The U.S. Treasury Premium*

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Abstract

We quantify the difference in the convenience yield of U.S. Treasuries and government bonds of other developed countries by measuring the deviation from covered interest parity between government bond yields. We call this wedge the "U.S. Treasury Premium." We document a secular decline in the U.S. Treasury Premium at medium to long maturities. The five-year U.S. Treasury Premium averages approximately 21 basis points prior to the Global Financial Crisis, increases up to 90 basis points during the crisis, and has disappeared after the crisis with the post-crisis mean at -8 basis points. Meanwhile, the short-term U.S. Treasury Premium remains positive post-crisis. We discuss the impact of sovereign credit risk, FX swap market frictions, and the relative supply of government bonds on the U.S. Treasury Premium.

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1 Introduction

If investors value the liquidity and safety of government bonds, they may be willing to accept lower yields to hold them over alternative investments that offer the same cash flows. The extent to which they value these non-pecuniary benefits is often referred to as the "convenience yield." Krishnamurthy and Vissing-Jorgensen (2012) quantify this convenience yield for U.S. Treasuries and provide evidence for the specialness of U.S. Treasuries relative to other safe dollar assets. In this paper, we measure the difference in the convenience yield of U.S. Treasury bonds and government bonds in other developed countries as the deviation from covered interest parity (CIP) between government bond yields in the United States and foreign countries.

We call this measure the "U.S. Treasury Premium." For each foreign country, a positive Premium implies that the convenience yield of U.S. Treasuries is higher than the convenience yield of that country's government bonds. The U.S. Treasury Premium directly measures the difference between the yield paid by the U.S. government on Treasuries and the synthetic dollar borrowing cost faced by foreign governments after their bonds are swapped into U.S. dollars. We show that the U.S. Treasury Premium is equal to the Treasury convenience yield differential under the assumption that government bonds are default-free and international financial markets are frictionless. More generally, we also consider the impact of sovereign credit risk and FX swap frictions on our U.S. Treasury Premium measure.

We measure the U.S. Treasury Premium vis-à-vis government bonds in Australia, Canada, Denmark, Germany, Japan, New Zealand, Norway, Sweden, Switzerland and the United Kingdom, commonly referred to as the G10 currency countries. [1] Except for Japan, all sample countries have a AAA or near-AAA sovereign credit ratings and are perceived as

[1] Strictly speaking, the Danish krone (DKK) is not among the ten most liquid currency based on trading volume and turnover. However, market participants still often refer the DKK as a G10 or a G11 currency. For example, Bloomberg lists the DKK as a G10 currency.

near default-free by global investors.[2] From 2000-2016, we find the average premium on U.S. Treasuries was 10 basis points at the five-year horizon and 26 basis points at the three-month horizon. The premia also differ significantly across countries, with the mean five-year premium ranging from -26 to 61 basis points.

Furthermore, we document a steady decline in the U.S. Treasury Premium at medium- and long-term maturities since the Global Financial Crisis (GFC). The average five-year premium is 21 basis points pre-crisis, increases up to 90 basis points during the crisis, and declines to -8 basis points post-crisis. In contrast, the three-month premium averages 20 basis points before the crisis, increases up to 280 basis points during the crisis, but remains at 20 basis points after the crisis. The decline in the medium- and long-term U.S. Treasury Premia after the GFC is accompanied by a sharp inversion of the term structure of the premia.

The benchmark U.S. Treasury Premium measures the relative convenience yield of government bonds if all government debt is default-free and the swap market is frictionless. While this is a useful benchmark to begin with, we also examine alternative measures of the premium where we adjust for sovereign credit risk differences using credit default swaps (CDS) and FX swap market frictions as proxied by deviations from CIP for observed risk-free rate proxies (Du et al. (Forthcoming)). We show that in the pre-crisis period, measured credit spread differentials and CIP deviations for interbank rates were both negligible. During this period, our benchmark U.S. Treasury Premium measure therefore gives a clean measure of the relative convenience yield. In the post-crisis period, both CIP deviations for interbank rates and sovereign CDS spread differentials tend to increase the U.S. Treasury Premium. This is because the U.S. has lower sovereign CDS spreads than the average G10 country and CIP deviations for these risk-free rate proxies makes the average swap-implied dollar

[2] The long-term local currency bonds in seven of 11 countries are AAA-rated throughout the sample (Australia, Canada, Denmark, Germany, Norway, Sweden and Switzerland). The other four countries (Japan, New Zealand, United States and United Kingdom) do not have a perfect credit rating. The United States was downgraded to AA+ in 2011 and New Zealand was downloaded to AA in 2011 and the United Kingdom lost its AAA rating after the Brexit in 2016. Japan was downgraded several times in our sample, currently rated A+, several notches lower than all the other sovereigns and the lowest in our sample.

yield higher than the direct dollar yield. Therefore, the secular decline in the medium- to long-term U.S. Treasury Premium is not explained away by differential credit risk or FX market frictions, but rather a fall in the relative convenience yield.

Furthermore, we connect the U.S. Treasury Premium measure to the difference in the swap spread between the Libor interest rate swap rate and the Treasury yield across countries. We show that the decline in the U.S. Treasury Premium is largely driven by a decline in the spread between U.S. Treasuries and either the U.S. or the foreign Libor benchmark. To the extent that the swap spread sheds light on the Treasury convenience yield in each country, our results suggest that the decline in the U.S. Treasury Premium is largely driven by a decline in the convenience yield of the U.S. Treasuries, rather than an increase in the convenience yield of foreign government bonds.

We then examine the behavior of the U.S. Treasury Premium measure against other measures of the convenience component of U.S. Treasury yields. At the short horizon, the general collateral (GC) repo-Treasury bill (repo-Tbill) spread is considered a measure of the convenience premium in Treasury bill yields, as the GC repo is secured by Treasury collateral and has very little credit risk, but is not as liquid as Treasury bills (Nagel (2016)). We find that variations in the average three-month premium of U.S. Treasury bills are strongly correlated with the U.S. repo-Tbill spread. When the repo-Tbill spread is high, our average three-month U.S. Treasury Premium is also high. Furthermore, we find that a higher repo-Tbill spread in foreign countries is correlated with a reduction in the U.S. Treasury Premium at the three-month horizon, which supports the notion that our premium measures the relative convenience of U.S. Treasury bills vis-à-vis foreign Treasury bills.

At longer maturities, the conventional Treasury convenience yield measure is given by the yield spread between near risk-free agencies and Treasuries (for example, Fleckenstein et al. (2014), Negro et al. (2017) and Schwartz (2015)). We choose the risk-free agency to be KfW, a German development bank, fully backed by the German government. The advantage of focusing on KfW is that it issues debt in multiple currencies. We calculate the convenience yield of the German bund as the euro-denominated KfW spread over the German bund yield, and the convenience yield of the U.S. Treasury as the dollar-denominated KfW spread over the U.S. Treasury yield. We find the U.S. Treasury Premium vis-à-vis the German bund closely tracks the difference in the two convenience yields based on KfW yields, which also exhibits a secular decline. This provides further support that our measure of the convenience yield is indeed capturing relative convenience benefits.

