When Do Treasuries Earn the Convenience Yield? — A Hedging Perspective

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Abstract

We document that the convenience yield of U.S. Treasuries exhibits properties consistent with a hedging perspective of safe assets; i.e., Treasuries are valued highly if they appreciate with poor aggregate shocks. In particular, the convenience yield tends to be low when the covariance of Treasury returns with the aggregate stock market returns is high. A decomposition of the aggregate stock-bond covariance into terms corresponding to the convenience yield, the frictionless risk-free rate, and default risk reveals that the covariance between stock returns and the convenience yield itself drives the effect in a substantive capacity.

Keywords: Stock-bond covariance, safety premium, liquidity premium, money premium, exorbitant privilege, safe assets, bubble, inflation, debt ceiling

JEL: G11, G12, G15, E4, E5, F3

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The United States dollar plays a central role in the international monetary system as a reserve currency for settling the transactions underlying global trade. Relatedly, the dollar and safe dollar-based fixed-income assets, notably the U.S. Treasuries, command a so-called *exorbitant privilege* in their pricing, due to heightened demand from the international community (central banks, for instance) looking for places to park dollar reserves. However, U.S. safe assets – and safe assets more generally – can command such a premium in their pricing due not just to an international demand but also due to domestic demand, driven by the hedging properties of these assets.

Distilled to its essence, this "hedging" perspective of safe assets assumes that markets are effectively incomplete. Households, for example, face consumption shocks, which can cause severe disutility if not smoothed across states and over time. Corporations face liquidity shocks in their production and financing needs, potentially leading to costly asset liquidations. Financial investors may face uninsurable background shocks due to exposure to illiquid assets, such as housing and private equity. Households, corporations, and financial investors therefore have a demand for assets that are safe enough to hedge against the impact of these (uninsurable) shocks. Similarly, banks prefer to make inter-bank loans collateralized by highest quality assets rather than take on each others' counterparty credit risk, as credit risk shocks may coincide with their own funding shocks.

Important early contributions to the literature on the safe asset premium often assume a built-in preference for such assets in investor or household objective functions.[1] The recent literature, however, has sought to micro-found these features. It emerges from this approach that prices of assets whose financial values or liquidity covary inversely with aggregate risk should reflect an excess premium, as these assets provide hedging value to investors when unspanned shocks materialize. In other words, the safe asset premium is magnified if assets provide a hedging benefit in a retrading sense: investors value assets whose secondary market prices rise in times of aggregate risk, as in Brunnermeier et al. (2024), or whose liquidity rises in times of aggregate risk, as in Acharya and Pedersen (2005). This combination of appreciation and liquidity in bad states of the world is dubbed the "good friend property" by Brunnermeier et al. (2024). U.S. Treasuries are considered a primary candidate for being such assets, and the associated premium that is reflected in their pricing is referred by the literature with a variety of terms, such as "convenience yield," "money premium," or "bubble."[2]

We establish that this premium, which, for fixing terminology, we refer to as the *convenience yield* of U.S. Treasuries, exhibits time-series properties consistent with the hedging perspective of safe assets. Specifically, the Treasury convenience yield is high when the covariance of returns on Treasuries and the aggregate stock market is low. Moreover, we find that innovations to the convenience yield itself comove with the aggregate equity market returns, contributing to the hedging properties of Treasuries, a result suggestive of the service-flow value of ease of retrading safe assets.

[1] See, e.g., Holmström and Tirole (2001) and Krishnamurthy and Vissing-Jorgensen (2012).

[2] A broad definition of the convenience yield is that it is any value of Treasuries above the present value their explicit cash-flows could contribute. For instance, extra demand due to regulatory requirements, such as the High Quality Liquid Assets (HQLA) requirement under Basel III (see Fuhrer et al. (2017)), could also contribute to the convenience yield.

We motivate our analysis using a simple intertemporal framework where Treasury convenience flows are modeled as (unobservable) time-varying payments accruing to the bondholder. The discounting of these convenience flows reflects the potential systematic nature of their variation: if the flows are higher in bad times, their present value is commensurately higher. The theoretical framework clarifies that the effect we seek to document differs from a hedging premium that would arise whenever interest rates are procyclical. We argue that the convenience flows themselves may have a negative beta with respect to stock market returns, contributing to a reduction of expected returns of safe bonds over and above any factors relevant in a frictionless world. Motivated by the analytical framework, we document three sets of empirical findings.

In the first set of results, we provide a new decomposition of the aggregate stock-bond covariance, separating out the contribution of the convenience yield. In Panel A of Figure 1, we plot the covariance between the daily returns on 10-year nominal Treasuries and the aggregate stock market in a 30-trading day look-back window. Prior research has found that this covariance exhibits substantial time variation; in particular, note the periodic large negative spikes in the post-2000 data.[3]

To decompose the covariance, we express the 10-year bond yield as the sum of a "frictionless" risk-free rate, the Treasury convenience yield, and a term corresponding to default risk, proxied by the credit default swap (CDS) rate. Using this yield decomposition, we calculate three corresponding covariance terms that comprise the aggregate stock-bond covariance. We find that both the frictionless risk-free rate component as well as the convenience yield component of the stock-bond covariance contribute in about equal measure to the stock-bond covariance of long maturity bonds. We plot the stock-bond covariance resulting from the convenience yield component of the 10-year yield in Panel B of Figure 1, illustrating the substantial contribution of convenience yield innovations to the aggregate covariance. In particular, the substantial hedge that long maturity bonds provided to equity market risk around the Global Financial Crisis (GFC), the Eurozone crisis, and most recently, the onset of the COVID pandemic, stems in good measure from the convenience yield component. The convenience yield contribution to the overall hedge is particularly notable at the height of the GFC: without the increase in convenience yields, the stock-bond covariance would have been positive in November 2008.

In our second and main set of results, we document support for the hedging perspective on safe assets: the convenience yield is high precisely when the covariance between stocks and bonds is low. Using the stock-bond covariance decomposition (into terms corresponding to the frictionless risk-free rate, the convenience yield, and default risk), we find that the covariance attributable to the convenience-yield fluctuations is the most robust in explaining the convenience yield of safe fixed income assets. The covariance attributable to the frictionless risk-free rate fluctuations also play a meaningful role.

These results obtain using a number of alternative convenience yield proxies as the dependent variable, both at the short and long maturities. Our baseline measure of the Treasury convenience

[3]See Duffee (2022) for a survey on the literature on stock-bond covariance.

yield is the TIPS-Treasury premium, which captures the yield differential between a synthetic nominal Treasury—constructed out of Treasury Inflation Protected Security (TIPS) and inflation swaps—and a traded nominal Treasury. This measure is based on the work by Fleckenstein et al. (2014), who document that, from 2004 to 2010, nominal Treasuries had almost always been more expensive than their synthetic counterparts. We choose the TIPS-Treasury spread as the baseline convenience yield measure, as we have high-quality daily smoothed yield curve data for both real and nominal Treasuries and both of the underlying securities have the exact same regulatory treatment, allaying concerns that balance sheet frictions drive the pricing differential.

Using the the TIPS-Treasury premium at the 10-year maturity as the convenience yield proxy, we find that a one standard deviation drop in the stock-bond covariance arising from innovations to the TIPS-Treasury premium corresponds to a 0.6 standard deviation increase in the convenience yield. Relationships of similar magnitudes emerge for seven alternative convenience yield proxies, with maturities ranging from three months to 30 years. The covariance terms attributable to the CDS premium fluctuations contribute to the convenience yield with a markedly smaller magnitude.

The results described so far are documented in the 2005-2024 sample, owing to the availability of the daily TIPS-Treasury premium. This recent sample is unusual, compared to the historical experience, in that the aggregate stock-bond covariance is negative. The relationship between stock-bond covariance and the level of the convenience yields that we establish in the recent sample, however, reaches back to earlier periods with positive aggregate stock-bond covariance. We document this robustness of the main finding by repeating the baseline analysis with six alternative convenience yield proxies. For each proxy, we decompose the aggregate stock-bond covariance and estimate the relationship with the level of the respective convenience yield. For each proxy, we thus find that the covariance term arising from convenience yield innovations relates negatively to the level of the same convenience yield. For two of these alternative convenience yield measures, the sample reaches back to 1972, spanning in roughly equal measure periods of both substantial positive and negative stock-bond covariance, indicating that our result is not limited to the most recent sample. Further, our results hold across a number of convenience yield proxies, which suggests a common driver. Although Siriwardane et al. (Forthcoming) has documented low correlations between various arbitrage spreads, our findings suggest the part of convenience yield movements explained by stock-bond covariance is shared across various proxies.

In the third set of results, we rely on the common component in convenience yield proxies to carry out further analyses. We extract the first principal component of the convenience yield proxies to confirm that our results are not driven by extreme realizations of convenience yields during the Global Financial Crisis; we also document that the results are robust to controlling for the VIX. We then show that expected inflation and default risk in Treasuries do not explain our findings. We also use principal component analysis to establish an additional empirical regularity in keeping with our theory. Namely, the analytic framework suggests the possibility that different parts of the yield curve reflect differential convenience yield dynamics. For instance, concerns about the long-term safety of U.S. Treasuries might cut into the hedging properties of the long maturity bond, in turn reducing its convenience yield today. To test for the presence of maturity-specific effects, we construct principal components separately for the short- and long-term convenience yield proxies. In line with our analytical framework, we find that the short-term stock-bond covariance relates particularly strongly to the first principal component of the short-term convenience yields. At the same time, the degree of commonality in the short- and long-maturity proxies indicates that factors operating through the entire yield curve are important drivers of the convenience yield.

In the final part of the paper, we discuss certain drivers of the TIPS-Treasury premium and Treasury convenience in general: factors specific to the TIPS market, factors specific to the creditworthiness of the United States, and factors relating to inflation dynamics.[4] Notably, we demonstrate that the resolutions of two debt ceiling standoffs (in 2011 and 2023) saw marked increases in the convenience yield.

Overall, the relationship between the level of the convenience yield and the hedging properties of the security supports the theoretical models of Acharya and Pedersen (2005) and Brunnermeier et al. (2024) regarding a liquidity premium arising from covariance of a security's liquidity with negative aggregate shocks. Put differently, the convenience yield reflected in the price of a long-maturity security does not only reflect expected convenience flows in future periods but also a substantial risk adjustment, owing to the fact that such flows are elevated in periods of poor aggregate realizations. As mentioned above, the channel we document is thus distinct from the standard negative beta channel of low bond yields.

These results have several implications for theoretical and empirical work on safe assets as well as for policy. Time-series variation in the covariance of U.S. Treasury returns with the aggregate stock market return implies that the moneyness or safe-asset properties of Treasuries and fixed-income assets are not a given. Instead, these properties are likely tied to macroeconomic and financial developments. Our findings present a complementary rationale for why the U.S. Treasuries may become "inconvenient" to the one offered by Duffie (2020), He et al. (2022), and Haddad et al. (2021). These papers document that, during the peak of the market turmoil during the COVID outbreak of March 2020, U.S. Treasuries—especially the long-term ones—did not benefit from a flight to quality observed during the Global Financial Crisis (GFC) of 2007-2009, and, if anything, they appeared to be experiencing fire sales until the Federal Reserve stepped in to provide liquidity. These authors attribute this outcome to the unwinding of leveraged positions in cash-futures basis market, limited intermediation capacity of dealer banks due to post-GFC reforms, and rollover risk faced by nonbank financial intermediaries. In contrast to this episodic and market-function-linked erosion of convenience yield of Treasuries (see also Duffie (2023)), the recent erosion we document is linked to a rise in the covariance of Treasury returns with aggregate stock returns, moves more slowly, and resembles that observed also in 1970s and 1980s, representing possibly a risk to investors' ability to hedge aggregate risks.

[4] Inflation dynamics have been shown to play an important role in the literature on convenience yields; for instance, see Cieslak et al. (2023) and Li et al. (Forthcoming), among others.

1 Decomposing the Stock-Bond Covariance

1.A Mechanics of Return and Covariance Calculations

Our analysis relies on decomposing Treasury yields into three constituent elements: a term corresponding to the convenience yield, a term corresponding to the default risk, and a residual term, the "frictionless" risk-free rate. We apply this decomposition at different maturities as well as with a variety of proxies for the convenience yield.

Formally, let $\text{Yield}_{t,n}$ be the time t, maturity n nominal Treasury yield, let $\text{CDS}_{t,n}$ denote the corresponding credit default swap rate, and let $\text{Convenience}_{t,n}$ stand for a proxy for the convenience yield. We can then back out the time t, maturity n frictionless rate, denoted $\text{Frictionless}_{t,n}$, from the following equation:

$$\text{Yield}_{t,n} = \text{Frictionless}_{t,n} + \text{CDS}_{t,n} - \text{Convenience}_{t,n}. \tag{1}$$

This decomposition implies a closely related decomposition of Treasury returns into components arising from innovations to each of the three constituent elements. Specifically, for maturity n we calculate:

$$\begin{aligned}
\widehat{R}^{\text{Yield}}_{t,n} &= -\, n \times \Delta\text{Yield}_{t,n} \\
\widehat{R}^{\text{Frictionless}}_{t,n} &= -\, n \times \Delta\text{Frictionless}_{t,n} \\
\widehat{R}^{\text{CDS}}_{t,n} &= -\, n \times \Delta\text{CDS}_{t,n} \\
\widehat{R}^{\text{Convenience}}_{t,n} &= \quad n \times \Delta\text{Convenience}_{t,n}.
\end{aligned} \tag{2}$$

Note the lack of a minus sign in the last row, reflecting the convention that high convenience implies low yields, as seen in Equation (1). For that reason, an increase in the convenience yield indicates an increase in the price of the bond. With the return decomposition in hand, we calculate the stock-bond covariance, both in the aggregate and as it separately arises from each of the components.

We are particularly interested in conditional covariances that reflect the recent importance of various drivers of stock and bond returns. For that reason, our baseline calculations use a short lookback window of 30 trading days. One potential concern with measuring covariances in such a short window is that times of market stress might see price pressure in either the stock or the bond market, potentially leading to sharp return reversals. To mitigate the impact of this market illiquidity, we construct overlapping three-day returns that average across consecutive trading days

$$R^i_{t,n} = \left(1/\sqrt{3}\right)\left(\widehat{R}^i_{t,n} + \widehat{R}^i_{t-1,n} + \widehat{R}^i_{t-2,n}\right) \tag{3}$$

for each of the four returns described in Equation (2) as well as the equity market return.[5] The adjustment factor of one over square root three ensures that the volatility of returns remains

[5] Our approach resembles that of Dimson (1979) beta but allows for potential illiquidity in both of the constituent assets.

unaltered. With the three-day returns, we calculate the stock-bond covariance and the constituent elements:

$$\text{Cov}_t(R^{\text{Yield}}, R^{\text{Stocks}}) = \text{Cov}_t(R^{\text{Frictionless}}, R^{\text{Stocks}}) + \text{Cov}_t(R^{\text{CDS}}, R^{\text{Stocks}}) + \text{Cov}_t(R^{\text{Convenience}}, R^{\text{Stocks}}) \quad (4)$$

where we have dropped the time and maturity subscripts from returns for ease of reading. Our convention in constructing the returns ensures that negative covariance values always mean that returns arising from that piece of the yield reflect a hedge with respect to stock market returns.

1.B Proxying for the convenience yield

The above decomposition can be carried out with a variety of convenience yield measures. Our principal proxy for the Treasury convenience yield is based on the relative pricing of nominal and real Treasury bonds. As shown by Fleckenstein et al. (2014), the prices of nominal Treasuries consistently exceed the prices of matched maturity TIPS prices, accounting for the variable inflation coupon payment via traded inflation swaps. Specifically, combining TIPS, inflation swaps, and Treasury STRIPS allows these authors to construct "synthetic" nominal Treasury bonds with cash-flows identical to traded nominal Treasuries but at lower prices than the traded counterparts. Because two such securities—a nominal bond and a maturity-matched synthetic nominal bond—have identical cash-flows, we interpret the gap in their prices as a proxy for the convenience flows afforded by the nominal Treasury. Our interpretation is consistent with the result of Fleckenstein et al. (2014) that this gap increased substantially during the Global Financial Crisis and has a common component with other proxies of Treasury specialness, namely the on-the-run/off-the-run spread and the Refcorp-Treasury spread.[6]

Relative to the approach of Fleckenstein et al. (2014), we use a simpler method to construct a high-frequency TIPS-Treasury premium. Instead of comparing the prices of matched pairs of nominal and real Treasuries, we employ the continuously compounded fitted nominal and real yield curves from Gürkaynak et al. (2007) and Gürkaynak et al. (2010), respectively. We combine this data with interpolated inflation swap rates to account for the inflation coupon part and calculate the TIPS-Treasury premium for maturity n on date t as:

$$\text{Premium}_{n,t} = \text{TIPS Yield}_{n,t} + \text{Inflation Swap}_{n,t} - \text{Yield}_{n,t} \quad (5)$$

$$= \text{Synthetic Yield}_{n,t} - \text{Yield}_{n,t}, \quad (6)$$

where the second equation emphasizes the terminology of "synthetic yield" to refer to the yield on a nominal bond constructed out of TIPS and inflation swaps.

This method results in a day- and maturity-level proxy of the Treasury convenience yield in the 2005-2024 sample, with the availability of inflation swap data being the constraint. Our measure

[6]See Krishnamurthy (2002) and Longstaff (2004) for more on the on-the-run/off-the-run and Refcorp-Treasury spreads, respectively.

is not identical but highly correlated with the measure documented by Fleckenstein et al. (2014), with correlation of 0.91 between the two calculations in a sample ending in 2014. Relative to that proxy, our construction has the advantage that the yield curve estimation smooths over some of the security-specific pricing factors that could introduce noise to the estimation using matched pairs of actual securities.

