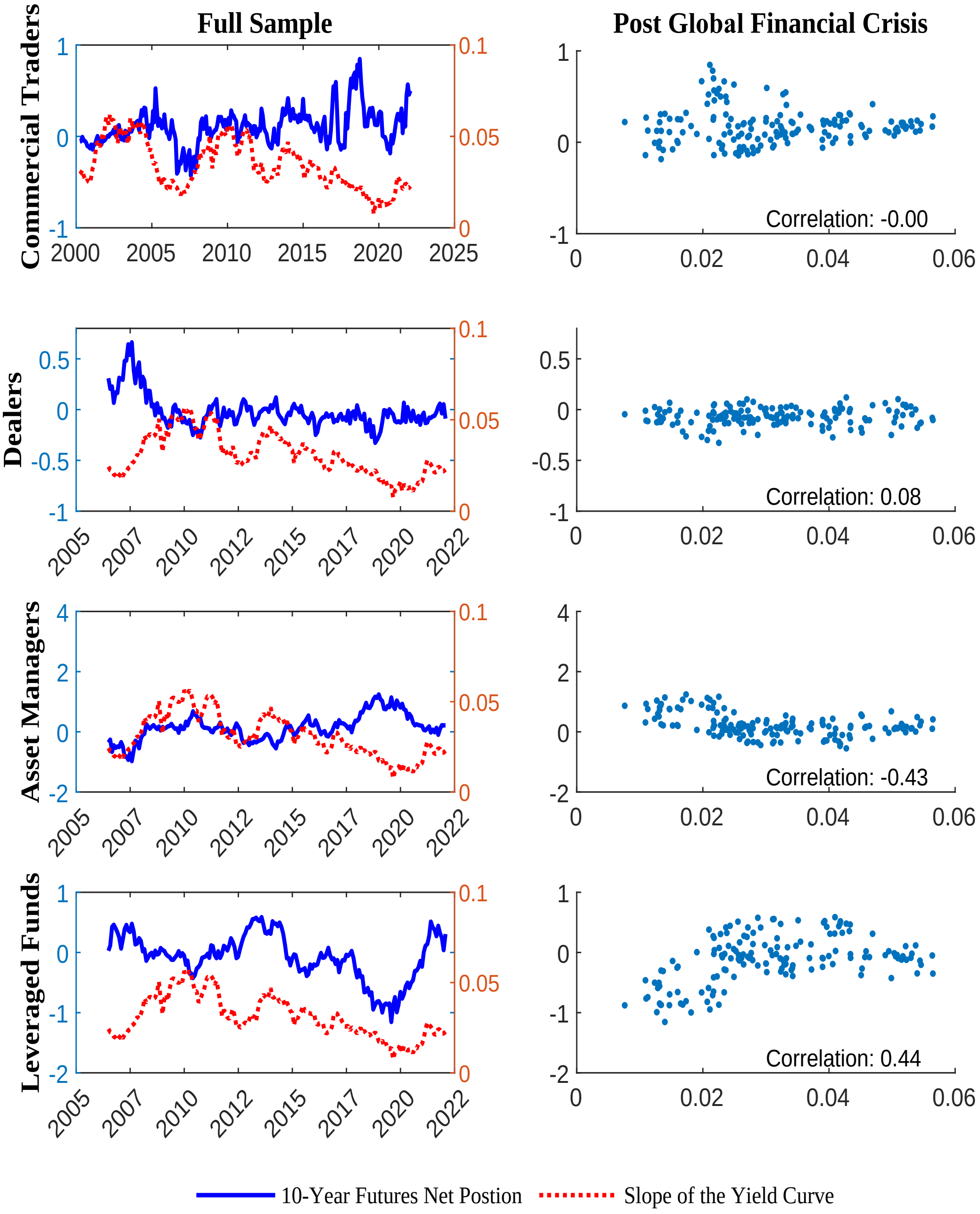
Appendix: Additional Figures and Tables

Figure IA1: Ten-Year Treasury Futures Net Position and the Yield Curve Factors

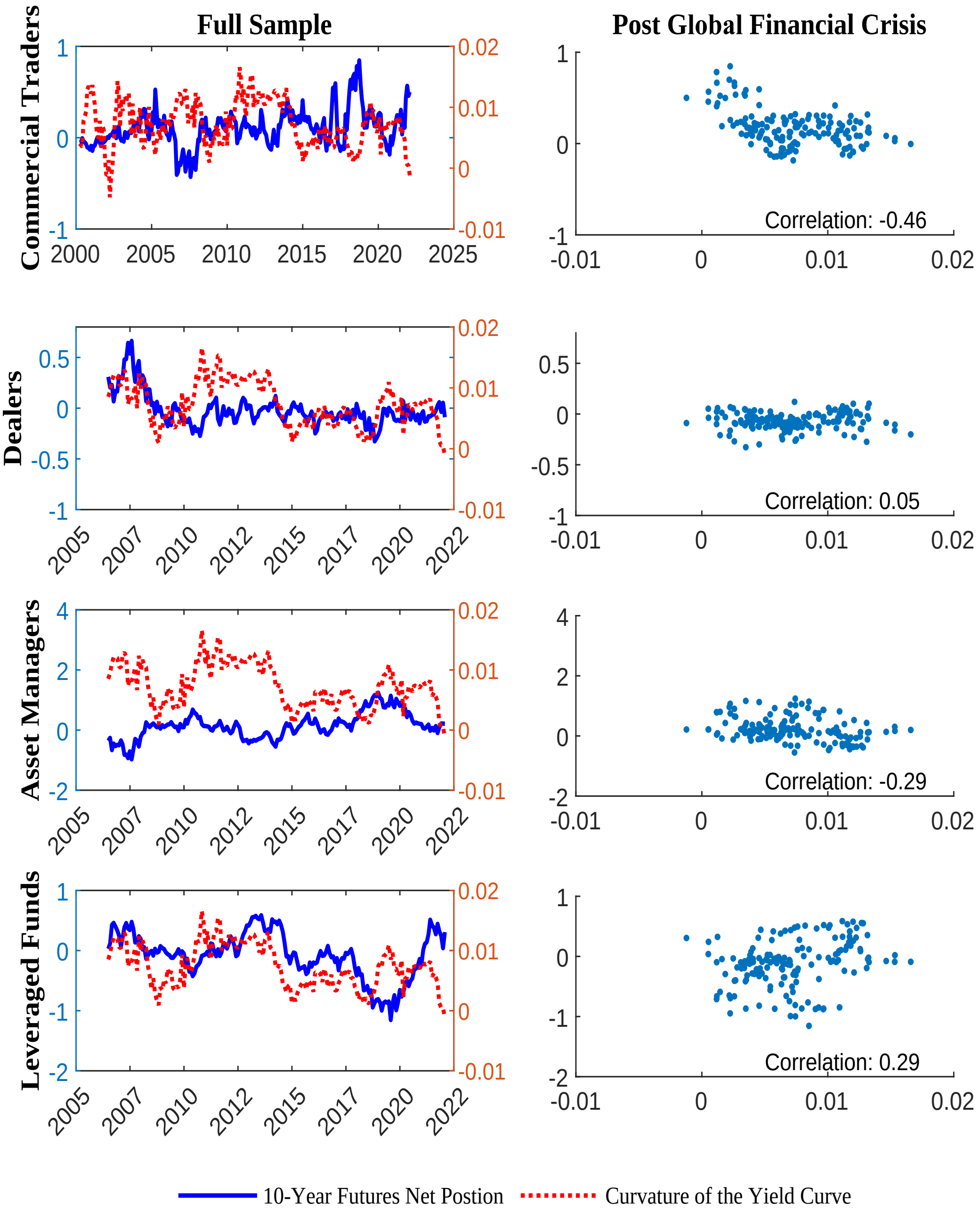
(a) Level of the Yield Curve



(b) Slope of the Yield Curve



(c) Curvature of the Yield Curve



Notes: This figure plots the relationship between the 10-year Treasury futures net position and the level (a), slope (b), and curvature (c) of the yield curve. We use the first three principal components of Treasury yields with 3- and 6-month, 1-5, 10, and 30-year maturities as proxies for the level, slope, and curvature of the yield curve respectively. The four panels in the first column of each figure plot the net position of 10-year futures held by different market participants (solid line in blue, left y-axis, in millions): commercial traders, dealers, asset managers, and leveraged funds in our full sample: 2000:03 to 2022:01 for the commercial traders and 2006:06 to 2022:01 for the other three groups of traders. Commercial traders' net positions are from the CFTC COT legacy report. The net positions of the other three trading groups are from the CFTC COT FTT report. The yield curve factors are plotted as a dashed line in red, right y-axis in all figures. The four panels in the second column of each figure plot the relationship between the two time series in the corresponding first column panels post-2009 in a scatter plot. The y-axis is the trader's net position in millions. The x-axis is the yield curve factor.