Finally, we examine how the relative supply of U.S. Treasuries and foreign government bonds affects the U.S. Treasury Premium. Krishnamurthy and Vissing-Jorgensen (2012) show that the U.S. public debt to GDP ratio is inversely related to the convenience yield on U.S. Treasuries. When the debt to GDP ratio is low, Treasuries are more scarce and therefore commands a higher premium compared to private paper. Consistent with their results, we find that an increase in the supply of foreign government bonds relative to U.S. Treasuries is associated with a higher U.S. Treasury Premium.

The U.S. Treasury Premium measure is related to a number of papers that examine the convenience yields of U.S. Treasuries, in particular Krishnamurthy and Vissing-Jorgensen (2012), Nagel (2016) and Greenwood et al. (2015). Krishnamurthy and Vissing-Jorgensen (2012) examine the effect of the amount of debt outstanding on the liquidity and safety premia of U.S. Treasuries. The authors estimate the average "liquidity convenience" at 46 basis points, which they identify off of the effect of Treasury issuance on AAA-Treasury spreads. While our benchmark estimates are lower than those in Krishnamurthy and Vissing-Jorgensen (2012), this should not be surprising as we are measuring a different concept. We are considering the U.S. Treasury's liquidity and safety premia relative to other governments rather than relative to safe agencies and corporates. Greenwood et al. (2015) estimate the convenience yield of T-bills using the differential between the actual T-bill yield and the fitted yield based on the estimated yield curve, and find a premium of 40 basis points for one-week bills. Nagel (2016) measures the liquidity premium on T-bills as their spread relative to a three-month general collateral repo with the mean premium equal to about 24 basis points.

The question of how much less the U.S. government pays on its debt because of its "specialness" is also related to the question of the "Exorbitant Privilege" and the source of the return differentials between the United States and the rest of the world. This question is examined by Gourinchas and Rey (2007a,b), Gourinchas et al. (2010), and Curcuru et al. (2008). By converting all foreign government bond yields into U.S. dollars, we contribute to this literature by quantifying the degree to which the U.S. government pays less than foreigners, above and beyond differences in currency risk premia. By focusing on the specialness of government bonds within a currency, this measure is largely distinct from the question of why the U.S. dollar is the global reserve currency (Maggiori (Forthcoming), Farhi and Maggiori (Forthcoming)) and attempts to measure premium on U.S. dollar-denominated assets (Maggiori (2013)).

Recently, a number of papers in international finance have examined how changes in the relative convenience yield of government bonds across countries can help resolve a number of exchange rate puzzles. Engel (2016) and Valchev (2017) argue that time variation in bond convenience yields can explain the term structure of violations of uncovered interest rate parity. Itskhoki and Mukhin (2017) looks at how a similar shock can generate exchange rate disconnect. Our measure of the U.S. Treasury Premium provides an empirical counterpart to the shocks in these papers. While we focus on the long-term behavior of the average U.S. Treasury Premium, the high frequency, currency and maturity specific measures of the U.S. Treasury Premium we construct can be used as an input in this growing literature.

In terms of the construction of the U.S. Treasury Premium measure itself, this paper build on the earlier work of Du and Schreger (2016a,b). Du and Schreger (2016a) construct the "local currency credit spread" in an identical way as the measure used in this paper, but has a different interpretation.[3] This is because sovereign default risk is very low in G10 countries, and therefore, it is likely that the factors such as the convenience yield differential and financial market frictions play more important roles than default risk in explaining the

[3]Hofmann et al. (2016) studies this same measure in connection to currency appreciation.

U.S. Treasury Premium vis-à-vis G10 government bonds. The measure in this paper is closely related to the analysis of "Relative Swap Spreads" in Codogno et al. (2003).[4] Finally, our paper is also related works on frictions in the interest rate and FX swap markets. Feldhütter and Lando (2008), Klingler and Sundaresan (2016) and Jermann (2016) on the U.S. swap spreads, and Ivashina et al. (2015), Liao (2016), Du et al. (Forthcoming), and Avdjiev et al. (2016) on CIP violations post-crisis.

The paper is organized as follows. In Section 2, we discuss the methodology behind calculating the premium and our data sources. In Section 3, we present the main results on the behavior of the U.S. Treasury Premium across time, currency, and maturity. In Section 4, we compare this premium to existing measures of the safety and liquidity of U.S. Treasuries. In Section 5, we examine the relationship between the relative bond supply and the premium. Section 6 concludes.

2 Methodology and Data

2.1 Bond Prices and Convenience Yields

In this section, we will define the U.S. Treasury Premium and discuss how it relates to the concept of bond convenience yields. We begin with the simplest case in which we assume that the local currency government bonds of developed countries are default-free and international financial markets are frictionless. In this case, government bond yields can still be different from the risk-free rate in the local currency if government bonds offer convenience benefits.

We let $\Lambda_{i,t+1}$ denote the convenience benefit of the government bond of country i realized at $t+1$, and let $y_{i,t}^{rf}$ denote the risk-free rate in currency i. Then we can price a one-period

[4] Codogno et al. (2003) decompose yield spreads in euro area countries into international risk factors, default, and liquidity, while accounting for the fact that bonds are in different currencies by using interest rate swaps. Our measure differs from the measure in that paper by including the cross-currency basis swap, but would be the same if this basis was close to zero as was generally the case pre-crisis.

Treasury bond in country i as

$$P_{i,t}^{Govt} = \exp(-y_{i,t}^{rf})\mathbb{E}_{i,t}[(1 + \Lambda_{i,t+1})], .$$

where $\mathbb{E}_{i,t}$ refers to the risk-neutral expectation in country i. In logs, we have

$$\lambda_{i,t} = y_{i,t}^{rf} - y_{i,t}^{Govt}. \tag{1}$$

where $y_{i,t}^{Govt} = -\log(P_{i,t}^{Govt})$ is the yield on the government bond, and $\lambda_{i,t} \equiv \ln \mathbb{E}_{i,t}(1+\Lambda_{i,t+1})$ is the Treasury convenience premium in country i at time t. Therefore, the convenience yield in country i is equal to the spread between the risk-free rate and the government bond yield. In this case, the government bond yield can be lower than the risk-free rate if there is a positive convenience benefit associated with holding government bonds.

Similarly, we can write the convenience yield of the U.S. Treasury, $\lambda_{USD,t}$, as the spread between the U.S. risk-free rate, $y_{USD,t}^{rf}$, and U.S. Treasury yield, $y_{USD,t}^{Govt}$:

$$\lambda_{USD,t} = y_{USD,t}^{rf} - y_{USD,t}^{Govt}. \tag{2}$$

Then the difference in the convenience yield between the United States and country i is given by

$$\hat{\lambda}_{i,t} \equiv \lambda_{USD,t} - \lambda_{i,t} = (y_{USD,t}^{rf} - y_{USD,t}^{Govt}) - (y_{i,t}^{rf} - y_{i,t}^{Govt}). \tag{3}$$

In addition, we define the market-implied forward premium, $\rho_{i,t}$, as the log difference in the outright forward $F_{i,t,t+1}$ and spot exchange rate $S_{i,t}$

$$\rho_{i,t} = \log(F_{i,t,t+1}) - \log(S_{i,t}),$$

where both $F_{i,t,t+1}$ and $S_{i,t}$ are expressed as units of foreign currency i per dollar. If international financial markets are frictionless, the CIP condition holds for risk-free rates. So we therefore have:

$$\rho_{i,t} = y^{rf}_{i,t} - y^{rf}_{USD,t}.$$

2.2 The U.S. Treasury Premium and Convenience Yields: Frictionless Benchmark

We now formally define our U.S. Treasury Premium measure as follows.