Note that changes in realized or expected inflation should not have any directional impact on this measure of the convenience yield: the dependence of TIPS payouts on the inflation rate is hedged away using swap rate data. Indeed, Fleckenstein et al. (2014) provide evidence against the view that the TIPS-Treasury premium reflects mispricing in the inflation swap market by showing that real and nominal corporate bond prices constructed using an identical methodology do not exhibit corresponding price disparities. They also discuss the potential impact of credit risk, tax differences, trading costs, and other aspects on the dynamics of the TIPS-Treasury premium.[7] Finally, note that the prices of TIPS themselves might incorporate some degree of convenience, which would imply our measure understates the true level of convenience yield.

1.C The Aggregate Stock-Bond Covariance

We are now in a position to calculate the stock bond covariance and its constituent elements as captured in Equation (4). On the stock side, we use the daily arithmetic CRSP value-weighted return. For the baseline calculation, we focus on the 10-year maturity, and the bond return is calculated following Equation (2) using the continuously compounded zero-coupon constant-maturity nominal Treasury yield from the Gürkaynak et al. (2007) fitted yield curve. The use of a fitted yield curve ensures the bond prices involved always correspond to the exact same maturity and smooths over the impact of any potential bond-specific demand effects. For the convenience yield proxy, we use the TIPS-Treasury premium constructed at the 10-year maturity.

In the baseline stock-bond covariance calculation, we use a 30-trading day lookback window. A short lookback window comports with the approach of Duffee (2022), the rationale being that each monthly covariance should reflect the arrival of recent information. Having calculated covariances in daily data, we collapse down to a monthly variable by keeping the last available calculation in each calendar month. We report the covariances on an annualized basis in percent units. For example, if the daily stock return volatility is 2%, daily bond return volatility is 0.5% and the correlation between the two return series is -0.6, the covariance would be reported as $-0.6 \times 0.02 \times 0.005 \times 252 = -1.512\%$.

The summary statistics of the aggregate stock-bond covariance in the 2005-2024 sample are

[7] There is a potential bias on the TIPS-Treasury premium that stems from the contractual features of TIPS: these bonds pay a variable inflation coupon, but in the event of deflation, the inflation coupon payment is bounded below at zero. This means that TIPS prices incorporate a put premium if the distribution of the future price level includes deflationary outcomes. For that reason, a shift away of the probability mass from deflationary outcomes, such as that in 2021 and 2022, would reduce TIPS prices, hence increasing TIPS yields and, everything else equal, increasing our proxy of the Treasury convenience yield. As discussed below, directionally this effect contravenes our findings regarding the relationship between the TIPS-Treasury premium and inflation. Note too that recent work by Dittmar et al. (Forthcoming) documents a link between U.S. default risk and the TIPS-Treasury premium, a result we discuss in Section 3.B.

reported in Panel A of Table 1. In this sample, the stock-bond covariance is negative, and the standard deviation of the monthly values is about 0.9. The time-series of stock-bond covariance over a longer period is plotted in Panel A of Figure 1. Both low- and high-frequency changes in the stock-bond covariance are evident. Over a long timeframe, the stock-bond covariance declined markedly from the 1980s through the 2010s. Over shorter timeframes, the stock-bond covariance exhibited periodic spikes. In the sample since the turn of the century, in particular, the spikes in the stock-bond covariance tend to be on the negative side: during the 2001 recession, notably during the Global Financial Crisis, the Eurozone crisis, and at the onset of the COVID pandemic. The exception is the recent post-pandemic era, which saw positive stock-bond covariance during times of unexpectedly high inflation.

1.D Constituent Elements of the Stock-Bond Covariance

We now present our decomposition of the aggregate stock-bond covariance using the TIPS-Treasury premium as a convenience yield proxy. Panel A of Table 1 reports summary statistics for these three constituent terms of the aggregate stock-bond covariance in the monthly sample from 2005 to 2024. We find that both the covariance stemming from the frictionless risk-free rate as well as the Treasury premium contribute to the overall hedging properties of the long bond. The averages of the convenience yield and frictionless risk-free rate parts are both negative, with means of -0.18 and -0.26, respectively, and have similar standard deviations of 0.87 and 0.78, respectively. The covariance component stemming from innovations to CDS rate has a mean of 0.05 and contributes much less to the variation of the stock-bond comovement with a standard deviation of 0.18. The covariance component corresponding to CDS innovations likewise has the expected sign, to the extent increases in default probability coincide with poor stock market realizations.

The time-series of the stock-bond covariance calculated with innovations to the convenience yield is plotted in Panel B of Figure 1. For comparison, we also include the full stock-bond covariance using 10-year nominal Treasury prices. As the figure shows, much of the aggregate variability stems from the convenience yield component: note the spikes during the GFC, the Eurozone crisis, and, most recently, during the onset of the COVID pandemic. Indeed, in November 2008, at the height of the GFC, the hedging properties of the nominal Treasury – summarized in the stock-bond covariance – were entirely accounted for by the convenience yield term, with no contribution from the frictionless risk-free rate.

Nevertheless, for most of the 2005-2024 sample, both the covariance terms corresponding to the Treasury convenience yield and the frictionless risk-free rate have contributed to the bond being a hedge to stock market returns. Both components have a positive correlation with the aggregate stock-bond covariance. In Online Appendix Table OA1, we document that the correlations with the aggregate stock-bond covariance are 0.65 and 0.46 respectively for the covariance terms corresponding to the convenience yield and the frictionless risk-free rate. The correlation coefficients indicate that these two components explain 42% and 21% of the variation in the aggregate covariance. In contrast, the correlation of the covariance term corresponding to CDS innovations with the aggregate covariance is -0.21.

Overall, the descriptive results in this section show that the convenience yield is an important driver of the aggregate stock-bond covariance. Even though the existence of Treasury convenience yields is well established in the literature, it is not a foregone conclusion that the covariance between stock and bond returns stemming from the convenience yield is substantial or that it has a negative sign. Indeed, a large but stable convenience yield would entail no stock-bond covariance emanating from this part of the Treasury yield.

One potential limitation in interpreting our calculations is that the duration of a portfolio of a zero-coupon bond and default protection is stochastic: in the event of a default, the terminal cash-flow is paid out prior to maturity. For that reason, changes in CDS rates always correspond to changes in duration of the CDS payout. In the context of our decomposition in Equation (2), an increase in the CDS rate would bring about a shortening of the duration; hence the multiplication with 10 in the right-hand-side decomposition would tend to somewhat overstate the contribution of CDS rates to bond returns. The magnitude of such an effect is likely to be quite small in the context of U.S. Treasuries, where the unconditional default rate is low: assuming a risk-free rate of 2%, a CDS rate of 30bps, and a 30% loss given default (the value used by Chernov et al. (2020)), a two standard deviation daily shock to the 10-year CDS rate starting from the in-sample mean value would see the duration of the CDS contract decrease only by 0.01 years. Given the quantitatively small importance of this effect, we ignore stochastic duration in calculating our decomposition, though we caution that it could have a quantitatively important role in contexts with higher default probabilities.[8] A final complication facing this decomposition is potential staleness in CDS quotes. For instance, Boyarchenko and Shachar (2020) find a decreasing amount of "risk-forming" transactions in which participants take change their risk exposures in the CDS market, while Klingler and Lando (2018) argue that safe sovereign debt CDS rates are affected by regulatory frictions. Any such staleness relative to the true default risk would tend to attribute the default risk variation to the frictionless risk-free rate instead.

1.E Alternative Proxies of the Convenience Yield

In addition to the 10-year TIPS-Treasury premium, we employ various alternative proxies for the Treasury convenience yield, both at shorter and longer maturities. We collect details about variable construction and data sources in Appendix Table A1 and provide a high-level overview here. We plot all the series described below in Appendix Figure A1.

Our second proxy for Treasury convenience yield is the spread between the Treasury yield and the equivalent maturity risk-free interest rate implied by put-call parity on options contracts (the "box rate"). We use the USD convenience yield, labeled "Box USD," as calculated by van Binsbergen et al. (2022) and updated by Diamond and Van Tassel (Forthcoming).

Our third proxy for the convenience yield is the spread between three-month General Collateral (GC) repo contract rates and the three-month Treasury bill rate, labeled "GC-Tr 3m." This measure

[8] See Fleckenstein and Longstaff (2024) Section II for more on the stochastic duration of Treasury bonds.

has been widely used as a proxy for the short-term convenience yield, as the GC repo contract is devoid of credit risk but is less liquid than Treasury bills; for instance, see Gorton et al. (2022). The fourth proxy for the convenience yield is the spread between the effective Fed funds rate and the three-month Treasury bill rate, denoted "FF-Tr 3m," again seeking to capture the special value attributed to Treasury bills over alternative safe short-term investments. One complication facing this proxy is the maturity mismatch between Fed Funds, which is an overnight rate, and the three-month Treasury bill. In line with the approach of Stein and Wallen (Forthcoming), we adjust for the term structure effect by using the three-month OIS rate instead. The resulting convenience yield proxy, denoted "OIS-Tr 3m," is available in a shorter sample, and we use one of the two proxies, depending on the context.

The fifth proxy is the negative of the Z-spread, constructed after Greenwood et al. (2015). These authors measure the yield difference of n month maturity Treasury bills from the fitted yield curve of Gürkaynak et al. (2007) and call the gap the n-month Z-spread. We follow their methodology by calculating the average Z-spread of Treasury bills with four to 26 weeks until maturity. In contrast to Greenwood et al. (2015), we report the negative of the difference between the T-bill rate and the fitted yield curve, so that higher values of the Z-spread correspond to higher levels of convenience. We emphasize this distinction by calling the measure "-1*Z-Spr." Like the FF-Tr spread, the Z-spread can be constructed going back to the 1970s.

Our sixth proxy for the convenience yield is the 30-year Overnight Indexed Swap (OIS) spread, denoted "OIS Spr." Interest rate swaps are one of the largest derivative markets, and the literature has interpreted the swap spread as a proxy for the Treasury convenience yield. In particular, Feldhütter and Lando (2008) decompose swap spreads into a credit risk component, a swap market-specific component, and the Treasury convenience yield, with the estimated convenience yield representing the majority of the gap. In recent data, swap spreads have been negative, suggesting potential Treasury "inconvenience"; for instance, see Du et al. (2023). Despite this finding, we include the swap spread in our baseline set, noting that the variation in this proxy can reflect convenience yield changes, even if its level is negative.

The seventh proxy, "FN-Tr," is the spread between Agency MBS and Treasury yields, established as a proxy for Treasury convenience by He and Song (Forthcoming). These authors construct an MBS convenience yield with respect to AAA corporates, adjusting for both duration mismatch as well as the value of the prepayment option in MBS. The eighth proxy is the Treasury richness measure from recent work of Fleckenstein and Longstaff (2024). This measure, denoted "Rich.," discounts the promised cash-flows of Treasuries using OIS linked to GC repo rates (and other swap curves prior to the availability of repo swap rates).

With the exception of the AAA-Tr. spread, all of these proxies are effectively devoid of default risk in that they employ securities that have implicit or explicit government guarantees or are fully collateralized. Our preferred measure, the TIPS-Treasury premium, stands apart in that it is available at long maturities and both its legs are backed by the U.S. Treasury, hence having the exact same regulatory treatment.

1.F Alternative Decompositions of the Stock-bond Covariance

Finally, a number of the convenience yield proxies are available at daily frequencies, allowing for alternative decompositions of the stock-bond covariance, as captured in Equation (4). These alternative decompositions allow us to carry out a decomposition prior to 2005, when the TIPS-Treasury premium becomes available. However, the CDS rates used in Equation (4) are also unavailable for much of the sample prior to 2005. For that reason, we carry out a simpler covariance decomposition that expresses the aggregate stock-bond covariance as the sum of two covariance terms: one stemming from innovations to the convenience yield proxy and the residual term:

$$\text{Cov}(R^{\text{Yield}}, R^{\text{Stocks}}) = \text{Cov}(R^{\text{Convenience}}, R^{\text{Stocks}}) + \text{Cov}(R^{\text{Yield}} - R^{\text{Convenience}}, R^{\text{Stocks}}) \tag{7}$$

In our baseline calculation, we focus on the 10-year maturity and correspondingly use the 10-year TIPS-Treasury premium as the convenience yield proxy. The alternative convenience yield proxies that are available daily are constructed at various maturities, ranging from three months to 10 years. To maintain easy comparability with the baseline 10-year calculation, we adjust the $\text{Cov}(R^{\text{Convenience}}, R^{\text{Stocks}})$ term such that it corresponds to a return from a hypothetical 10-year instrument with the same convenience yield as the given proxy. For instance, if the convenience yield proxy is constructed at the two-year maturity, we multiply the resulting covariance term by five. We use this hypothetical 10-year convenience yield covariance term to decompose the aggregate stock-bond covariance at the 10-year maturity.

2 Convenience Yield and the Stock-Bond Covariance

In this section, we establish our second main result: the level of the convenience yield is high precisely when Treasuries represent a good hedge to stock market returns, as proxied by a low covariance of Treasury and stock returns. In line with our analytical framework, we find that much of this effect stems from the covariance of convenience yield innovations with stock market returns.

2.A Analytical Setup

We first outline the steps to establish this prediction analytically while relegating the details to Online Appendix OA.A. Consider a zero-coupon bond with a safe terminal payment at time T that affords its owner a potentially time-varying convenience flow in each period prior to the maturity date. The convenience flows are not directly observable, but the present value of the bond reflects the terminal payment as well as the value of the expected future convenience flows. Our claim is that the discounting of the future convenience flows reflects a substantial risk adjustment, because the convenience flows tend to be high in states with poor aggregate realizations. In other words, the price of the bond with convenience flows does not just reflect the expectation of such nonpecuniary benefits but also a premium for a predicted increase of the nonpecuniary benefits in bad states. The effect we are interested in therefore differs from a negative bond beta that would arise whenever interest rates are procyclical.

Because convenience benefits are not directly observable, we cannot directly associate convenience flows with aggregate risk. We can, however, calculate the returns of a bond that conveys future convenience flows and associate the returns with stock market returns. Specifically, employing the standard Campbell and Shiller (1988) decomposition, the time $t+1$ return innovation (denoted sr_{t+1} for surprise return) on a bond with convenience flows is given by:

$$sr_{t+1} = (\mathrm{E}_{t+1} - \mathrm{E}_t) \left[\sum_{j=1}^{T-1} \rho^j [(1-\rho) k_{t+j+1} - r_{t+j+1}] \right], \tag{8}$$

where k_t and r_t are the log convenience flow and the log expected return in period t, respectively, and ρ is a constant that depends on the unconditional level of the convenience yield. In words, the surprise return on the bond with convenience flows equals the innovation to the discounted value of the expected convenience flows, minus the innovations to expected returns.[9]

Part of the surprise return in Equation (8) are innovations to the present value of the terminal payment at time T. To isolate the effect of convenience flows, we subtract out returns on a maturity T bond that conveys no such nonpecuniary benefits. Applying a Campbell and Shiller (1988) return decomposition to a bond without convenience flows and setting the dividend yield equal to the expected level of convenience flows, the surprise returns at time $t+1$ are simply:

$$sr_{t+1}^{f,T} = (\mathrm{E}_{t+1} - \mathrm{E}_t) \left[-\sum_{j=1}^{T-1} \rho^j r_{t+j+1}^{f,T} \right], \tag{9}$$

where $r_{t+j+1}^{f,T}$ stands for the return on a safe claim on a time T cash-flow and ρ is the same log-linearization constant as in Equation (8). With these two surprise returns in hand, we can calculate the portion of returns that do not stem from changes to the present value of the terminal payment as

$$\begin{aligned} sr_{t+1} - sr_{t+1}^{f,T} &= (\mathrm{E}_{t+1} - \mathrm{E}_t) \left[\sum_{j=1}^{T-1} \rho^j [(1-\rho) k_{t+j+1} - r_{t+j+1}] - \sum_{j=1}^{T-1} \rho^j r_{t+j+1}^{f,T} \right] \\ &= (\mathrm{E}_{t+1} - \mathrm{E}_t) \left[\sum_{j=1}^{T-1} \rho^j [(1-\rho) k_{t+j+1} - rp_{t+j+1}] \right], \end{aligned} \tag{10}$$

where rp_t stands for risk premium, defined as the return on the bond with convenience flows minus the return on the bond without such flows.

The formulation in Equation (10) captures the key object we are interested in: the innovations to expected convenience flows and the associated risk premia. With an empirical proxy of this quantity,

[9] An alternative conceptualization of the convenience yield models it as a "wedge" in an investor's Euler equation; see Jiang et al. (2021). In Online Appendix OA.A, we show the equivalence between that formulation and the one used here.

we can estimate the covariance between innovations to convenience flows, inclusive of risk premium innovations and market returns:

$$\mathrm{Cov}_t\left(sr_{t+1} - sr_{t+1}^{f,T}, r_{t+1}^{M}\right). \tag{11}$$

Our main prediction is that this conditional covariance is proportional to the level of convenience yields, as it captures the risk adjustment that contributes to the present value of each of the convenience flows:[10]

$$\mathrm{Convenience}_t \approx \alpha g(Y_t) - \Lambda\,\mathrm{Cov}_t\left(sr_{t+1} - sr_{t+1}^{f,T}, r_{t+1}^{M}\right). \tag{12}$$

Put differently, our analytic framework indicates a negative relationship between the stock-bond covariance arising from convenience yield innovations and the level of the convenience yield. The term $g(Y_t)$ indicates that our analytic framework does not rule out the contribution of other drivers of the convenience yield. To give one important example, the literature has emphasized a strong relationship between the level of the risk-free interest rate and the level of the convenience yield; see Nagel (2016). This relationship is intuitive, as the nominal interest rate captures the opportunity cost of holding cash, another asset with high convenience flows. To account for this separate source of variation in the level of the convenience yield, we include the risk-free interest rate as a control variable in our benchmark specifications. Note too that the role played by the level of interest rates ensures that the sign of the stock-bond covariance does not represent a breakpoint for the convenience yield: both negative and positive stock-bond covariance can be consistent with positive convenience yields to the extent other forces elevate the level of the convenience yield.

