Treasury Richness

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ABSTRACT

We provide estimates of Treasury convenience premia across the entire term structure of Treasury bills, notes, and bonds over more than a quarter of a century and document a variety of key stylized facts about their time-series and cross-sectional patterns. These results raise concerns about the evolving nature of Treasury markets and suggest that investors may now place less weight on the traditional role of Treasury securities as liquid trading vehicles. These stylized facts provide empirical benchmarks that could help guide future theoretical and empirical work about the economics of safe assets in financial markets.

One of the most important issues in asset pricing is whether investors should be willing to pay a premium above intrinsic fair value for Treasury securities because of their money-like characteristics. This type of premium is often called a convenience premium in the literature and is widely known as Treasury "richness" by market participants. A Treasury security is said to be rich/cheap if its convenience premium is positive/negative.

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There is an extensive theoretical literature focusing on convenience premia in Treasury markets. This literature can be divided into two contrasting streams. The first seeks to explain why Treasuries are rich, while the second seeks to explain why some Treasuries are cheap. On the one hand, the safe-asset literature argues that investors may pay a premium for Treasury securities because of the safety and liquidity Treasuries provide.[1] On the other hand, the negative-swap-spread literature argues that limited arbitrage or intermediary constraints and balance sheet costs may explain why long-term Treasury bonds appear cheap relative to swaps during the post-crisis period.[2]

There is also a rapidly-growing empirical literature seeking to quantify the convenience premia in Treasury security prices. This literature is likewise fragmented with estimates of the average convenience premium ranging from close to zero to more than 100 basis points.[3] Important recent work by Augustin, Chernov, Schmid, and Song (2021), van Binsbergen, Diamond, and Grotteria (2022), and others, however, suggests that this heterogeneity may be an artifact of how Treasury credit risk is controlled for in the estimation, as well as differences in the credit risk and/or liquidity of the benchmark used for comparison.

Motivated by the diverse state of the theoretical and empirical literatures, the objective of this paper is to obtain robust estimates of the convenience premia across the entire term

[1]Examples include Krishnamurthy and Vissing-Jørgensen (2012), Greenwood, Hanson, and Stein (2015), Nagel (2016), He, Krishnamurthy, and Milbradt (2016, 2019), Infante (2020), and Liu, Schmid, and Yaron (2021).

[2]Examples include Liu, Longstaff, and Mandell (2006), Feldhütter and Lando (2008), Boyarchenko, Gupta, Steele, and Yen (2018), Klingler and Sundaresan (2019), Jermann (2020), Augustin, Chernov, Schmid, and Song (2021), Du, Hébert, and Li (2023), and Hanson, Malkhozov, and Venter (2022).

[3]For example, Longstaff (2004) estimates the convenience premium in Treasuries to be on the order of 10 basis points. In contrast, the Krishnamurthy and Vissing-Jørgensen (2012) Aaa-corporate/Treasury spread measure implies values ranging from about 100 to 140 basis points during much of the post-crisis period (see Figure XII of van Binsbergen, Diamond, and Grotteria (2022)).

structure of Treasury bills, notes, and bonds over an extensive sample period, and then provide a comprehensive description of their time-series and cross-sectional patterns. By documenting key stylized facts about the term structure of Treasury convenience premia over more than a quarter of a century, we hope to provide clear empirical benchmarks to guide future theoretical and empirical work in this important area. Rather than taking a stand on any particular theory, our approach will simply be to present the stylized facts, identify their broader implications, and put them into perspective relative to the literature.

In doing this, we use a uniform estimation framework that allows us to compare convenience premia across maturities and over time. First, following Augustin, Chernov, Schmid, and Song (2021) and others, we use Treasury credit default swap (CDS) spreads to control for Treasury credit risk in estimating convenience premia. Second, following Augustin, Chernov, Schmid, and Song (2021), He, Nagel, and Song (2022), Du, Hébert, and Li (2023), and others, we use the term structure of overnight index swaps (OIS) to specify a benchmark curve. Rather than using OIS tied to the effective fed funds rate (EFFR), however, we use the term structure of swaps based on the overnight repo rate, which we denote as repo OIS. The reason for this is that the repo rate is based on secured repo lending and is, therefore, more interpretable as a riskless rate than the unsecured fed funds rate.[4] Thus, the use of repo OIS provides us with an objective risk-free benchmark curve in estimating convenience premia. An important advantage of this approach is that by using the term structure of CDS spreads and repo OIS, the entire term structure of convenience premia essentially becomes directly observable. Some of the key stylized facts we document are summarized below.

The Average Premium is Surprisingly Small. We confirm that there are significant convenience premia in Treasury security prices. Surprisingly, however, the average premium

[4]See Augustin, Chernov, Schmid, and Song (2021) for a discussion of the credit risk inherent in the unsecured EFFR rate.

taken over all Treasuries over the entire sample period is only 8.21 basis points. This average is much smaller than many of the estimates previously reported in the literature.

Convenience Premia are Frequently Negative. Many Treasury bills, notes, and bonds have repeatedly traded at significant discounts to their intrinsic fair values for extended periods throughout the entire sample period. We find that 36.86 percent of all convenience premium estimates are negative, and that negative premia occur in 70.83 percent of the months in the sample period. Negative convenience premia are frequently observed well before the beginning of the financial crisis.

The On-the-Run Effect Has Largely Disappeared. Krishnamurthy (2002), Pasquariello and Vega (2009), and others show that on-the-run Treasuries are rich relative to off-the-run Treasuries during the early part of our sample period. We confirm their results, but also show that the on-the-run effect has essentially disappeared during the post-financial-crisis period. On-the-run Treasuries are generally no longer richer than either off-the-run Treasuries with the same tenor, or Treasuries with similar maturities but different tenors.

Treasuries Richen Significantly in the Money Market. We find that the convenience premia begin to increase substantially as Treasury securities approach their maturity date and become eligible to be held by money market funds. Furthermore, the premia are almost linearly related to the security's effect on the weighted-average-maturity constraint faced by money market funds.

The Maturity-Crossing Effect. We find that Treasuries often richen as they age and attain more popular maturities. Furthermore, the convenience premium tends to jump significantly when the maturity of a Treasury crosses a specific threshold such as two, five, seven, or ten years.

Convenience Premia have Little to do with Safety. We find that convenience premia do not always increase during a crisis, and that there is no clear pattern in the response of the premia to major shocks in the financial markets. There is little evidence that premia are related to changes in measures proxying for the risk of a major adverse event in the market.

Treasuries have Cheapened Dramatically Since 2015. One of the most striking results is that the convenience premia of longer-term Treasuries have become dramatically more negative since 2015. Aggregate Treasury market cheapness ranges from about $100 billion to more than $300 billion during this period.

Convenience Premia are Driven by Multiple Factors. No single factor fully explains the variation in convenience premia. In particular, the first principal component of changes in the convenience premia explains only about two thirds of the variation. The convenience premia for short-term, medium-term, and long-term Treasuries all behave very differently from each other.

These stylized facts have important implications for a number of current models of Treasury convenience premia. For example, the evidence of frequent negative premia across multiple tenors and maturities throughout the sample period poses challenges to many safe-asset theories since they generally imply uniformly positive premia.[5] The evidence that negative premia occurred frequently well before the financial crisis suggests that the post-financial-crisis constraints and frictions that play a major role in the negative-swap-spread literature cannot fully explain historical patterns of Treasury richness/cheapness.[6] Furthermore, the evidence that some Treasuries actually cheapen during major shocks in the financial markets appears inconsistent with theories focusing on the safe-haven

[5]For example, see Krishnamurthy and Vissing-Jørgensen (2012), Greenwood, Hanson, and Stein (2015), Nagel (2016), He, Krishnamurthy, and Milbradt (2016, 2019), and Diamond (2020).

[6]For example, Klingler and Sundaresan (2019), Jermann (2020), Du, Hébert, and Li (2023), and Hanson, Malkhozov, and Venter (2022) present models in which the mechanisms allowing swap spreads to become negative are based on the frictions introduced by balance sheet constraints, financing and regulatory costs, or capital requirements.

protection that Treasuries may provide during flights-to-safety.[7]

These stylized facts also offer guidance for future theoretical work about the convenience premia in Treasury security prices. For example, the results raise concerns about the evolving nature of Treasury market liquidity as evidenced by the changes in the on-the-run effect. These changes suggest that investors may now place less weight on the traditional role of Treasury securities as liquid trading vehicles, and more weight on other characteristics such as their ability to be used as collateral in financing markets or as high-quality liquid assets (HQLA) for regulatory capital purposes. Furthermore, the relation between institutional portfolio requirements and convenience premia indicated by the evidence of links to money-market-fund eligibility and broader maturity-range constraints suggests a number of new demand-related directions in the development of models of Treasury richness/cheapness.

Finally, these results also have implications for Treasury debt management. Issuing Treasury securities at a premium to their intrinsic value can be viewed as a type of seigniorage that reduces the overall cost of government debt, while the opposite is true for Treasury securities issued at a discount to fair value. The evidence indicates that the yields of long-term Treasury debt securities have consistently been 30 to 50 basis points above their fair values since 2015. This clearly could have major implications for Treasury borrowing costs and the optimal structure of Treasury debt maturities.

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[7] Examples of this literature include Longstaff (2004), Vayanos (2004), Beber, Brandt, and Kavajecz (2009), Nagel (2016), Musto, Nini, and Schwarz (2018), Adrian, Crump, and Vogt (2019), Duffie (2020), Baele, Bekaert, Inghelbrecht, and Wei (2020), Haddad, Moreira, and Muir (2021), and Ma, Xiao, and Zeng (2022).

I. Related Literature

This paper contributes to an extensive empirical literature documenting that Treasury securities tend to trade rich relative to other securities. This literature is sometimes known as the safe-asset literature since it often focuses on the safety and liquidity features that near-money assets such as Treasuries offer investors. Examples include Amihud and Mendelson (1991), Kamara (1988, 1994), Duffee (1996), Grinblatt and Longstaff (2000), Jordan, Jorgensen, and Kuipers (2000), Krishnamurthy (2002), Krishnamurthy and Vissing-Jørgensen (2012), Fleckenstein, Longstaff, and Lustig (2014), Nagel (2016), Musto, Nini, and Schwarz (2018), Fleckenstein and Longstaff (2020b), van Binsbergen, Diamond, and Grotteria (2022), and many others. Our paper is most closely related to the subset of this literature that estimates Treasury convenience premia while controlling for differences in the credit risk between Treasuries and the benchmark used for comparison. This subset includes Longstaff (2004), Lewis, Longstaff, and Petrasek (2021), Augustin, Chernov, Schmid, and Song (2021), and Joslin, Li, and Song (2021). This paper extends the literature by using a standardized estimation framework in which convenience premia are measured relative to a risk-free repo OIS benchmark. We use this framework to document key stylized facts about convenience premia across the entire term structure and over an extended period of time.

This paper also contributes to an alternative literature showing that some Treasuries appear to trade at a discount relative to other financial instruments. Much of this literature focuses on the phenomenon of negative swap spreads. One stream of this negative-swap-spread literature focuses on whether intermediary constraints and frictions may play a role in explaining the negative long-term swap spreads observed since the financial crisis. Klingler and Sundaresan (2019) find that negative long-term swap spreads during the post-financial-crisis period are related to the demand for duration by underfunded pension plans. Boyarchenko, Gupta, Steele, and Yen (2018) and Jermann (2020) present evidence that negative long-term swap spreads may be related to regulatory leverage constraints. Du, Hébert, and Li (2023), and Hanson, Malkhozov, and Venter (2022) show that the timing of the 30-year swap spread becoming negative coincides with a change in the Treasury positions of primary dealers from net short to net long. Augustin, Chernov, Schmid, and Song (2021) argue that Treasury credit risk may be an important factor in explaining negative swap spreads. Our paper differs from this literature in two ways. First, swap spreads are fundamentally different from convenience premia since swap spreads include Treasury credit risk as a component, while our measure of convenience premia does not. Thus, stylized facts about swap spreads do not necessarily carry over to convenience premia. Accordingly, our paper focuses exclusively on convenience premia rather than swap spreads. Second, we extend the literature by showing that negative convenience premia have occurred frequently across the entire maturity spectrum throughout the entire sample period even after controlling for Treasury credit risk. Our results also complement and extend a set of papers showing that Treasury convenience premia have recently declined or even become negative during the Covid crisis. Examples include Du, Im, and Schreger (2018), Haddad, Moreira, and Muir (2021), and He, Nagel, and Song (2022).

Another stream of the swap spread literature uses term structure modeling techniques to identify the components of swap spreads. For example, Liu, Longstaff, and Mandell (2006) present a five-factor affine model of swap spreads and argue that credit-adjusted swap spreads were negative from 1992 to 1998 (see their Figure 2). Feldhütter and Lando (2008) extend the affine framework to a six-factor model and provide estimates of the convenience component of swap spreads that parallel ours (see their Figure 1). Similarly, Augustin, Chernov, Schmid, and Song (2021) use an affine modeling framework to show that negative long-term swap spreads may be partially explained by Treasury credit risk. A common feature of these papers is that a latent liquidity factor is estimated as part of the model-fitting process and then extrapolated to provide estimates of the term structure of convenience premia. Our paper differs fundamentally since by using the full term structure of CDS spreads and repo OIS rates, convenience premia essentially become directly observable and no longer need to be extrapolated from a fitted affine model.

II. Identifying Treasury Richness

We define a Treasury security as being rich/cheap if its market value is greater/less than its intrinsic fair value. We define the convenience premium as the difference between the yield implied by the intrinsic fair value of a Treasury security and the yield implied by its market value. Treasuries trading rich have positive convenience premia, while Treasuries trading cheap have negative convenience premia. In this section, we describe how Treasury convenience premia can be identified using Treasury CDS data in conjunction with a risk-free discounting curve.[8]

To convey the intuition, let us begin by considering the case of a Treasury with a coupon rate of c percent and a maturity of T. Let $P(c, T)$ denote the market price of this Treasury bond. If there were no possibility of default, we could measure the richness of this bond by simply comparing its market price to the sum of the present values of its cash flows discounted using the risk-free discounting curve.

In reality, however, Treasury securities are not completely risk-free and the possibility of default needs to be taken into account. To do this, we follow the literature in recognizing that a Treasury security can essentially be converted into a risk-free security by buying default protection via a CDS contract. To illustrate this, Table I uses a stylized replication strategy to show that a long position in a risky Treasury security paying a continuous coupon of c combined with the purchase of CDS protection at a cost of s has the same cash flows as a risk-free bond with a coupon of $c - s$.

[8]The Appendix provides full details about the data. The Internet Appendix describes the algorithms and methodology used in this paper to estimate Treasury convenience premia.

[**Insert Table I here**]

One interesting feature of the replication strategy is that the maturity of the risk-free bond is actually stochastic. This is because the par amount of the bond is paid at the time of default of the Treasury security, or at its final maturity, whichever is earliest. While this may seem surprising at first, the same is true for any defaultable bond. For example, the final cash flow received from a defaulted corporate bond often occurs at the resolution of the bankruptcy process which can be much earlier than the stated maturity date of the debt.

To take the stochastic maturity into account, we assume a standard reduced-form Duffie and Singleton (1999) framework in which default is triggered by the first jump of a Poisson process with constant intensity λ. From the properties of the Poisson process, the probability of no default prior to time T is $e^{-\lambda T}$. Furthermore, the density of the default time τ is $\lambda e^{-\lambda\tau}$. Conditional on default occurring at time $\tau < T$, the present value of the risk-free bond is given by

$$(c-s)\int_0^\tau D(t)\ dt + D(\tau), \tag{1}$$

where $D(t)$ is the risk-free present value factor for one dollar to be paid at time t. Integrating over all default times gives

$$\begin{aligned} R(c-s,\lambda,T) = & \int_0^T \lambda\ e^{-\lambda\tau}\left((c-s)\int_0^\tau D(t)\ dt + D(\tau)\right)\ d\tau \\ & +\ e^{-\lambda T}\left((c-s)\int_0^T D(t)\ dt + D(T)\right), \end{aligned} \tag{2}$$

where $R(c-s,\lambda,T)$ denotes the present value of a risk-free bond with coupon rate $c-s$, early maturity triggered with intensity λ, and final maturity T.

As mentioned above, a portfolio consisting of a Treasury bond with coupon c and the purchase of CDS protection with a spread s has the same cash flows as a risk-free bond with a coupon rate of $c - s$. Thus, a simple no-arbitrage argument implies that the two positions should have the same price. Since the initial value of the CDS contract is zero, this also implies that the following equality should hold,

$$P(c, T) = R(c - s, \lambda, T). \tag{3}$$

If the Treasury bond is rich or cheap, however, then the market price of the Treasury $P(c, T)$ will differ from its intrinsic fair value $R(c - s, \lambda, T)$. Thus, we can directly measure the richness of a Treasury security as the difference between $P(c, T)$ and $R(c - s, \lambda, T)$. If there is a positive difference, the Treasury security is rich, and vice versa.