Definition 1. At time t, we define the n-year U.S. Treasury Premium vis-à-vis country i as the deviation from covered interest rate parity between government bond yields in the United States and country i:

$$\Phi_{i,n,t} = y^{Govt}_{i,n,t} - \rho_{i,n,t} - y^{Govt}_{USD,n,t}, \tag{4}$$

where $\rho_{i,n,t}$ is the n-year market-implied forward premium for hedging currency i against the U.S. dollar.

Under the assumption of frictionless international financial markets and default-free government bonds, we now show that the U.S. Treasury Premium vis-à-vis country i measures the Treasury convenience yield differential between the United States and country i:

$$\Phi_{i,n,t} = \hat{\lambda}_{i,n,t},$$

where $\hat{\lambda}_{i,n,t} \equiv \lambda_{USD,n,t} - \lambda_{i,n,t}$. To see this, we know that if covered interest rate parity holds between risk-free rates, then $\rho_{i,n,t} = y^{rf}_{i,n,t} - y^{rf}_{USD,n,t}$. We can substitute this expression into

Equation 4 and rearrange:

$$\begin{aligned}
\Phi_{i,n,t} &= y^{Govt}_{i,n,t} - \rho_{i,n,t} - y^{Govt}_{USD,n,t}, \\
&= y^{Govt}_{i,n,t} - (y^{rf}_{i,n,t} - y^{rf}_{USD,n,t}) - y^{Govt}_{USD,n,t}, \\
&= (y^{rf}_{USD,n,t} - y^{Govt}_{USD,n,t}) - (y^{rf}_{i,n,t} - y^{Govt}_{i,n,t}) \\
&= \lambda_{USD,n,t} - \lambda_{i,n,t} \equiv \hat{\lambda}_{i,n,t}.
\end{aligned}$$

Intuitively, since $y^{Govt}_{i,n,t} - \rho_{i,n,t}$ measures the synthetic dollar borrowing cost of swapping the cash flows of foreign currency Treasury bonds into U.S. dollars, our U.S. Treasury Premium $\Phi_{i,n,t}$ measures the difference in borrowing costs between foreign governments and the U.S. Treasury, all expressed in U.S. dollars. Under the assumptions that government bonds are default-free and FX swap markets are frictionless, the synthetic dollar yields of foreign Treasuries can be higher than the U.S. Treasury yield if and only if the convenience yield of the U.S. Treasury bond is higher than that of the foreign government bond.

2.3 The U.S. Treasury Premium and Convenience Yields: Default Risk and FX Swap Market Frictions

There are a number of places where the assumptions made in the previous section could fail. First, each sovereign bond could have some default risk, and $\Phi_{i,n,t}$ could be capturing sovereign credit risk differentials. Second, there could be frictions in the swap market, such that the observed forward premium $\rho_{i,n,t}$ is different than the hypothetical premium $\tilde{\rho}_{i,n,t}$ that ensures CIP for risk-free rates. Third, government bonds could be mispriced due to market segmentation, financial repression, or other frictions. Since a systematic study of Treasury bond mispricing is beyond the scope of this paper, we maintain the assumption throughout the paper that Treasury bonds are correctly priced for our sample of developed countries. However, we do consider the other two sources of frictions more formally.

For default risk, we use $\hat{l}_{i,n,t}$ to denote the difference between the expected default loss of the U.S. Treasury bond, $l_{USD,n,t}$, and the expected default loss of the Treasury bond in country i, $l_{i,n,t}$, .

$$\hat{l}_{i,n,t} \equiv l_{USD,n,t} - l_{i,n,t}.$$

For the FX swap market frictions, we define a wedge $\tau_{i,n,t}$ that is equal to the difference between the hypothetical premium, $\tilde{\rho}_{i,n,t}$, and the observed forward premium, $\rho_{i,n,t}$:

$$\tau_{i,n,t} \equiv \tilde{\rho}_{i,n,t} - \rho_{i,n,t}.$$

In the presence of these two sources of frictions, the U.S. Treasury Premium becomes a collection of the convenience yield differential, differential default risk, and swap market frictions:

$$\Phi_{i,n,t} = \hat{\lambda}_{i,n,t} - \hat{l}_{i,n,t} + \tau_{i,n,t}. \tag{5}$$

where $\hat{x}_{i,n,t} \equiv x_{USD,n,t} - x_{i,n,t}$.[5]

As can we be seen in Equation 5, the U.S. Treasury premium approximates the convenience yield

$$\Phi_{i,n,t} \approx \hat{\lambda}_{i,n,t} \tag{6}$$

if swap market frictions ($\tau_{i,n,t}$) and credit spread differentials $\left(\hat{l}_{i,n,t}\right)$ are small. However, if we believe that swap market frictions are and credit spread differentials are sizable, then we would need to adjust the U.S. Treasury Premium for these frictions in order for the Premium to provide an accurate measure of the relative convenience yield $\hat{\lambda}_{i,n,t}$. We define two such

[5] A full derivation of this expression is given in the appendix.

adjusted versions of the U.S. Treasury Premium:

$$\Phi_{i,n,t}^{CIP} \equiv \Phi_{i,n,t} - \tau_{i,n,t} \tag{7}$$

$$\Phi_{i,n,t}^{CIP,CDS} \equiv \Phi_{i,n,t} - \tau_{i,n,t} + \hat{l}_{i,n,t} \tag{8}$$

where $\Phi_{i,n,t}^{CIP}$ is the premium adjusted for swap market frictions, and $\Phi_{i,n,t}^{CIP,CDS}$ is the premium adjusted for both swap market frictions and the credit differential between foreign and U.S. Treasuries. Our proxies for $\tau_{i,n,t}$ and $\hat{l}_{i,n,t}$ are discussed in the next sub-section.

2.4 Data and Measurement

In this section, we briefly discuss our data sources and some measurement issues.

2.4.1 Bond Yields and the Market-Implied Forward Premium

We use Bloomberg BFV curves for government bond yields in the United States and G10 countries; BFV curves are fitted par yield curves based on secondary market bond prices estimated by Bloomberg. We also use Bloomberg data for yields on interest rate swaps and cross-currency basis swaps. Bloomberg and Thomson Reuters Eikon tickers used in the paper can be found in the Appendix B.

For short-term maturities less than one year, we calculate the market implied forward premium directly from the forward and spot exchange rates:

$$\rho_{i,n,t} = \frac{1}{n}[\log(F_{i,t,t+n}) - \log(S_{i,t})],$$

where $F_{i,t,t+n}$ is n-year ($n < 1$) outright forward rate, measured in terms of units of currency i per dollar, and $S_{i,t}$ is the spot exchange rate.