2.B Baseline results

Having established the theoretical framework, we now turn to empirical tests of our main hypothesis. We document a strong association between the level of the Treasury convenience yield and the aggregate stock-bond covariance. In Panel A of Table 2, we report monthly regressions in the 2005 to 2024 sample of eight distinct measures of the convenience yield on the monthly stock-bond covariance using the 10-year zero-coupon nominal Treasury return and controlling for the effective Fed Funds rate. (We indicate the time span for convenience yield proxies that are unavailable for the full period.)

We find consistently negative relationships, statistically significant at the 10% level for all of the eight proxies. The estimated effect size is economically significant: a one standard deviation decrease in the aggregate stock-bond covariance (about 0.89) corresponds to a half standard deviation increase of the 10-year TIPS-Treasury premium. Relationships of similar magnitudes obtain for the other convenience yield proxies. We estimate positive coefficients on the effective Fed Funds

[10] There are other ways to reach a similar prediction. For instance, within the framework of Acharya and Pedersen (2005), we can conceptualize the return gap between the two bonds–one with convenience flows and the other without–as a liquidity premium. In their setup, the expected level of such liquidity premium would be primarily determined by the covariance of the realized premium with market returns $\mathrm{E}[\text{Premium}] \cong -\lambda\,\mathrm{Cov}(\text{Premium}, R_M)$.

rate, consistent with the findings of Nagel (2016) regarding the positive relationship on convenience yields and the level of the short-term risk-free rate.

Our principal empirical finding is reported in Panel B of Table 2. Here we decompose the aggregate stock-bond covariance into three constituent parts in keeping with Equation (4). The decomposed stock-bond covariance allows us to directly test our hypothesis: the covariance of stock returns with the convenience yield itself contributes to the level of the convenience yield. We find results exactly in line with the hypothesis: the first column shows that the strong negative relationship between the TIPS-Treasury spread and stock-bond covariance is mostly on account of the covariance between the Treasury premium and the aggregate stock market. In terms of magnitudes, a one standard deviation decrease in the stock-bond covariance estimated from the Treasury premium corresponds to a 0.6 standard deviation (nine basis points) increase in the 10-year TIPS-Treasury premium. By contrast, the estimated coefficient on the frictionless risk-free rate covariance with the stock market is only 0.01, while the standard deviations of these two main parts of the stock-bond covariance are of comparable magnitude: 0.87 and 0.78 respectively. The impact of the third component, corresponding to the covariance between stock returns and default risk, varies more across specifications. A one standard deviation decrease in the Cov(CDS 10y, St.) term corresponds to a four basis point drop in the TIPS-Treasury premium.

Regressions estimated with alternative proxies of the Treasury convenience yield convey the same message and confirm the spirit of Equation (12): the negative relationship between the level of the convenience yield and the stock-bond covariance arises primarily from the covariance component stemming from Treasury convenience yield, an effect that is both economically and statistically significant at the 5% level for all eight proxies of the convenience yield as the dependent variable. The second row of the table documents that the frictionless risk-free rate has a generally negative relationship with the level of convenience yield proxies, but the statistical strength of these relationships varies greatly across proxies. The third row of the table documents that the relationship between convenience yield proxies and the covariance term owing to default risk innovations is less clear-cut than the other two constituent elements, both in magnitude and sign. We return to the statistical significance and economic interpretation of these last two findings using principal components analysis.

2.C Alternative Decompositions of Stock-Bond Covariance

We use the TIPS-Treasury premium as the principal measure of the convenience yield because we can construct it at a daily frequency exactly at the 10-year maturity. Furthermore, the nominal and real yields that are part of this calculation reflect prices of instruments with identical regulatory treatment, mitigating worries about various balance sheet frictions driving the measure. A shortcoming of this proxy is that it is only available starting in 2005. The recent sample is potentially special, as it reflects a period of negative aggregate stock-bond covariance, outside of the most recent data. Another possible concern is that the TIPS-Treasury premium reflects idiosyncratic factors, such as potential price pressures in the inflation swap market or illiquidity in the TIPS market.

In this section, we repeat the above analysis with stock-bond covariance decompositions that use alternative convenience yield proxies. Across six proxies, some with data reaching back to 1972, we again find that a negative stock-bond covariance arising from convenience yield innovations is robustly linked to the level of the respective convenience yield proxy. In these longer samples, we typically don't have CDS rate data, and we use the simpler decomposition captured in Equation (7) that splits the aggregate covariance into a term corresponding to convenience yield innovations and the residual. As the covariance component reflecting CDS innovations has the weakest estimated relationship with convenience yields, this simplification is unlikely to matter quantitatively. The six measures we use are the GC-Treasury spread, the Fed Funds-Treasury spread, and the negative of the Z-spread at the short horizon, and the 10-year Treasury Richness, the 10-year OIS Swap spread, and the AAA-Treasury spread at the long end.[11]

In Table 3, we document that the respective covariance terms arising from the innovations to these convenience yield measures are robustly negatively correlated with the level of the convenience yield. For ease of interpretation, we scale each of these covariances terms so that the returns correspond to a hypothetical 10-year maturity instrument with the same convenience yield. Such scaling ensures that the coefficients are comparable to the baseline estimates in Panel B of Table 2. Recall that, in the baseline calculation, we found that a one standard deviation decrease in Cov(Prem. 10y, St.) corresponded to a 0.6 standard deviation increase in the 10-year TIPS-Treasury premium. The estimated magnitudes are similar here: for instance, a one standard deviation drop in the covariance between the 10-year Treasury Richness innovations and the stock market return corresponds to about 0.25 standard deviation increase in the corresponding spread. The covariances estimated from the two convenience yield series with data staring in 1972, the Z-spread and the Fed Funds Treasury bill spread, imply about a 0.3 to 0.45 standard deviation increase in the respective spreads, respectively.

The second row reports the coefficients on the residual covariance term. Again, we find negative signs throughout, in keeping with the baseline results, but not always statistically significant at the 5% level, also in keeping with the baseline results. Because we don't have CDS data available, the residual covariances reflect both the frictionless risk-free rates as well as innovations to default risk. In all, the results in Table 3 provide a sense of the robustness of our baseline decomposition and suggest that TIPS-specific factors are unlikely to drive the baseline results. These results additionally illustrate that the negative relationship is not limited to the recent period, where the aggregate stock-bond covariance is negative.[12] As shown in Panel A of Figure 1, the aggregate stock-bond covariance was typically positive until the turn of the century, and the samples that reach back to 1972 see roughly half of the sample in aggregate positive stock-bond covariance times.

[11] The AAA-Treasury spread stands out among the other convenience yield proxies in that it reflects credit risk. We include here because of its availability back to the 1980s. The AAA-Treasury spread has been studied as a proxy for the convenience yield by Krishnamurthy and Vissing-Jorgensen (2012).

[12] In Online Appendix Table OA2 we estimate these regressions in the subsample excluding post-2000 data, again finding results in line with the baseline estimates.

3 Supporting Results

3.A Principal Component Construction

Our baseline results show a negative relationship between the stock-bond covariance and the level of eight different proxies of the convenience yield. These proxies differ across multiple dimensions: maturity, ranging from three months to 30 years, issuer characteristics, and the balance sheet treatment of the securities involved. Despite these differences, the regression results suggest a substantial common component, and the correlation matrix of the proxies confirms a strong commonality. This commonality suggests the use of a combined convenience yield proxy in place of the individual variables, with the expectation that, in the combined proxy, some of the asset-specific variation is diversified away. To this end, we estimate the first principal component of the proxies used in Table 2, labeled PC1.

We estimate PC1 separately in two samples, starting in May 1991 and starting in January 2005, reflecting availability of the different proxies. In the 2005-2024 sample, we use all of the proxies in Panel A of Table 2 except Box USD, which is only available until July 2020. The Fleckenstein and Longstaff (2024) 10-year Treasury Richness measure is only available through the end of 2022 and, to include it in the PC, we project its value to 2024 using the 10-year OIS Spread. (The two series have a correlation of 81%.) The resulting principal component PC1 is plotted in Panel A of Figure 2. As the figure shows, there is a substantial commonality with the 10-year TIPS-Treasury Premium. In Online Appendix Table OA3, we document the betas of PC1 with respect to the eight convenience yield proxies. We find strong correlations throughout, with the correlation coefficient between the 10-year TIPS-Treasury Premium and PC1 being second-lowest, only above the correlation coefficient for the Z-Spread. Notably, the two-year Box Spread, not included in the PC1 construction due to lack of availability past 2020, is strongly positively correlated with PC1, and the R^2 in the univariate regression is 65%. In the May 1991–2024 sample, we can use the three short-term convenience yield proxies—GC-Treasury spread, FF-Treasury spread, and the Z-Spread—to construct PC1, again finding that Z-Spread has the weakest correlation with the estimated first principal component.

3.B Robustness of Main Results Using PC1

In Table 4, we use the first principal component of convenience yields, PC1, to carry out robustness checks of the main analysis. In the first column, we document a strong negative relationship between the level of PC1 and the aggregate stock-bond covariance. The standard deviation of PC1 is normalized to one, so the coefficient of -0.45 indicates that a one standard deviation increase in the stock-bond covariance corresponds to about two-fifths of a standard deviation decrease in the convenience yield, an estimate in line with the proxy-by-proxy regressions detailed above. This strong relationship is illustrated in Figure 3. The plot of the PC1 in Panel A of Figure 2 suggests an elevated convenience yield during the Global Financial Crisis. To establish that the results are not driven solely by crisis periods, we include a dummy variable for the Global Financial Crisis years 2008-2009 as well as an interaction term with the covariance term corresponding to convenience yield innovations. We find that, while the crisis dummy absorbs some of the variation in the first principal component, the relationship between stock-bond covariance and the level of the convenience yields is in fact larger than in the baseline and statistically significant at the 5% level.

In the third column, we include all the constituent elements of the aggregate stock-bond covariance. Consistent with the results employing individual convenience yield proxies, we find that the relationship with the covariance term corresponding to the convenience yield is stronger than in the baseline specification, with an estimated coefficient close to -0.57. The coefficient indicates that a one standard deviation increase in the covariance term representing convenience yields sees a half a standard deviation drop in PC1. We also find a statistically significant relationship with the covariance term representing the frictionless risk-free rate. What explains this finding? The simplest explanation is that prices of TIPS themselves reflect some measure of convenience flows, and the frictionless risk-free rate covariance hence reflects a dynamic similar to what we have outlined in the analytical setup in Section 2.A. Another explanation we discuss later is that higher-than-expected inflation drives up this covariance while reducing the convenience yield.

The final two columns pertaining to the 2005-2024 sample carry out further robustness analyses. In the fourth column, we additionally control for the VIX to establish that the relationship between the convenience yield and the stock-bond covariance does not just reflect changes in market-wide volatility. Column five controls for the level of CDS and the level of inflation expectations. These controls are motivated by two strands of recent literature. First, Dittmar et al. (Forthcoming) argue that default risk can explain the TIPS-Treasury premium. To the extent TIPS and nominal Treasuries represent a different default risk—owing to differential recovery rates, relative pricing of real and nominal payoffs in the default state, or dependence of inflation rates on the default event—the TIPS-Treasury spread could be driven by shocks to U.S. creditworthiness. Motivated by their findings, we include the 10-year CDS rates as a control variable to ensure that the documented relationship is not accounted for by the level of default risk. (We separately check that the regressions in Table 2 remain after controlling for CDS rates.) Secondly, research by Cieslak et al. (2023) and Li et al. (Forthcoming) has established an important role of inflation expectations on convenience yields. To account for the potential direct impact of expected inflation, we include the 10-year expected inflation series produced by the Cleveland Federal Reserve Bank.

We find that our results are robust to both control variables: the coefficients on the covariance terms representing convenience yield innovations and the frictionless risk-free rate are each close to the corresponding baseline estimate. In line with the results of Nagel (2016), the coefficients on expected inflation are positive and account for some of the contribution of the Fed Funds rate.

The last two columns of Table 4 show robustness to the inclusion of VIX and expected inflation in the 1991/5-2024 sample. In this longer sample, we lose the covariance breakdown into constituent elements as well as the measures of default risk, leading to an abbreviated version of the prior table. In the longer sample, we are also limited to the PC1 that uses only short-term convenience yield proxies. Still, we find results in keeping with the most recent sample. The stock-bond covariance has a strong negative association with the level of the convenience yield, and this relationship remains when interacting with the Global Financial Crisis dummy and when controlling for the VIX or expected inflation at different maturities.

3.C Maturity-specific Effects

Our theoretical framework in Section 2.A establishes a link between the convenience yield and the hedging behavior of the particular fixed income instrument. The framework therefore suggests the possibility that different maturity convenience yields differ because of differences in the corresponding hedging properties of the bond. At the same time, standard yield curve models would suggest a substantial common element in convenience yields across maturities. To give an extreme example, consider a frictionless yield curve and a time-varying convenience flow that only accrues to, say, the 10-year zero-coupon bond. In this setup, one would still expect to see positive convenience yields percolate throughout the term structure. Any investor who does not benefit from the convenience flows directly would look to substitute away from the 10-year maturity, ensuring that other yields are affected as well. In other words, unless investors have extreme preferences for a given maturity, "local" convenience flows at any given maturity could affect the entire yield curve.

To explore the relative importance of these two features, we construct principal components at both the short and long maturities. The construction of these two series follows that of PC1 in the same period, with the three proxies with under one-year maturity making up "Short PC1" and the other four proxies making up "Long PC1."[13] Panel B of Figure 2 shows that the two principal components track one another closely until 2015 but, at times, have diverged substantially since then. In particular, the plot highlights a relative drop of long-term convenience yields since the Global Financial Crisis. Such an erosion of longer-term convenience yields has been noted before; for instance, see Du et al. (2018) or Du et al. (2023).

Our analytical framework suggests that the the corresponding hedging properties of long- and short-term bonds may drive part of this variation. To study this link, we construct stock-bond covariance using shorter maturity Treasuries: we follow the construction described in Section 1 and calculate the stock-bond covariance using two- and five-year Treasury returns. In Table 5, we estimate regressions of both Short and Long PC1 on the different maturity stock-bond covariance measures. The first three columns show that the short-term convenience yields are particularly exposed to the two-year stock-bond covariance. While we find a statistically significant negative relationship throughout, the two-year stock-bond covariance explains more of the variation in Short PC1 than the 10-year covariance: 18% versus 12%. The pattern for the long-horizon proxy Long PC1 is less clear. Across different maturity stock-bond covariance measures, the five-year stock-bond covariance has the highest explanatory power over this convenience yield proxy, with both the two- and 10-year covariances seeing lower R^2s.[14] Overall, the results in the table emphasize a strong sense of commonality in the three different maturity stock-bond covariance measures and suggest a

[13] Online Appendix Table OA4 documents the loadings of these two principal components on all the convenience yield proxies.

[14] For comparability across regressions, we multiply the two-year bond return with five and the five-year bond return with two, so that they both capture 10 year duration.

special role for short term convenience yields.

Indeed, the findings in Table 5 suggest that the relationships we document can offer an alternative perspective on the increasing "inconvenience" of longer-term Treasuries. In Table 6, we document the conditional averages of the stock-bond covariance measures. The first three columns report regressions of the two-, five-, and 10-year Treasury covariance with stock returns on dummies representing the post-2011 and the post-2021 periods. We find that the increase in stock-bond covariances in the post-2021 data is particularly pronounced for the 10-year calculation, with the coefficient on the relevant dummy variable being more than twice that of the five-year calculation and more than five times larger than that of the two-year calculation. (Note that for level shifts in the yield curve the 10-year covariance measure would be equal to twice the five-year covariance and five times the two-year covariance.) In this way, the link between stock-bond covariance and convenience yields that we document can account for a part of the decrease in long-term convenience yields.

Our results also illustrate the difficulty in attributing the drivers of the convenience yield to any specific source. Consider a formulation[15] of the convenience yield of maturity i at time t as a function of maturity-specific supply $Q_{i,t}$, maturity-specific safety demand $X_{i,t}$, and an asset-class level specialness of Treasuries λ_t:

$$\text{Convenience}_{i,t} = \lambda_t v(Q_{i,t}, X_{i,t}).$$

To the extent it is possible to identify supply or demand shifters—for instance around announcements of quantitative easing purchases or through different investment mandates—this formulation suggests a potential decomposition of the convenience yield variation into its drivers. However, the factor structure of the yield curve complicates any such analysis by inducing a strong response to supply and demand effects of other maturities and we interpret our findings as operating primarily via the common component in convenience yields λ_t. That said, our finding that there is a distinct short-term convenience yield component with a stronger relation to the short-term bond covariance with the stock market (compared to that of longer-maturity bonds), even as there is a common component of convenience yields across short-term and long-term maturities, offers one avenue for future study of the term structure of convenience yields.

3.D Robustness to Implementation Choices

Our focus on the hedging properties of Treasuries requires measuring the conditional covariance between Treasuries and the aggregate stock market. While the theoretical object of interest is made clear in the analytical framework in Section 2.A, we face a number of potentially meaningful empirical choices in our implementation. Here, we summarize results in the Online Appendix that show that our main results are robust to a variety of permutations of data construction. The summary statistics for all the below tables are in Online Appendix Table OA5.