To define the convenience premium $PREM$, let $YTM(P(c, T))$ denote the standard yield to maturity of the Treasury bond. Similarly, let $YTM(R(c - s, \lambda, T))$ denote the yield to maturity of the risk-free bond. The convenience premium can now be defined as the difference in the yields to maturity of the two bonds,

$$PREM = YTM(R(c - s, \lambda, T)) - YTM(P(c, T)). \tag{4}$$

Note that a positive convenience premium means that the Treasury bond has a higher market price (lower yield to maturity) relative to the risk-free bond.

We acknowledge that our approach to identifying Treasury richness requires several assumptions. First, we assume that the cash flows associated with the CDS contract are unaffected in the event that the protection seller defaults. This assumption, however, is minor since full bilateral collateralization of CDS liabilities is standard industry practice. Second, we assume that the market CDS spread is unaffected by the potential default risk of protection sellers. As shown by Arora, Gandhi, and Longstaff (2012), this assumption is also a modest one since counterparty credit risk has little effect on market CDS spreads.[9]

III. The Risk-Free Discounting Curve

We describe next how a risk-free discounting curve can be obtained from the term structure of fixed-for-floating interest rate swaps in which the floating leg of the swap is tied to the overnight repo rate. Using the overnight repo rate allows the resulting discounting curve to be independent of credit risk since the overnight repo rate can be viewed as a risk-free rate. Furthermore, repo swaps and repo loans are purely financial contracts rather than securities and, therefore, the repo OIS discounting curve is less likely to be affected by the various supply, liquidity, or intermediary balance sheet cost factors that may drive the specialness of cash market instruments such as Treasuries.[10]

A. The Overnight Repo Rate

In this approach, we take the position that the overnight repo rate can be viewed as a risk-free rate in the most basic sense of the term. There are a number of reasons for this. First, overnight general collateral Treasury repo loans are fully secured by the highest-quality and most-liquid collateral in the market—Treasury securities. Second, repo loans are not only fully secured, but are actually overcollateralized since repo borrowers face haircuts and cannot borrow the full value of the Treasuries they provide as collateral.

[9]Boyarchenko and Shachar (2020) argue that recent declines in market liquidity may have reduced the information content of Treasury CDS spreads. We provide a detailed review of the liquidity of the Treasury CDS market in Section IA.II of the Internet Appendix. Our results suggest that the Treasury CDS market remains an active venue for price discovery, particularly when trade compression activity is taken into account.

[10]For a discussion of this facet of financial/derivative contracts, see Longstaff, Mithal, and Neis (2005), He, Nagel, and Song (2022), and Du, Hébert, and Li (2023).

This haircut or margin requirement provides an additional layer of safety to the repo lender (Gorton and Metrick (2012), Krishnamurthy, Nagel, and Orlov (2014)). Finally, the risk-free nature of collateralized repo contracts has long been recognized in the finance literature. Key examples include Longstaff (2000), Nagel (2016), Du, Im, and Schreger (2018), Klingler and Sundaresan (2020), Infante (2020), and He, Nagel, and Song (2022).

Given the central role that short-term repo loans play as financing vehicles in the financial markets, it is important to consider whether the overnight repo rate might itself include a convenience component. If so, then this convenience component would propagate to the fixed leg of fixed-for-floating swaps tied to the overnight repo rate and, in turn, impact the entire term structure of swap rates.[11] To explore this, we examine whether there is evidence that overnight repo rates are "special" relative to other longer-term repo rates. First, we note that Longstaff (2000) compares the overnight repo rate to term repo rates with tenors of up to three months over the 1991–1999 sample period. He finds that the average compounded overnight rate is statistically indistinguishable from the term repo rates, implying that the expectations hypothesis holds in the repo market. Second, we conduct an analysis similar to Longstaff (2000) using overnight and term repo rates for our 1997–2022 sample period and again find that the average overnight repo rate is very close to average term repo rates. For example, the annualized average overnight, one-week, two-week, and three-week repo rates over our sample period are 2.0396, 2.0480, 2.0513, and 2.0565 percent, respectively.

B. Repo Overnight Index Swaps

To identify the risk-free discounting curve, we use the term structure of fixed-for-floating interest rate swap rates in which the floating rate is the overnight repo rate. Since repo OIS may be less familiar than conventional swaps, we begin with a brief introduction to

[11] We are grateful to the referee for raising this point.

this market and then describe how the data set of repo OIS rates is constructed.

A repo OIS is a specific type of a swap known as an overnight index swap. In a standard fixed-for-floating OIS, the counterparties agree to exchange floating rate cash flows based on a geometrically compounded overnight index rate (such as the effective overnight fed funds rate (EFFR)) for fixed cash flows over the life of the swap. A repo OIS is a swap in which the floating index rate is the overnight repo rate. As discussed earlier, we use repo OIS rather than EFFR OIS since the secured repo rate is more directly interpretable as a riskless rate than the unsecured effective fed funds rate.

Repo OIS with maturities of less than one year pay a single cash flow on the fixed leg and the floating leg at maturity. For longer-dated swaps, both the fixed and floating legs have annual cash flows. The day-count convention for repo OIS is actual/360. To illustrate, consider a one-year repo OIS with a notional amount of \$100 and a quoted swap rate of 1.200 percent. In one year (365 days), the fixed rate payer pays $1.200 \times 365/360 = 1.21667$ and receives the compounded overnight repo rate for 365 days.[12]

The current repo OIS market is based primarily on a specific overnight repo rate known as the Secured Overnight Financing Rate (SOFR). SOFR measures the cost of borrowing cash in the repo market via overnight loans collateralized by U.S. Treasury securities. Specifically, SOFR is calculated using a broad basket of transactions from three segments of the \$800 billion overnight Treasury repo market. First, Fixed Income Clearing Corporation (FICC) member banks trade general Treasury collateral repos which are cleared through the FICC's General Collateral Finance (GCF) repo service. Second, FICC members trade repos for specific Treasury securities in the FICC Delivery-versus-Payment (DvP) repo market. Third, in the tri-party repo market, security dealers trade repos with

[12]The repo rate for the last day of the compounding period is not known prior to the morning of the expiration day. Hence, the market convention is to use a fixing lag of one day and the final payment occurs with a lag of two days. EFFR OIS use the same convention.

the Bank of New York Mellon acting as the clearing agent. SOFR is calculated each day as the volume-weighted median of overnight repo rates on transactions in the GCF, FICC DvP, and tri-party repo markets.[13] The Federal Reserve Bank of New York, in cooperation with the Office of Financial Research (OFR), provides SOFR rates going back to August 2014. The Alternative Reference Rates Committee (ARRC) has selected SOFR to become the new benchmark interest rate to replace U.S. Libor.[14] SOFR swaps are actively traded in financial markets, either as basis swaps or fixed-for-floating swaps. The total notional amount of SOFR swaps is estimated to be nearly $30 trillion as of March 2023.[15]

Since SOFR is a relatively new index, actual market SOFR OIS rate data are only available beginning in 2017. It is straightforward, however, to extend the repo swap data set backward by making minor adjustments to EFFR OIS rates which are available/computable throughout the entire sample period. To describe how this is done, we first need to introduce some formal notation. Let F denote the repo OIS rate for a given maturity T. Similarly, let FF denote the rate for an EFFR OIS.

To infer values for the repo swap rates for the 1997–2016 period, we adjust the EFFR OIS rates downward by a small spread ϕ, giving

[13]The repo rates from all three segments of the repo market are used to calculate SOFR, with the exception of FICC DvP trades with rates falling below the 25th percentile of all FICC DvP data for a given day. The reason for this is that these repos are considered to be "special" and are hence excluded from the calculations.

[14]The Alternative Reference Rates Committee is a group of private-market participants convened by the Federal Reserve Board and the New York Federal Reserve Bank to assist in the transition from U.S. Libor. See https://www.newyorkfed.org/arcc.

[15]See Figure 3 in https://www.newyorkfed.org/medialibrary/Microsites/arrc/files/2023/ARRC-Readout-April-2023-Meeting.pdf.

$$F = FF - \phi. \tag{5}$$

The spread ϕ is a reflection of the fact that repo OIS rates tend to be lower than EFFR OIS rates. Intuitively, this is because secured overnight repo rates tend to be lower on average than the unsecured EFFR rate. One way to parameterize the spread ϕ might be to use its observed value during the 2017–2022 period when both SOFR and EFFR OIS rates are available. In particular, the average spread between long-term EFFR and SOFR OIS rates during the 2017–2022 period is 3.77 basis points.[16] Given the many changes in the repo market during the post-crisis period, however, it is also important to consider the stability of the relation between EFFR and repo rates over time. Fortunately, the relation between these two rates appears to be very stable throughout the entire sample period. Specifically, the average spread between the EFFR and overnight repo rates is 2.76 basis points during the 1997–2016 period, which is comparable to the average value of 0.36 basis points during the 2017–2022 period. In light of this, it is reasonable to expect that the spread ϕ between the EFFR and repo OIS rates would likewise be stable over time. This suggests an approach of either using the average spread of 3.77 basis points observed during the 2017–2022 period as the estimate of ϕ, or adjusting for the difference in the spreads between the EFFR and repo OIS rates across the two periods to give a value of 3.77 + (2.76 - 0.36) = 6.17 basis points. To keep things simple, we will basically just split the difference and use a value of 4.50 basis points for ϕ.[17] The Internet Appendix shows

[16]The averages for other tenors are very similar.

[17]As another robustness check, we note that the Bloomberg system also provides an indicative set of SOFR OIS rates for the 2007–2016 period. These rates imply an average spread between long-term EFFR and SOFR OIS rates of 4.81 basis points. We acknowledge, however, that very few of these indicative SOFR OIS rates are likely to be based on actual market quotes or transactions.

that the results are very robust to small perturbations in the value of ϕ.[18]

We obtain the term structure of EFFR OIS rates FF from the Bloomberg system. For some early portions of the sample period, Bloomberg quotes EFFR OIS in terms of the EFFR/Libor basis swap spread rather than as a rate. Let FL denote the rate for a standard fixed vs. three-month Libor interest rate swap, and FB the rate for a basis swap exchanging EFFR for three-month Libor. The corresponding EFFR OIS rate FF, however, follows immediately from the identity

$$FF = FL - FB. \tag{6}$$

The reason for this is simply that the cash flows for an EFFR OIS are the same as those from a standard fixed vs. three-month Libor interest rate swap combined with a basis swap exchanging EFFR for three-month Libor.[19] We use this identity to compute the EFFR OIS rates for the relatively small subset of cases where EFFR OIS are quoted in terms of the basis swap spread.

Given this parameterization, we can now use Equation 5 to solve for the repo OIS rates. This process results in a data set of daily observations of the repo OIS rate F for 1-, 3-, and 6-month, and 1-, 2-, 3-, 5-, 7-, 10-, 15-, 20-, and 30-year maturities for the period from January 23, 1997 to December 16, 2022. Sections IA.I.D and IA.I.E of the Internet Appendix provide summary statistics for the repo OIS rates and describe how the discounting curve can be bootstrapped from these rates.

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[18] We acknowledge that because of the small value of ϕ, our estimates of the convenience premia are likely to be very similar to those that would be obtained by simply using the EFFR OIS curve directly to specify the risk-free discounting curve. We are grateful to the referee for this observation.

[19] This is shown in Section IA.I.C of the Internet Appendix.

IV. Treasury Convenience Premia

Using the discounting curve, we can now estimate the convenience premium for individual Treasury bills, notes, and bonds across the entire maturity spectrum. As shown in the Appendix, the sample consists of all Treasury securities (with maturities in excess of one month) for the period from January 23, 1997 to December 16, 2022. We begin with an introductory look at the key time-series and cross-sectional properties of the premia.

A. The Convenience Premia

Table II reports summary statistics for the convenience premia by tenor (original maturity of the security) and by maturity categories. As shown, there are significant premia incorporated into the prices of many Treasury securities. The average premium taken across all observations is 8.21 basis points, indicating that Treasuries are rich on average.

[**Insert Table II here**]

The results indicate, however, that there are significant differences in the average premium across tenors and maturity categories. For example, the average premium for Treasury bills is 24.51 basis points. In contrast, the average premium for 30-year Treasury bonds is -2.12 basis points. Similarly, the average premium for Treasury securities with maturities of less than one year is 17.22 basis points, while the average for Treasury bonds with maturities between 20 and 30 years is -10.06 basis points.

To provide a visual perspective, Figure 1 graphs the time series of the average premium for each tenor by maturity category. Figure 2 graphs the time series of the average premium for each maturity category by tenor. The graphs confirm that the premia for most tenors and maturity categories tend to be positive on average. This is particularly true during the earlier part of the sample period. These graphs also confirm that the patterns of richness and cheapness differ markedly across tenors and maturity categories.

[**Insert Figure 1 here**]

[**Insert Figure 2 here**]

Figures 1 and 2 also show that the average premium varies significantly over time. In particular, the average premium for some tenors and maturity categories displays a range of well over 100 basis points. The highest values of the premia tend to occur during the early 2000s, as well as during the financial crisis following the Lehman bankruptcy in 2008. The lowest values of the premia tend to occur during the latter part of the sample period.

Our estimates of Treasury convenience premia are smaller than many of those previously reported in the literature. For example, Feldhütter and Lando (2008) report an average premium of roughly 50 basis points for the 1996–2005 period. Krishnamurthy and Vissing-Jørgensen (2012) measure the convenience premium relative to Aaa-rated corporate bond yields and report an average value of 73 basis points over the 1926–2008 period. van Binsbergen, Diamond, and Grotteria (2022) show that the Krishnamurthy and Vissing-Jørgensen (2012) measure of the convenience premium ranges from about 100 to 140 basis points during the post-crisis period. Del Negro, Eggertsson, Ferrero, and Kiyotaki (2017) calibrate a DSGE model and report convenience premia that average roughly 125 basis points over the 2004–2014 period. Greenwood, Hanson, and Stein (2015) report that the average premium in one-month Treasury bills is about 40 basis points over the 1983–2009 period. Van Binsbergen, Diamond, and Grotteria (2022) and Diamond and Van Tassel (2023) estimate the convenience premium in shorter-term Treasuries using index option prices and report average values of 40 and 35 basis points over the 2004–2018 and 2004–2020 periods, respectively. Joslin, Li, and Song (2021) estimate the average premium to be on the order of 65 basis points over the 2002–2019 period. Longstaff, Mithal, and Neis (2005) report that the average nondefault component of corporate bond spreads relative to Treasuries is about 65 basis points over the 2001–2002 period. A careful reading of the literature suggests that much of the variation in estimates across studies may simply be due to differences in the relative credit risk and liquidity of the benchmarks used in estimating convenience premia.

On the other hand, our estimates of Treasury convenience premia are consistent with other estimates that have appeared in the literature. Longstaff (2004) measures convenience premia relative to guaranteed Agency bonds and reports averages ranging from about 10 to 16 basis points for the 1991–2001 period. Nagel (2016) measures the premium in three-month Treasury bills relative to the three-month repo rate and reports an average value of 24 basis points for the 1991–2011 period. Du, Im, and Schreger (2018) measure the premium relative to other sovereign bonds and report an average value of 10 basis points for 10-year Treasuries. Lewis, Longstaff, and Petrasek (2021) measure the premium relative to guaranteed corporate bonds and report an average value of 20 basis points for the 2008–2012 period. A common feature of these studies is that they attempt to measure convenience premia relative to a benchmark with a level of credit risk similar to that of Treasuries.

B. Negative Premia

One of the most-striking aspects of the convenience premia is that they are not uniformly positive. Figures 1 and 2 show that negative premia occur frequently and can persist for extended periods of time. This is true across all tenors and maturity categories. For example, the graphs indicate that the average premium for Treasury bills is often negative during the 2002–2004 and post-financial-crisis periods. Similarly, the average premium for many Treasury notes and bonds is negative in early 1997, during the 2002–2004 period, during the 2008–2012 post-financial-crisis period, and throughout most of the 2015–2022 period. These results are important since they indicate that negative premia occurred much earlier than the 2008 financial crisis and, therefore, cannot be due solely to post-financial-crisis capital regulation. These results confirm and extend those of He, Nagel, and Song (2022) and Klingler and Sundaresan (2020) who report evidence of negative convenience premia in short-term Treasury bills during the post-financial-crisis and/or Covid-19 crisis periods.

Figures 1 and 2 also show that the negative premia can be very large in magnitude. In particular, the average premium for many maturity categories attains negative values as low as -25 to -50 basis points. These values are very significant from an economic perspective. For example, these values indicate that some of the longer-term Treasury bonds in the sample have traded at prices ten percent or more below their intrinsic value.