For longer maturities equal to or greater than one year, the liquidity of outright forward contracts is quite poor. The market convention is instead to quote the forward premium through a collection of interest rate swaps and cross-currency basis swaps based on the following formula:

$$\rho_{i,n,t} = irs_{i,n,t} + bs_{i,n,t} - irs_{USD,n,t}, \tag{9}$$

where $irs_{i,n,t}$ denotes the n-year interest rate swap rate that exchanges fixed currency i cash flows into the floating interbank interest rate benchmark (referred to as the Libor interest rate swap) in country i, $bs_{i,n,t}$ is the n-year cross-currency basis swap that exchanges the floating benchmark interbank rate in country i for U.S. Libor, and $irs_{USD,n,t}$ is U.S. Libor interest rate swap rate that exchange fixed dollar cash flows into U.S. Libor.[6]

In order to hedge long-term currency risk for currency i, a dollar investor has to go through three steps. First, the investor pays the foreign currency interest rate swap, $irs_{i,n,t}$, to swap fixed foreign currency cash flows into floating foreign currency Libor cash flows. Second, she pays the cross-currency basis swap, $bs_{i,n,t}$, to swap floating foreign currency Libor into U.S. dollar Libor cash flows. Third, she receives the U.S. interest rate swap, $irs_{USD,n,t}$, to swap floating dollar U.S. Libor cash flows into fixed U.S. dollar cash flows. The combination of the three steps eliminates all floating cash flows, and only exchanges of fixed cash flows in foreign currency and the U.S. dollar at the inception and maturity of the swap remain, which is exactly analogous to a long-term forward contract.

2.4.2 FX Swap Market Mispricing

We proxy for FX swap market mispricing $\tau_{i,n,t}$ in Equation 7, as the deviation from the CIP condition for proxies of risk-free rates. In the benchmark calculation, we use the Libor interest rate swap as our risk-free rate proxy, $y^{rf}_{i,n,t} = irs_{i,n,t}$.[7] Alternatively, we also consider the Overnight Indexed Swap (OIS) rate as an alternative measure of the risk-free rate in Section 3.4, and yields on bonds issued by KfW, a German development bank with liabilities

[6] Du et al. (Forthcoming) provides detailed discussion and cash flow diagrams for these transactions.

[7] Interest rate swaps have long been used as proxies for risk-free rates in the academic literature. Duffie and Huang (1996) show that the credit risk component of the benchmark interest rate swap is less than 2 basis points under reasonable calibrations.

fully backed by the German government in Section 4.2. Our main empirical results are robust to the choice of these alternative risk-free rates.

When using the Libor interest rate swap rate as the risk-free rate proxy, the Libor-based swap market mispricing measure is given by

$$\tau_{i,n,t}^{Libor} = (irs_{i,n,t} - irs_{USD,n,t}) - \rho_{i,n,t}. \tag{10}$$

Substituting the expression for the observed swap rate in Equation 9 into Equation 10, we have that the Libor-based swap market mispricing is given by

$$\tau_{i,n,t}^{Libor} = -bs_{i,n,t}.$$

In other words, the Libor-based swap market mispricing is equal to the negative of the cross-currency basis swap rate. As shown in Du et al. (Forthcoming), the CIP condition holds very well for Libor interest rate swaps before the Global Financial Crisis ($\tau_{i,n,t}^{Libor} \approx 0$), but large CIP violations emerge during the crisis and persist after the crisis.[8] As a result, our benchmarkFX swap mispricing measure based on Libor interest rate swap rates is very close to zero before the GFC and becomes sizable during and after the GFC.

2.4.3 Sovereign Credit Risk Differential

We measure the credit risk differential between sovereigns, $\hat{l}_{i,n,t}$ in Equation 8, as the difference in CDS spreads. CDS data are from Markit and are on senior, unsecured credit default swap contracts denominated in U.S. dollars. They were obtained for the six-month, and one to 10-year contracts. Because data on the 3-month contract is unavailable, we use the six-month contract for the three-month contract instead. However, there is the question of what

[8]Du et al. (Forthcoming) argue the CIP deviations exist due to constraints on the balance sheet capacity of financial intermediaries, and CIP deviations can be viewed as an intermediation fee that financial intermediaries are earning to justify the marginal cost of balance sheet capacity while providing currency hedging.

exactly developed country sovereign CDS spreads capture. G10 Sovereign CDS markets are not very liquid: Klingler and Lando (2016) show that CDS premiums for sovereigns with low default risk are primarily driven by regulatory demand. One alternative assumption is to assume that all sovereigns in the sample are risk-free and therefore, $\hat{l}_{i,n,t} = 0$, as we do in the benchmark U.S. Treasury Premium calculation Φ, as well as in the measure adjusted only for CIP differentials, Φ^{CIP}.

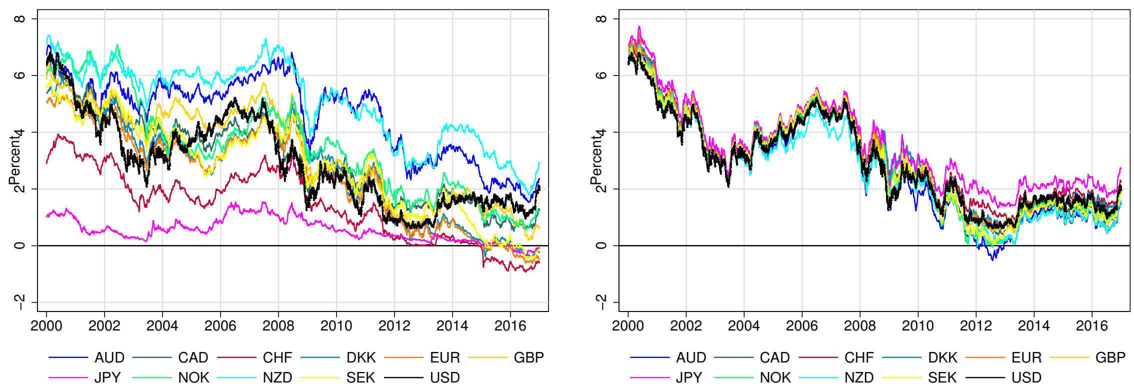
3 The U.S. Treasury Premium: 2000-2016

3.1 Summary Statistics and Stylized Facts

In Figure 1a, we plot the currency-specific nominal yields of our ten country sample at the 5-year horizon. The variation across country is wide. In Figure 1b, we report the swap-implied dollar yields for each country $y^{Govt}_{i,n,t} - \rho_{i,n,t}$ at the five-year tenor. It is immediately clear that these swap-implied dollar yields track the yield on U.S. Treasuries very closely, with significantly less dispersion than currency-specific yields. Our U.S. Treasury Premium can be visualized as the spread between these swap-implied dollar yields and the U.S. Treasury yield.

Figure 1: Nominal and Synthetic Dollar Yields

(a) Nominal Yields (b) Synthetic Dollar Yields

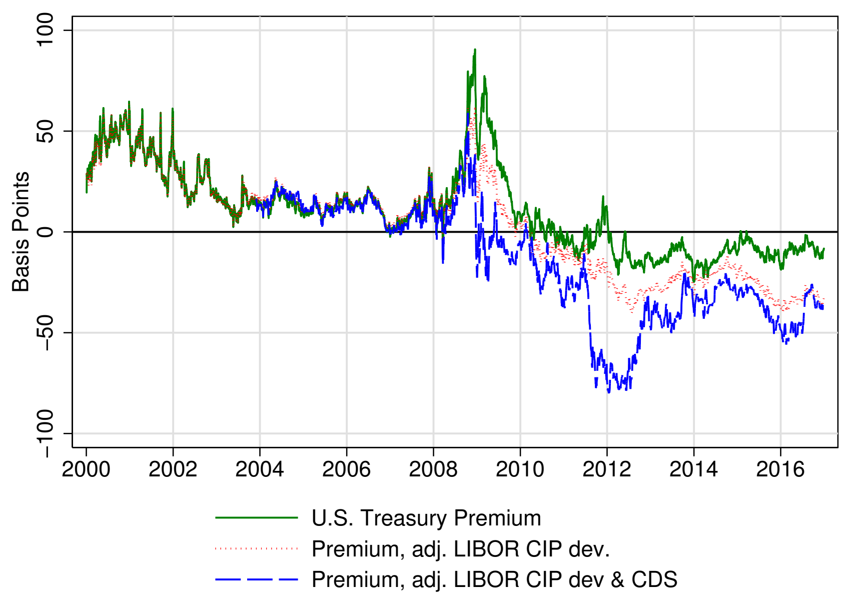


Notes: Figure 1a plots currency-specific yields on five-year government bonds in G10 countries and the United States. Figure 1b plots the five-year synthetic dollar yields on these government bonds after hedging foreign currency risk. Series are seven-day moving averages. EUR refers to Germany.