[15] We thank Arvind Krishnamurthy for suggesting this framework.

i) Alternative measures of stock and bond returns. In the baseline estimation, we use the fitted yield curve of Gürkaynak et al. (2007) and the value-weighted CRSP index return for bonds and stocks, respectively. In Panel A of Online Appendix Table OA6, we re-estimate the relationship of stock-bond covariance and the first principal component of convenience yield, PC1, using three alternative measures of the covariance.

In the first alternative, we use the 10-year bond return implied by the yield curve of Liu and Wu (2021), which is designed to better capture various maturity-specific effects. In the second alternative, we construct a daily return series for the most recently issued ten-year Treasury using the CRSP daily Treasury file. We switch the return series to the new 10-year bond on the first day for which a return is available. Unlike the calculations based on fitted yield curves, this return series represents an actual tradeable portfolio. In the third alternative, we replace the CRSP index return with a broader return calculated from the MSCI World Index. Across all three alternative calculations, we find results robustly in line with the baseline estimates with a one standard deviation increase in the covariance representing about 0.4 standard deviation decrease in PC1 in the 2005-2024 sample.

ii) Stock-bond covariance lookback window. The choice of a lookback window in the conditional covariance calculations represents a potentially important trade-off. With shorter lookback windows, we are more likely to capture the true conditional covariance in the period at hand, which might be particularly important during times of sudden changes in the economic environment, such as around the Global Financial Crisis or the COVID pandemic. With longer lookback windows, in contrast, the measurement is more likely capture dynamics that are no longer relevant at the end of the period. At the same time, short lookback windows are subject to being unduly influenced by outlier returns. In the baseline calculations, we used a 30-trading day lookback window. Additionally, we used three day returns as shown in Equation (3) to mitigate the importance of market reversals in times of illiquidity.

In Panel B of Table OA6, we establish robustness with respect to both of these choices. In the first and fourth columns, we instead use single day returns for the stock-bond covariance calculation.[16] In the second and third columns of both sets, we use 60 and 252 trading day lookback windows. To ease interpretation, these covariance calculations are annualized just like the baseline measure. Across the three alternative covariance calculations, we again find robust negative relationships with the level of the first principal component of convenience yield proxies, in line with the baseline estimates, suggesting that the particular choice of a lookback window is not driving our results.

iii) Lagged covariance calculation. In the results reported so far, we associate end-of-month covariance values with end-of-month convenience yields. However, the results do not depend on measuring both variables in the same month. In Online Appendix Table OA7, we re-estimate the baseline Table 2 but lag the covariance measure by one month. In both panels, we find that the negative relationship between the covariance and convenience yield remains quantitatively similar, with some reduction in statistical significance.

iv) Bond beta and the stock-bond correlation. In the main analysis, we use the stock-bond

[16]We plot this alternative covariance calculation in Online Appendix Figure OA1.

covariance as the main right-hand-side variable. We motivate this choice in the analytical setup by noting that, if the SDF is an affine function of the stock market return, the expected return on a bond is proportional to a measure of risk aversion times the covariance between stocks and bonds. In Online Appendix Table OA8, we instead use the stock-bond correlation, the stock beta of bonds, and the associated decompositions as the right hand side variables.

We find that the negative relationship between the stock-bond comovements and the level of the convenience yield holds when employing correlation or stock market betas as the right-hand-side variable. In the first two columns of Table OA8, we use the Treasury beta with respect to the stock market, again separating out three terms corresponding to the convenience yield, the frictionless risk-free rate, and the CDS innovations. In the third and fourth columns, we repeat the analysis with correlation coefficient. In line with the results reported in the main text, we find that the beta or correlation corresponding to convenience yield innovations is robustly negatively related to the level of the convenience yield.

4 Discussion

Our main result establishes a connection between the covariance between stock and bond returns and the level of the convenience yield. The theoretical framework sketched in Section 2.A motivates this relationship by capturing the convenience flows in a given period as functions of state variables that also drive equity returns. In this section, we briefly discuss various economic forces potentially underlying time variation in convenience flows.

4.A Potential TIPS-specific Factors

Our preferred decomposition of the stock-bond covariance uses the TIPS-Treasury premium, a measure of relative convenience between two Treasury securities. Because these two securities differ little in their balance sheet treatment and in their default risk, we have argued that the price gap between them most likely reflects the higher convenience yield on the nominal Treasuries.

Another potential driver of the TIPS-Treasury premium could be variation in the relative supply of the two types of securities. In Appendix Figure OA2, we plot the total amount of nominal and real Treasuries outstanding. Two aspects are worth noting: one, the TIPS supply is an order of magnitude smaller than the nominal supply, with yearly issuance representing about 5%-10% of the total Treasury supply; two, the TIPS supply grows at a steady rate. These two observations suggest to us that fluctuations in TIPS supply are not major drivers of the TIPS-Treasury premium.

TIPS prices themselves may reflect some amount of convenience, which would make our proxy an underestimate of the total convenience afforded by nominal Treasuries. For one look at this question, we compare the "synthetic" nominal Treasury yield, constructed from TIPS and inflation swaps, with the AAA-rated corporate bond yield. We find that, in the 2005-2024 sample, the 10-year "synthetic" nominal Treasury yield is 14 bps lower than the Bank of America AAA-rated corporate bond index yield, consistent with a convenience yield on TIPS. (For reference, the level of the 10-year TIPS-Treasury premium in this period is 25 bps.) That said, there are prolonged periods when either of the rates is higher: for instance, from 2010 to 2015, the AAA yield was lower than the 10-year "synthetic" nominal rate. We conclude that there is some evidence for the convenience yield of TIPS, but it is not as robust as the TIPS-Treasury premium, which is positive in every month of the sample.

4.B Debt Ceiling Standoffs

Next, we seek to provide evidence regarding the convenience yield and the stock-bond covariance around two debt ceiling standoffs in the United States, one in summer 2011 and the other in spring 2023. These events are unique in that they represent substantial potential disruptions to the near-term cash-flows and liquidity of Treasuries while not necessarily calling into question the long-term creditworthiness of the U.S. government. To the extent the convenience yield of Treasuries depends on the ease of re-trading, these events could see substantial increases in the stock-bond covariance and decreases in the convenience yield.

The two panels of Table 7 document the behavior of both short- and long-term convenience yield proxies around these events. We use the 10-year TIPS-Treasury Premium as well as three versions of a daily first Principal Component of the convenience yield proxies: aggregate, short, and long. The three daily PCs are constructed analogously to the monthly PCs described in Section 3.A, with the exception that we don't use the Agency MBS-Treasury spread, as it's only available at a monthly frequency.

In Panel A of Table 7, we document that the 10-year TIPS-Treasury premium as well as the aggregate and maturity-specific PCs increased with the resolution of the 2011 standoff on August 1, 2011, when the House of Representatives passed a debt ceiling bill. We use 20 trading days of data before and after the event day in these regressions, resulting in an event window that starts on July 1. Our choice of look-back window length is motivated by the sharp increase in two-year CDS rates in the first week of July, indicating a material increase about debt ceiling worries. In terms of magnitudes, we see a nearly nine basis point increase in the 10-year TIPS-Treasury premium, a sizable amount relative to the unconditional mean of 25 basis points. Similarly, both the short and long PCs increase, with the increase in Long PC1 amounting to 0.1 standard deviations.

Panel B of Table 7 reports the corresponding analysis for the 2023 debt ceiling standoff that was resolved with congressional action on May 31, 2023. We again use 20 trading days before the resolution day as the pre-event window, coinciding with a run-up in the CDS rates at the one- and two-year horizons. We again find that the 10-year TIPS-Treasury premium increases on announcement. We also document a positive and statistically significant effect of debt ceiling resolution on the three PCs, with Long PC1 increasing by over 0.1 standard deviations.

Overall, these two event studies highlight the importance of sovereign default risk on convenience yields. Further, that both short- and long-term proxies are positively affected—even though the debt ceiling standoff primarily affects the short-term securities—highlights the importance of asset-class level variation (i.e., the presence of a common convenience yield factor in Treasuries) relative to maturity-specific effects.

Finally, in Figure 4, we show a link of these convenience yield results to the three constituent elements of the stock-bond covariance. The aggregate stock-bond covariance dropped after the debt ceiling resolution on August 1, 2011, with both the convenience yield component and especially the frictionless risk-free rate component dropping after the event day. As also shown in Figure 4, despite a rise in the U.S. CDS premium in the build-up to the crisis date, its covariance with aggregate stock returns is quantitatively too small to explain the pre-resolution fall in the convenience yield.[17]

4.C The Role of Inflation Expectations

Our finding that the time-variation in the convenience yield can materially contribute to the hedging properties of Treasuries additionally suggests a novel way inflation can affect the stock-bond covariance. The literature has extensively studied the link between realized and expected inflation shocks and the stock-bond covariance and has attributed the long-term shift from positive to negative stock-bond covariance to changes in inflation dynamics, for instance; see Campbell et al. (2017). Our results open the possibility, however, that inflation also affects the stock-bond covariance via its impact on the convenience yield, particularly the convenience yield component that is driven by hedging properties of bonds. Duffee (2018) has argued that inflation volatility can explain only a small part of long-term nominal yield volatility and, more recently, Duffee (2022) has shown that inflation news has historically not been volatile enough to justify the role inflation has been given in accounting for the stock-bond covariance. To the extent inflation news also affect convenience yields, it could be another means by which inflation affects excess returns of long bonds.

Specifically, our analytic framework emphasizes that the variation in convenience flows is a function of various systematic factors. With respect to inflation, Cieslak et al. (2023) has emphasized the tension between two forces in the link between expected inflation and convenience yields. On the one hand, high expected inflation increases convenience yields by virtue of increasing the opportunity cost of holding cash, suggesting a "money" channel positive relationship between expected inflation and Treasury convenience. On the other hand, a "New Keynesian" channel sees positive shocks to demand of liquid stores of wealth as drivers of lower aggregate demand and hence lower inflation.

Our findings suggest some of the relationship between inflation on convenience yields could stem from forward-looking inflation dynamics. For instance, with a shift to the regime where the money channel dominates, expected future convenience flows depend positively on expected future short rates. To the extent short rates are procyclical, such a regime would see a positive beta on convenience flows, reducing the convenience yield today. Market dynamics in response to the post-COVID surge in inflation are broadly in line with this mechanism: the TIPS-Treasury premium and PC1 saw low values in 2021 as inflation expectations started to tick up.

[17] The pattern in stock-bond covariances is less stark around the 2023 event date, with small post-event increases in the different covariance terms.

5 Related Literature

Our paper brings together two large literatures: one on stock-bond comovement and the other on the convenience yield on Treasury securities. The literature on the aggregate stock-bond comovement extends back to the work of Shiller and Beltratti (1992) and Campbell and Ammer (1993). An important part of this literature has studied stock and bond returns jointly in affine economies, for instance Bekaert and Grenadier (1999), Bekaert et al. (2010), and Lettau and Wachter (2011). Cieslak and Pang (2021) uses sign-restriction identification to decompose stock and bond returns. Further work studying stock-bond comovements, including nonlinearities and the term structure, includes Connolly et al. (2005), Baele et al. (2010), Adrian et al. (2019), Koijen et al. (2017), Xu (2017), Backus et al. (2018), Chang et al. (Forthcoming), and Ermolov (2022).

Many papers have focused on the sign shift in the aggregate stock-bond comovement in the early 2000s. Campbell et al. (2017) study the risk exposures of nominal bonds and attribute the changing covariance to a shift in the covariance between nominal interest rates and the real economy, while Campbell et al. (2020) study the impact of monetary policy rules. Other recent work, such as Laarits (2021), Choi et al. (2022), Jones and Pyun (2025), Kozak (2022), and Chernov et al. (2023), explore non-inflation accounts of stock-bond comovement, in line with the argument of Duffee (2022) that inflation innovations have not been the main driver of the time-varying stock-bond comovement.

Quantitatively, Laarits (2021) shows that the variability of the aggregate stock-bond covariance can be captured using a price of risk process calibrated to match moments of the equity market. In particular, he finds that the real bond-stock covariance is well captured by a frictionless model of price of risk, while the nominal bond-stock covariance exhibits additional volatility, a finding in line with the argument here on the important role of convenience yields. Hu et al. (2023) use intraday data to measure the conditional correlation between stocks and bonds. They show that days with substantial negative stock-bond correlations see poor equity market returns, appreciation of Treasuries, appreciation of the yen with respect to the US dollar, spikes in implied volatility, and a widening of Treasury specialness, in line with the findings here. Also part of this literature has studied the relationship between aggregate stock-bond covariance and the cross-section of stock and bond returns; for instance, see Baker and Wurgler (2012).

The literature on Treasury convenience yields goes back to Duffee (1996) and Longstaff (2004). Fleckenstein and Longstaff (2024) provide a recent overview and re-evaluation of absolute Treasury convenience using the term structure of repo swap rates. Krishnamurthy and Vissing-Jorgensen (2012) document a strong relationship between the aggregate supply of Treasuries and the spread between safe corporate bonds and Treasury yields, while He et al. (2019) model the determination of the safe asset in a model of two sovereigns. The relationship between Treasury supply and the convenience yield is explored by Greenwood et al. (2015), while Sunderam (2015) studies private market response to Treasury scarcity. Jiang et al. (2024) show that convenience yields of long-term bonds are more sensitive to supply shocks. Di Tella et al. (2023) estimate zero-beta rates from risky asset returns and interpret the difference between zero-beta and risk-free assets as the convenience yield. Krishnamurthy and Li (forthcoming) study the substitutability between different types of money and money-like claims, while Eren et al. (2023) estimate a demand system for Treasury securities. D'Avernas and Vandeweyer (2024), Stein and Wallen (Forthcoming), and Doerr et al. (2023) study intermediation frictions pertaining to the near end of the yield curve.

Two other recent papers study the relationship between convenience yields and inflation. Li et al. (Forthcoming) study this link using a model of fiscal policy in which deficit shocks lead to both higher expected inflation as well as lower convenience yields from additional future issuance. Cieslak et al. (2023) document two specific regimes in the inflation-convenience yield relationship: a "money channel" regime in which high inflation corresponds to high convenience yields and a "New Keynesian" regime in which shocks to liquid stores of wealth drive aggregate demand and inflation, resulting in a negative stock-bond covariance. Relative to these two papers, we emphasize the importance of the covariance of Treasury convenience with aggregate shocks as an important driver of the level of the convenience yield and emphasize that one channel via which inflation affects the convenience yield is through its impact on this covariance.

Finally, the convenience yield of Treasuries also relies on the proper functioning of the associated markets; for instance, see Amihud and Mendelson (1991). Adrian et al. (2017) construct a daily measure of Treasury market liquidity and contrast it with existing measures of market liquidity, such as Hu et al. (2013). In contrast to existing measures, they find higher illiquidity at the onset of the COVID pandemic in March 2020. A recent literature has studied these dislocations in the Treasury market in that tumultuous period; see He et al. (2022), Haddad et al. (2021), and Duffie (2020). Other market microstructure issues can be important, such as specific Treasury securities being cheapest-to-deliver into futures contracts or going on special in the repo market, as illustrated and analyzed by Duffie (1996), and Jappelli et al. (2022). Relative to the literature on the convenience yield, our work's novelty lies in the focus on the dynamics of this part of Treasury yields, particularly with respect to aggregate equity market movements.

6 Conclusion

We argue—and empirically establish—that the hedging perspective for safe assets is a quantitatively important channel to capture the time-variation in the Treasury convenience yield. We document that times when the aggregate stock-bond covariance is large and negative see a widening of Treasury convenience yields. In a decomposition of the aggregate stock-bond covariance into terms corresponding to the frictionless risk-free rate, default risk, and the convenience yield, we find that the convenience yield component contributes most robustly to the aggregate hedging properties of the Treasury, particularly during times of market stress. We estimate the convenience yield separately at short and long maturities and find a strong common component, though also some evidence of recent reduction in long-term convenience yields. We additionally show that debt ceiling standoffs eroded the convenience yield, again both at the short and long maturities. In all, our results support the view that investors pay for the convenience yield they enjoy from holding safe assets in a service-flow or an ease-of-retrading sense.

These results also imply that that the safe asset properties of U.S. Treasuries are not to be taken as given but need to be ensured via prudent macroeconomic outcomes. In other words, the convenience yield of government bonds must be "earned" by the central bank and the government by ensuring bonds retain their hedging properties for unspanned shocks faced by households, investors, financial firms, and corporations. Finally, our results can be used to test various theories of the convenience yield. The systematic time variation documented here is evidence that models beyond the money-in-the-utility framework are likely needed, while the observation that the covariance of the convenience yield itself with the stock market accounts for the level of the convenience yield is suggestive of theories of coordination, such as in He et al. (2019). More research is warranted to better understand this time variation.

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7 Tables

Panel A.

	mean	p1	p10	p50	p90	p99	sd	count
Cov(Tr 10y, St.)	-0.40	-4.18	-1.13	-0.20	0.31	1.22	0.89	240
Cov(Prem. 10y, St.)	-0.18	-4.58	-0.29	-0.04	0.08	0.37	0.87	240
Cov(Rf 10y, St.)	-0.26	-3.38	-0.93	-0.15	0.30	2.25	0.78	240
Cov(CDS 10y, St.)	0.05	-0.12	-0.02	0.00	0.18	0.96	0.18	240

Panel B.

	mean	p1	p10	p50	p90	p99	sd	count
Prem. 10y	0.25	-0.01	0.12	0.24	0.35	1.13	0.15	240
GC-Tr 3m	0.12	-0.12	0.01	0.10	0.29	0.62	0.13	240
OIS-Tr 3m	0.15	-0.09	0.01	0.08	0.41	0.87	0.19	240
-1*Z-Spr.	0.13	-0.24	-0.03	0.12	0.27	0.78	0.16	240
OIS Spr. 30y	-0.45	-1.08	-0.94	-0.53	0.30	0.52	0.42	240
FN-Tr 30y	0.48	0.09	0.21	0.42	0.81	1.42	0.27	240
Rich. 10y [2005-2022]	0.09	-0.26	-0.16	0.08	0.37	0.53	0.21	216
Box USD 2y [2005/9-2020/7]	0.36	0.12	0.18	0.30	0.62	1.33	0.22	179
Eff. Fed Funds	1.68	0.05	0.07	0.31	5.29	5.33	1.97	240

Table 1: Main Summary Statistics. Monthly data 2005-2024. Panel A: the stock-bond covariance calculated using 10-year constant maturity Treasury returns and the CRSP value-weighted stock market return in a 30 trading-day look-back window, collapsed to a monthly variable by keeping the last available calculation in each month. Stock-bond covariance calculated separately using the convenience yield, the frictionless risk-free rate, and the CDS rate as described in Section 1.D. Panel B: various proxies of the Treasury convenience yield described in Section 1.E.