Table IA1: Explaining Futures Risk Premiums: 4-6 Months Maturity

Panel A: 5-Year Treasury Futures

	(1)	(2)	(3)	(4)	(5)
Level	-0.51***		-0.52***		-0.38***
	(0.05)		(0.04)		(0.06)
Slope	2.80***		2.81***		2.48***
	(0.12)		(0.12)		(0.12)
Curvature	5.22***		5.31***		4.41***
	(0.57)		(0.58)		(0.53)
Easing		0.02**	0.0049		
		(0.01)	(0.0032)		
Tightening		-0.06***	0.0049		
		(0.01)	(0.0036)		
Unemployment Rate				0.02***	0.0056***
				(0.0039)	(0.0017)
Constant	0.12***	0.22***	0.12***	0.11***	0.09***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.01)
Adj Rsquare	0.88	0.17	0.88	0.53	0.91

Panel B: 10-Year Treasury Futures

	(1)	(2)	(3)	(4)	(5)
Level	-1.41***		-1.43***		-1.01***
	(0.14)		(0.14)		(0.18)
Slope	6.73***		6.73***		5.71***
	(0.40)		(0.39)		(0.45)
Curvature	15.66***		15.79***		13.09***
	(1.79)		(1.80)		(1.71)
Easing		0.05*	0.0076		
		(0.03)	(0.0074)		
Tightening		-0.15***	0.0077		
		(0.02)	(0.012)		
Unemployment Rate				0.05***	0.02***
				(0.01)	(0.01)
Constant	0.24***	0.51***	0.24***	0.19***	0.16***
	(0.03)	(0.02)	(0.03)	(0.06)	(0.04)
Adj Rsquare	0.84	0.14	0.84	0.55	0.88

Panel C: 30-Year Treasury Futures

	(1)	(2)	(3)	(4)	(5)