Figure 2 plots the cross-country mean of the five-year U.S. Treasury Premium and the two versions of the adjusted premium as defined in Equations 7-8, respectively. The difference between these measures are smallest from 2000-2006. During that time, CIP held for interbank rates and sovereign CDS spreads between U.S. and foreign countries were approximately zero. Therefore, the U.S. Treasury Premium Φ and the adjusted versions, Φ^{CIP} and $\Phi^{CIP,CDS}$, were all nearly equal with cross-country averages at the five-year tenor equal to about 21 basis points. During the GFC (2007-2009), all three measures widened with the benchmark premium widening most significantly. This is, however, the period in which CIP for interbank rates broke down, and U.S. and foreign sovereign CDS spreads diverged. The two adjusted premia also widened during the GFC, but by significantly less than the benchmark premium.

In the post-GFC sample (2010-2016), we document a steady decline in the U.S. Treasury Premium at the medium to long tenors. The Premium trended down to the negative territory in 2010 with the 5-year cross-country average premium at -8 basis points for the 2010-2016 period. The 5-year premium adjusted for CIP deviations in interbank rates is more negative over that period with an average equal to -22 basis points. In other words, if the swap rate was such that the CIP condition for interbank rates held, the U.S. Treasury Premium would be even lower. In addition, since the U.S. sovereign CDS spread is lower than the average G10 sovereign CDS spread, the CDS differential adjustment brings down the premium even further to an average -38 basis points in the post-GFC period. Therefore, the decline in the average U.S. Treasury Premium at medium to long tenors post-GFC can neither be attributed to swap market frictions nor to perceived credit quality differentials between the U.S. and foreign sovereigns.

Figure 2: Five-Year Average U.S. Treasury Premium



Notes: This figure plots the average 5-year U.S. Treasury Premium (in solid green), the average premium adjusted for CIP deviations (in dotted red), and the average premium adjusted for CIP deviations and CDS differentials (in dashed blue) for 2000-2016. Series are seven-day moving averages.

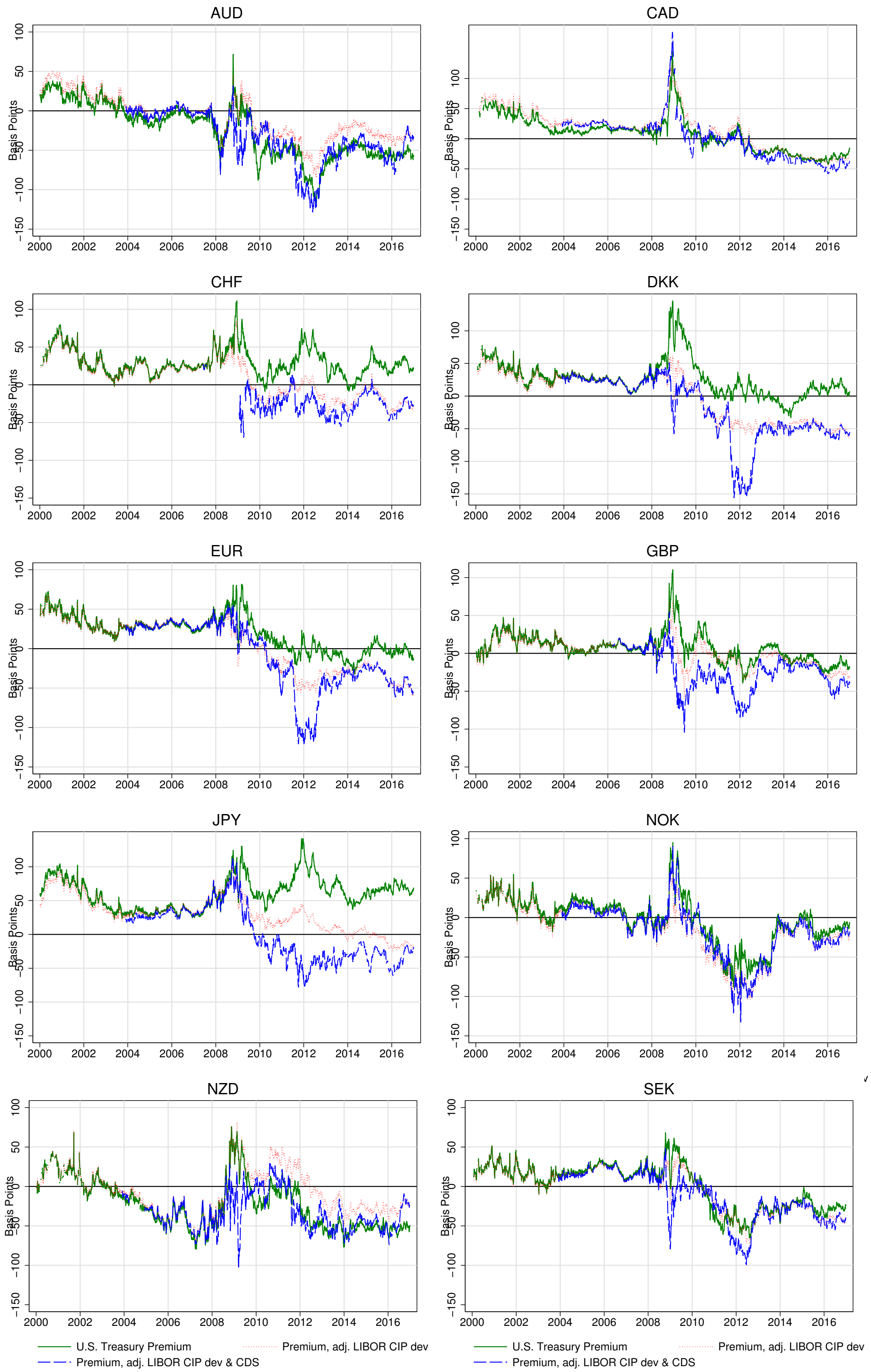
Figure 3 shows the three measures by country and Table 1 reports the mean and standard deviations of the U.S. Treasury Premium by country.[9] As shown in Table 1, cross-country heterogeneity is large: the U.S. Treasury Premium is highest for Japan with the average equal to 61 basis points and lowest for Australia and New Zealand at about -25 basis points.

[9]Summary statistics by country of the adjusted premia can be found in Appendix Tables A3 and A4.

With the exception of Japan, however, the U.S. Treasury premiums vis-à-vis other sample countries all exhibit a decline post-crisis.