As another way of demonstrating that negative premia occur frequently throughout the entire sample period, Table III provides summary statistics for the percentage of negative convenience premium estimates during the sample period by tenor and maturity category. The table also reports the percentage of months for which there is at least one negative convenience premium estimate. As shown, 36.86 percent of all convenience premia estimates are negative. Furthermore, negative convenience premia occur for all tenors and maturity categories. For example, 4.53 percent of the convenience premia for Treasury bills are negative, while 53.22 percent of the convenience premia for 30-year Treasury bonds are negative. More than 70.83 percent of the months in the sample period have at least one Treasury security with a negative convenience premium.

[**Insert Table III here**]

Figure 3 plots the time series of the percentage of negative premia by tenor. Figure 4 plots the percentage of negative premia by maturity category. As illustrated, negative convenience premia occur repeatedly throughout the sample period for all tenors and maturity categories. Furthermore, there are many instances when the fraction of negative convenience premia for a specific tenor or maturity category is 90 percent or more. Figures 3 and 4 also illustrate that the persistence of negative premia varies over time. During the first part of the sample period, episodes characterized by many instances of negative premia tend to persist for roughly one or two years. In contrast, these episodes become much more persistent beginning in 2015.

[**Insert Figure 3 here**]

[**Insert Figure 4 here**]

There is an extensive recent literature documenting that longer-term swap spreads have become negative since the financial crisis. This is true whether swap spreads are measured relative to the Libor swap curve or OIS curve. Key examples include Boyarchenko, Gupta, Steele, and Yen (2018), Klingler and Sundaresan (2019), Jermann (2020), Du, Hébert, and Li (2023), and Hanson, Malkhozov, and Venter (2022). Given this, it is natural to ask whether our results about negative premia simply echo well-known results in the negative-swap-spread literature.

While swap spreads and convenience premia are related, it is important to recognize that they are not the same. The reason for this is that swap spreads include the Treasury credit spread as a component, while robust measures of convenience premia do not. This is emphasized in an important recent paper by Augustin, Chernov, Schmid, and Song (2021) who find that Treasury credit risk may be of first-order importance in explaining the puzzling patterns of negative long-term swap spreads observed in the markets.[20] Treasury credit risk can drive a substantial wedge between swap spreads and estimated convenience premia. To illustrate, imagine that the 30-year overnight index swap rate is 4.00 percent and that the 30-year Treasury rate is 4.10 percent. This implies a negative swap spread of −10 basis points. Now imagine that the Treasury CDS spread is 30 basis points. Following

[20] Augustin, Chernov, Schmid, and Song (2021) show that Treasury CDS spreads vary widely during the post-crisis period. Thus, much of the variation in swap spreads may be a reflection of time varying Treasury credit risk, potentially impacting the interpretation of the empirical results in the swap spread literature. We are grateful to the Associate Editor for this insight.

Augustin, Chernov, Schmid, and Song (2021), this implies that the credit-adjusted Treasury yield is 3.80 percent, which, in turn, implies a positive convenience premium of 20 basis points. This example shows that swap spreads and convenience premia are separate concepts with different economic interpretations.[21] Furthermore, this example shows that the existence of a negative swap spread does not necessarily imply that the convenience premium is also negative. Thus, the results about negative convenience premia in this section represent new findings and are not simply implications of previous results in the negative-swap-spread literature.

We note that some of the earlier swap spread literature does attempt to control for the difference in credit risk between Treasuries and swaps as part of the process of estimating the convenience component of swap spreads. Examples include Liu, Longstaff, and Mandell (2006) and Feldhütter and Lando (2008). Our results harmonize with Liu, Longstaff, and Mandell (2006) who find that the latent convenience factor incorporated into swap spreads was negative during the 1992–1998 period. Similarly, Feldhütter and Lando (2008) find that the convenience component in swap spreads attains a value of roughly 80 basis points during the 2000–2001 period. Our results confirm and extend their findings.

C. The Factor Structure of the Premia

The time-series plots in Figure 1 also suggest that there could be a fair degree of commonality in convenience premia across tenors and maturity categories. To explore this, we conduct a simple principal components analysis using the correlation matrix of

[21]To provide a more specific example showing that swap spreads and convenience premia are not the same, we observe that the average 30-year swap spread and convenience premium for 30-year Treasuries (based on the repo OIS curve) over the 2015–2022 period are −60.47 and −38.90 basis points, respectively. Furthermore, the correlation of monthly changes in the 30-year swap spreads and convenience premia is only 59.13 percent.

monthly changes in the average premia. Section IA.III of the Internet Appendix provides summary statistics for the results.

The results indicate that there is a significant amount of commonality in the dynamic behavior of premia across tenors and maturity categories. The first principal component explains 61.49 percent of the variation in the average premium across tenors, and 65.93 percent of the variation in the average premium across maturity categories. The first principal component is essentially a parallel shift in the level of the average premia.

The results also indicate, however, that there are multiple sources of variation in the average premium and that they do not move in complete lockstep. The second and third principal components explain an additional 19.26 and 9.45 percent of the variation in the average premium across tenors, and an additional 15.17 and 9.42 percent of the variation in the average premium across maturity categories. The second principal component can be viewed as a slope factor across the various tenors or the maturity categories. The third principal component appears to be a contrast between intermediate tenors or maturity categories and the other tenors or maturity categories. Taken together, these results imply a rich multi-factor structure to the underlying nature of Treasury convenience premia and suggest that Treasury richness is unlikely to be fully explained by any single factor.

Finally, these results are consistent with Krishnamurthy and Vissing-Jørgensen (2012) who present a model in which the safety attributes of short-term and long-term Treasuries may differ. An implication of their model is that convenience premia may behave differently across the term structure.

D. The Term Structure of the Premia

Turning now to the term structure of convenience premia, we note that the term structure can take on a wide variety of complex shapes. Figure 5 plots the premia for all Treasury bills, notes, and bonds for selected dates during the sample period. As shown, the shape of the term structure ranges from being essentially monotone increasing, monotone decreasing, nearly flat, humped, or even multimodal at times. Furthermore, the term structure can often be a complex blend of these patterns across different parts of the curve.

[**Insert Figure 5 here**]

To provide a broad overview of the general shape of the term structure throughout the sample period, we use a simple cross-sectional regression approach. Let $PREM_{i,t}$ and $MATURITY_{i,t}$ denote the premium and maturity for Treasury security i for month t, respectively. For each month t, we estimate the following cross-sectional regression

$$PREM_{i,t} \;=\; \alpha_t \;+\; \beta_t \; MATURITY_{i,t} \;+\; \epsilon_{i,t}, \tag{7}$$

where α_t and β_t are the regression intercept and slope coefficient for month t, and $\epsilon_{i,t}$ is the residual for security i for month t. We acknowledge, of course, that the linear relation imposed by this regression specification likely oversimplifies the actual relation between the premia and maturity. This approach, however, has the advantage of providing us some intuition about the basic nature and evolution of the term structure of premia over the course of the sample period.

Figure 6 plots the basic regression results. The upper panel shows the time series of intercepts α_t from the cross-sectional regressions. Note that the intercept can be interpreted as the implied convenience premium for a Treasury security with a maturity that is essentially zero (say, one or two days). As shown, the intercepts are generally positive during the first part of the sample period, ranging from zero to roughly 70 basis points. Beginning in 2015, however, the intercepts become negative more frequently. The average value of the intercepts is 16.66 basis points which is comparable to the average premium for the ≤ 1 year maturity category reported in Table II.

[**Insert Figure 6 here**]

The middle panel in Figure 6 shows the time series of slope coefficients β_t for the maturity of the Treasury securities. As illustrated, most of the slope coefficients are negative. In particular, 267 (or 85.58 percent) of the 312 monthly slope coefficients are negative in sign. The average slope coefficient is -0.7567 As is the case for the intercepts, the pattern of slope coefficient changes in 2015 when they begin to be consistently more negative.

The lower panel in Figure 6 plots the R^2s from the regressions. As shown, the R^2s average less than 20 percent during the earlier part of the sample. Once again, however, the pattern of the R^2s changes markedly beginning in 2015. During this latter part of the sample period, the R^2s increase significantly and are consistently in the range of about 60 to 100 percent. This dramatic increase in the R^2s raises a strong possibility of a regime shift in the nature of convenience premia beginning in 2015 in which they become much more closely linked to the maturity of the Treasury securities.

Finally, to give additional perspective on the various shapes that the term structure can display, we examine where the maximum, minimum, and median values on the term structure tend to occur. Table IV reports the frequency distribution of how often the cheapest, median, and richest Treasury securities are within the indicated tenor and maturity categories. As shown, Treasury bills tend to be the richest securities, while 30-year Treasury bonds tend to be the cheapest. The richest security is a Treasury bill 59.29 percent of the time, and the cheapest security is a 30-year Treasury bond 54.49 percent of the time. Interestingly, the shortest-maturity category is the richest part of the term structure 66.99 percent of the time, but also the cheapest part of the term structure 39.74 percent of the time. In contrast, the 20–30 year maturity category is the richest only 3.53 percent of the time, but the cheapest 40.06 percent of the time.

[**Insert Table IV here**]

V. Are On-The-Run Treasuries the Richest?

There is a broad literature suggesting that on-the-run Treasuries are particularly rich relative to other Treasuries. In this section, we look at this issue through the lens of the convenience premium estimates.

A. *The On-The-Run Effect*

Krishnamurthy (2002) shows that on-the-run (the most-recently-auctioned) Treasuries tend to trade rich relative to older Treasuries with the same tenor. The on-the-run spread is often viewed as a proxy for market liquidity.[22]

To examine the on-the-run effect, Figure 7 graphs the time series of the on-the-run spread for individual tenors, where the on-the-run spread is the difference between the convenience premium of the current on-the-run Treasury and that of the first off-the-run (the previous on-the-run) Treasury. Using the premium rather than the yield in this analysis has the advantage of controlling for term structure effects. For example, if the term structure is upward sloping, then part of the spread between, say, the yields of an on-the-run 5-year bond and an off-the-run 4.75 year bond could be due to the slope of the term structure. In contrast, the premium is measured relative to a benchmark with a matching maturity.

[**Insert Figure 7 here**]

The most-striking aspect shown in Figure 7 is that the on-the-run spread has all but disappeared since the financial crisis of 2008. As illustrated, there was a substantial on-the-run spread for all tenors during the early part of the sample period. This on-the-run spread was often as large as ten basis point, particularly during the 2000–2004 period.

[22]For example, see Vayanos and Weill (2008), Banerjee and Graveline (2013), and Hu, Pan, and Wang (2013).

These values are consistent with Krishnamurthy (2002) and Pasquariello and Vega (2009). After the financial crisis, however, the on-the-run spreads decline precipitously and remain near zero for almost all tenors throughout the rest of the sample period.

To show this more formally, Panel A of Table V presents summary statistics for the on-the-run spreads for the 1997–2007 and 2008–2022 subperiods. The average on-the-run spreads for the pre-crisis subperiod range from roughly two to seven basis points and are highly significant. In contrast, the average on-the-run spreads for the post-crisis subperiod are all much smaller in magnitude and typically only a small fraction of a basis point.

[**Insert Table V here**]

B. The Cross-The-Run Effect

If there is a unique premium associated with being the most-recently-auctioned Treasury security, then we may observe not only the on-the-run effect discussed above, but also cross-the-run effects in which the current on-the-run Treasury is richer than other Treasuries with a similar maturity. If so, then we might for example expect to find that the current 5-year on-the-run Treasury note was richer than the seasoned 7-year, 10-year, 20-year, and 30-year Treasuries with a remaining maturity of 5 years.

To test this implication, Panel B of Table V provides summary statistics for the cross-the-run spreads between the premium for the current on-the-run Treasury and that of other Treasuries with essentially the same maturity. Specifically, we report the average spread between the premium of the current on-the-run Treasury with a maturity of N years and the premia for all other Treasuries with a maturity in the range of $[N - 0.10, N + 0.10]$.

As shown, the on-the-run Treasury is significantly richer than older Treasuries with similar maturities during the pre-crisis period. On average, the on-the-run Treasury is richer by one to six basis points. These values are highly significant. In contrast, there is little evidence that the on-the-run Treasury is richer than older Treasuries with similar maturities during the post-crisis period. In fact, the on-the-run Treasury tends to be cheaper on average than the older bonds, with the exception of the ten-year tenor.

VI. Are Premia Related to Money-Like Features?

In this section, we explore whether the convenience premia are related to the near-money nature of Treasury securities. In doing this, we will focus primarily on short-term Treasuries eligible to be held by money market funds since these funds provide investors with a liquid near-money alternative to holding cash balances. If investors value the near-money nature of money market funds, their preferences may be reflected in the prices funds are willing to pay for securities that allow them to provide this liquidity.

A. Maturity Constraints

Our approach to identifying the relation between premia and the near-money characteristics of short-term Treasuries is based on the empirical implications of the maturity constraints faced by money market funds. SEC Rule 2a-f of the 1940 Investment Company Act places a number of strict maturity limitations on the portfolios that money market funds can hold. These limitations have the net effect of making some short-term Treasury securities more money-like than others. First, SEC Rule 2a-f places an upper limit of 397 days on the maturity of Treasury securities that are eligible to be held by a money market fund. Second, Rule 2a-f places a upper limit on the weighted average maturity of a money market fund's portfolio. Prior to June 30, 2010, this limit was 90 days. After June 30, 2010, however, the limit was reduced to 60 days.

If investors value the near-money characteristics of money market funds, then these maturity restrictions should have direct empirical implications for the richness of the short-term Treasury securities these funds hold. In particular, we would expect that Treasuries that satisfy the 397-day eligibility constraint might be richer than those that do not. Because of the weighted average maturity constraint, however, there could be cross-sectional differences in richness even across eligible Treasuries. To illustrate this, consider the case where a money market fund can invest in either a 30-day Treasury, or a 397-day Treasury. Under Rule 2a-f, both securities are eligible to be held by the money market fund. If the fund chooses the 397-day Treasury, however, the fund finds itself much more constrained in terms of the maturity of the remainder of its portfolio than if it had chosen the 30-day Treasury instead. Intuitively, this suggests that there might be a direct linear relation between the richness of eligible Treasuries and their maturity as a simple mechanical consequence of their marginal effect on the weighted average maturity of the portfolio.

B. The Premia for Money-Market-Fund-Eligible Treasuries

To provide perspective on the convenience premia for short-term Treasury securities eligible to be held by money market funds, Figure 8 plots the average premia for monthly maturity categories ranging from 2 months to 24 months. Recall that Treasuries with a maturity of roughly 13 months (397 days) are eligible to be held by money market funds, while those with a longer maturity are not. The upper graph shows the averages taken across all Treasuries; the lower graph shows the averages taken across just Treasury notes and bonds.

[**Insert Figure 8 here**]

The graphs shown in Figure 8 reveal a number of striking patterns. First, the average premium for Treasuries eligible to be held by money market funds are substantially higher than those for other short-term Treasuries (at least out to a two-year horizon). Second, the graphs illustrate that short-term Treasuries begin to richen almost as soon as they cross the eligibility threshold at about 13 months. Furthermore, the differences in means across maturity categories are both economically and statistically significant. For example, the average premium for the 2-month category shown in the upper graph in Figure 8 is 29.29 basis points, which is 22.61 basis points higher than the average premium of 6.68 basis points for the 13-month category. The t-statistic for the difference in means is 27.08. The difference in means is economically very significant relative to the average size of convenience premia in general. Similar results hold for the other maturity categories relative to the 13-month category with the t-statistics for the differences in means ranging from 2.80 to 26.30. Finally, the graphs show that the average premium for the eligible Treasuries is almost a linear function of their maturity. In stark contrast, there is little evidence of a similar pattern in the average premium for ineligible Treasuries.

Taken together, these results support the view that the near-money nature of short-term Treasuries may account for a large portion of their convenience premia. In particular, the results provide evidence that the convenience premia are directly related to the maturity restrictions imposed on money market funds in the way expected. In turn, this implies a connection between the premia and the unique near-money services that money market funds provide to investors.

C. The Change in the Weighted-Average-Maturity Rule

To explore the link between the convenience premia and the maturity restrictions imposed on money market funds in more depth, we make use of a natural experiment. As discussed above, SEC Rule 2a-f requires that the weighted average maturity of a money market fund be less than or equal to 90 days during the first part of the sample period. However, because of general concerns about the risk of money market funds "breaking the buck," this limit was reduced to 60 days as of June 30, 2010.

This exogenous change in the weighted-average-maturity requirement provides us with a natural experiment for testing whether the premia are actually related to their potential inclusion in money market fund portfolios. Specifically, if the linear relation between the average premia and maturity shown in Figure 8 is an artifact of having to satisfy the weighted-average-maturity restriction, we would expect the linear relation to become steeper and more pronounced after June 30, 2010.