Panel A.

	2005-2024						2005-2022	2005/9-2020/7
	Prem. 10y	GC-Tr 3m	OIS-Tr 3m	-1*Z-Spr.	OIS Spr. 30y	FN-Tr 30y	Rich. 10y	Box USD 2y
Cov(Tr 10y, St.)	-0.079**	-0.039**	-0.043*	-0.047*	-0.088**	-0.140***	-0.060***	-0.117***
	(-2.26)	(-2.38)	(-1.82)	(-1.72)	(-2.17)	(-3.94)	(-3.44)	(-2.76)
Eff. Fed Funds	0.008	0.007	0.054***	-0.005	0.071	0.040***	0.055***	0.059***
	(1.31)	(0.63)	(3.38)	(-0.63)	(1.52)	(3.33)	(4.31)	(5.81)
Constant	0.208***	0.096***	0.040*	0.123***	-0.601***	0.355***	-0.010	0.214***
	(9.50)	(4.71)	(1.94)	(6.84)	(-9.92)	(8.79)	(-0.26)	(11.71)
R^2	0.198	0.067	0.297	0.084	0.109	0.229	0.219	0.371

Panel B.

	2005-2024						2005-2022	2005/9-2020/7
	Prem. 10y	GC-Tr 3m	OIS-Tr 3m	-1*Z-Spr.	OIS Spr. 30y	FN-Tr 30y	Rich. 10y	Box USD 2y
Cov(Prem. 10y, St.)	-0.106***	-0.051***	-0.050***	-0.074***	-0.083***	-0.165***	-0.051***	-0.141***
	(-7.22)	(-4.88)	(-2.97)	(-5.57)	(-2.60)	(-8.52)	(-3.53)	(-8.43)
Cov(Rf 10y, St.)	-0.005	-0.025	-0.039	0.001	-0.120**	-0.078**	-0.062***	-0.042
	(-0.25)	(-1.15)	(-1.13)	(0.03)	(-2.02)	(-2.20)	(-2.91)	(-1.44)
Cov(CDS 10y, St.)	0.229*	-0.126*	-0.143**	-0.025	-0.328*	0.059	0.112	0.011
	(1.86)	(-1.93)	(-2.00)	(-0.55)	(-1.73)	(0.74)	(1.29)	(0.22)
Eff. Fed Funds	0.009	0.006	0.053***	-0.006	0.070	0.040***	0.058***	0.059***
	(1.63)	(0.49)	(3.29)	(-0.80)	(1.49)	(3.31)	(4.69)	(5.41)
Constant	0.204***	0.105***	0.047**	0.132***	-0.593***	0.356***	-0.022	0.227***
	(10.82)	(5.00)	(2.25)	(8.04)	(-9.60)	(8.78)	(-0.61)	(12.61)
Observations	240	240	240	240	240	240	216	179
R^2	0.446	0.103	0.308	0.184	0.120	0.281	0.244	0.480

Table 2: Stock-Bond Covariance and Proxies of the Treasury Convenience Yield. Monthly data for the indicated time periods. Left-hand-side variables are proxies of the convenience yield. The right-hand-side variables are the stock-bond covariance, its constituent elements, and the effective Fed Funds rate. Heteroskedasticity and autocorrelation robust t statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. The regression specification is

$$\text{Convenience}_t = a + b \times \text{Cov} + c \times \text{Eff. Fed Funds} + \epsilon_t,$$

where Convenience_t stands for the indicated convenience yield proxy and the selection of variables in the group

$$\text{Cov} \in \{\text{Cov(Tr. 10y, St.)}, \text{Cov(Prem. 10y, St.)}, \text{Cov(Rf 10y, St.)}, \text{Cov(CDS 10y, St.)}\}$$

is indicated in the table.

	1991/5	1972	1972	1997-2022	1997	1983
	GC-Tr 3m	FF-Tr 3m	-1*Z-Spr.	Rich. 10y	OIS Spr. 10y	AAA-Tr
Cov(Conv., St.)	-0.067***	-0.126***	-0.052**	-0.180***	-0.218**	-0.146***
	(-2.67)	(-2.63)	(-2.13)	(-4.82)	(-2.42)	(-6.05)
Cov(Tr. - Conv., St.)	-0.017	-0.121***	-0.013	-0.039**	-0.020	-0.103***
	(-1.33)	(-2.69)	(-0.65)	(-1.98)	(-0.70)	(-3.74)
Eff. Fed Funds	0.022***	0.199***	-0.036***	0.076***	0.077***	-0.022**
	(3.31)	(11.31)	(-7.91)	(5.59)	(4.24)	(-2.29)
Constant	0.070***	-0.382***	0.165***	-0.004	-0.310***	0.949***
	(3.73)	(-5.34)	(8.60)	(-0.10)	(-8.92)	(20.93)
Observations	404	636	636	312	336	504
R^2	0.157	0.570	0.314	0.429	0.346	0.247

Table 3: Alternative Decompositions of the Stock-Bond Covariance. Monthly data. Column headers show start date, and, if different from 2024, the end date. Left-hand-side variables are proxies of the convenience yield. Right-hand-side variables represent alternative decompositions of the aggregate stock-bond covariance into a term reflecting convenience yield innovations, and a residual term. Each of the covariance calculations is scaled to reflect a hypothetical 10-year maturity instrument with the same level of convenience yield as the indicated variable. Heteroskedasticity and autocorrelation robust t statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. The regression specification is

$$\text{Convenience}_t = a + b_1 \times \text{Cov(Conv., St.)} + b_2 \times \text{Cov(Tr - Conv., St.)} + c \times \text{Eff. Fed Funds} + \epsilon_t,$$

where Conv. stands for the convenience yield proxy indicated in the table header.

	PC1, 2005-2024					PC1, 1991/5-2024	
Cov(Prem. 10y, St.)	-0.454***	-0.671***	-0.574***	-0.487***	-0.598***		
	(-9.55)	(-2.59)	(-6.81)	(-5.14)	(-7.14)		
Cov(Rf 10y, St.)			-0.328**	-0.297*	-0.366**		
			(-1.97)	(-1.96)	(-2.50)		
Cov(CDS 10y, St.)			-0.319	-0.489	0.059		
			(-0.55)	(-0.83)	(0.13)		
Crisis		1.264**					
		(2.55)					
Crisis x Cov(Prem. 10y, St.)		0.397					
		(1.45)					
Cov(Tr 10y, St.)						-0.194**	-0.294***
						(-1.97)	(-2.77)
VIX				1.561		2.358**	
				(1.08)		(2.33)	
E[Inflation] 10y					1.115***		-0.161
					(3.24)		(-0.53)
CDS 10y					-1.437*		
					(-1.89)		
Eff. Fed Funds	0.165*	0.186**	0.192**	0.201**	-0.008	0.198***	0.238**
	(1.75)	(1.97)	(2.04)	(2.08)	(-0.10)	(4.35)	(2.42)
Constant	-0.365***	-0.521***	-0.503***	-0.785***	-1.898***	-1.036***	-0.328
	(-3.42)	(-4.94)	(-4.48)	(-2.69)	(-2.98)	(-4.32)	(-0.62)
Observations	240	240	240	240	240	404	404
R^2	0.219	0.333	0.264	0.272	0.405	0.207	0.187

Table 4: Stock-Bond Covariance and 1st Principal Component the Convenience Yield Proxies. Monthly data in the indicated periods. The left-hand-side variable is the first principal component of the convenience yield proxies available in the entire indicated period. The right-hand-side variables are components of the aggregate stock-bond covariance, corresponding to the convenience yield, the frictionless risk-free rate, and the CDS rate, as well as the effective Fed funds rate, an indicator variable for the Global Financial Crisis, and the VIX. Heteroskedasticity and autocorrelation robust t statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. The regression specification is

$$\text{PC1}_t = a + b_1 \times \text{Cov} + b_2 \times \text{Interaction} + b_3 \times \text{Controls} + c \times \text{Eff. Fed Funds} + \epsilon_t,$$

where the selection of variables in the groups

$$\begin{aligned} &\text{Cov} \in \{\text{Cov(Tr 10y, St.)}\, \text{Cov(Prem. 10y, St.)}, \text{Cov(Rf 10y, St.)}, \text{Cov(CDS 10y, St.)}\} \\ &\text{Interaction} \in \{\text{Crisis}, \text{Crisis} \times \text{Cov(Prem. 10y, St.)}\} \\ &\text{Controls} \in \{\text{VIX}, \text{CDS}, \text{E[Inflation]}\} \end{aligned}$$

is indicated in the table.

	2005-2024					
	Short PC1	Short PC1	Short PC1	Long PC1	Long PC1	Long PC1
5 x Cov(Tr 2y, St.)	-0.507**			-0.626***		
	(-2.24)			(-3.62)		
2 x Cov(Tr 5y, St.)		-0.427**			-0.614***	
		(-2.35)			(-4.27)	
Cov(Tr 10y, St.)			-0.308**			-0.492***
			(-2.22)			(-4.99)
Eff. Fed Funds	0.097	0.124	0.129	0.113	0.153**	0.166**
	(1.36)	(1.64)	(1.63)	(1.42)	(1.96)	(2.06)
Constant	-0.405***	-0.471***	-0.453***	-0.341**	-0.464***	-0.468***
	(-3.26)	(-3.50)	(-3.69)	(-2.33)	(-3.17)	(-3.11)
Observations	240	240	240	240	240	240
R^2	0.184	0.165	0.125	0.218	0.250	0.217

Table 5: Short and Long Maturity Convenience Yield Measures. Monthly data 2005-2024. The left-hand-side variables are the first principal components of the short- and long-term convenience yield proxies. The right-hand-side variables are the aggregate stock-bond covariance, calculated with the indicated maturity bond return, as described in Section 3.C. Heteroskedasticity and autocorrelation robust t statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. The regression specification is

$$\text{PC1}_t = a + b \times \text{Cov} + c \times \text{Eff. Fed Funds} + \epsilon_t,$$

where PC1 and Cov stand for the indicated principal component and stock-bond covariance calculation.

	Cov(..., St.)					
	Tr 2y	Tr 5y	Tr 10y	Prem. 10y	Rf 10y	CDS 10y
Crisis	-0.199***	-0.488***	-0.737	-1.020	0.238	0.047
	(-3.38)	(-2.84)	(-1.54)	(-1.48)	(0.63)	(0.48)
Post 2011	0.022	0.103	0.289	0.073	0.279	-0.059
	(1.03)	(1.30)	(1.13)	(1.08)	(1.21)	(-1.30)
Post 2021	0.061	0.240***	0.526***	0.113**	0.408***	0.004
	(1.57)	(2.79)	(3.97)	(2.45)	(2.90)	(0.24)
Constant	-0.054***	-0.228***	-0.588**	-0.147**	-0.531**	0.088**
	(-2.71)	(-3.03)	(-2.35)	(-2.19)	(-2.36)	(2.03)
Observations	240	240	240	240	240	240
R^2	0.291	0.304	0.202	0.146	0.073	0.042

Table 6: Conditional Averages of Stock-Bond Covariance Measures. Monthly data 2005-2024. The left-hand-side variables are the indicated stock-bond covariance measures. The right-hand-side variables are dummies indicating the Global Financial Crisis, and periods after 2011, and after 2021. Heteroskedasticity and autocorrelation robust t statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. The regression specification is

$$\text{Cov}_t = a + b_1 \times \text{Crisis} + b_2 \times \text{Post 2011} + b_3 \times \text{Post 2021} + \epsilon_t$$

where Cov_t stands for the indicated component of the stock-bond covariance.

Panel A. 2011 debt crisis. Cutoff August 1, 2011

	Prem. 10y	PC1	Short PC1	Long PC1
After Cutoff Date	0.087***	0.097**	0.052	0.109**
	(3.91)	(2.40)	(1.14)	(2.12)
Constant	0.201***	-0.050	-0.203***	0.105**
	(12.78)	(-1.24)	(-8.09)	(2.16)
Observations	41	41	41	41
R^2	0.406	0.217	0.051	0.123

Panel B. 2023 debt crisis. Cutoff May 31, 2023

	Prem. 10y	PC1	Short PC1	Long PC1
After Cutoff Date	0.040**	0.141**	0.365***	0.137***
	(2.36)	(2.36)	(2.58)	(3.17)
Constant	0.270***	-0.788***	-0.692***	-0.682***
	(17.58)	(-24.48)	(-5.94)	(-24.78)
Observations	41	41	41	41
R^2	0.295	0.218	0.244	0.391

Table 7: Convenience Yields and Stock-Bond Covariances Around Two Debt Ceiling Deals. Daily data around the indicated event window. 2011 debt ceiling standoff sample from June to September 2011; 2023 debt ceiling sample from April to June 2023. Heteroskedasticity and autocorrelation robust t statistics. ***, **, and * denote significance at the 1%, 5%, and 10% levels. The regression specification is

$$\text{LHS}_t = a + b \times \text{Event} + \epsilon_t$$

where Event is a dummy variable that indicates days starting with the event day listed in the table header and

$\text{LHS}_t \in \{$ Prem. 10y, PC1, Short PC1, Long PC1$\}$
as indicated in the table.

8 Figures

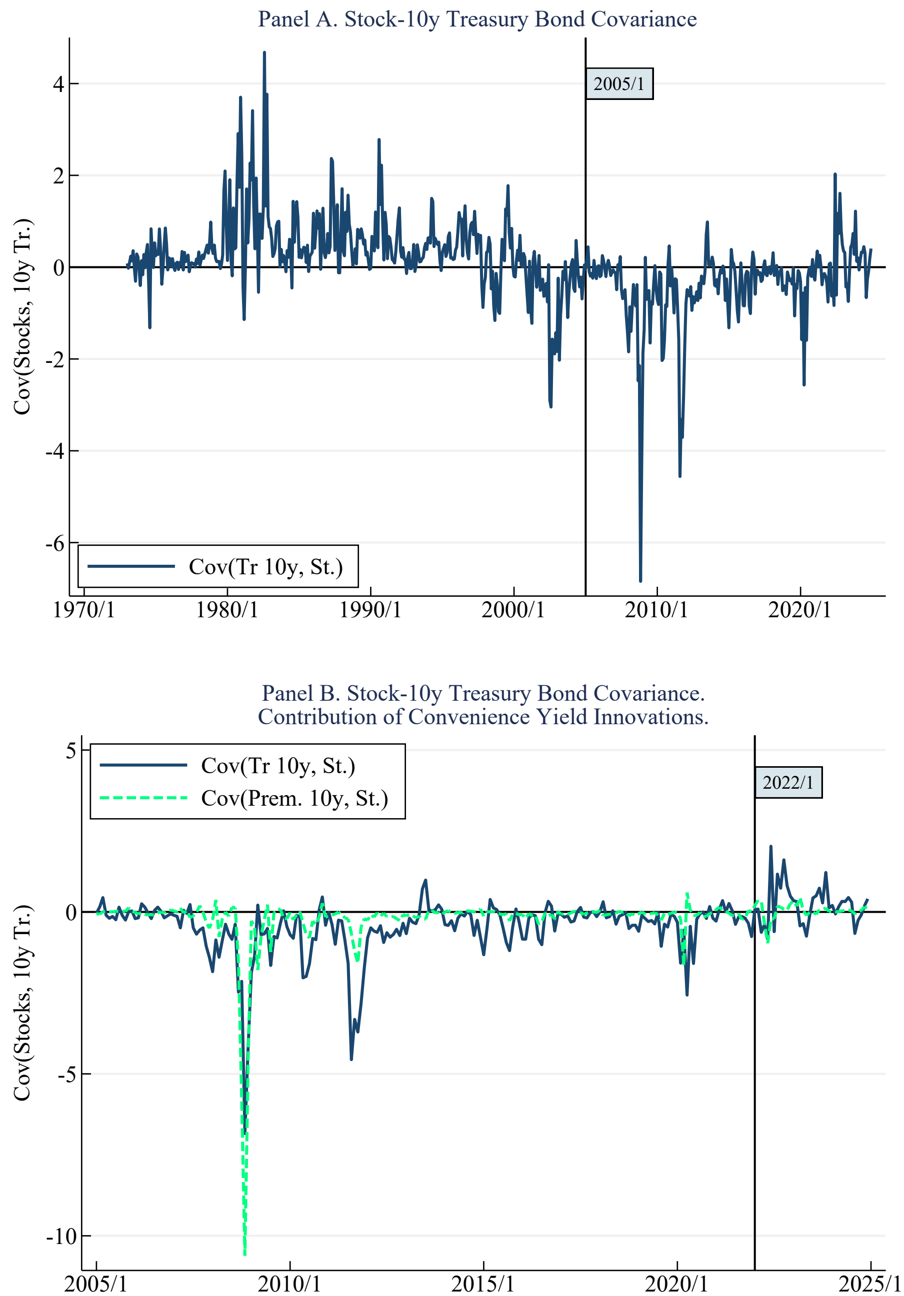

Figure 1: The Stock-Bond Covariance. Panel A shows the covariance between a nominal 10-year constant maturity bond and the aggregate stock market in a 30 trading-day lookback window. The bond return is calculated based on the yield from the Gürkaynak et al. (2007) fitted yield curve and the stock return is the CRSP value-weighted market return. Plot shows end of month values. Monthly data 1973-2024. Panel B repeats the aggregate stock-bond covariance and plots separately the contribution of convenience yield innovations as described in Section 1.D. Monthly data 2005-2024.