Level	-5.08***		-5.12***		-3.60***
	(0.55)		(0.53)		(0.70)
Slope	21.28***		21.33***		17.48***
	(1.51)		(1.48)		(1.90)
Curvature	57.56***		57.89***		47.98***
	(6.98)		(7.00)		(6.81)
Easing		0.12	0.0056		
		(0.10)	(0.0259)		
Tightening		-0.50***	0.0203		
		(0.08)	(0.0446)		
Unemployment Rate				0.18***	0.07***
				(0.04)	(0.02)
Constant	0.45***	1.33***	0.44***	0.20	0.16
	(0.11)	(0.08)	(0.11)	(0.21)	(0.16)
Adj Rsquare	0.81	0.12	0.81	0.56	0.85

This table presents the regressions for the risk premiums of futures with 4-6 months maturity using monthly data from 2000:03 to 2022:06. Panels A-C are for the futures contracts on 5-, 10-, and 30-year Treasuries, respectively. Level, slope, and curvature are the first three principal components of Treasury yields with 3- and 6-month, 1- to 5-, 10-, and 30-year maturities. Easing and tightening are dummy variables indicating whether the Federal Reserve was easing or tightening monetary policy one year ago based on observed changes in the target rate, which is obtained from the Federal Reserve Economic Data (FRED). Unemployment rate is also from FRED. The Newey-West standard errors with automatic bandwidth selection are reported in parentheses. $*$, $**$, and $***$ indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table IA2: Explaining Futures Risk Premiums: 7-9 Months Maturity