In terms of the time series variation by country, pre-GFC, the 5-year U.S. Treasury premium and the adjusted versions are nearly identical for all countries. Broadly, this remains true for Australia, Canada, Norway, Sweden, and New Zealand during and after the GFC, suggesting that for this subset of countries, variations in the U.S. Treasury Premia are largely independent of swap market frictions or credit spread differentials. For Switzerland, Denmark, Germany, and the United Kingdom, outside the GFC and the European Debt Crisis, the U.S. Treasury Premia are generally higher than the version adjusted for CIP deviations. With the adjustment, the premia vis-à-vis this subset of countries falls more precipitously in the post-GFC period, more so when adjusting for both CIP deviations and the CDS spreads. Notably, outside crises, the two adjusted series are very similar; this is unsurprising as CDS spreads are narrow in tranquil periods.

Figure 3: 5-Year Average U.S. Treasury Premium by Country



Notes: This figure plots the 5-year U.S. Treasury Premium (in solid green), the premium adjusted for CIP deviations (in dotted red), and the premium adjusted for CIP deviations and CDS differentials (in dashed blue) by country from 2000-2016. Series are seven-day moving averages. EUR refers to Germany. Series are seven-day moving averages.

Table 1: Summary Statistics of the 5-Year U.S. Treasury Premium

		Full Sample	2000-2006	2007-2009	2010-2016
AUD	Mean	-24.9***	5.1*	-15.9***	-58.3***
	Std. Error	(4.0)	(2.7)	(6.0)	(2.7)
	N	4406	1797	783	1826
CAD	Mean	7.0**	24.2***	29.4***	-17.8***
	Std. Error	(3.4)	(2.6)	(7.7)	(2.7)
	N	4215	1609	782	1824
CHF	Mean	29.0***	28.6***	40.2***	24.6***
	Std. Error	(2.0)	(2.9)	(4.8)	(2.8)
	N	4186	1603	770	1813
DKK	Mean	25.4***	31.7***	56.5***	6.6***
	Std. Error	(3.2)	(2.1)	(9.8)	(2.4)
	N	4201	1599	776	1826
EUR	Mean	18.6***	32.0***	38.4***	-2.2
	Std. Error	(2.5)	(1.7)	(3.5)	(1.8)
	N	4287	1692	770	1825
GBP	Mean	7.1***	13.1***	21.9***	-4.8*
	Std. Error	(2.2)	(1.6)	(6.3)	(2.6)
	N	4220	1665	775	1780
JPY	Mean	61.1***	50.5***	64.7***	70.0***
	Std. Error	(2.7)	(4.0)	(6.6)	(3.3)
	N	4397	1787	784	1826
NOK	Mean	-4.7	15.1***	12.1*	-28.9***
	Std. Error	(3.5)	(1.9)	(6.6)	(4.1)
	N	4110	1545	772	1793
NZD	Mean	-26.4***	-15.1***	-15.8	-39.1***
	Std. Error	(3.5)	(4.3)	(11.0)	(3.8)
	N	3912	1307	780	1825
SEK	Mean	-0.3	19.6***	24.8***	-28.7***
	Std.Dev.	(3.3)	(1.5)	(3.2)	(2.6)
	N	4235	1630	779	1826
Total	Mean	9.6***	21.3***	25.6***	-7.8***
	Std. Error	(1.4)	(1.3)	(3.2)	(2.2)
	N	42169	16234	7771	18164

Significance levels: * $p<0.10$ ** $p<0.05$ *** $p<0.01$

Notes: This figure table reports the mean, standard error of the mean based on Newey-West standard errors with a 91-day lag, and number of observations of the 5-year U.S. Treasury Premium by country, and period (pre-GFC (2000-2006), GFC (2007-2009), post-GFC (2010-2016)).

3.2 Term Structure of the U.S. Treasury Premium

Next, we turn our attention to the term structure of the U.S. Treasury Premium. Table 2 presents summary statistics of the benchmark version of the U.S. Treasury Premium and the adjusted versions of the U.S. Treasury Premium by tenor and subsamples. Figure 4 plots the benchmark premium by maturity. As we can see from Table 2 and Figure 4, before the GFC, the term structure of the U.S. Treasury Premium is upward sloping and the average premia are positive across all maturities.

During the GFC, we see an inversion in the term structure of the premia, and an increase the U.S. Treasury Premium across maturities, with the increase concentrated at shorter maturities. The cross-country average for the 3-month premium nearly reaches 300 basis points at the peak of the crisis. The increase in the 10-year premium during the GFC is much more subdued with the highest level only around 50 basis points.

After the GFC, the term structure remains inverted and the 3-month, 1-year, 5-year, and 10-year premia are no longer strongly correlated, nor of the same sign. Post-GFC, the 3-month and 1-year premia are positive and have been trending up; meanwhile, the 5-year and 10-year premia have been negative and approximately flat. Strikingly, the 3-month and 1-year premia begin their upward trend in 2014, with the 3-month premium rising from nearly 0 basis points to 70 basis points.

The inversion of the term structure of the U.S. Treasury Premium also holds for the premia adjusted for swap market frictions and credit spread differentials. Figure 5 plots the term spread of the U.S. Treasury Premium, which we define as the 10-year premium minus the 1-year premium, for the U.S. Treasury premium and the two adjusted versions. The term spread becomes negative for all three premium measures post-GFC.

Therefore, we find that even though medium- to-long-term U.S. Treasuries have lost their specialness relative to other near-default-free government bonds since the GFC, short-dated U.S. Treasury bills still command a sizable premium.

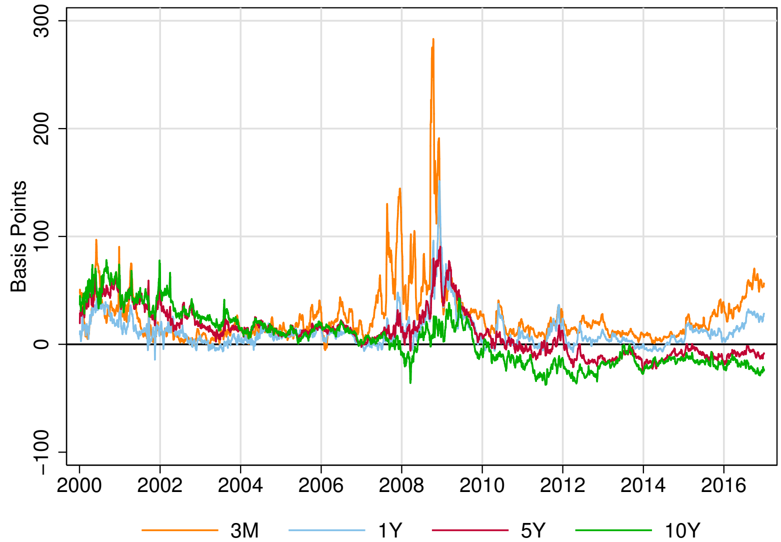
Table 2: Average U.S. Treasury Premium by Tenor and Period