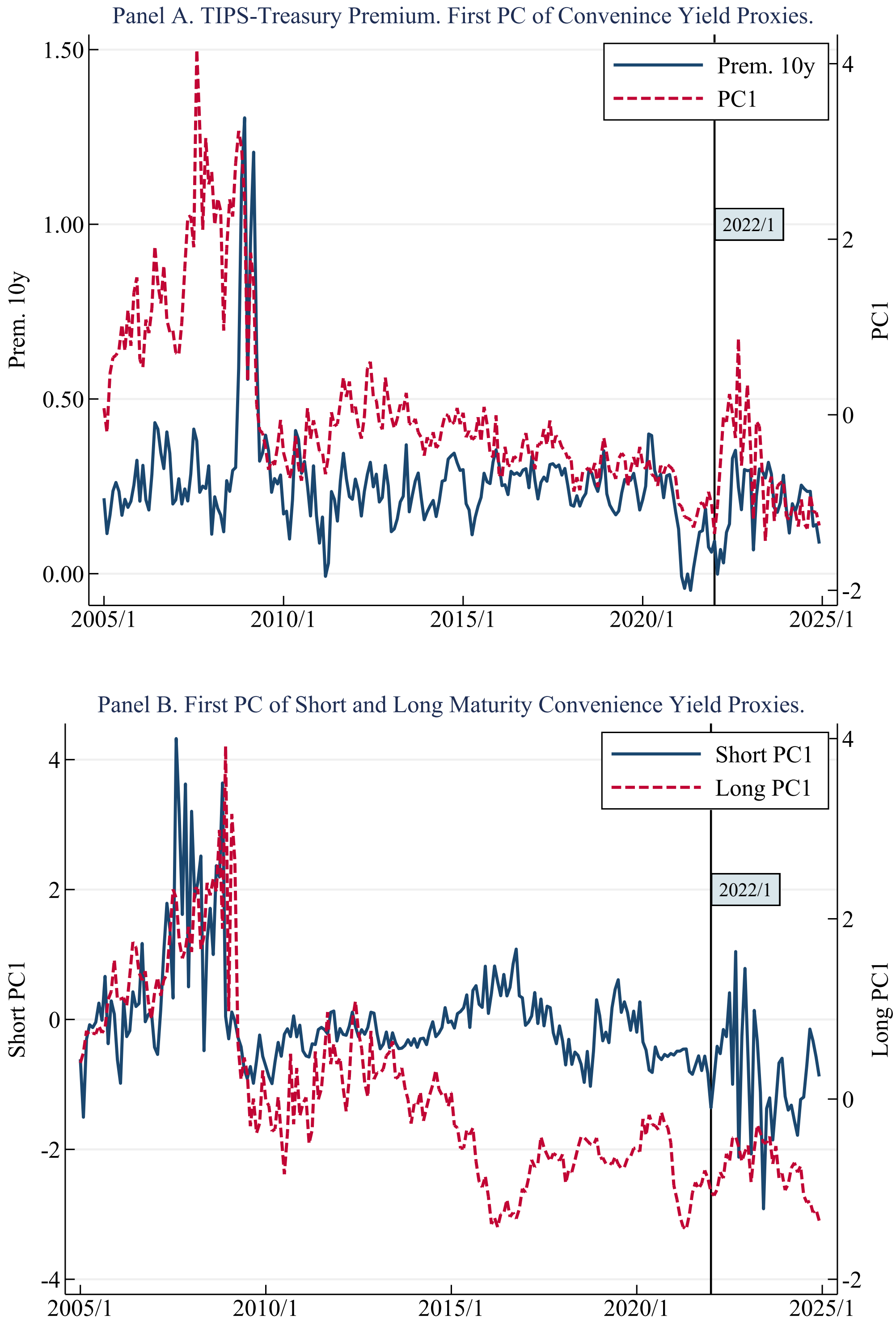

Figure 2: Time Series of Convenience Yield Proxies. Monthly data 2005-2024. Panel A plots the 10-year TIPS-Treasury premium and the first Principal Component (PC1) of the convenience yield proxies. The construction of PC1 is described in Section 3.A. Panel B plots the first Principal Component of the short- and long-maturity convenience yield proxies, as described in Section 3.C.

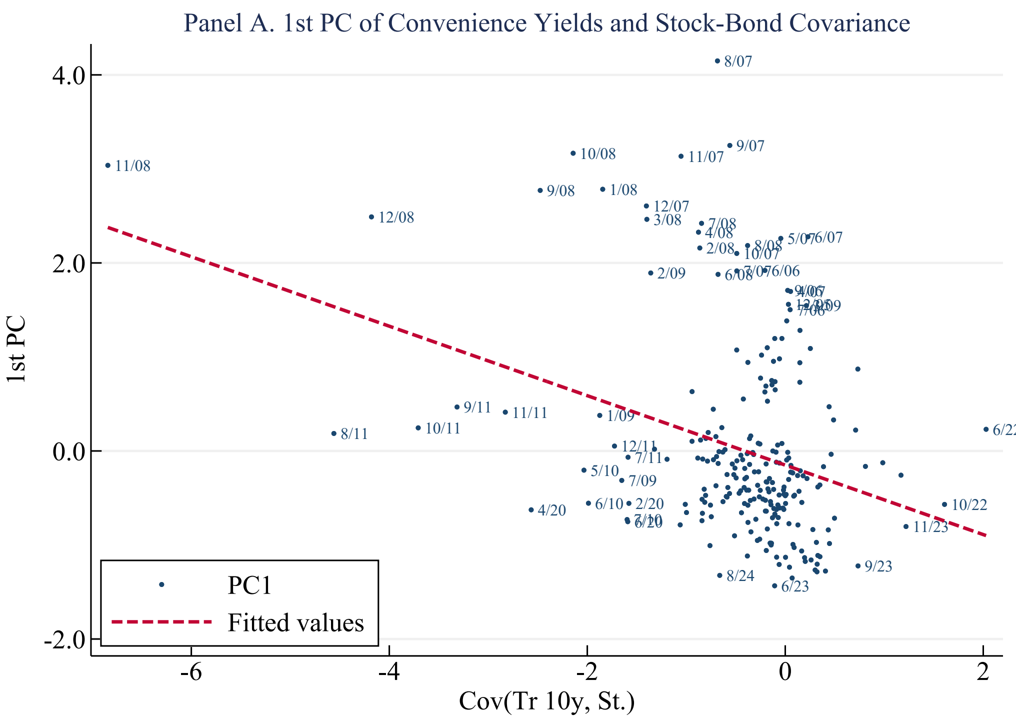

Figure 3: Treasury Convenience Yields and the Stock-Bond Covariance. Monthly data 2005-2024. Scatterplot of the first principal component of the convenience yield proxies against the aggregate stock-bond covariance.

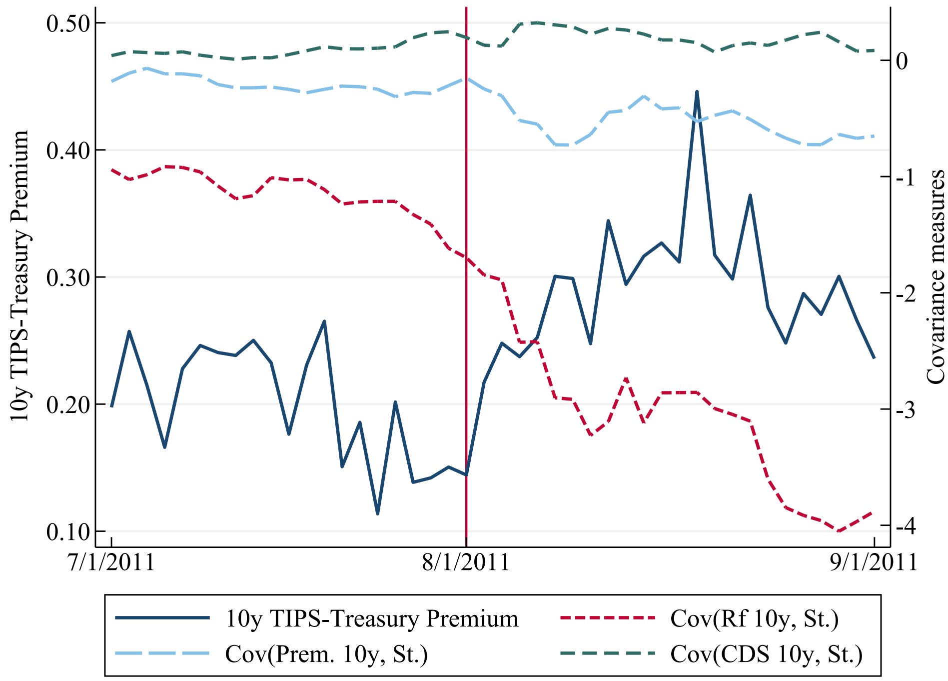

Figure 4: TIPS-Treasury Premium and the Stock-Bond Covariance around the 2011 Debt Ceiling Standoff. The 10-year TIPS-Treasury premium and the aggregate stock-bond covariance, as well as the components of the stock-bond covariance corresponding to the convenience yield, the frictionless risk-free rate, and the CDS rate. Red vertical line indicates August 1, 2011, the date of the debt ceiling standoff resolution.

A Appendix

Abbrev.	Full Label	Description
Prem.	TIPS - Treasury Premium	The yield spread between a synthetic nominal Treasury, constructed out of Treasury Inflation Protected Security (TIPS) plus inflation swap of the same maturity and a nominal Treasury. The yields on TIPS and nominal Treasuries are from the fitted yield curves constructed in Gürkaynak et al. (2007) and Gürkaynak et al. (2010) with identifiers SVENYxx and TIPSYxx, respectively. The inflation swap data is from the Bloomberg system, ticker stem USSWITxx Curncy and the maturities available on any given day are smoothed using a cubic spline with knots at 0 and 25 years. We carry out a daily calculation of the TIPS-Treasury Premium at the 2-, 5, and 10-year maturities.
GC-Tr	General Collateral - Treasury Bill Spread	The yield spread between the three-month General Collateral (GC) repo rate, and the three-month Treasury Bill rate. The GC repo rate is from the Bloomberg system, ticker USRGCGC ICUS Curncy, and the Treasury Bill rate is from the St. Louis Fed FRED database, ticker DGS3MO. In calculating the end-of-month values we drop the December 31, 2018 observation because of a repo market specific spike. Similarly we exclude the spike at the end of April 1993. All our results are robust to including these spikes in the GC-Tr spread.
FF-Tr	Fed Funds - Treasury Bill Spread	The yield spread between the overnight Fed funds rate and the three-month Treasury Bill rate. Both data series are from the St. Louis Fed FRED database, tickers are DFF and DGS3MO, respectively.
OIS-Tr	OIS - Treasury Bill Spread	The yield spread between the three month OIS rate and the three-month Treasury Bill rate. The OIS rate if from the Bloomberg system, ticker USSOC. Three month Treasury bill yield from the St. Louis Fed FRED database, ticker DGS3MO.
-1*Z-Spr.	Negative of the Z-Spread	A measure of the "richness" of the short end of the yield curve, constructed after Greenwood et al. (2015). These authors calculate the average yield difference of n-month maturity Treasury Bills and the fitted yield curve of Gürkaynak et al. (2007) and label it the n-month Z-spread. This measure is typically negative, reflecting lower yields on T-bills relative to those implied by the fitted yield curve. We follow their methodology by calculating the average Z-spread of T-bills with 4 to 26 weeks until maturity. In our empirical analysis we use the negative of the Z-spread to ensure that higher values correspond to high convenience yield of Treasury, consistent with other proxies of the convenience yield.
OIS Spr.	OIS Swap Spread	The OIS Swap rate data is from the Bloomberg system, ticker stem USSOxx. The swap spread is calculated by comparing the quoted swap rate with the swap rate implied by the Gürkaynak et al. (2007) nominal risk-free yield curve, recognizing that OIS swaps are on an annual schedule.

Table continues on next page...

Table A1: Labeling and Construction of the Main Variables. Abbreviated label, full label, and description with data sources. Tables and figures use the abbreviated label and indicate the maturity, in either months ("m") or years ("y").

...table continued from previous page.

Abbrev.	Full Label	Description
FN-Tr	Fannie MBS - Treasury Spread	The option-adjusted spread between Agency MBS and Treasury yields, as suggested as a convenience yield proxy by recent work in He and Song (Forthcoming). Data from the Bloomberg system, the ticker is I00098US and option-adjusted spread is available in the analytics menu.
Rich.	Treasury Richness	Treasury Richness as constructed in Fleckenstein and Longstaff (2024) and available in the replication package on the *Journal of Finance* website. Treasury Richness measures the value of a given Treasury bond relative to the value from discounting the promised cash-flows with a risk-free curve implied by fixed-to-floating repo swap rates (and OIS swap rates in the earlier sample). For this measure we use the Richness, quoted as a yield spread, of the most recently issued 10-year Treasury Note.
Box USD	USD Box Rate	The yield spread between two-year Treasury yield and the risk-free interest rate implied by put-call parity on options contracts (the “box rate”) as calculated in van Binsbergen et al. (2022) and available on Will Diamond’s website.
CDS	U.S. Credit Default Swap Rate	The data on CDS rates is from Markit and reflects quotes provided by different brokers. We use daily data for the 2-, 5-, and 10-year tenors. On any given day, both EUR and USD denominated contracts are available, as are up to four contracts with different contract clauses. These different contract clauses differ in what constitutes a restructuring event. We use the contracts corresponding to Full Restructuring (CR). With the introduction of the 2014 ISDA Credit Derivatives Definitions we use the CR14 designation, whenever available, CR otherwise. For compatibility with the pre-2008 data we use the Par Spread throughout.
E[Inflation]	Expected Inflation	Expected inflation series constructed by the Cleveland Fed. Data from the St. Louis Fed FRED database, ticker stem EXPINF.
AAA-Tr	AAA - Treasury Spread	The option-adjusted yield spread of the ICE BofA AAA US Corporate Index. Data from the St. Louis Fed FRED database, ticker BAMLC0A1CAAA.

Table A1, continued: Labeling and Construction of the Main Variables. Abbreviated label, full label, and description with data sources. Tables and figures use the abbreviated label and indicate the maturity, in either months (“m”) or years (“y”)

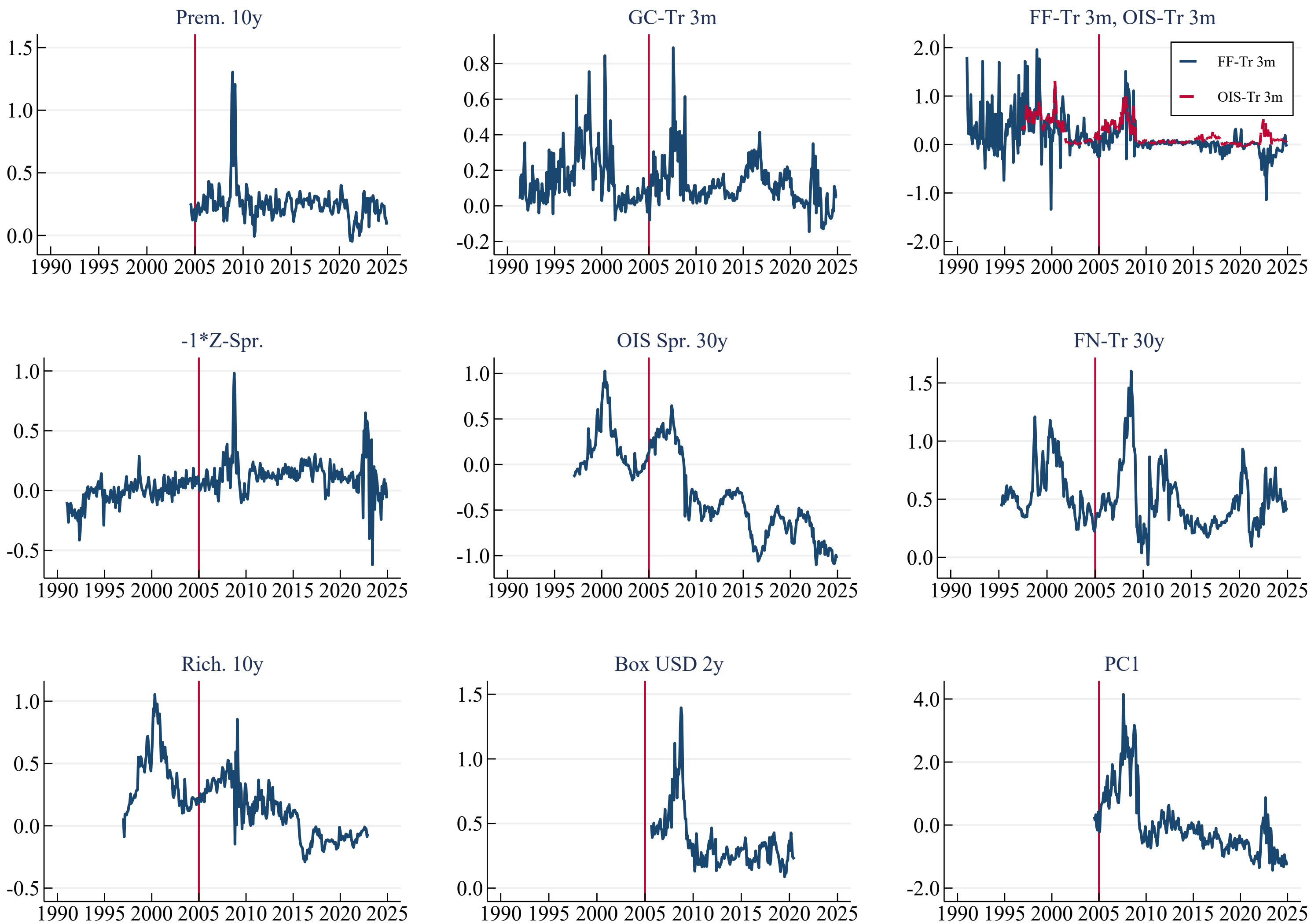

Figure A1: Convenience Yield Proxies. Monthly data from 1991 to 2024. The vertical lines indicate 2005/1.