Panel A: 5-Year Treasury Futures

	(1)	(2)	(3)	(4)	(5)
Level	-0.53***		-0.58***		-0.36***
	(0.07)		(0.07)		(0.08)
Slope	3.04***		3.03***		2.43***
	(0.21)		(0.21)		(0.21)
Curvature	5.76***		5.85***		4.54***
	(0.79)		(0.79)		(0.73)
Easing		0.03*	0.0074**		
		(0.02)	(0.0037)		
Tightening		-0.04**	0.0149***		
		(0.02)	(0.005)		
Unemployment Rate				0.02***	0.0074***
				(0.0033)	(0.0022)
Constant	0.12***	0.23***	0.12***	0.10***	0.09***
	(0.01)	(0.01)	(0.01)	(0.02)	(0.02)
Adj Rsquare	0.87	0.06	0.87	0.66	0.90

Panel B: 10-Year Treasury Futures

	(1)	(2)	(3)	(4)	(5)
Level	-1.43***		-1.46***		-1.00***
	(0.16)		(0.16)		(0.20)
Slope	7.02***		7.02***		5.89***
	(0.44)		(0.43)		(0.51)
Curvature	16.48***		16.61***		13.62***
	(1.97)		(1.98)		(1.93)
Easing		0.06**	0.01		
		(0.03)	(0.0079)		
Tightening		-0.15***	0.01		
		(0.02)	(0.0126)		
Unemployment Rate				0.05***	0.02***
				(0.01)	(0.01)
Constant	0.24***	0.53***	0.24***	0.19***	0.16***
	(0.03)	(0.02)	(0.03)	(0.06)	(0.04)
Adj Rsquare	0.83	0.15	0.83	0.56	0.87

Panel C: 30-Year Treasury Futures

	(1)	(2)	(3)	(4)	(5)
Level	-5.04***		-5.09***		-3.52***
	(0.59)		(0.57)		(0.74)
Slope	21.91***		21.94***		17.89***
	(1.59)		(1.55)		(2.02)
Curvature	58.79***		59.14***		48.63***
	(7.39)		(7.43)		(7.37)
Easing		0.18*	0.0168		
		(0.1)	(0.0262)		
Tightening		-0.50***	0.0203		
		(0.08)	(0.045)		
Unemployment rate				0.18***	0.07***
				(0.04)	(0.02)
Constant	0.43***	1.33***	0.42***	0.20	0.14
	(0.12)	(0.08)	(0.12)	(0.21)	(0.16)
Adj Rsquare	0.81	0.13	0.81	0.56	0.85

This table presents the regressions for the risk premiums of futures with 7-9 months maturity using monthly data from 2000:03 to 2022:06. Panels A-C are for the futures contracts on 5-, 10-, and 30-year Treasuries, respectively. Level, slope, and curvature are the first three principal components of Treasury yields with 3- and 6-month, 1- to 5-, 10-, and 30-year maturities. Easing and tightening are dummy variables indicating whether the Federal Reserve was easing or tightening monetary policy one year ago based on observed changes in the target rate, which is obtained from the Federal Reserve Economic Data (FRED). Unemployment rate is also from FRED. The Newey-West standard errors with automatic bandwidth selection are reported in parentheses. $*$, $**$, and $***$ indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table IA3: Explaining Futures Risk Premium Using Trader's Position: 4-6 Months and 7-9 Months Maturities