To test this, we compare the slope of the linear relation during the first six months of 2010 with the slope during the second six months. Specifically, we collect the month-end premia for all money-market-fund-eligible Treasury securities for the year 2010. We then construct an indicator variable I_t that takes a value of zero during the first six months of 2010, and a value of one during the last six months. We estimate the following regression

$$PREM_{i,t} \;=\; FE_t \;+\; \beta\; MATURITY_{i,t} \;+\; \gamma\; MATURITY_{i,t} \;\times\; I_t \;+\; \epsilon_{i,t}, \tag{8}$$

where $PREM_{i,t}$ denotes the premium for security i for month t, $MATURITY_{i,t}$ denotes the maturity of security i for month t, and $MATURITY_{i,t} \times I_t$ denotes the interaction of the maturity of the security and the indicator variable. The terms β and γ denote the regression coefficients, and FE_t denotes monthly fixed effects.

Table VI reports the regression results. As shown, there is a significant change in the slope of the relation between premia and maturity after June 30, 2010. In particular, the slope becomes much more negative. This is exactly what we would expect since, for example, taking a position in a one-year Treasury security would make it more difficult to satisfy the weighted-average-maturity limit after June 30, 2010, than before. The significant decline in the slope of the premium/maturity relation after the SEC rule change provides evidence of the link between premia and money-market-fund characteristics. Furthermore, the results suggest that the SEC rule change also had an economically significant effect. In particular, the coefficient for the interaction term implies that one-month Treasuries become about 7.90 basis points richer relative to one-year Treasuries following the rule change. Finally, Figure 6 shows that the relation remains very stable over the subsequent five years following the SEC rule change. This supports the view that the change in the weighted-average-maturity rule may have had long-term effects on the institutional demand for shorter-term Treasuries which, in turn, impacted their convenience premia.

[**Insert Table VI here**]

VII. Are Premia Related to Liquidity?

There is an extensive literature focusing on how security-specific liquidity or illiquidity may impact the value of a security. In this section, we examine whether the convenience premia are related to security-specific liquidity factors.

A. Age

The age (time since issuance) of a Treasury security is often used as a proxy for the liquidity of the security in empirical studies. Generally, older Treasuries are considered to be less liquid than newer Treasuries. To examine the connection between convenience premia and the age of the Treasury security, Figure 9 graphs the median premium by remaining maturity for the two-year, three-year, five-year, and ten-year tenors.

[**Insert Figure 9 here**]

As shown, there is no uniform pattern to the relation between the age of a Treasury security and its convenience premium. For example, two-year Treasury notes tend to cheapen as they age, at least during the first year of their life. By contrast, there are a number of instances where Treasuries actually become richer as they age. In particular, the five-year Treasury note initially tends to cheapen after issuance, but then begins to richen after about one year. Similarly, the ten-year Treasury note begins to richen about two years after issuance. These patterns imply that the relation between the age and convenience premia of Treasuries is more complex than previously documented.

B. *Maturity Thresholds*

One intriguing aspect of the premia shown in Figure 9, however, is that some of the term structures appear to have slight discontinuities at specific integer maturities such as two, five, and seven years. We note that this is not a composition effect since the various tenors shown in Figure 9 are essentially continuously present in data throughout the sample period.

To examine this maturity-related pattern more formally, we regress the change in the premium on a set of indicator variables for whether the maturity of the security is near a specific threshold such as two, three, five, and seven years. The regression specification is

$$\Delta PREM_{i,t} \ = \ \alpha \ + \ \sum_j \beta_j \ I_{i,t,j} \ + \ \gamma \ MATURITY_{i,t} \ + \ \epsilon_{i,t}, \tag{9}$$

where $\Delta PREM_{i,t}$ denotes the change in the month-end convenience premium for bond i, $I_{i,t,j}$ is an indicator variable that takes value one if the maturity for bond i at the beginning of the month is within 0.15 years of maturity threshold j, and zero otherwise, and j takes on the values of the set {2-Year, 3-Year, 4-Year, 5-Year, 6-Year, 7-Year, 8-Year, 9-Year, 10-Year}. To control separately for maturity effects, we also include the maturity $MATURITY_{i,t}$ of the bond. The terms α, β_j, and γ denote the regression coefficients. Note that this specification is essentially a regression-discontinuity approach to test for pricing differences across maturity thresholds. Table VII reports the regression results.

[**Insert Table VII here**]

The results indicate that there are significant jumps in the premia when the maturity of the various Treasury securities crosses specific maturity thresholds. In particular, there is a significant discontinuity when their maturities cross the two-year, five-year, seven-year, and ten-year thresholds.[23]

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[23]As a robustness check, we estimate the regression separately for the pre-crisis and post-crisis periods.

In theory, crossing an integer maturity threshold such as five years is just an arbitrary mechanical event that should have no direct impact on the valuation of a Treasury security, unless the crossing affects the number and types of investors that can hold the security. In this case, the crossing could be accompanied by an exogenous change in the liquidity/illiquidity of that security which, in turn, might impact its value.

A potential reason why this might occur is that many types of financial intermediaries face either explicit or implicit restrictions on the range of maturities that they are allowed to hold in their portfolios. To illustrate this, we manually collect data on the investment policies of 75 of the largest Treasury-related fixed income mutual funds and identify the range of maturities that these investment policies allow the funds to hold in their portfolios. Section IA.IV of the Internet Appendix shows that the eligible range of maturities is almost always expressed in terms of an integer number of years. As examples, the Vanguard Short-Term Treasury Index Fund has a maturity range of 1–3 years, the T. Rowe Price U.S. Treasury Intermediate Index Fund has a maturity range of 4–10 years, and the Fidelity Long-Term Treasury Bond Index Fund has a maturity range of 10–30 years. Typical maturity ranges for short-term bond funds are 1–3 years or 1–5 years. Common maturity ranges for intermediate-term bond funds include 3–5 years, 3–7 years, 5–7 years, 5–10 years, and 7–10 years.

Although the results shown in Table VII indicate that the average premium declines when the maturity crosses a key threshold, it is not clear why the effect should always go in the same direction. We believe that the best way of interpreting the evidence is that there are at least two dimensions to Treasury security liquidity. First, there is a level of liquidity that is associated with a specific category such as notes with maturities

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The results show that the maturity-crossing effect is significant in both subperiods, although it appears to be stronger in the post-crisis period. See Section IA.VI.B of the Internet Appendix for a discussion of these robustness results.

from two to three years. As a Treasury security moves from one category to another, its premium changes simply as a result of being in a different bucket. Furthermore, we could envision market environments in which the jump in the premium could be either positive or negative as a security moves from one category to another. The change in category is the primary effect, the sign of the change in the premium is incidental. Second, there is a level of liquidity that is security specific. For example, even within a specific category, premia may either increase or decrease as a security ages. We believe that the dual nature of security liquidity is probably the most important takeaway from this analysis.

It is also useful to consider whether the results in Table VII can provide perspective on how much of the convenience premium may be directly related to liquidity effects.[24] While the relation between maturity and the premia is clearly very complex, the maturity-crossing results in Table VII may at least provide some bounds on the size of the liquidity component in the premia. Intuitively, we might expect that the liquidity component in the premium would be at least as large as the largest change associated with a maturity crossing. Similarly, we could also view the sum of the changes associated with all key maturity crossings as a potential upper bound on the size of the liquidity component. Applying this logic and using the coefficients in Table VII in conjunction with the average premia reported in Table II suggests lower and upper bounds for the size of the liquidity component in the premia of 10.1 percent and 28.9 percent, respectively.

Finally, to explore the possibility that crossing specific maturities is associated with a change in trading patterns, we manually collect data from the Bloomberg system on trading activity for five-year and ten-year Treasury notes for the January 2018 to December 2022 period. We regress trading volume on indicator variables measuring whether the maturity of the security is $+/-$ one month of the specific maturity. Since the regression is estimated in levels, we also include CUSIP and monthly fixed effects. The regression

[24]We are grateful to the Associate Editor for suggesting this analysis.

specification is

$$VOL_{i,t} = FE_i + FE_t + \sum_j \beta_j \; I_{i,t,j} \;\; + \epsilon_{i,t}, \tag{10}$$

where $VOL_{i,t}$ denotes the trading volume for CUSIP i at time t, FE_i denotes CUSIP fixed effects, FE_t denotes monthly fixed effects, $I_{i,t,j}$ is an indicator variable that takes value one if the maturity of security i is within one month of maturity j, where j takes on the relevant values from the elements of the set {1-Year, 2-Year, 3-Year, 4-Year, 5-Year, 7-Year}. The terms β_j denote the regression coefficients. Table VIII reports the regression results.

[**Insert Table VIII here**]

As shown, crossing specific maturities appears to be significantly related to trading activity. In particular, trading activity is significantly higher around the one-year, two-year, and three-year maturities for both five-year and ten-year notes. Trading activity is also significantly higher around the four-year and five-year maturities for the ten-year notes. These results lend support to the hypothesis that the maturity-crossing-related jumps in the premia may be related to institutional trading and portfolio holding patterns. Furthermore, the results in Table VII showing that the maturity-crossing effect is significant for key benchmark maturities such as two, five, seven, and ten years, but not for maturities that may receive less institutional attention such as four, six, and eight years, provides additional support for an institutional demand mechanism.

VIII. Are Premia Related to Treasury Safety?

There is an extensive literature suggesting that Treasury securities should trade at a premium because of their unique role as safe assets. One stream of this literature focuses on the credit safety that Treasuries offer during flights-to-quality in the financial markets.

Another stream focuses on the liquidity-of-last-resort safety that Treasury securities offer by remaining tradeable during extreme market events in which other asset classes may become partially or completely illiquid. A common implication of both streams, however, is that safe assets such as Treasuries should tend to richen during times of distress in the financial markets.[25]

A. *The Response to Shocks*

In reality, however, Treasuries do not always richen when financial markets experience a significant shock. To illustrate this, Figure 10 plots the changes in the convenience premia surrounding a number of major events that were accompanied by dramatic spikes in stock market volatility, interest rate volatility, or credit spreads such as the Long Term Capital Management (LTCM) crisis of 1998, the Lehman bankruptcy of September 2008, and the onset of the Covid-19 pandemic in March 2020. In particular, we focus primarily on events identified by Baele, Bekaert, Inghelbrecht, and Wei (2020) as flights-to-safety based on their regime switching model framework.

[**Insert Figure 10 here**]

As shown, the responses to these major shocks display very mixed patterns. For example, most Treasuries richened during the Asian Debt Crisis of 1997 and the LTCM Crisis of 1998. In contrast, premia decreased across virtually all maturities following the September 2001 attacks and the Bear Stearns crisis in March 2008. The pattern of changes following the Lehman bankruptcy in September 2008, the credit downgrade of the U.S. Treasury in August 2011, and the beginning of the Covid-19 pandemic in March 2020 are all mixed with roughly half of the Treasuries richening and the others cheapening.

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[25]Examples include Longstaff (2004), Beber, Brandt, and Kavajecz (2009), Nagel (2016), Musto, Nini, and Schwarz (2018), He, Nagel, and Song (2022), and Haddad, Moreira, and Muir (2021).

Figure 10 also shows that there is significant heterogeneity across maturities in response to a shock. The response of medium-term Treasuries can be very different from that of short-term Treasuries, which, in turn, can differ markedly from that of long-term Treasuries. This is consistent with the multifactor nature of the premia discussed earlier. We note also that the effects of these shocks on the premia are fairly transitory, and tend to mean revert quickly.[26]

B. The Response to Changes in Event Risk

To explore the relation between the safety provided by Treasury securities and convenience premia in more depth, we regress changes in the average premium on changes in exogenous variables that may proxy for the risk of a major credit or liquidity event occurring. Specifically, we estimate the following regression separately for each tenor and maturity category,

$$\Delta PREM_t = c_0 + c_1\ \Delta VIX_t + c_2\ \Delta AAA_t + c_3\ \Delta FUND_t + c_4\ \Delta NFCI_t + \epsilon_t, \qquad (11)$$

where $\Delta PREM_t$ denotes the change in average convenience premium from month $t-1$ to t, ΔVIX_t denotes the corresponding change in the VIX index, ΔAAA_t the change in the AAA corporate spread above Treasuries, $\Delta FUND_t$ the change in the funding spread between three-month Libor and the three-month repo rate, and $\Delta NFCI_t$ the change in the Chicago Federal Reserve National Financial Conditions (NFCI) Index (which aggregates over 100 financial and economic measures). The first three of these explanatory variables proxy for changes in financial market risk, while the fourth proxies for changes in macroeconomic risk. The regression coefficients are denoted as $c_i, i = 0, 1, 2, 3, 4$. Table IX reports the

[26] In particular, the correlation between the changes shown in Figure 10 and the changes during the subsequent month are negative for all eight of the events.

regression results.

[**Insert Table IX here**]

The regression results confirm that there is little in the way of a consistent pattern between the premia and the event risk proxies. Changes in the VIX Index, the AAA corporate spread, and the funding spread are only significant for a few of the tenors and maturity categories, and typically with the wrong sign. In contrast, changes in the NFCI Index are often significantly and positively related to changes in the premia. This relation, however, appears limited to the shorter-maturity Treasuries.

IX. Are Premia Related to Intermediary Frictions?

A rapidly-growing literature focuses on how balance-sheet constraints and regulatory frictions affect the ability of financial intermediaries to make markets and provide liquidity. This literature is particularly relevant in the context of this paper since post-financial-crisis regulation has imposed significant new capital costs on intermediaries that hold Treasury securities on their balance sheet. These holding costs could dramatically change the economics of owning Treasuries.

The Supplementary Leverage Ratio (SLR) is potentially one of the most-costly new capital requirements imposed by post-financial-crisis regulation. The SLR is the ratio of Tier 1 capital to total exposures. Total exposures are the sum of on-balance-sheet assets including Treasury securities, cash, and central bank deposits, regardless of their risks, and off-balance-sheet exposures.[27] The SLR applies to large financial institutions with $250 billion or more in total consolidated assets, or $10 billion or more of on-balance-sheet

[27] Off-balance-sheet exposures include derivatives, repo-style transactions, lending commitments, guarantees, warranties, and financial standby letters of credit. For details, see Fleckenstein and Longstaff (2020a).

foreign exposures.[28] The SLR was finalized in October 2014, and G-SIBs and other large banking institutions have been required to include the SLR in public disclosures since January 2015.

To examine whether balance-sheet-related holding costs impact Treasury premia, we use a natural experiment in which the applicability of the SLR to Treasuries was temporarily suspended. In a press release on April 1, 2020, the Federal Reserve announced that it would exclude Treasury securities and deposits in Federal Reserve Banks from the calculation of the SLR requirement until March 31, 2021.[29] Since the motivation for the change stemmed from the exogenous Covid-19 shock, the suspension of the SLR requirement gives us a direct way of examining the causal effect of a change in the cost of holding Treasury securities on their premia. To do this, we use a simple event-study methodology in which we measure the changes in the premia for all Treasury notes and bonds on the announcement date and then study their cross-sectional properties.

It is important to recognize that the definition of the SLR implies that the capital requirement for holding a Treasury security is proportional to its market value. In particular, the SLR capital requirement for a bond with a balance-sheet carrying value of 150 is exactly twice that of a bond carried at 75. This contrasts with other types of capital requirements which are typically risk based. If the changes in premia on the announcement date are due to the suspension of the SLR capital requirement, then there could be a relation between the changes and the price of the individual Treasury securities. This feature provides us with an identification strategy for validating that the observed changes in the premia are attributable to the change in the SLR capital requirement.

To explore this potential relation, Figure 11 graphs the changes in the premia of the

[28] U.S. regulators require global systemically important institutions (G-SIBs) to maintain an SLR of at least five percent on a consolidated basis and at least six percent for their depository subsidiaries.

[29] See https://www.federalreserve.gov/newsevents/pressreleases/bcreg20200401a.htm.

individual Treasury notes and bonds as a function of their prices. In doing this, we use the full price (which includes any accrued coupon) of each bond since it reflects the value at which the Treasury security would be carried on an intermediary's balance sheet. As shown, there is a very strong positive relation between the changes in premia and the price level of the individual securities. The simple correlation between the changes in the premia over the event window and the pre-event market prices is 78.25 percent. This implies that 61.23 percent of the cross-sectional variation in the changes in the premia on the event date is explained by security prices. To put this value into perspective, we estimate the same measure for every day in the sample period. The average and standard deviation of these daily estimates of the percentage of cross-sectional variation explained by security prices are 11.52 and 11.96 percent, respectively. Thus, the 61.23 percent value is 5.12 standard deviations above the mean. Furthermore, this 61.23 percent value is at the 99.8466 percentile of the distribution taken over all of the daily observations during the sample period. Finally, we note that the average change in premia on the event date is 3.09 basis points. The standard deviation of the average daily changes in the convenience premia over the entire sample period is 2.06 basis points.

[**Insert Figure 11 here**]

The evidence that the correlation between changes in convenience premia and Treasury prices is much higher on the event day than on virtually any other day during the sample period makes a strong case that the suspension of the SLR capital requirement for Treasuries was the primary driver of changes in premia on that date.[30] In turn, this allows us to interpret the changes in the premia of individual Treasury notes and bonds on the event date as providing direct measures of their sensitivity to changes in balance-sheet

[30] This is compatible with the pattern shown in Figures 1 and 2 in which the average premia generally increased around April 1, 2020, remained at roughly the same level over the next year, and then tended to decline.

holding costs.