		U.S. Treasury Premium				Premium Adj. CIP Deviations				Premium Adj. for CIP Dev. and CDS Diff.			
		Full	00-06	07-09	10-16	Full	00-06	07-09	10-16	Full	00-06	07-09	10-16
3M	Mean	25.9***	18.5***	58.8***	19.3***	12.2***	15.9***	37.4***	-2.2	3.0	12.6	21.2***	-2.0
	SE	(1.2)	(1.1)	(4.2)	(1.6)	(1.1)	(1.0)	(3.7)	(1.3)	(2.2)	(8.1)	(6.8)	(2.1)
	N	42,314	17,425	7,433	17,456	42,314	17,425	7,433	17,456	14,569	615	2,752	11,202
1Y	Mean	11.4***	9.7***	24.5***	7.3***	0.5	9.9***	9.7***	-11.3***	-8.9***	7.479	-0.776	-13.4***
	SE	(1.1)	(1.1)	(3.5)	(1.6)	(1.0)	(1.0)	(3.0)	(1.3)	(1.7)	(4.8)	(4.2)	(1.8)
	N	40,717	15,064	7,684	17,969	40,717	15,064	7,684	17,969	18,135	1,303	4,314	12,518
5Y	Mean	9.6***	21.3***	25.6***	-7.8***	2.0*	22.0***	17.4***	-22.4***	-18.2***	13.1***	5.0	-38.1***
	SE	(1.4)	(1.3)	(3.2)	(2.2)	(1.2)	(1.2)	(2.5)	(1.4)	(1.6)	(1.9)	(3.1)	(1.5)
	N	42,169	16,234	7,771	18,164	42,169	16,234	7,771	18,164	30,490	5,928	7,005	17,557
10Y	Mean	3.5**	24.8***	6.4**	-18.1***	-2.1	24.9***	0.3	-29.0***	-35.1***	12.2***	-13.2***	-55.2***
	Std. Error	(1.6)	(1.6)	(2.7)	(2.6)	(1.3)	(1.4)	(2.4)	(1.5)	(1.9)	(2.5)	(3.2)	(1.7)
	N	41,082	16,264	7,746	17,072	41,082	16,264	7,746	17,072	26,496	4,057	6,162	16,277

Significance levels: * $p<0.10$ ** $p<0.05$ *** $p<0.01$

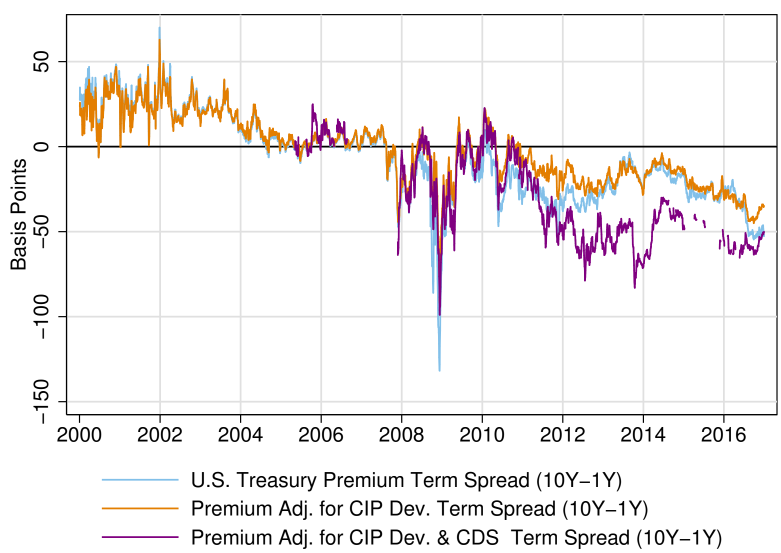
Notes: This table reports the mean, standard error of the mean based on Newey-West standard errors with a 90-day lag, and number of observations of the U.S. Treasury Premium (rows 1-3), premium adjusted for CIP deviations (rows 4-6), and the premium adjusted for CIP deviations and CDS differentials (rows 7-9) across the following tenors: 3-month, 1-year, 5-year, and 10-year, and the following periods: full sample (2000-2016), pre-GFC (2000-2006), GFC (2007-2009), and post-GFC (2010-2016).

Figure 4: The U.S. Treasury Premium, by Maturity



Notes: This figure plots the U.S. Treasury Premium at the 3-month horizon (in orange), the 1-year horizon (in blue), the 5-year horizon (in red), and the 10-year horizon (in green) from 2000-2016. Series are seven-day moving averages.

Figure 5: Term spread of the U.S. Treasury Premium



Notes: This figure plots the spread between the 10-year and 1-year premium for the U.S. Treasury Premium (in blue), for the premium adjusted for CIP deviations (in orange), for the premium adjusted for CIP deviations and CDS differentials (in purple). Series are seven-day moving averages.

3.3 The U.S. Treasury Premium and Relative Swap Spreads

In this subsection, we explore the connection between our U.S. Treasury Premium measure and the relative swap spread between the Libor interest rate swap and the Treasury bond yield across countries. In particular, using Libor interest rate swaps as the risk-free rate proxies, we find that the decline in the U.S Treasury convenience relative to foreign government bonds is mainly driven by a decline in the USD swap spread, rather than an increase in the foreign swap spread. \

To demonstrate this, we re-write the U.S. Treasury Premium as:

$$\begin{aligned}
\Phi_{i,n,t} &= y_{i,n,t}^{Govt} - \rho_{i,n,t} - y_{USD,n,t}^{Govt} \\
&= y_{i,n,t}^{Govt} - (irs_{i,n,t} + bs_{i,n,t} - irs_{USD,n,t}) - y_{USD,n,t}^{Govt} \\
&= \underbrace{(irs_{USD,n,t} - y_{USD,n,t}^{Govt})}_{\text{USD Swap Spread}} - \underbrace{(irs_{i,n,t} - y_{i,n,t}^{Govt})}_{\text{Currency } i \text{ Swap Spread}} - \underbrace{bs_{i,n,t}}_{\text{Cross-Currency Basis}} \\
&\equiv ss_{USD,n,t} - ss_{i,n,t} - bs_{i,n,t}, \qquad (11)
\end{aligned}$$

where $ss_{USD,n,t} \equiv irs_{USD,n,t} - y_{USD,n,t}^{Govt}$ and $ss_{i,n,t} \equiv irs_{i,n,t} - y_{i,n,t}^{Govt}$ are swap spreads in the United States and country i, respectively. As discussed in Section 2, in the absence of sovereign credit risk, the currency-specific convenience yield is defined as the wedge between the risk-free rate in currency i and the government bond yield in currency i. If we assume that the Libor interest rate swap rate is a measure of the risk-free rate, then the swap spread becomes a measure of the currency-specific Treasury convenience yield. The first two terms of Equation 11 are equal to $\lambda_{USD,n,t}$ and $\lambda_{i,n,t}$ respectively, as shown in equations 2 and 1. The final term is the CIP deviations for Libor interest rate swap rates between the U.S. dollar and currency i. Note that the difference in the U.S. and foreign swap spread is exactly equal to the U.S. Premium adjusted for Libor CIP, defined in equation 7, as follows:

$$\Phi_{i,n,t}^{CIP} \equiv \Phi_{i,n,t} - \tau_{i,n,t}^{Libor} = \Phi_{i,n,t} - (-bs_{i,n,t}) = ss_{USD,n,t} - ss_{i,n,t} \qquad (12)$$

In Table 3, we report the decomposition given by Equation 11 for our three sub-periods for all 10 currencies, and the average of all non-dollar currencies, at the 5-year maturity. As reported in Table 1, the US Treasury Premium fell from an average of 21 basis points in 2000-2006 to -8 basis points in 2010-2016. This decomposition shows that the decline in the U.S. Treasury Premium is largely driven by the decline in the U.S. swap spread from 52 basis points pre-crisis to 13 basis points after the crisis. Meanwhile, the average non-U.S. swap spread only increased slightly from 30 basis points to 35 basis points.