	Fut. Mat. 4-6 months		Fut. Mat. 7-9 months	
	5-Year Treasury	10-Year Treasury	5-Year Treasury	10-Year Treasury
Panel A: Commercial Traders				
Commercial Net Position	-0.1259***	-0.0361	-0.1425***	-0.0446
	(0.016)	(0.1007)	(0.0175)	(0.1039)
Constant	0.2294***	0.5001***	0.2456***	0.5152***
	(0.0068)	(0.0225)	(0.0081)	(0.0240)
Adj Rsquare	0.31	0.00	0.38	0.00
Panel B: Dealers				
Dealer Net Position	0.1598***	-0.0789	0.1907***	-0.0754
	(0.0279)	(0.1078)	(0.0314)	(0.1118)
Constant	0.2326***	0.4973***	0.2538***	0.5114***
	(0.0089)	(0.0239)	(0.0108)	(0.0252)
Adj Rsquare	0.29	0.01	0.34	0.01
Panel C: Asset Mangers				
Asset Manager Net Position	-0.0553***	-0.1016*	-0.0643***	-0.1022*
	(0.0072)	(0.0548)	(0.009)	(0.0572)
Constant	0.2404***	0.5129***	0.2605***	0.5272***
	(0.0086)	(0.0263)	(0.0103)	(0.0277)
Adj Rsquare	0.47	0.09	0.53	0.09
Panel D: Leveraged Funds				
Leveraged Fund Net Position	0.0654***	0.1707***	0.0774***	0.1758***
	(0.0097)	(0.0398)	(0.012)	(0.0434)
Constant	0.2333***	0.5111***	0.2524***	0.5266***
	(0.0083)	(0.0226)	(0.0099)	(0.0241)
Adj Rsquare	0.41	0.21	0.47	0.20

This table presents the regressions for the risk premiums of futures with 4-6 months and 7-9 months maturities using monthly data from 2000:03 to 2022:01 (Panel A) and from 2006:06 to 2022:01 (Panels B-D). Panels A-D are for the net positions of commercial traders, dealers, asset managers, and leveraged funds, respectively. The Newey-West standard errors with automatic bandwidth selection are reported in parentheses. $*$, $**$, and $***$ indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table IA4: Explaining Futures Risk Premium Using Trader's Position and the Yield Curve: 4-6 Months Maturity

Panel A: Commercial Traders

	5-Year Treasury Futures	10-Year Treasury Futures
Level	-0.5162***	-1.4200***
	(0.0463)	(0.1728)
Slope	2.6134***	6.799***
	(0.1243)	(0.4004)
Curvature	4.7038***	16.5031***
	(0.6512)	(1.9810)
Commercial Net Position	-0.0275***	-0.0108
	(0.0099)	(0.0326)
Constant	0.1297***	0.2347***
	(0.0117)	(0.0361)
Adj Rsquare	0.89	0.85

Panel B: Dealers

	5-Year Treasury Futures	10-Year Treasury Futures
Level	-0.594***	-1.8498***
	(0.0520)	(0.2102)
Slope	2.4677***	7.1107***
	(0.2004)	(0.6151)
Curvature	5.5397***	18.3977***
	(0.7551)	(2.0899)
Dealer Net Position	0.0551***	0.1095***
	(0.0136)	(0.0355)
Constant	0.1334***	0.2317***
	(0.0111)	(0.0298)
Adj Rsquare	0.89	0.85

Panel C: Asset Managers

	5-Year Treasury Futures	10-Year Treasury Futures
Level	-0.5581***	-1.6193***
	(0.0542)	(0.1830)
Slope	2.4332***	6.8825***
	(0.2768)	(0.6694)
Curvature	5.3717***	18.1354***
	(1.0728)	(2.1922)
Asset Manager Net Position	-0.0131*	-0.0298**
	(0.0069)	(0.0137)
Constant	0.1342***	0.2320***
	(0.0197)	(0.0366)
Adj Rsquare	0.88	0.85

Panel D: Leveraged Funds

	5-Year Treasury Futures	10-Year Treasury Futures
Level	-0.5510***	-1.5494***
	(0.0613)	(0.1604)
Slope	2.6596***	6.6766***
	(0.3427)	(0.6670)
Curvature	5.9832***	17.8722***
	(1.0026)	(1.9686)
Leveraged Fund Net Position	0.0070	0.0449***
	(0.0098)	(0.0132)
Constant	0.1187***	0.2361***
	(0.0209)	(0.0314)
Adj Rsquare	0.87	0.85