As a final robustness check, we compute Treasury convenience premia using the credit-adjusted Refcorp curve as the risk-free benchmark instead of the repo swap curve. Intuitively, if the post-crisis cheapening of Treasuries is solely the result of the increased cost of holding cash instruments such as Treasuries on balance sheet, then we might expect to see little change in the premia when measured relative to Refcorp bonds since both Treasuries and Refcorp bonds face the same balance-sheet costs.[31]

The results reported in Section IA.VI.C of the Internet Appendix show that Treasury premia measured relative to Refcorp bonds are largely positive throughout the entire sample period, implying that Treasuries are generically rich relative to Refcorp bonds. This is consistent with Longstaff (2004). Surprisingly, the relative richness of Treasuries actually increases significantly during the post-crisis period. In most cases, the increase is on the order of 25 to 50 basis points. Since Treasuries and Refcorp bonds face the same balance-sheet costs, these results indicate that additional factors are impacting the relative pricing of Treasuries and Refcorp bonds.

X. Discussion

In documenting key stylized facts about Treasury convenience premia, a key objective is to provide empirical benchmarks that may help rule in or rule out some of the mechanisms proposed in the literature.

First, we find that convenience premia are often negative for extended periods of time throughout the sample period. These results make a case against some mechanisms in the safe-assets literature that imply that convenience premia should be uniformly positive in sign. Second, we find that negative convenience premia occur well before the financial crisis.

[31]We are grateful to the referee for suggesting this analysis.

This argues against post-financial-crisis regulation being the sole driver of the mechanisms leading to Treasuries trading at prices below their intrinsic values. Third, finding that convenience premia have little relation to measures of event risk and sometimes actually decrease during crisis periods suggests that a safety-related flight-to-quality mechanism may not be among the primary drivers of convenience premia. Fourth, the multifactor structure of convenience premia across the term structure essentially rules out the possibility that convenience premium are entirely due to a single mechanism. Finally, since on-the-run Treasuries continue to be the most-actively-traded Treasuries during the post-crisis period, the results about the fading on-the-run and cross-the-run effects suggest that investors may now place less weight on the traditional role of Treasuries as liquid trading vehicles.

In contrast, the evidence that convenience premia have become much more negative since 2015 and appear to have been impacted by the suspension of SLR capital requirements argues that financial intermediary frictions and balance-sheet costs may now play a major role.[32] Furthermore, the evidence that Treasury convenience premia are related to their money-market-fund eligibility as well as maturity-related portfolio-inclusion properties argues that institutional demand for specific security characteristics may also be a important factor impacting premia. Finally, our approach allows us to estimate premia across the entire maturity spectrum. This raises the possibility of identifying the mechanisms driving convenience premia through their cross-sectional effects. For example, understanding why intermediate-maturity Treasuries are often the richest or why convenience premia have recently become much more correlated with maturity may shed new light on the nature of convenience premia.

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[32]This is consistent with Boyarchenko, Gupta, Steele, and Yen (2018) who argue that post-crisis regulatory leverage requirements may have impacted the incentives of supervised intermediaries to enter into swap spread arbitrage trades taking advantage of the negative swap spreads observed in markets since the financial crisis.

XI. Conclusion

This paper uses a uniform framework to obtain consistent estimates of Treasury convenience premia across the entire term structure of Treasury bills, notes, and bonds over more than a quarter of a century. We provide a comprehensive description of their time-series and cross-sectional patterns. By documenting the key stylized facts, our goal is to provide empirical benchmarks that can help guide future theoretical and empirical research in this field.

In particular, our results point towards a number of new directions that may be helpful in understanding better the nature and sources of Treasury convenience premia. For example, the results suggest that the traditional role of Treasury securities as liquid trading vehicles may be evolving. The results also suggest that the role of institutional demand for specific bond maturities may also be an important factor to consider in the development of future models of Treasury richness/cheapness. Finally, our results also have implications for Treasury debt management.

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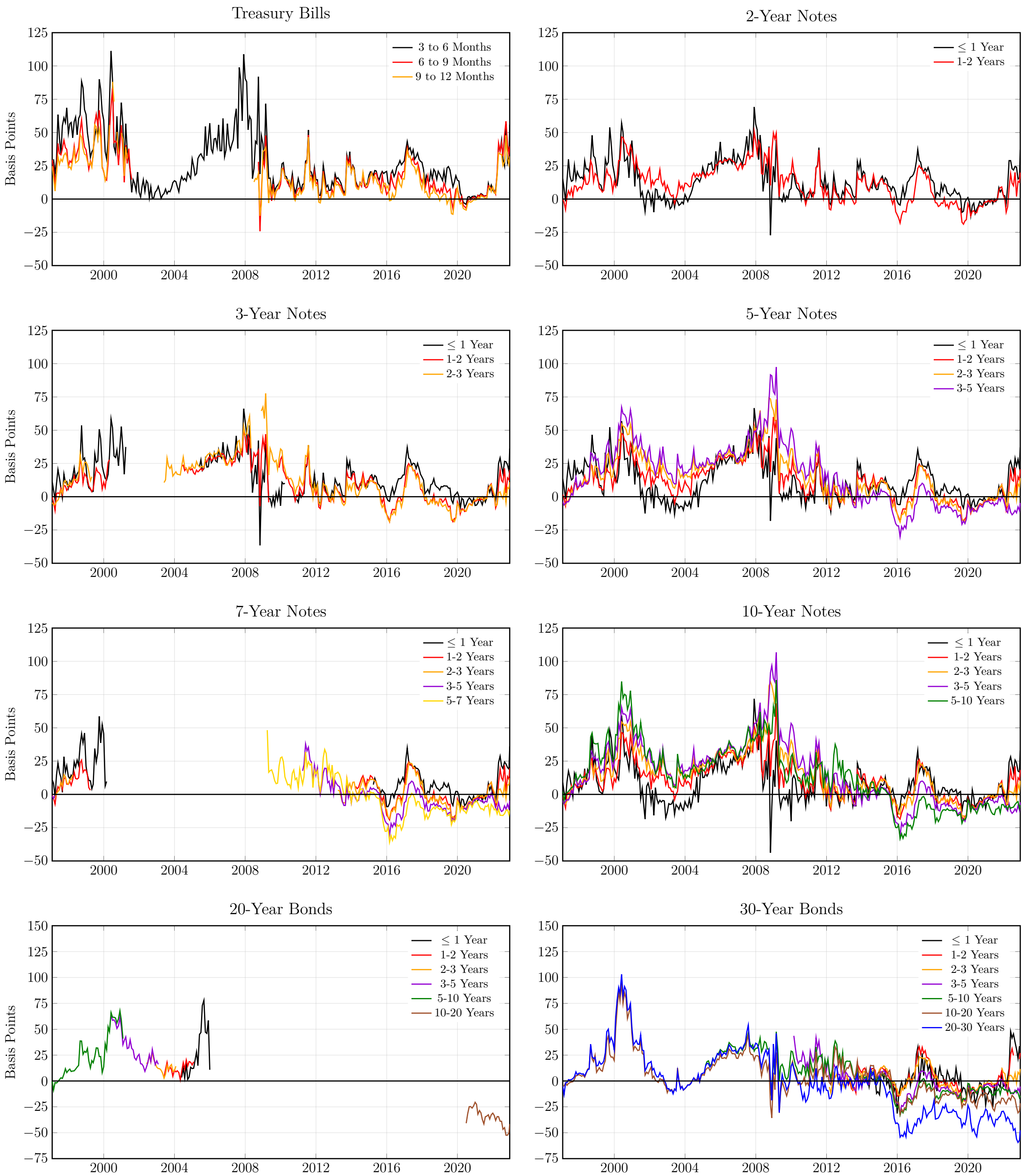

Figure 1. Time Series of Convenience Premia by Tenor. These graphs show the time series of the average premium for each tenor by maturity category.

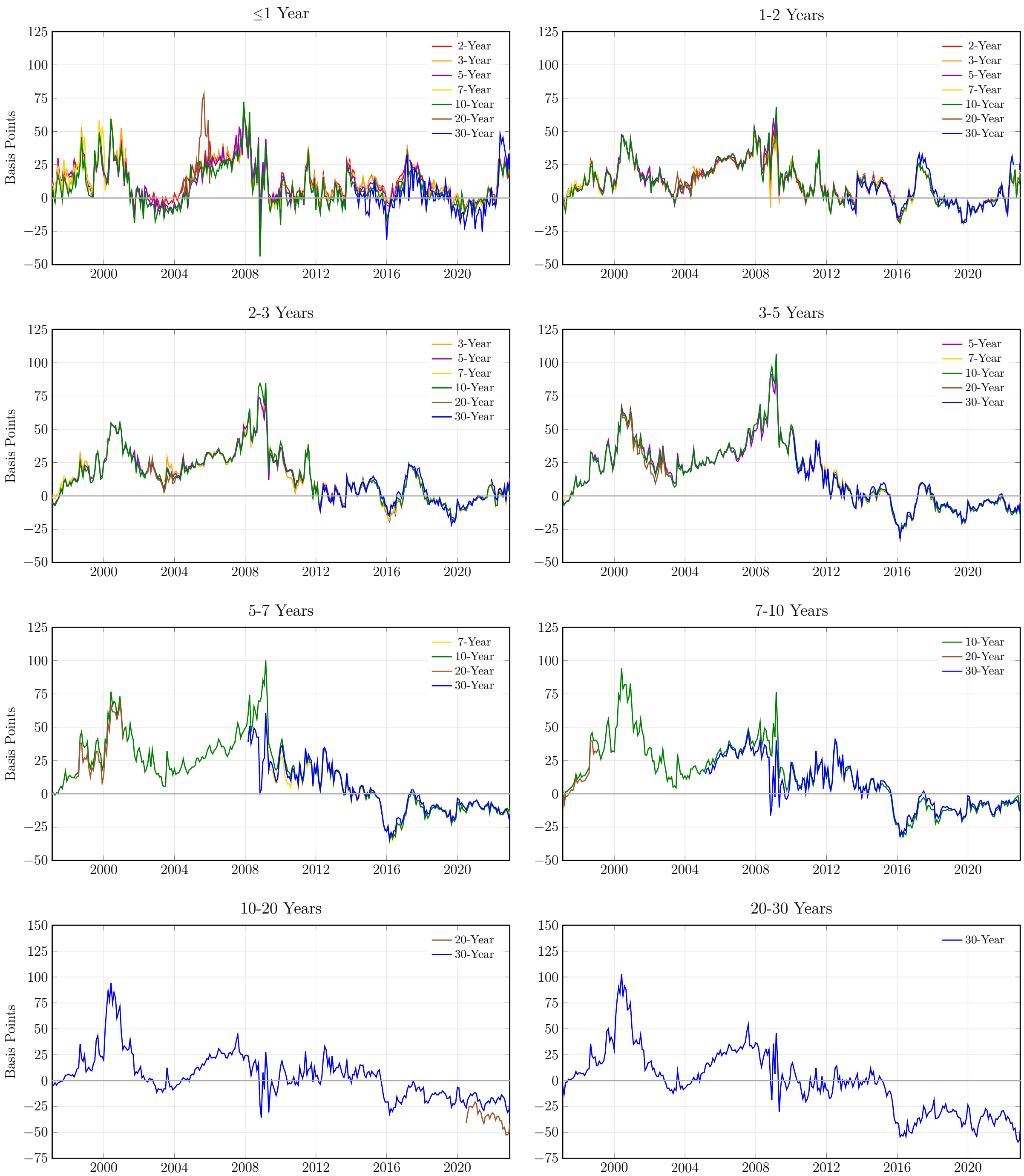

Figure 2. Time Series of Convenience Premia by Maturity Category. These graphs show the time series of the average premium for each maturity category by tenor.

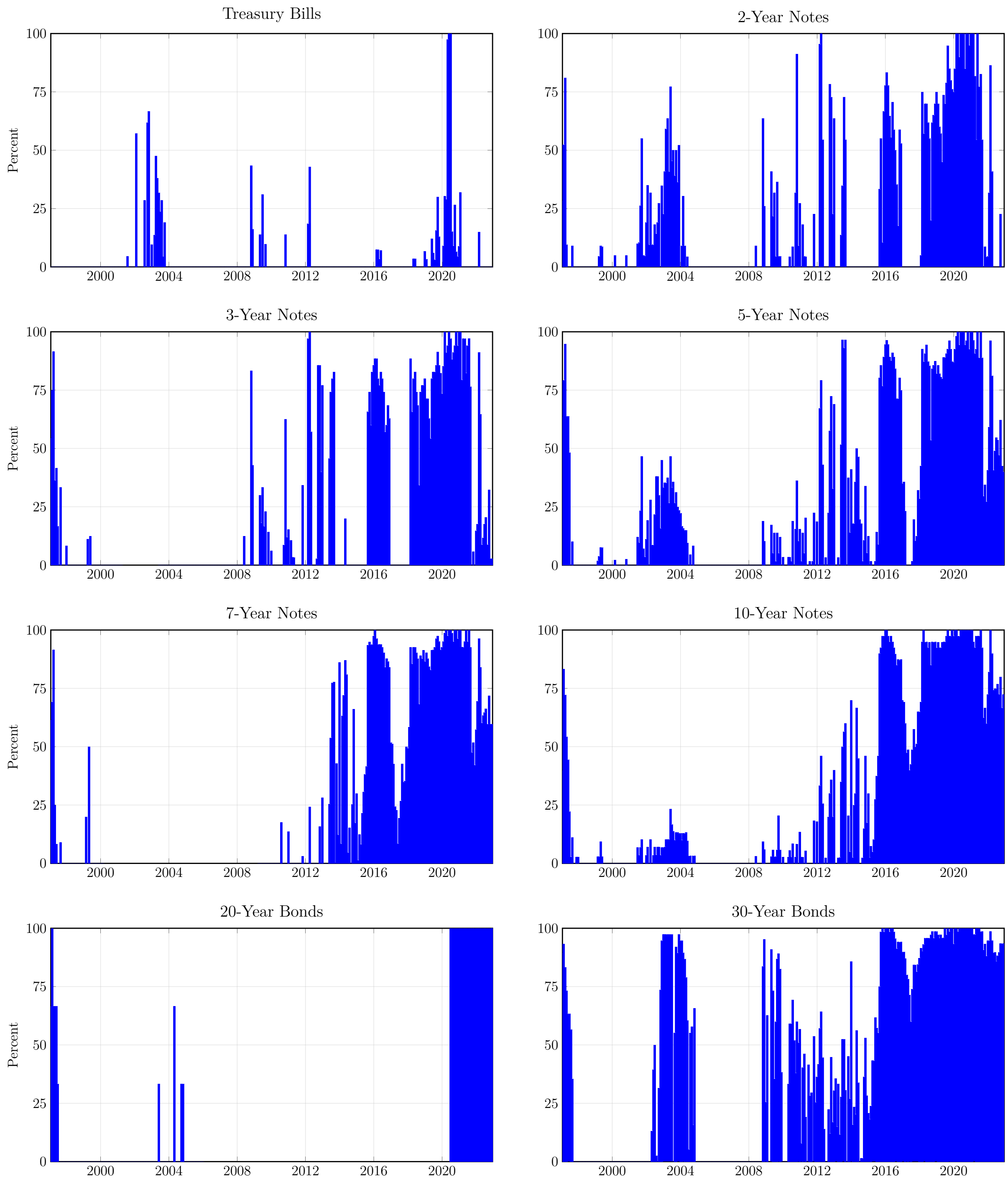

Figure 3. Time Series of the Percentage of Negative Convenience Premia by Tenor. These graphs show the time series of the percentage of negative premia by tenor.