OA Online Appendix

OA.A Analytical Setup Details

Consider a zero-coupon safe bond with face value 1 and maturity T. In periods $t < T$, the holder of the bond accrues a non-pecuniary and potentially time-varying convenience flow $K_t = b + f(X_t)$, where X_t captures market conditions at time t: the demand for safety, supply of safe assets and so on. The present value of the bond is given by:

$$P_0 = \frac{\mathrm{E}_0[K_1]}{1+\mathrm{E}_0[R_{0,1}]} + \frac{\mathrm{E}_0[K_2]}{1+\mathrm{E}_0[R_{0,2}]} + ... + \frac{\mathrm{E}_0[K_{T-1}]}{1+\mathrm{E}_0[R_{0,T-1}]} + \frac{1}{1+\mathrm{E}_0[R_{0,T}]} \tag{OA1}$$

where $\mathrm{E}_0[R_{0,t}]$ is the fair discount rate for the time t flows, made up of explicit cash payments, if any, and the non-pecuniary convenience benefits. Consequently, the discount rate at each maturity captures both a pure risk-free discount, as well as a potential risk adjustment on account of the time-variation in convenience flows. To see explicitly how the expected returns are determined, consider a hypothetical security that only earns the time $t < T$ convenience flow with time 0 price $P_{0,t}$. The hold-to-maturity return is a function of the state variable X_t:

$$1 + R_{0,t} = \frac{b + f(X_t)}{P_{0,t}}. \tag{OA2}$$

Suppose the aggregate market return $R^M_{0,t}$ prices assets and is itself a function of the same state variable. In that case, the expected hold-to-maturity returns are given by:

$$\mathrm{E}_0[R_{0,t}] = R^f_{0,t} + \Lambda\,\mathrm{Cov}_0\left(R_{0,t}, R^M_{0,t}\right), \tag{OA3}$$

where Λ captures risk aversion.

If the convenience service flow is good precisely when the market return is poor, the covariance term is negative and the expected return on the hypothetical single convenience flow paying bond will be below the frictionless risk-free rate. As a result, the price of the bond as calculated in Equation (OA1) depends on such covariance terms as well.

By contrast, consider a zero-coupon bond with maturity date t but with no associated convenience services. The present value of this bond is just

$$P^f_{0,t} = \frac{1}{1+\mathrm{E}_0[R^f_{0,t}]}, \tag{OA4}$$

where the superscript f indicates the frictionless risk-free rate. Because the single cash-flow is fixed, the hold-to-maturity expected returns do not reflect any risk adjustment and are known with certainty at time $t = 0$

$$\mathrm{E}_0[R^f_{0,t}] = R^f_{0,t}. \tag{OA5}$$

The gap, then, between the two expected returns at any maturity t is given by

$$\mathrm{E}_0\left[R^f_{0,t}\right] - \mathrm{E}_0\left[R_{0,t}\right] = -\Lambda\,\mathrm{Cov}_0(R_{0,t}, R^M_{0,t}), \tag{OA6}$$

This simple setup illustrates that in the presence of convenience flows, the hold-to-maturity returns on safe zero-coupon bonds are risky, and the expected returns can therefore reflect a risk adjustment. Our empirical analysis is motivated by Equation (OA6): the gap in hold-to-maturity returns (or, equivalently, yields) is proportional to the covariance of hold-to-maturity returns—inclusive of the convenience flows—with the market return.

In practice, we do not observe the value of the non-pecuniary flows accruing to the bondholder, making it impossible to estimate Equation (OA6) directly. We do, however, observe a proxy for the present value of such convenience flows. Our empirical analysis, therefore, proceeds by calculating the single-period returns on bonds with convenience flows and estimating their covariance with market returns.

Let r_t with a single subscript denote the single-period log returns and let k_t denote the log convenience flow in period t. By the Campbell and Shiller (1988) decomposition, the log price of the bond described in Equation (OA1) follows[18]

$$p_t \approx \frac{c}{1-\rho} + \mathrm{E}_t\left[\sum_{j=0}^{T-1} \rho^j[(1-\rho)k_{t+j+1} - r_{t+j+1}]\right], \tag{OA7}$$

where $\rho = 1/\left(1+\exp(\overline{k-p})\right)$ is a constant depending on the unconditional level of the convenience yield and $c = -\ln(\rho) - (1-\rho)\ln(1/\rho - 1)$.

The time $t+1$ return on the bond exclusive of the convenience flows is just $p_{t+1} - p_t$ (recall we do not observe the convenience flows so we cannot calculate a with-dividend return):

$$xr_{t+1} = p_{t+1} - p_t = (\mathrm{E}_{t+1} - \mathrm{E}_t)\left[\sum_{j=1}^{T-1} \rho^j[(1-\rho)k_{t+j+1} - r_{t+j+1}]\right] - \mathrm{E}_t[(1-\rho)k_{t+1} - r_{t+1}], \tag{OA8}$$

and the surprise returns at time $t+1$ are given by

$$sr_{t+1} = (\mathrm{E}_{t+1} - \mathrm{E}_t)\,(xr_{t+1}) = (\mathrm{E}_{t+1} - \mathrm{E}_t)\left[\sum_{j=1}^{T-1} \rho^j[(1-\rho)k_{t+j+1} - r_{t+j+1}]\right]. \tag{OA9}$$

In words, the surprise return on the bond with convenience flows equals the innovation to the discounted value of the expected convenience flows, minus the innovations to expected returns.

The surprise return on the bond without convenience flows can be calculated in a similar manner. Let $r^{f,T}_t$ denote the single-period return on the safe bond with maturity T and a coupon rate set to

[18] See Campbell (2017) Section 5.3 for derivation.

equal the unconditional level of the convenience yield. The surprise return on the bond is given by:

$$sr_{t+1}^{f,T} = (\mathrm{E}_{t+1} - \mathrm{E}_t)\left[-\sum_{j=1}^{T-1} \rho^j r_{t+j+1}^{f,T}\right]. \tag{OA10}$$

With these two return innovations in hand we are in position to calculate the exposure of convenience flows to market returns. The difference in the surprise return in Equation (OA9) and Equation (OA10) captures the return due to changes in expected convenience flows, as well as changes in the risk premium:

$$sr_{t+1} - sr_{t+1}^{f,T} = (\mathrm{E}_{t+1} - \mathrm{E}_t)\left[\sum_{j=1}^{T-1} \rho^j [(1-\rho)k_{t+j+1} - r_{t+j+1} - r_{t+j+1}^{f,T}]\right] \tag{OA11}$$

$$= (\mathrm{E}_{t+1} - \mathrm{E}_t)\left[\sum_{j=1}^{T-1} \rho^j [(1-\rho)k_{t+j+1} - rp_{t+j+1}]\right], \tag{OA12}$$

where in the second equation rp stands for the risk premium: the gap between returns on the bond with convenience yield minus the return on the bond without such convenience flows. With the surprise returns in hand we are able to estimate the covariance between innovations to convenience flows (inclusive of risk premium innovations) and market returns:

$$\mathrm{Cov}\left(sr_{t+1} - sr_{t+1}^{f,T}, r^M\right). \tag{OA13}$$

In our empirical work we estimate Equation (OA13) with rolling lookback windows and then show that it accounts for the level of the convenience yield, as described in Equation (OA6). Namely, we regress proxies of the Treasury convenience yield on the conditional covariance between the stock market and the Premium component of nominal Treasury returns.

Finally, we have modeled convenience yield as an unobservable cash-flow accruing to the holder of the bond. Recent literature has frequently captured the convenience yield as a "wedge" in the investor's Euler equation, see Jiang et al. (2021). Such a formulation is essentially identical to the one used in this paper. To see the equivalence, start with the Euler equation for the return r_{t+1} on a bond that earns a convenience yield. The "wedge" formulation of the convenience yield is:

$$\mathrm{E}_t[\exp(m_{t+1} + r_{t+1})] = \exp(-\lambda_t) < 1$$

where m_{t+1} is the SDF and λ_t the convenience yield prevailing at time t. In words, the return on the security with convenience flows is low, such that the Euler equation is below 1 by the amount of $-\lambda_t$. Moving the term λ_t over to the left-hand-side results in

$$\mathrm{E}[\exp(m_{t+1} + r_{t+1} + \lambda_t)] = 1$$

and the quantity $\{r_{t+1} + \lambda_t\}$ can be thought of as the total return (the with-dividend return) on the bond, comprised of the capital gains term, and dividend yield that stems from the unobservable convenience flow.

OA.B Online Appendix Tables

Panel A. Correlation matrix.

	2005-2024			
	Cov(Tr 10y, St.)	Cov(Prem. 10y, St.)	Cov(Rf 10y, St.)	Cov(CDS 10y, St.)
Cov(Tr 10y, St.)	1.000			
Cov(Prem. 10y, St.)	0.650***	1.000		
Cov(Rf 10y, St.)	0.455***	-0.359***	1.000	
Cov(CDS 10y, St.)	-0.206***	-0.076	-0.377***	1.000

Panel B. Autocorrelations.

	2005-2024			
	Cov(Tr 10y, St.)	Cov(Prem. 10y, St.)	Cov(Rf 10y, St.)	Cov(CDS 10y, St.)
L.Cov(Tr 10y, St.)	0.658***			
	(9.80)			
L.Cov(Prem. 10y, St.)		0.662***		
		(4.95)		
L.Cov(Rf 10y, St.)			0.530***	
			(5.47)	
L.Cov(CDS 10y, St.)				0.432***
				(5.18)
Constant	-0.135***	-0.062**	-0.124***	0.031***
	(-3.89)	(-2.17)	(-3.03)	(2.97)
Observations	239	239	239	239
R^2	0.431	0.439	0.280	0.186

Table OA1: Correlation Coefficients. Autocorrelation Coefficients of the Stock-Bond Covariance Components. Monthly data 2005-2024. Panel A shows the correlation matrix of the aggregate stock-bond covariance and its components corresponding to the convenience yield, the risk-free rate, and the CDS rate. Panel B reports the autocorrelation coefficients of the four stock-bond covariance measures. Heteroskedasticity and autocorrelation robust t statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. The regression specification is

$$\text{Cov}_t = a + b \times \text{Cov}_{t-1} + \epsilon_t$$

where Cov_t stands for the indicated component of the stock-bond covariance.

Panel A. Full Sample.

	1991/5	1972	1972	1997-2022	1997	1972
	GC-Tr 3m	FF-Tr 3m	-1*Z-Spr.	Rich. 10y	OIS Spr. 10y	AAA-Tr
Cov(Conv., St.)	-0.060**	-0.010	-0.040**	-0.169***	-0.197**	-0.061***
	(-2.21)	(-0.45)	(-2.47)	(-5.13)	(-2.37)	(-3.29)
Eff. Fed Funds	0.019***	0.185***	-0.037***	0.071***	0.074***	-0.036***
	(3.11)	(12.01)	(-10.94)	(5.17)	(4.05)	(-3.75)
Constant	0.080***	-0.320***	0.172***	0.019	-0.297***	1.005***
	(4.86)	(-4.97)	(10.14)	(0.58)	(-9.32)	(20.79)
Observations	404	636	636	312	336	504
R^2	0.150	0.562	0.313	0.415	0.343	0.187

Panel B. Sample ending in 2000.

	1991/5	1972	1972	1997	1997	1972
	GC-Tr 3m	FF-Tr 3m	-1*Z-Spr.	Rich. 10y	OIS Spr. 10y	AAA-Tr
Cov(Conv., St.)	-0.050	-0.007	-0.040**	-0.236**	-0.606***	-0.099*
	(-1.13)	(-0.30)	(-2.17)	(-2.42)	(-3.12)	(-1.90)
Eff. Fed Funds	0.070***	0.261***	-0.040***	0.107	0.176**	0.011
	(4.76)	(10.02)	(-7.70)	(1.07)	(2.10)	(0.79)
Constant	-0.157**	-0.997***	0.183***	-0.171	-0.814*	0.696***
	(-2.38)	(-5.91)	(4.25)	(-0.33)	(-1.88)	(7.59)
Observations	116	348	348	48	48	216
R^2	0.243	0.549	0.215	0.165	0.284	0.058

Table OA2: Alternative Decompositions of the Stock-Bond Covariance. Monthly data for the indicated time period. Left-hand-side variables are proxies of the convenience yield. Right-hand-side variables represent alternative decompositions of the aggregate stock-bond covariance into a term reflecting convenience yield innovations, and a residual term. Each of the covariance calculations is scaled to reflect a hypothetical 10-year maturity instrument with the same level of convenience yield as the indicated variable. Heteroskedasticity and autocorrelation robust t statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. The regression specification is

$$\text{Convenience}_t = a + b_1 \times \text{Cov(Conv., St.)} + b_2 \times \text{Cov(Tr - Conv., St.)} + c \times \text{Eff. Fed Funds} + \epsilon_t,$$

where Conv. stands for the convenience yield proxy indicated in the table header.

Panel A. Correlation matrix.

	2005-2024							
	Prem. 10y	GC-Tr 3m	OIS-Tr 3m	-1*Z-Spr.	OIS Spr. 30y	FN-Tr 30y	Rich. 10y	Box USD 2y
Prem. 10y	1.000							
GC-Tr 3m	0.235***	1.000						
OIS-Tr 3m	0.053	0.652***	1.000					
-1*Z-Spr.	0.317***	0.396***	0.239***	1.000				
OIS Spr. 30y	0.061	0.317***	0.616***	-0.044	1.000			
FN-Tr 30y	0.369***	0.241***	0.306***	0.335***	0.249***	1.000		
Rich. 10y	0.262***	0.160**	0.504***	-0.025	0.770***	0.478***	1.000	
Box USD 2y	0.417***	0.421***	0.616***	0.472***	0.538***	0.713***	0.551***	1.000

Panel B. First PC Loadings.

	2005-2024						2005-2022	2005/9-2020/7
	Prem. 10y	GC-Tr 3m	OIS-Tr 3m	-1*Z-Spr.	OIS Spr. 30y	FN-Tr 30y	Rich. 10y	Box USD 2y
PC1	0.062**	0.087***	0.150***	0.063***	0.313***	0.161***	0.159***	0.172***
	(2.02)	(6.61)	(6.24)	(2.87)	(6.86)	(3.89)	(9.14)	(5.07)
Constant	0.252***	0.124***	0.149***	0.134***	-0.445***	0.478***	0.073***	0.323***
	(13.97)	(10.02)	(9.51)	(8.38)	(-10.60)	(15.31)	(3.84)	(20.24)
Observations	240	240	240	240	240	240	216	179
R^2	0.169	0.461	0.648	0.164	0.560	0.378	0.588	0.653

Table OA3: Convenience Yield Proxy Variation Explained by the First Principal Component. Monthly data 2005-2024. Panel A shows the correlation matrix of the eight main proxies of the convenience yield. Panel B reports regressions of the convenience yield proxies on the first principal component (PC1). Heteroskedasticity and autocorrelation robust t statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. The regression specification is

$$\text{Convenience}_t = a + b \times \text{PC1} + \epsilon_t$$

where Convenience_t stands for the indicated convenience yield proxy.

Panel A. Short PC1 loadings.

	2005-2023						2005-2022	2005/9-2020/7
	Prem. 10y	GC-Tr 3m	OIS-Tr 3m	-1*Z-Spr.	OIS Spr. 30y	FN-Tr 30y	Rich. 10y	Box USD 2y
Short PC1	0.041**	0.129***	0.175***	0.110***	0.192***	0.107**	0.071***	0.150***
	(1.98)	(16.44)	(8.27)	(3.88)	(3.75)	(2.37)	(2.82)	(3.62)
Constant	0.257***	0.138***	0.168***	0.146***	-0.425***	0.489***	0.091***	0.354***
	(12.77)	(19.40)	(10.68)	(9.13)	(-6.56)	(12.34)	(2.88)	(12.64)
Observations	240	240	240	240	240	240	216	179
R^2	0.058	0.800	0.690	0.393	0.166	0.130	0.092	0.380

Panel B. Long PC1 loadings.

	2005-2023						2005-2022	2005/9-2020/7
	Prem. 10y	GC-Tr 3m	OIS-Tr 3m	-1*Z-Spr.	OIS Spr. 30y	FN-Tr 30y	Rich. 10y	Box USD 2y
Long PC1	0.072**	0.045**	0.103***	0.028	0.337***	0.177***	0.187***	0.159***
	(2.12)	(2.31)	(3.28)	(1.25)	(5.61)	(4.94)	(14.52)	(5.40)
Constant	0.252***	0.123***	0.147***	0.134***	-0.449***	0.476***	0.071***	0.324***
	(14.49)	(7.87)	(6.71)	(7.96)	(-11.74)	(16.25)	(6.15)	(16.20)
Observations	240	240	240	240	240	240	216	179
R^2	0.227	0.120	0.302	0.033	0.637	0.451	0.827	0.563

Table OA4: Convenience Yield Proxy Variation Explained by the First Principal Component. Short and long maturity Principal Components. The regression specification is

$$\text{CONV}_t = a + b \times \text{PC1} + \epsilon_t$$

where CONV_t stands for the indicated convenience yield proxy and

$$\text{PC1} \in \{\text{Short PC1}, \text{Long PC1}\}$$

as indicated in the table.