This table presents the regressions for the risk premiums of futures with 4-6 months maturity using monthly data from 2000:03 to 2022:01 (Panel A) and from 2006:06 to 2022:01 (Panels B-D). Panels A-D are for the net positions of commercial traders, dealers, asset managers, and leveraged funds, respectively. Commercial traders' net positions are from the CFTC COT legacy report. The net positions of the other three trading groups are from the CFTC COT FTT report. Level, slope, and curvature are the first three principal components of Treasury yields with 3- and 6-month, 1- to 5-, 10-, and 30-year maturities. The Newey-West standard errors with automatic bandwidth selection are reported in parentheses. $*$, $**$, and $***$ indicate statistical significance at 10%, 5% and 1% levels, respectively.

Table IA5: Explaining Futures Risk Premium Using Trader's Position and the Yield Curve: 7-9 Months Maturity

Panel A: Commercial Traders

	5-Year Treasury Futures	10-Year Treasury Futures
Level	-0.5271***	-1.4457***
	(0.0696)	(0.1903)
Slope	2.7933***	7.1071***
	(0.1876)	(0.4369)
Curvature	4.8962***	17.4117***
	(0.8385)	(2.1512)
Commercial Net Position	-0.0355***	-0.0128
	(0.0103)	(0.0343)
Constant	0.1374***	0.2353***
	(0.0135)	(0.0391)
Adj Rsquare	0.88	0.84

Panel B: Dealers

	5-Year Treasury Futures	10-Year Treasury Futures
Level	-0.6631***	-1.9077***
	(0.0732)	(0.2275)
Slope	2.6473***	7.3570***
	(0.2447)	(0.6560)
Curvature	5.6624***	19.3005***
	(0.8256)	(2.2103)
Dealer Net Position	0.0654***	0.1141***
	(0.0165)	(0.0373)
Constant	0.1445***	0.2353***
	(0.0134)	(0.0324)
Adj Rsquare	0.90	0.85

Panel C: Asset Managers

	5-Year Treasury Futures	10-Year Treasury Futures
Level	-0.6185***	-1.6700***
	(0.0761)	(0.1992)
Slope	2.586***	7.1274***
	(0.3093)	(0.7128)
Curvature	5.4040***	19.0413***
	(1.1493)	(2.3131)
Asset Manager Net Position	-0.0164**	-0.0325**
	(0.0075)	(0.0144)
Constant	0.1464***	0.2355***
	(0.0215)	(0.0394)
Adj Rsquare	0.88	0.84

Panel D: Leveraged Funds

	5-Year Treasury Futures	10-Year Treasury Futures
Level	-0.6152***	-1.5988***
	(0.0833)	(0.1736)
Slope	2.837***	6.9058***
	(0.3714)	(0.7119)
Curvature	6.1377***	18.8050***
	(1.0983)	(2.0802)
Leveraged Fund Net Position	0.0094	0.0492***
	(0.0103)	(0.0143)
Constant	0.1284***	0.2400***
	(0.0224)	(0.034)
Adj Rsquare	0.87	0.85

This table presents the regressions for the risk premiums of futures with 7-9 months maturity using monthly data from 2000:03 to 2022:01 (Panel A) and from 2006:06 to 2022:01 (Panels B-D). Panels A-D are for the net positions of commercial traders, dealers, asset managers, and leveraged funds, respectively. Commercial traders' net positions are from the CFTC COT legacy report. The net positions of the other three trading groups are from the CFTC COT FTT report. Level, slope, and curvature are the first three principal components of Treasury yields with 3- and 6-month, 1- to 5-, 10-, and 30-year maturities. The Newey-West standard errors with automatic bandwidth selection are reported in parentheses. $*$, $**$, and $***$ indicate statistical significance at 10%, 5% and 1% levels, respectively.