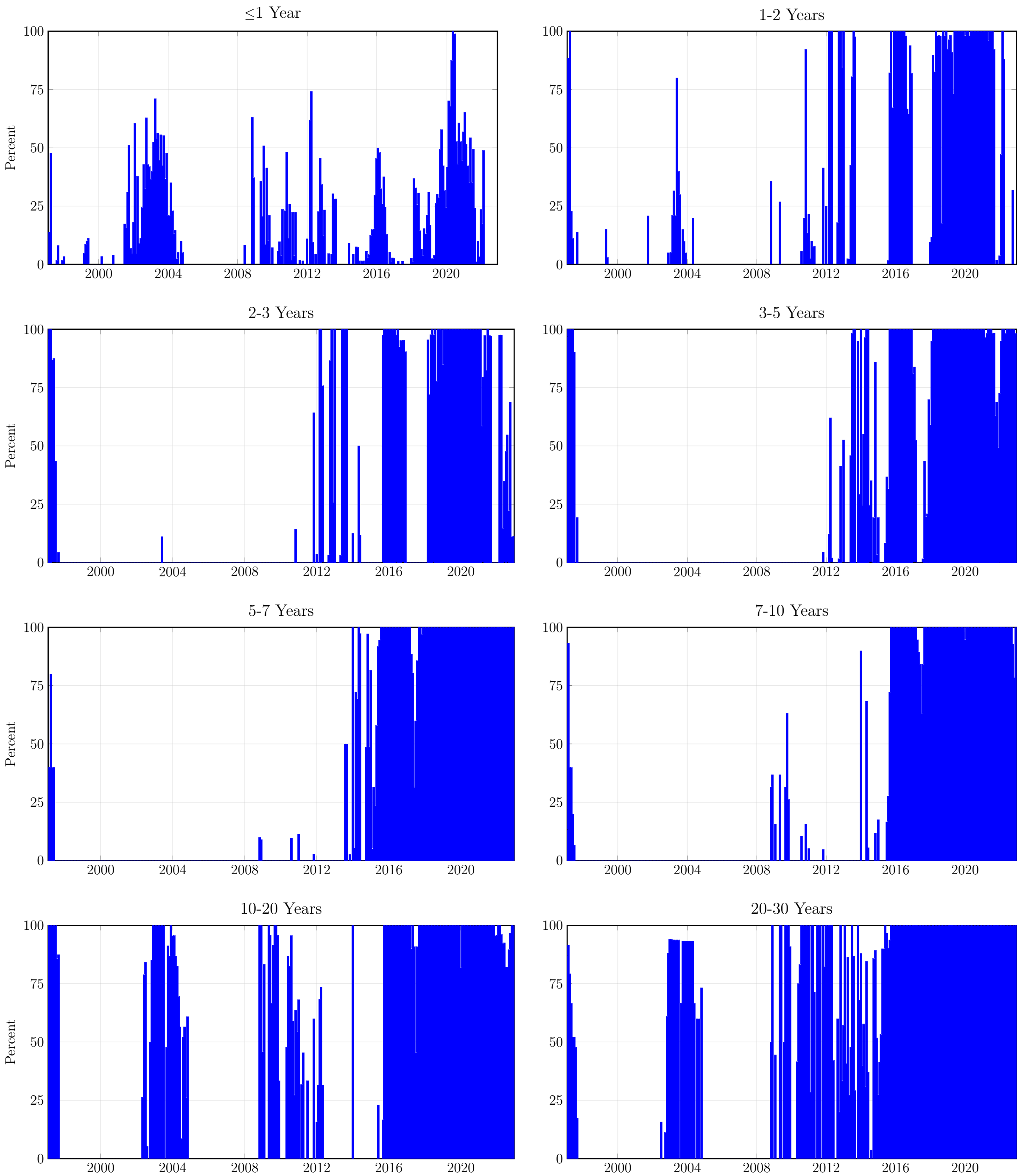

Figure 4. Time Series of the Percentage of Negative Convenience Premia by Maturity Category. These graphs show the time series of the percentage of negative premia by maturity category.

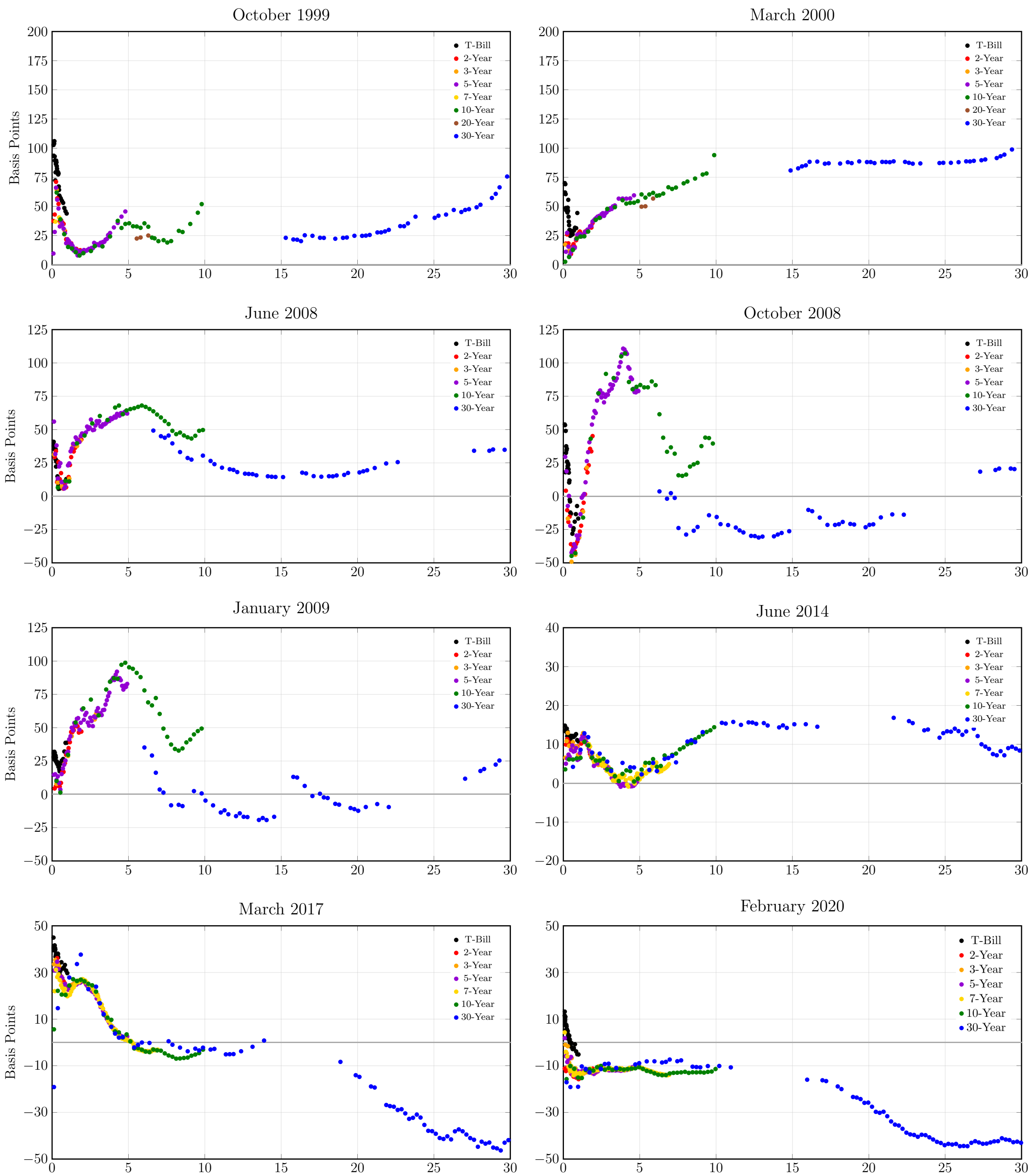

Figure 5. Term Structures of Convenience Premia for Selected Dates. These graphs show the term structure of month-end convenience premia for the indicated dates.

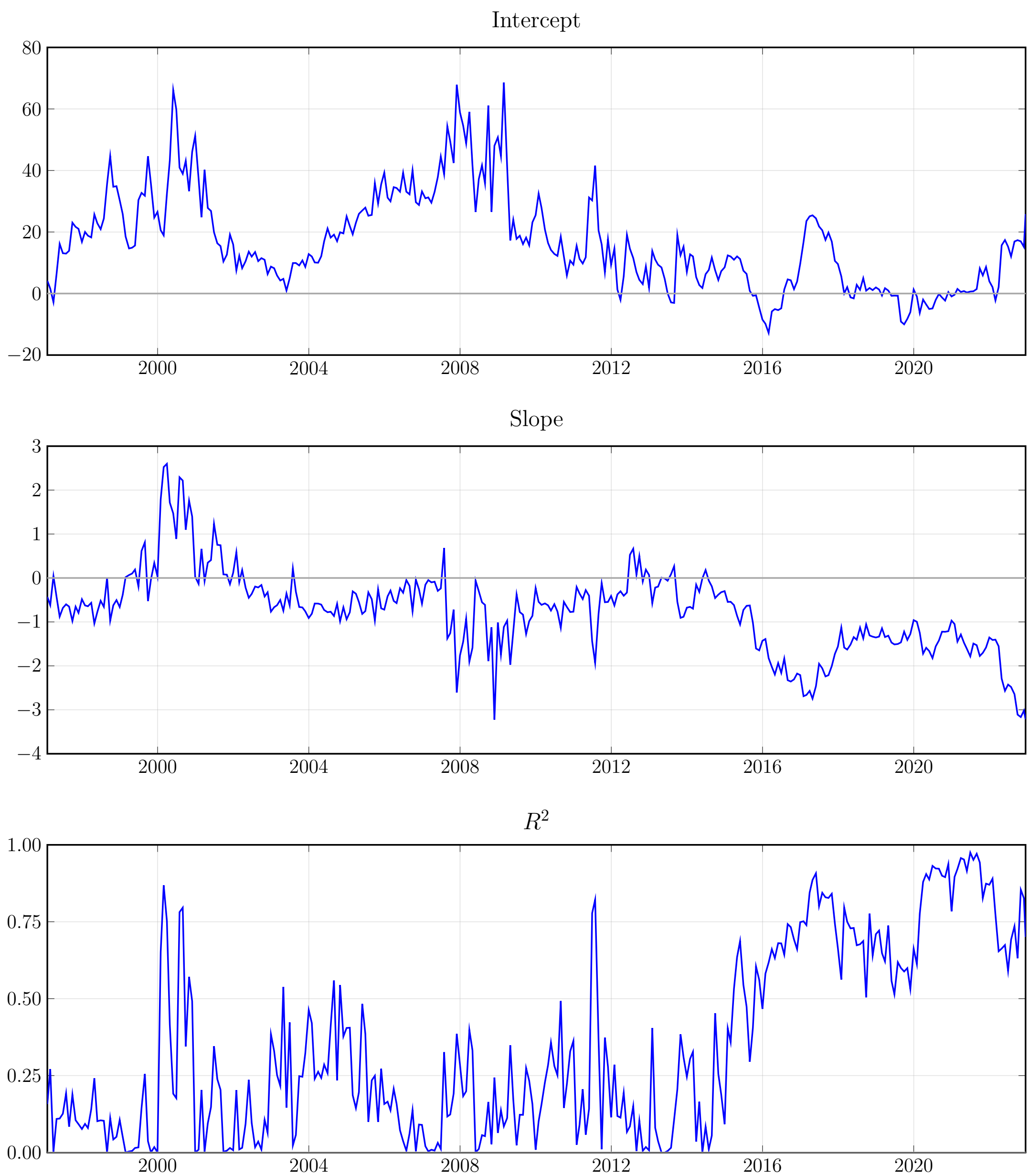

Figure 6. Results from Cross-Sectional Regressions of Convenience Premia on Maturity. These graphs show the results from the cross-sectional regressions of the convenience premia $PREM_{i,t}$ of individual Treasury securities i on time to maturity $MATURITY_{i,t}$ measured in years. The upper panel shows the time series of intercepts α_t. The middle panel shows the time series of slope coefficients β_t for the maturity of the Treasury securities. The lower panel plots the R^2s from the regressions. The regressions are estimated each month over the sample period from January 1997 to December 2022. The regression is

$$PREM_{i,t} = \alpha_t + \beta_t \, MATURITY_{i,t} + \epsilon_{i,t}.$$

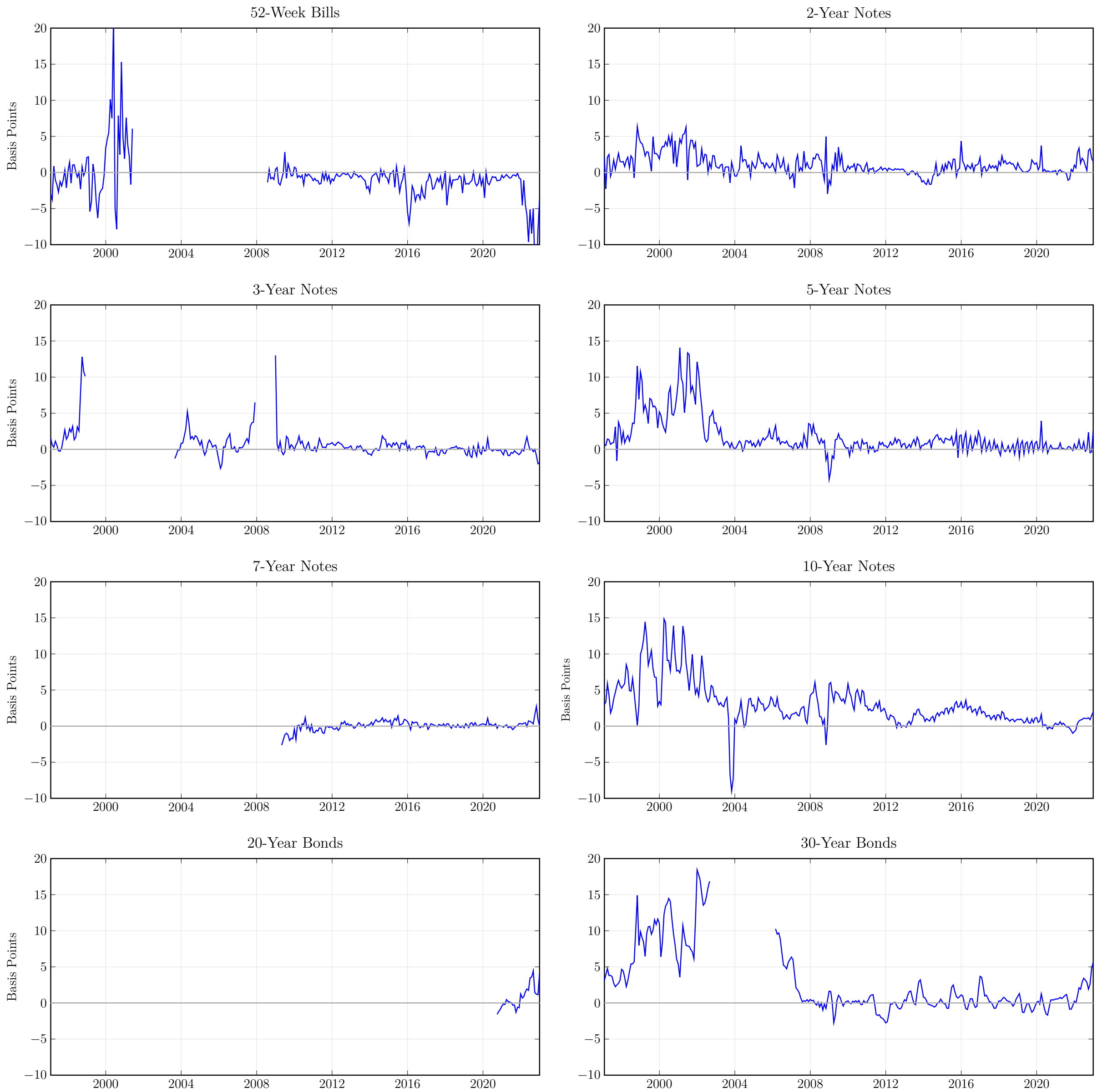

Figure 7. Time Series of the On-the-Run Spread. These graphs show the time series of the on-the-run spread for individual tenors, where the on-the-run spread is defined as the difference between the convenience premium of the current on-the-run Treasury and that of the first off-the-run (the previous on-the-run) Treasury.