Panel A.

	mean	p1	p10	p50	p90	p99	sd	count
GC-Tr 3m [1991/5-2024]	0.14	-0.10	0.01	0.11	0.31	0.62	0.14	404
FF-Tr 3m	0.61	-0.50	-0.04	0.32	1.70	4.55	1.01	636
-1*Z-Spr.	-0.01	-0.85	-0.27	0.03	0.21	0.58	0.30	636
Rich. 10y [1997 -2022]	0.18	-0.25	-0.13	0.17	0.52	0.92	0.26	312
OIS Spr. 10y [1997-2024]	-0.13	-0.64	-0.49	-0.21	0.29	0.72	0.31	336
AAA-Tr [1983-2024]	0.87	0.44	0.52	0.82	1.34	1.72	0.31	504
Eff. Fed Funds	5.02	0.06	0.09	5.06	10.43	17.46	4.08	636

Panel B.

	mean	p1	p10	p50	p90	p99	sd	count
Cov(GC-Tr 3m, St.)	-0.12	-2.85	-0.38	-0.01	0.19	0.75	0.57	404
Cov(FF-Tr 3m, St.)	-0.23	-10.40	-1.41	-0.00	0.97	4.80	2.52	636
Cov(-1*Z-Spr., St.)	-0.12	-8.14	-0.65	-0.03	0.64	3.68	1.70	636
Cov(Rich. 10y, St.)	-0.07	-1.42	-0.29	-0.01	0.15	0.85	0.37	312
Cov(OIS Spr. 10y, St.)	-0.00	-0.61	-0.17	-0.01	0.12	0.76	0.24	338
Cov(AAA-Tr 10y, St.)	-0.08	-1.58	-0.45	-0.00	0.33	1.12	0.86	504

Panel C. 2005-2024.

	mean	p1	p10	p50	p90	p99	sd	count
Cov(Tr 2y, St.)	-0.05	-0.53	-0.16	-0.02	0.03	0.32	0.13	240
Cov(Tr 5y, St.)	-0.17	-1.72	-0.60	-0.10	0.13	0.62	0.38	240
VIX	0.19	0.10	0.12	0.17	0.29	0.54	0.08	240
CDS 10y	0.33	0.02	0.03	0.32	0.58	0.71	0.18	240
E[Inflation] 10y	1.94	1.23	1.53	1.89	2.45	2.67	0.35	240

Panel D. 2005-2024.

	mean	p1	p10	p50	p90	p99	sd	count
Cov(Tr 10y LW, St.)	-0.42	-4.77	-1.29	-0.23	0.27	1.15	0.98	240
Cov(Raw Tr 10y, St.)	-0.35	-3.45	-1.15	-0.20	0.21	0.99	0.75	240
Cov(Tr 10y, MSCI)	-0.35	-4.00	-1.04	-0.21	0.34	1.33	0.85	240
Cov(Tr 10y, St.), Single Ret.	-0.53	-6.40	-1.33	-0.28	0.26	0.96	1.13	240
Cov(Tr 10y, St.), 60 days	-0.37	-3.14	-1.18	-0.25	0.20	1.12	0.70	240
Cov(Tr 10y, St.), 252 days	-0.39	-1.85	-1.20	-0.27	0.25	0.61	0.55	240

Table OA5: Additional Summary Statistics. Monthly data in the indicated period except as indicated in the variable label.

Panel A.

	PC1, 2005-2024			PC1, 1991/5-2024		
Cov(Tr 10y LW, St.)	-0.461***			-0.308***		
	(-4.42)			(-3.45)		
Cov(Raw Tr 10y, St.)		-0.595***			-0.386***	
		(-3.33)			(-3.01)	
Cov(Tr 10y, MSCI)			-0.491***			-0.370***
			(-3.10)			(-3.12)
Eff. Fed Funds	0.197**	0.199**	0.194**	0.204***	0.204***	0.203***
	(2.14)	(2.16)	(2.11)	(4.40)	(4.38)	(4.47)
Constant	-0.530***	-0.549***	-0.504***	-0.629***	-0.636***	-0.632***
	(-4.98)	(-4.97)	(-4.50)	(-5.99)	(-5.94)	(-6.04)
Observations	240	240	240	404	404	404
R^2	0.254	0.247	0.224	0.194	0.189	0.197

Panel B.

	PC1, 2005-2024			PC1, 1991/5-2024		
Cov(Tr 10y, St.), Single ret.	-0.398***			-0.280***		
	(-2.86)			(-3.10)		
Cov(Tr 10y, St.), 60 days		-0.624***			-0.346**	
		(-2.91)			(-2.42)	
Cov(Tr 10y, St.), 252 days			-1.079***			-0.528**
			(-2.94)			(-2.27)
Eff. Fed Funds	0.197**	0.218**	0.318**	0.203***	0.212***	0.261***
	(2.11)	(2.31)	(2.55)	(4.38)	(4.14)	(3.54)
Constant	-0.545***	-0.602***	-0.963***	-0.642***	-0.643***	-0.809***
	(-5.05)	(-4.56)	(-4.14)	(-5.94)	(-5.40)	(-3.90)
Observations	240	240	240	404	404	404
R^2	0.253	0.228	0.288	0.197	0.173	0.177

Table OA6: Alternative Stock and Bond Returns. Various Lookback Windows of the Covariance Calculation. In both panels the right-hand side variable is PC1 in the indicated time period. Panel A the right-hand-side variables are alternative measures of the stock-bond covariance, described in Section 3.D. In Panel B the right-hand-side variables are the aggregate stock-bond covariance, calculated over the indicated length look-back window. Heteroskedasticity and autocorrelation robust t statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. The regression specification is

$$PC1_t = a + b \times \text{Cov} + c \times \text{Eff. Fed Funds} + \epsilon_t,$$

where PC1 and Cov stand for the indicated principal component and stock-bond covariance calculation.

Panel A.

	2005-2024						2005-2022	2005/9-2020/7
	F.Prem. 10y	F.GC-Tr 3m	F.OIS-Tr 3m	F.-1*Z-Spr.	F.Libor Spr. 30y	F.FN-Tr 30y	F.Rich. 10y	F.Box USD 2y
Cov(Tr 10y, St.)	-0.080**	-0.024**	-0.020	-0.010	-0.068*	-0.147***	-0.073***	-0.095***
	(-2.12)	(-2.00)	(-1.22)	(-0.42)	(-1.95)	(-5.00)	(-5.33)	(-3.21)
Eff. Fed Funds	0.012**	0.014	0.064***	-0.001	0.106***	0.050***	0.060***	0.062***
	(2.08)	(1.05)	(3.74)	(-0.18)	(2.67)	(3.64)	(4.96)	(5.35)
Constant	0.204***	0.098***	0.046**	0.140***	-0.328***	0.340***	-0.022	0.222***
	(10.28)	(4.80)	(2.29)	(7.08)	(-6.28)	(9.02)	(-0.62)	(12.86)
Observations	228	228	228	228	228	228	215	179
R^2	0.204	0.053	0.361	0.004	0.262	0.272	0.272	0.322

Panel B.

	2005-2024						2005-2022	2005/9-2020/7
	F.Prem. 10y	F.GC-Tr 3m	F.OIS-Tr 3m	F.-1*Z-Spr.	F.Libor Spr. 30y	F.FN-Tr 30y	F.Rich. 10y	F.Box USD 2y
Cov(Prem. 10y, St.)	-0.113***	-0.031**	-0.024	-0.025	-0.067***	-0.159***	-0.066***	-0.110***
	(-11.68)	(-2.15)	(-1.60)	(-1.51)	(-2.61)	(-7.68)	(-5.36)	(-5.99)
Cov(Rf 10y, St.)	-0.007	-0.021	-0.022	0.014	-0.094*	-0.119***	-0.080***	-0.046
	(-0.43)	(-1.17)	(-0.81)	(0.56)	(-1.71)	(-3.20)	(-3.29)	(-1.58)
Cov(CDS 10y, St.)	0.087*	-0.109*	-0.113	-0.039	-0.317*	-0.084	-0.009	-0.006
	(1.72)	(-1.77)	(-1.49)	(-0.67)	(-1.81)	(-1.12)	(-0.14)	(-0.09)
Eff. Fed Funds	0.012**	0.013	0.063***	-0.002	0.104***	0.050***	0.061***	0.062***
	(2.19)	(0.97)	(3.70)	(-0.32)	(2.64)	(3.61)	(5.10)	(5.14)
Constant	0.209***	0.105***	0.052**	0.147***	-0.318***	0.343***	-0.028	0.230***
	(11.07)	(4.87)	(2.47)	(7.56)	(-5.89)	(9.05)	(-0.78)	(12.09)
Observations	228	228	228	228	228	228	215	179
R^2	0.426	0.071	0.368	0.038	0.276	0.281	0.279	0.368

Table OA7: Stock-Bond Covariance and Proxies of the Treasury Convenience Yield. Monthly data for the indicated time periods. Left-hand-side variables are proxies of the convenience yield. The right-hand-side variables are the stock-bond covariance, its constituent elements, and the effective Fed Funds rate, each lagged by one month. Heteroskedasticity and autocorrelation robust t statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. The regression specification is

$$\text{Convenience}_{t+1} = a + b \times \text{Cov}_t + c \times \text{Eff. Fed Funds}_t + \epsilon_t,$$

where Convenience_t stands for the indicated convenience yield proxy and the selection of variables in the group

$$\text{Cov} \in \{\text{Cov(Tr. 10y, St.)}, \text{Cov(Prem. 10y, St.)}, \text{Cov(Rf 10y, St.)}, \text{Cov(CDS 10y, St.)}\}$$

is indicated in the table.

Panel A. 2005-2024.

	mean	p1	p10	p50	p90	p99	sd	count
St. Beta Tr 10y	-0.13	-0.72	-0.44	-0.16	0.24	0.56	0.27	240
St. Beta Prem. 10y	-0.04	-0.25	-0.16	-0.03	0.05	0.15	0.08	240
St. Beta Rf 10y	-0.11	-0.65	-0.39	-0.15	0.23	0.61	0.26	240
St. Beta CDS 10y	0.02	-0.08	-0.02	0.00	0.08	0.18	0.04	240
Corr(Tr 10y, St.)	-0.25	-0.86	-0.71	-0.30	0.36	0.64	0.39	240
Corr(Prem. 10y, St.)	-0.12	-0.65	-0.48	-0.14	0.21	0.38	0.26	240
Corr(Rf 10y, St.)	-0.20	-0.79	-0.66	-0.27	0.37	0.67	0.37	240
Corr(CDS 10y, St.)	0.10	-0.59	-0.25	0.09	0.46	0.68	0.29	240

Panel B. 1991/5-2024.

	mean	p1	p10	p50	p90	p99	sd	count
St. Beta Tr 10y	-0.01	-0.60	-0.39	-0.08	0.47	1.06	0.35	404
Corr(Tr 10y, St.)	-0.08	-0.86	-0.65	-0.16	0.60	0.82	0.47	404

Table OA8: Table OA8. Stock-Bond Correlation, Stock Beta of Bonds, and the 1st Principal Component of Convenience Yield Proxies. Monthly data 2005-2024.

Panel C.

	PC1, 2005-2024				PC1, 1991/5-2024	
St. Beta Tr 10y	-0.887** (-2.39)				-0.565** (-2.57)	
St. Beta Prem. 10y		-2.890** (-2.45)				
St. Beta Rf 10y		-0.794** (-2.11)				
St. Beta CDS 10y		-2.765 (-1.48)				
Corr(Tr 10y, St.)			-0.732** (-2.41)			-0.499** (-2.33)
Corr(Prem. 10y, St.)				-0.931*** (-2.64)		
Corr(Rf 10y, St.)				-0.490 (-1.64)		
Corr(CDS 10y, St.)				-0.360 (-1.57)		
Eff. Fed Funds	0.175* (1.89)	0.198** (2.21)	0.185** (2.00)	0.200** (2.19)	0.200*** (3.88)	0.210*** (3.90)
Constant	-0.417*** (-2.82)	-0.494*** (-3.71)	-0.497*** (-3.26)	-0.516*** (-3.40)	-0.549*** (-4.96)	-0.614*** (-4.85)
Observations	240	240	240	240	404	404
R^2	0.118	0.149	0.139	0.148	0.155	0.165

Table OA8, continued. Stock-Bond Correlation, Stock Beta of Bonds, and the 1st Principal Component of Convenience Yield Proxies. The first Principal Component of convenience yield proxies available in the indicated period. The right-hand-side variables are stock betas of the bond returns, separately corresponding to the convenience yield, the frictionless risk-free rate, and the CDS rate, and the stock-bond correlation coefficients, corresponding to the convenience yield, the frictionless risk-free rate, and the CDS rate, as well as the effective Fed funds rate. Heteroskedasticity and autocorrelation robust t statistics in parentheses. ***, **, and * denote significance at the 1%, 5%, and 10% levels. Monthly data in the indicated period. The regression specification is

$$\text{PC1}_t = a + b_1 \times \text{Corr} + b_2 \times \text{St. Beta} + c \times \text{Eff. Fed Funds} + \epsilon_t,$$

where the selection of variables in the groups

$$\text{Corr} \in \{\text{Corr(Prem. 10y, St.)}, \text{Corr(Rf 10y, St.)}, \text{Corr(CDS 10y, St.)}\}$$
$$\text{St. Beta} \in \{\text{St. Beta Prem. 10y}, \text{St. Beta Rf 10y}, \text{St. Beta CDS 10y}\}$$

is indicated in the table.

OA.C Online Appendix Figures

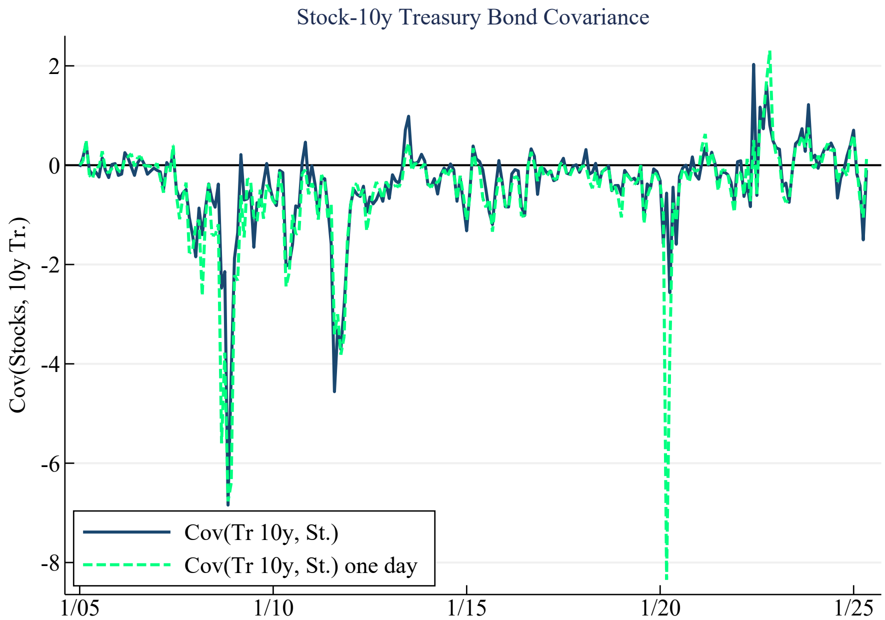

Figure OA1: Stock-bond Covariance. Calculation with three daily returns in blue, calculation with single daily returns in dashed neon green. Monthly data from 2005 to 2024. Vertical line indicates 2021/1.

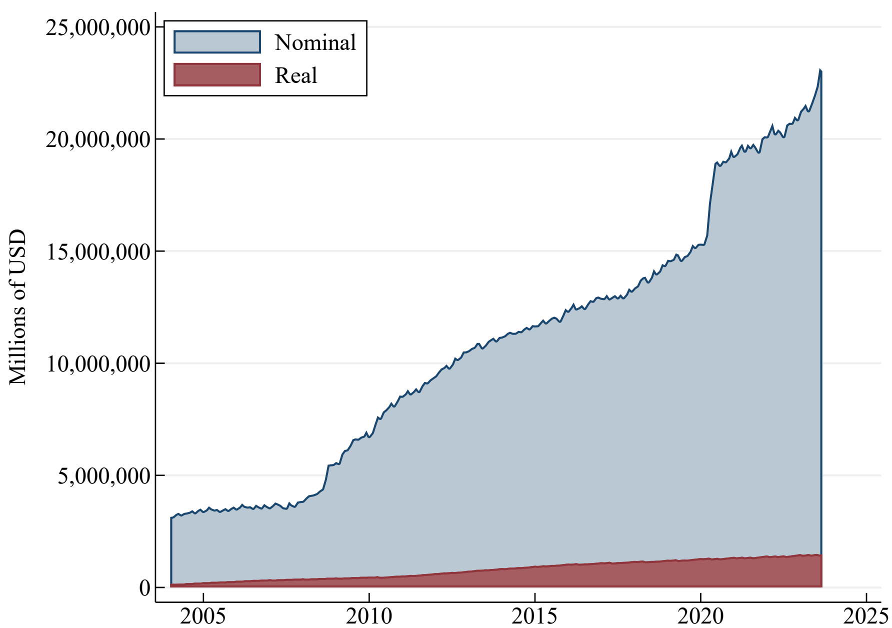

Figure OA2: Nominal and Real Treasuries Outstanding. Dollar value of Treasuries held by the private sector. Monthly calculation.