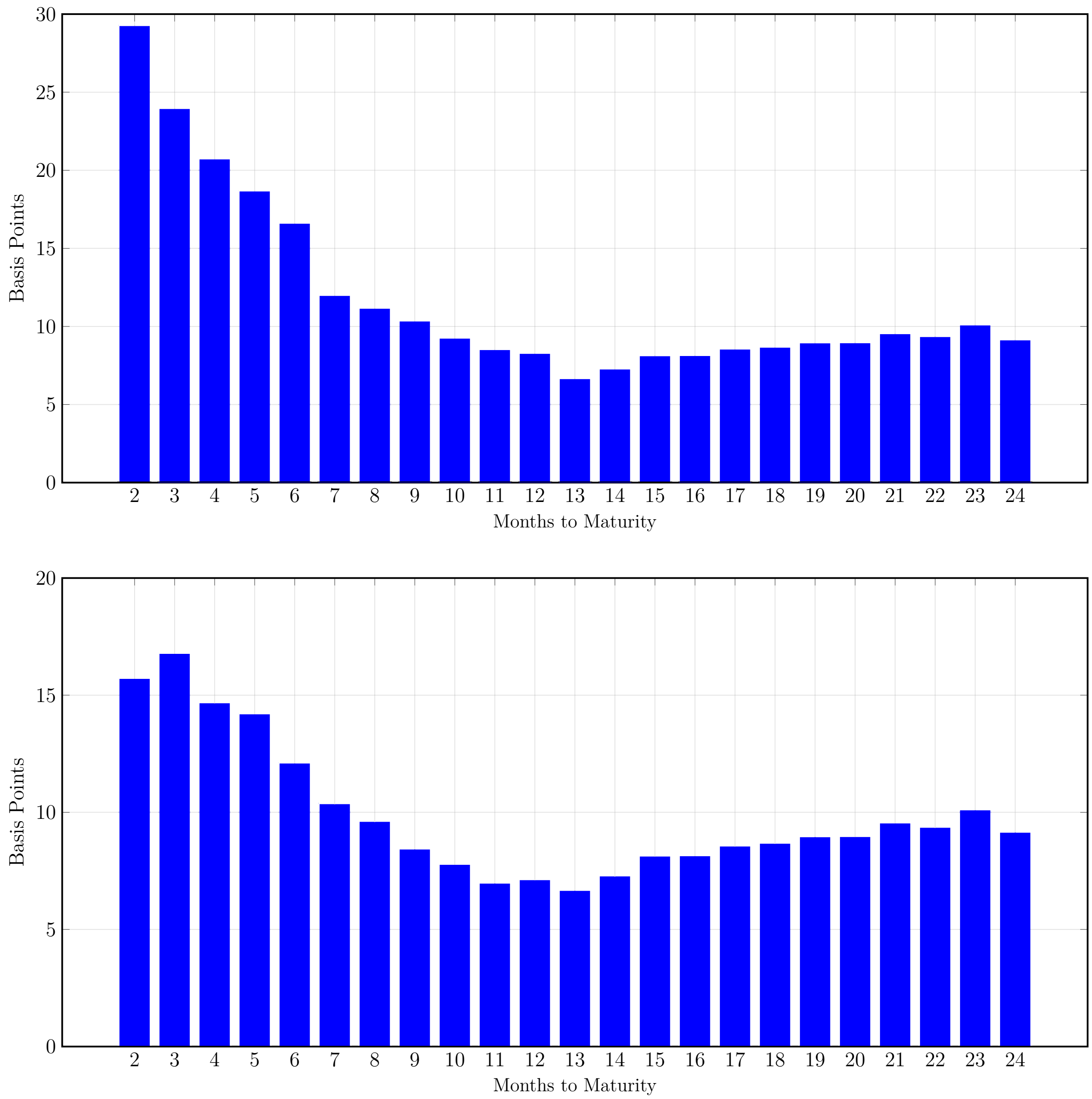

Figure 8. Average Convenience Premia for Monthly Maturity Categories. These graphs show the average premium for monthly maturity categories ranging from $T = 2$ months to $T = 24$ months, where each category T includes Treasury securities with maturities in the interval $(T - 1, T]$. The upper graph shows the averages taken across all Treasuries in each maturity category T; the lower graph shows the averages taken across just Treasury notes and bonds in each maturity category T.

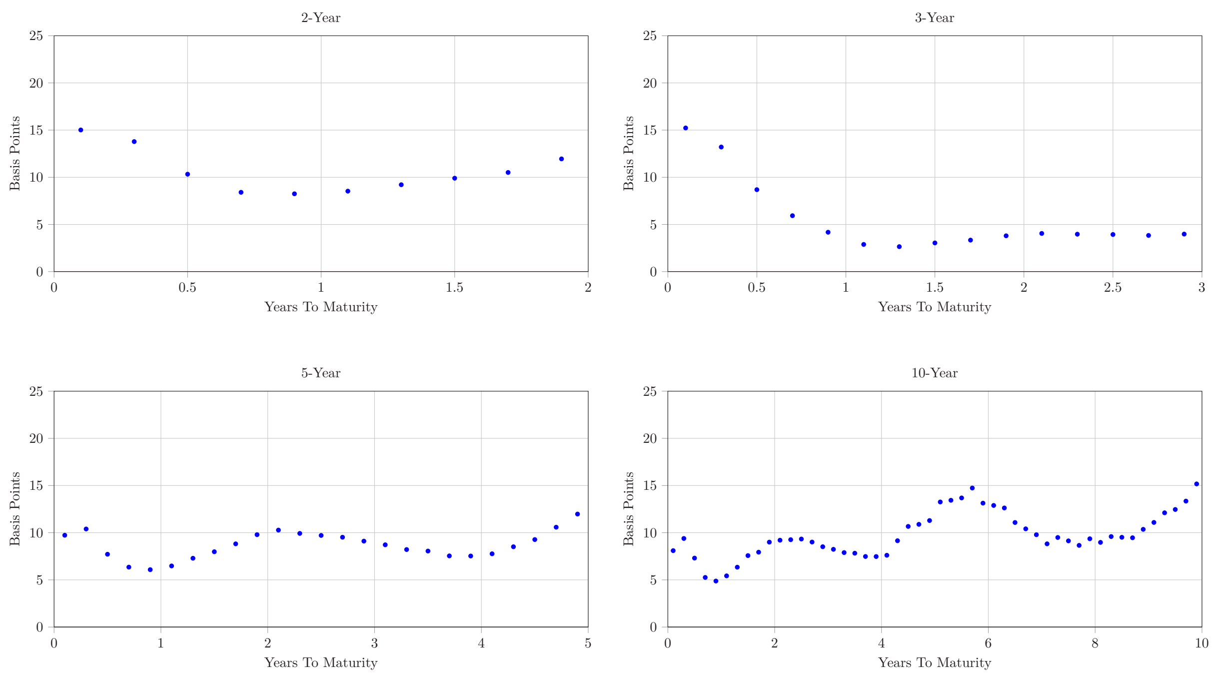

Figure 9. Average Convenience Premia by Remaining Maturity. These graphs show the median premium by remaining maturity for the 2-year, 3-year, 5-year, and 10-year tenors.

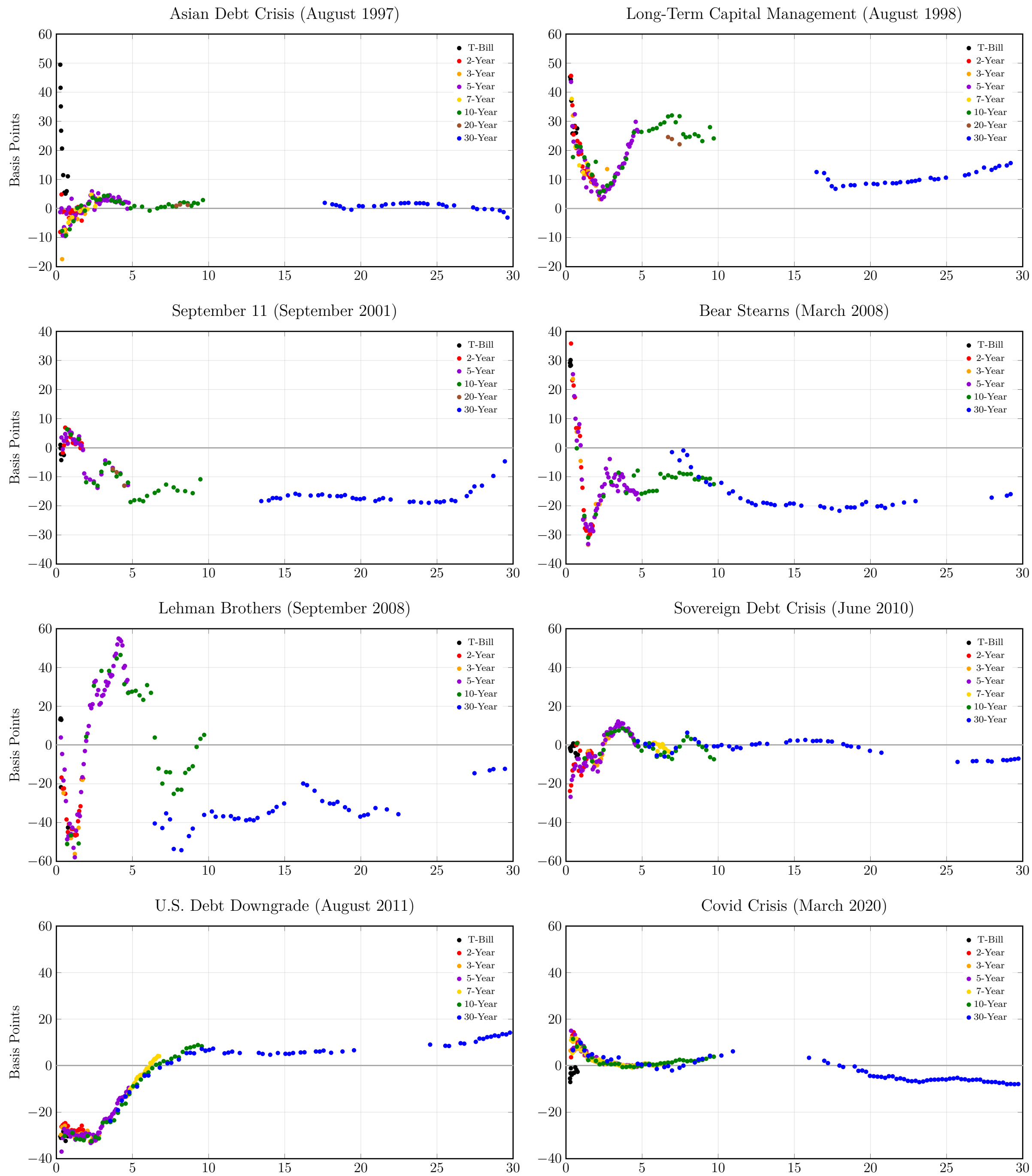

Figure 10. Term Structure of Changes in Convenience Premia Associated with Selected Market Events. These graphs show the change in the term structure of month-end convenience premia measured over a window +/- one month surrounding the event date (event dates shown in parentheses).

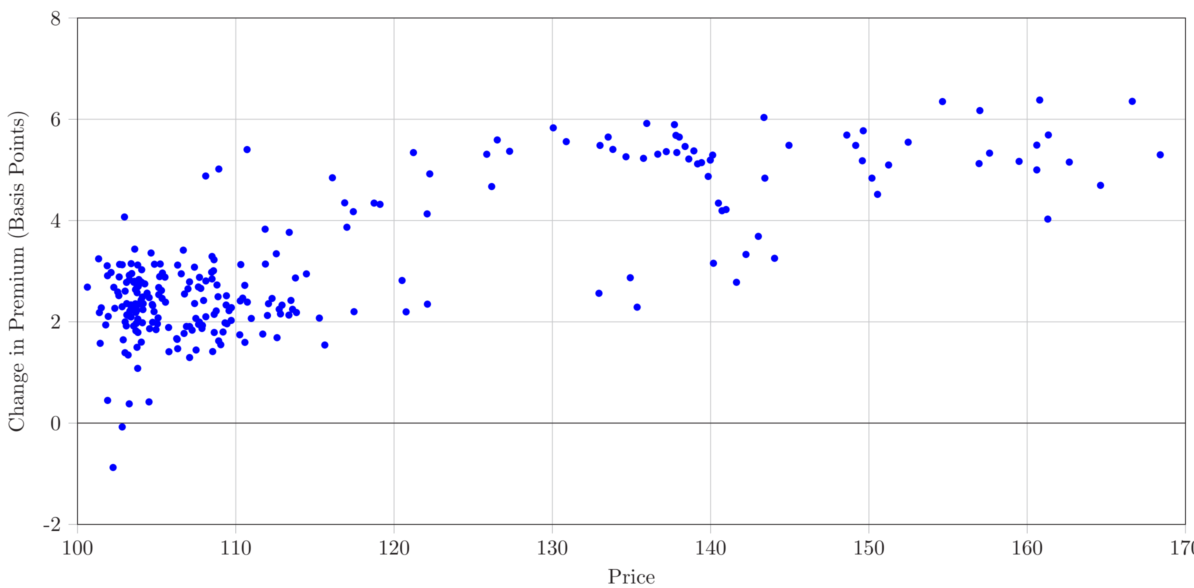

Figure 11. Changes in Convenience Premia on the SLR Event Date as a Function of the Price of the Treasury Security. This graph plots the change in the convenience premium of individual Treasury securities on the SLR event date as a function of the full price of the individual Treasury note or bond. The change in the premium is computed as the difference between the end-of-day premium on April 1, 2020 and the end-of-day premium on March 31, 2020. Securities with a maturity of one year or less are excluded.

Table I

Cash Flows from a Stylized Portfolio Consisting of a Treasury Bond and CDS Contract

This table presents the cash flows from a stylized portfolio consisting of a long position in a Treasury bond with time-zero price 100, coupon rate c, and maturity T, and the purchase of default protection via a CDS contract with a spread of s and maturity T. If a default occurs at time τ, the Treasury bond is sold at the market price of $c + 100 - w$ (coupon plus par minus w) where w denotes the default loss, and the protection leg of the CDS contract pays the protection buyer the default loss w. For expositional simplicity, this stylized example assumes that default can only occur on a coupon payment date, and that both the accrued coupon and CDS premium are paid at time τ if a default occurs.

	Timing of Cash Flow						
	0	1	2	$\ldots$	τ	$\ldots$	T
Default at Time τ							
Bond Cash Flow	-100	c	c	c	$c + 100 - w$		
CDS Cash Flow	0	$-s$	$-s$	$-s$	$-s + w$		
Total Cash Flow	-100	$c - s$	$c - s$	$c - s$	$c - s + 100$		
No Default							
Bond Cash Flow	-100	c	c	c	c	c	$c + 100$
CDS Cash Flow	0	$-s$	$-s$	$-s$	$-s$	$-s$	$-s$
Total Cash Flow	-100	$c - s$	$c - s$	$c - s$	$c - s$	$c - s$	$c - s + 100$

Table II

Summary Statistics for the Convenience Premia

This table presents the average convenience premium for the indicated Treasury types and maturity ranges. Security denotes the type of Treasury security. Maturity denotes the range of maturities included in the respective maturity range, where maturity is expressed in years. The convenience premia are expressed in basis points. The row labeled All presents the average convenience premium across all Treasury types for the indicated maturity ranges. The column labeled Ave presents the average convenience premium taken across all maturities for the indicated Treasury types. The last value in the row labeled All presents the average convenience premium taken across all observations. The sample period is monthly from January 1997 to December 2022.

	Maturity Range								
Security	≤ 1	$1-2$	$2-3$	$3-5$	$5-7$	$7-10$	$10-20$	$20-30$	Ave
T-Bills	24.51	–	–	–	–	–	–	–	24.51
2-Year	13.66	11.76	–	–	–	–	–	–	12.68
3-Year	11.36	5.70	6.38	–	–	–	–	–	7.64
5-Year	10.91	10.70	14.03	13.63	–	–	–	–	12.61
7-Year	7.88	1.33	0.01	−4.71	−3.68	–	–	–	−1.69
10-Year	8.92	9.21	11.72	13.66	14.22	12.02	–	–	12.20
20-Year	24.51	10.79	13.66	30.84	31.97	8.33	−38.53	–	−0.14
30-Year	0.70	2.22	0.93	−1.03	0.71	6.18	5.83	−10.06	−2.12
All	17.22	8.67	8.75	8.18	3.14	10.34	4.38	−10.06	8.21

Table III

Summary Statistics for the Fraction of Negative Convenience Premia

This table presents the fraction of the convenience premia that take negative values for the indicated Treasury types and maturity ranges. Security denotes the type of Treasury security. Maturity denotes the range of maturities included in the respective maturity range, where maturity is expressed in years. The fractions are expressed as percentages. The row labeled All presents the fraction of negative convenience premia across all Treasury types for the indicated maturity ranges. The column labeled Ave presents the fraction of negative convenience premia taken across all maturities for the indicated Treasury types. The last value in the row labeled All presents the fraction of negative convenience premia taken across all observations. The sample period is monthly from January 1997 to December 2022.

	Maturity Range								
Security	≤ 1	$1-2$	$2-3$	$3-5$	$5-7$	$7-10$	$10-20$	$20-30$	Ave
T-Bills	4.53	–	–	–	–	–	–	–	4.53
2-Year	18.67	23.01	–	–	–	–	–	–	20.92
3-Year	22.72	39.54	39.19	–	–	–	–	–	34.37
5-Year	26.01	28.89	28.66	36.08	–	–	–	–	31.20
7-Year	33.15	56.22	56.66	69.94	65.07	–	–	–	61.02
10-Year	31.97	30.13	29.40	35.90	36.40	32.83	–	–	33.47
20-Year	6.06	5.56	2.78	0.00	0.00	20.00	100.0	–	39.79
30-Year	52.23	52.16	52.63	58.19	54.36	41.89	39.68	64.35	53.22
All	15.70	32.84	37.20	45.82	53.61	35.20	41.65	64.35	36.86

Table IV

Frequency Distribution of the Cheapest, Median, and Richest Treasury Securities

This table presents summary statistics for the frequency distribution of the cheapest, median, and richest Treasury securities. The column titled Cheapest denotes the percentage of months for which the cheapest Treasury security is in the indicated category, and similarly for the columns titled Median and Richest. Panel A reports the results where the categories are the original tenors of the Treasury securities. Panel B reports the results where the categories are the maturity ranges of the Treasury securities. The sample is monthly from January 1997 to December 2022.

Panel A

Tenor	Cheapest	Median	Richest
T-Bill	0.32	7.19	59.29
2-Year	6.09	9.80	1.28
3-Year	2.88	11.11	3.21
5-Year	16.03	27.45	7.05
7-Year	0.96	11.76	0.00
10-Year	17.31	16.34	18.27
20-Year	1.92	0.66	1.61
30-Year	54.49	15.69	9.29
Total	100.00	100.00	100.00

Panel B

Maturity Range	Cheapest	Median	Richest
≤ 1	39.74	12.42	66.99
1-2	4.17	21.57	0.95
2-3	0.96	23.53	0.32
3-5	2.24	21.57	13.14
5-7	0.00	3.92	4.81
7-10	0.00	6.54	9.62
10-20	12.83	7.84	0.64
20-30	40.06	2.61	3.53
Total	100.00	100.00	100.00

Table V

Summary Statistics for the On-the-Run and the Cross-the-Run Spreads

This table presents summary statistics for the on-the-run and cross-the-run spreads. Panel A presents summary statistics for the on-the-run spread of individual tenors for the indicated subperiods, where the on-the-run spread is defined as the difference between the convenience premium of the current on-the-run Treasury and that of the first off-the-run (the previous on-the-run) Treasury. Panel B presents summary statistics for the cross-the-run spread of individual tenors for the indicated subperiods, where the cross-the-run spread is defined as the difference between the convenience premium of the current on-the-run Treasury and that of all other Treasuries with a maturity in the range of +/- 0.10 years of the maturity of the current on-the-run Treasury. In Panel A (Panel B), the column Spread presents the average on-the-run spread (cross-the-run spread) for the indicated tenors. Std. Dev. presents the standard deviation of the on-the-run spread (cross-the-run spread) for the indicated tenors. Negative presents the percentage of the observations where the on-the-run spread (cross-the-run spread) takes on a negative value. N denotes the number of observations. The row labeled All presents the average on-the-run spread (cross-the-run spread) across all Treasury types. The subperiod 1997–2007 is daily from January 23, 1997 to December 31, 2007, and the subperiod 2008–2022 is daily from January 1, 2008 to December 16, 2022.

	1997–2007				2008–2022			
	Spread	Std. Dev.	Negative	N	Spread	Std. Dev.	Negative	N
Panel A **On-the-Run Spread**								
2-Year	1.742	2.098	16.09	2,623	0.660	1.295	23.92	3,599
3-Year	1.505	2.715	23.64	1,502	0.218	1.789	43.15	3,370
5-Year	3.394	3.528	5.63	2,666	0.609	1.068	23.46	3,597
7-Year	–	–	–	–	0.078	0.690	39.38	3,291
10-Year	4.613	4.218	5.05	2,715	1.705	1.710	10.41	3,709
20-Year	–	–	–	–	0.704	1.584	41.68	571
30-Year	7.506	4.675	0.76	1,854	0.279	1.378	42.06	3,711
All	3.725	4.103	9.49	11,360	0.610	1.484	30.39	21,848
Panel B **Cross-the-Run Spread**								
2-Year	1.263	2.900	34.76	2,261	−0.009	3.308	31.06	3,599
3-Year	1.509	3.171	38.42	1,502	−0.007	1.822	48.19	3,378
5-Year	5.182	5.337	18.79	1,751	0.838	2.508	24.26	3,330
7-Year	–	–	–	–	−1.218	1.950	79.44	2,208
10-Year	6.477	2.123	0.00	495	4.191	11.121	47.31	1,858
20-Year	–	–	–	–	−2.330	4.553	78.23	634
All	2.896	4.290	28.16	6,009	0.423	4.910	44.53	15,007

Table VI

Regression Results for the Change in the Weighted-Average-Maturity Requirement for Money Market Funds

This table reports the results from the panel regression of month-end convenience premia $PREM_{i,t}$ for all Treasury securities i with a maturity of one year or less on the number of years to maturity $MATURITY_{i,t}$ at time t interacted with an indicator variable I_t that takes a value of zero during the first six months of 2010 and a value of one during the last six months, and monthly fixed effects FE_t. Standard errors are based on White (1980). The superscripts * and ** denote significance at the ten-percent and five-percent levels, respectively. The sample period is monthly from January 2010 to December 2010. The regression is

$$PREM_{i,t} = FE_t + \beta\, MATURITY_{i,t} + \gamma\, MATURITY_{i,t} \times I_t + \epsilon_{i,t}.$$

	Coeff	t-Stat
$MATURITY_{i,t}$	-3.771	-2.75^{**}
$MATURITY_{i,t} \times I_t$	-8.613	-4.60^{**}
Monthly Fixed Effects		Yes
Adj. R^2		0.625
N		623

Table VII

Maturity-Crossing Regressions for Changes in Convenience Premia

This table reports the results from the regression of changes in the convenience premia $\Delta PREM_{i,t}$ for Treasury note/bond i on its time to maturity measured in years $MATURITY_{i,t}$ and on indicator variables $I_{i,t,j}$ that take a value of one if the maturity of the Treasury note/bond at the beginning of the month is within $+/-$ 0.15 years of maturity j, and zero otherwise, and where j takes on the relevant values from the elements of the set {2-Year, 3-Year, 4-Year, 5-Year, 6-Year, 7-Year, 8-Year, 9-Year, 10-Year}. The change in the convenience premium is the difference between the convenience premium in month t and the convenience premium at the beginning of month t. Robust standard errors are clustered at the CUSIP level. The superscript * denotes significance at the ten-percent level; the superscript ** denotes significance at the five-percent level. The sample period is monthly from January 1997 to December 2022. The regression is

$$\Delta PREM_{i,t} \ = \ \alpha \ + \ \sum_j \beta_j \ I_{i,t,j} \ + \ \gamma \ MATURITY_{i,t} \ + \ \epsilon_{i,t}.$$

	Coeff	t–Stat
Intercept	0.261	7.98^{**}
$I_{\text{2-Year}}$	-0.339	-2.98^{**}
$I_{\text{3-Year}}$	-0.101	-0.79
$I_{\text{4-Year}}$	-0.205	-1.37
$I_{\text{5-Year}}$	-0.420	-2.45^{**}
$I_{\text{6-Year}}$	-0.198	-1.04
$I_{\text{7-Year}}$	-0.541	-2.17^{**}
$I_{\text{8-Year}}$	-0.387	-1.47
$I_{\text{9-Year}}$	-0.571	-2.14^{**}
$I_{\text{10-Year}}$	-0.839	-2.31^{**}
$MATURITY$	-0.020	-9.48^{**}
Adj. R^2		0.001
N		65,235

Table VIII

Maturity-Crossing Regressions for Trading Volumes

This table reports the results from the regression of trading volume $VOL_{i,t}$ for Treasury note i with the indicated initial tenor on indicator variables $I_{i,t,j}$ that take a value of one if the maturity of the Treasury note at time t is within +/- one month of maturity j, and zero otherwise, and where j takes on the relevant values from the elements of the set {1-Year, 2-Year, 3-Year, 4-Year, 5-Year, 7-Year}. CUSIP fixed effects FE_i and monthly fixed effects FE_t are included. Robust standard errors are clustered at the monthly level. The superscript * denotes significance at the ten-percent level; the superscript ** denotes significance at the five-percent level. The sample period is daily from January 4, 2018 to December 16, 2022. The regression is

$$VOL_{i,t} = FE_i + FE_t + \sum_j \beta_j \, I_{i,t,j} + \epsilon_{i,t}.$$

	5-Year Note Volume		10-Year Note Volume	
	Coeff	t–Stat	Coeff	t–Stat
$I_{\text{1-Year}}$	312.018	4.94^{**}	233.447	6.35^{**}
$I_{\text{2-Year}}$	196.511	3.89^{**}	229.400	5.88^{**}
$I_{\text{3-Year}}$	72.066	2.45^{**}	104.630	6.61^{**}
$I_{\text{4-Year}}$	−59.936	-3.29^{**}	32.538	3.25^{**}
$I_{\text{5-Year}}$			20.817	3.78^{**}
$I_{\text{7-Year}}$			−9.969	-1.97^{**}
CUSIP Fixed Effects		Yes		Yes
Monthly Fixed Effects		Yes		Yes
Adj. R^2		0.099		0.106
N		5,286		12,556

Table IX

Results from Regressions of Monthly Changes in Convenience Premia on Changes in Proxies for Event Risk

This table reports the results from the regressions of monthly changes in the average convenience premium $\Delta PREM_t$ for each tenor or maturity category on the monthly changes in the indicated variables proxying for the risk of a major event in the financial markets. ΔVIX_t denotes the corresponding change in the VIX index, ΔAAA_t is the change in the AAA corporate spread above Treasuries, $\Delta FUND_t$ denotes the change in the funding spread between three-month Libor and the three-month repo rate, and $\Delta NFCI_t$ is the change in the Chicago Federal Reserve National Financial Conditions Index (NFCI). Adj. R^2 and N denote the adjusted regression R-squared and the number of observations, respectively. The superscripts * and ** denote significance at the ten-percent and five-percent levels, respectively. Robust standard errors are based on Newey and West (1987). The sample period is monthly from February 1997 to December 2022. The regression is

$$\Delta PREM_t = c_0 + c_1\,\Delta VIX_t + c_2\,\Delta AAA_t + c_3\,\Delta FUND_t + c_4\,\Delta NFCI_t + \epsilon_t.$$

	Intercept		ΔVIX_t		ΔAAA_t		$\Delta FUND_t$		$\Delta NFCI_t$			
	Coeff	t–Stat	Coeff	t–Stat	Coeff	t–Stat	Coeff	t–Stat	Coeff	t–Stat	Adj. R^2	N
Panel A												
Tenor												
T-Bill	0.045	0.09	−0.527	−2.18**	−0.015	−0.25	0.106	1.56	0.245	2.36**	0.162	311
2-Year	0.050	0.13	−0.272	−1.81*	−0.001	−0.03	0.053	1.08	0.094	1.64	0.091	311
3-Year	0.147	0.43	−0.307	−1.36	0.005	0.11	0.063	1.36	0.073	1.36	0.069	285
5-Year	0.022	0.09	−0.033	−0.38	0.006	0.20	0.010	0.51	0.087	2.84**	0.071	311
7-Year	−0.075	−0.17	−0.078	−0.79	0.088	2.20**	0.016	0.54	0.050	0.85	0.046	202
10-Year	−0.010	−0.03	0.044	0.46	0.029	0.85	−0.019	−0.78	0.075	1.86*	0.055	311
20-Year	0.015	0.03	0.198	1.30	−0.051	−1.06	−0.187	−2.36**	0.159	1.57	0.037	137
30-Year	−0.079	−0.23	−0.037	−0.20	−0.011	−0.30	0.014	0.29	−0.019	−0.33	−0.009	311
Panel B												
Maturity Range												
≤ 1	0.063	0.14	−0.463	−2.25**	0.005	0.10	0.095	1.48	0.183	2.30**	0.162	311
1-2	0.052	0.16	−0.134	−0.97	−0.011	−0.30	0.018	0.59	0.073	1.65**	0.030	311
2-3	0.038	0.15	0.025	0.29	−0.005	−0.16	0.020	0.88	0.076	2.53**	0.063	311
3-5	−0.023	−0.08	0.147	1.42	0.005	0.12	−0.035	−2.27**	0.100	2.80**	0.084	311
5-7	−0.053	−0.19	0.100	0.87	0.055	1.51	−0.033	−1.04	0.068	1.45	0.062	311
7-10	−0.036	−0.13	0.018	0.12	0.049	1.25	−0.030	−0.98	0.038	0.90	0.012	311
10-20	−0.067	−0.19	−0.055	−0.30	0.005	0.13	0.020	0.38	−0.033	−0.56	−0.007	311
20-30	−0.137	−0.39	−0.036	−0.18	−0.052	−1.45	0.012	0.30	−0.006	−0.11	−0.002	311

Appendix A. Data

Table A.I provides a description of all the data and variables used in the study along with their definitions and corresponding sources.

[Insert Table A.I here]

Table A.I
Data Definitions and Sources

This table summarizes the datasets used in this study. Frequency shows at what intervals the data are available. Description and Source show the data source and its definition. All data are for the period from January 1997 to December 2022 unless indicated otherwise.

Data	Frequency	Description and Source
Treasury Auction Data	Weekly	Treasury auction results for all individual Treasury CUSIPs (2, 5, 7, and 10-year Treasury notes, 20 and 30-year Treasury bonds, and 8, 13, 26 and 52-week Treasury bills). For each Treasury security, the data include the auction, issue, and maturity date, the amount issued (including reopenings), and the coupon rate (for Treasury notes and bonds). Data collected from the website of the U.S. Treasury at https://www.treasurydirect.gov/instit/annceresult/press/press.htm.
Treasury Note and Bond Prices	Daily	U.S. Treasury note and bond end-of-day prices for all Treasury CUSIPs listed in the Treasury Auction Data for the period from January 23, 1997 to December 16, 2022. Data retrieved from the Bloomberg system.
Treasury Bill Prices	Daily	U.S. Treasury bill end-of-day prices for all Treasury bill CUSIPs listed in the Treasury Auction data for the period from January 23, 1997 and December 16, 2022. Data retrieved from the Bloomberg system.
Treasury CMT Rates	Daily	Treasury constant maturity (CMT) rates from the Federal Reserve H.15 Selected Interest Rates Release. Data retrieved from the Bloomberg system.
U.S. Sovereign CDS Spreads	Daily	End-of-day credit default swap mid spreads for 6-month, 1-year, 2-year, 3-year, 5-year, 7-year, 10-year, 15-year, 20-year and 30-year contracts written on U.S. Treasury debt for the period from December 1, 2003 to December 16, 2022. Data from Markit.
Fed Funds Rate	Daily	End-of-day overnight effective fed funds rate (EFFR). Data retrieved from the Bloomberg system.
Repo Rates	Daily	End-of-day overnight general-collateral (GC) repo rate and one-week, two-week, and three-week GC term repo rates from the Bloomberg system.
Libor Rates	Daily	End-of-day London Interbank Offered Rates (Libor) rates for tenors of 1, 3, 6, and 12 months from the Bloomberg system.
SOFR Overnight Index Swaps	Daily	SOFR overnight index swap (OIS) rates for tenors of 1, 3, and 6 months, and 1, 2, 3, 5, 7, 10, 15, 20, and 30 years for the period from January 1, 2017 to December 16, 2022. SOFR OIS exchange fixed for floating SOFR cash flows based on the daily compounded SOFR rate annually for maturities over one year and have a single cash flow at maturity for tenors up to one year. Data from the Bloomberg system.
EFFR Overnight Index Swaps	Daily	Effective federal funds rate (EFFR) OIS rates for tenors of 1, 3, and 6 months, and 1, 2, 3, 5, 7, 10, 15, 20, 30 years for the period from February 13, 2002 to December 16, 2022. EFFR OIS exchange fixed for floating cash flows based on the daily compounded effective overnight fed funds rate (EFFR) annually for maturities over one year, and have a single cash flow at maturity for tenors up to one year. Data from the Bloomberg system.
EFFR/Libor Basis Swaps	Daily	End-of-day EFFR/Libor basis swap rates for tenors of 1, 3, and 6 months, and 1, 2, 3, 5, 7, 10, 15, 20, 30 years from the Bloomberg system for the period from January 23, 1997 to July 31, 2008. Fed funds/Libor swaps exchange quarterly floating cash flows for the tenor of the basis swap based on the daily compounded effective overnight fed funds rate over the quarter plus a spread for floating cash flows based on the three month Libor rate set at the beginning of the quarter.
Libor Interest Rate Swaps	Daily	End-of-day Libor interest rate swap rates for tenors of 1, 3, and 6 months, and 1, 2, 3, 5, 7, 10, 15, 20, 30 years from the Bloomberg system for the period from January 23, 1997 to July 31, 2008. Libor interest rate swaps exchange quarterly floating cash flows for the tenor of the interest rate swap based on the three month Libor rate set at the beginning of the quarter for fixed semi-annual cash flows.
Refcorp Strips	Daily	Yields of Refcorp Strips for maturities of 0.25, 0.50, 1, 2, 3, 4, 5, 6, 7, 9, 10, 15, 20, and 30 years for the period from January 23, 1997 to December 16, 2022. Data from the Bloomberg system.
Treasury Trading Volume	Daily	Trading volume for 5-year and 10-year Treasury notes. Daily data available for the period from January 4, 2018 to December 16, 2023 for Treasury notes with maturity dates after May 31, 2023. Data from the Bloomberg system.
NFCI	Monthly	The Chicago Fed National Financial Conditions Index from the Federal Reserve Bank of Chicago. Data from the Bloomberg.
VIX	Monthly	The CBOE VIX index of implied volatilities of options on the S&P 500 Index. Data from the Bloomberg system.
AAA Spread	Monthly	The spread between yields on AAA corporate bonds and the 10-year Treasury rate. Data from the Bloomberg system.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Appendix S1: Internet Appendix.

Replication Code.