Table 3: Decomposition of the U.S. Treasury Premium

		Swap Spread				**Cross-Currency Basis**			
		Full Sample	2000-2006	2007-2009	2010-2016	Full Sample	2000-2006	2007-2009	2010-2016
AUD	Mean	47.9***	38.8***	71.1***	46.8***	15.7***	9.5***	9.3***	24.5***
	Std. Error	(2.6)	(1.9)	(8.2)	(3.6)	(1.1)	(0.5)	(2.9)	(0.9)
CAD	Mean	22.1***	15.7***	24.2***	26.9***	7.8***	10.7***	10.9***	3.9***
	Std. Error	(2.0)	(1.7)	(8.1)	(2.1)	(0.8)	(0.7)	(2.0)	(1.2)
CHF	Mean	28.8***	25.0***	37.2***	28.6***	-20.6***	-2.2***	-12.7***	-40.3***
	Std. Error	(1.1)	(1.0)	(2.9)	(1.7)	(2.4)	(0.1)	(3.4)	(2.1)
DKK	Mean	38.9***	22.3***	38.3***	53.8***	-27.2***	-2.6***	-30.3***	-47.4***
	Std. Error	(2.3)	(1.9)	(4.7)	(2.1)	(3.1)	(0.4)	(8.4)	(2.5)
EUR	Mean	34.2***	20.0***	41.1***	44.4***	-15.1***	0.1	-15.1***	-29.2***
	Std. Error	(2.2)	(2.0)	(4.9)	(2.6)	(2.1)	(0.4)	(4.4)	(2.4)
GBP	Mean	37.1***	39.7***	60.0***	24.7***	-6.4***	-0.9**	-17.2***	-6.8***
	Std. Error	(2.3)	(2.8)	(4.2)	(2.1)	(1.2)	(0.4)	(4.9)	(1.1)
JPY	Mean	8.1***	8.3***	13.2***	5.7***	-30.6***	-5.2***	-13.5**	-62.7***
	Std. Error	(0.8)	(1.0)	(1.8)	(1.0)	(3.7)	(0.8)	(5.5)	(3.1)
NOK	Mean	52.4***	39.8***	67.5***	56.8***	-11.1***	-4.7***	-14.7***	-15.0***
	Std. Error	(3.5)	(2.0)	(6.2)	(6.6)	(1.1)	(0.3)	(3.3)	(1.6)
NZD	Mean	44.1***	59.3***	72.4***	21.1***	17.2***	3.6***	7.9***	31.0***
	Std. Error	(4.4)	(3.9)	(13.0)	(3.4)	(1.8)	(0.5)	(2.0)	(1.4)
SEK	Mean	40.8***	33.3***	47.0***	44.9***	-3.4***	-1.8***	-7.2***	-3.2**
	Std. Error	(2.2)	(2.4)	(7.1)	(3.1)	(0.8)	(0.2)	(2.1)	(1.5)
Non-USD	Mean	35.3***	29.5***	47.2***	35.4***	-7.5***	0.6*	-8.2***	-14.5***
	Std. Error	(0.9)	(1.1)	(2.8)	(1.4)	(0.9)	(0.4)	(1.8)	(1.8)
USD	Mean	37.3***	51.5***	64.6***	13.0***				
	Std. Error	(1.0)	(1.0)	(2.0)	(0.7)				

Notes: This figure table reports the mean, standard error of the mean based on Newey-West standard errors with a 91-day lag of the 5-year U.S. and foreign swap spreads, defined as the difference between the Libor interest rate swap rate and the Treasury yield, and the 5-year cross-currency basis by currency.

The fact that the cross-currency basis is not zero post-crisis points to a conceptual challenge in comparing the levels of Libor-Treasury swap spread across countries. In the the case of a non-zero cross-currency basis, the two Libor interest rate benchmarks are no longer interchangeable, as market participants are willing to pay a spread equal to the cross-currency basis to exchange the Libor interest rate benchmarks across the two countries. As a result, a comparison of the level of the two swap spreads is potentially confounded by the differences in the Libor interest rate benchmarks. Indeed, one may argue that this calculation overstates the magnitude of the decline in the convenience yield of the U.S. Treasuries, as the U.S. Libor interest rate swap rate can be mispriced. In addition to the CIP deviations, the "negative swap spread" is another fixed-income anomaly that emerged after the GFC (for example, Jermann (2016) and Klingler and Sundaresan (2016)). The swap spread turned negative at the 30-year tenor during the GFC and has since remained negative. The 5-year and 10-year U.S. swap spread also turned negative in 2015. A negative swap spread implies an arbitrage opportunity,[10] which suggests that the observed U.S. interest rate swap market is lower than the hypothetical risk-free rate.

To mitigate this concern about frictions in the U.S. interest rate benchmark and imperfect substitutability between interest rate benchmarks, an alternative approach is to swap the U.S. Treasury yield into a foreign currency, and then measure the convenience yield of the U.S. Treasury relative to the foreign risk-free rate benchmark, denoted by $\tilde{ss}^{USD}_{i,n,t}$.[11] To do so, we first note that the swapped U.S. Treasury yield in currency i is given by $y^{Govt}_{USD,n,t} + \rho_{i,n,t}$.

[10]To see this, the arbitrageur can purchase a 30-year Treasury bond and finance the purchase by rolling over a three-month repo with the Treasury bond being the collateral. Meanwhile, the arbitrageur can pay the fixed 30-year interest rate swap rate, and receive the floating three-month U.S. Libor. The net cash flow of the arbitrageur is to receive the three-month Libor and to pay the three-month repo rate backed by Treasuries. Since the three-month Libor-repo spread is always positive, the trade involves zero upfront investment and has positive carry throughout the trading horizon, which is a violation of the no-arbitrage condition.

[11]Similarly, we can swap the foreign government bonds into dollars and compared with the U.S. benchmark interest rate. However, since there is more concern about anomalies associated the U.S. benchmark, we pick the foreign benchmark as the common reference instead.

Then this alternative U.S. Treasury convenience yield can be expressed as follows:

$$\begin{aligned}
\tilde{ss}^{USD}_{i,n,t} &= irs_{i,n,t} - (y^{Govt}_{USD,n,t} + \rho_{i,n,t}) \\
&= irs_{i,n,t} - y^{Govt}_{USD,n,t} - (irs_{i,n,t} + bs_{i,n,t} - irs_{USD,n,t}) \\
&= \underbrace{(irs_{USD,n,t} - y^{Govt}_{USD,n,t})}_{\text{USD Swap Spread}} - \underbrace{bs_{i,n,t}}_{\text{Cross-Currency Basis}} \\
&= ss_{USD,n,t} - bs_{i,n,t}
\end{aligned}$$

Once we measure both U.S. and foreign Treasury bonds against the same interest rate benchmark, and then the U.S. Treasury Premium is equal to the difference in the adjusted U.S. swap spread and the foreign swap spread:

$$\Phi_{it} = \tilde{ss}_{USD,t} - ss_{it}$$

The cross-currency adjustment of the U.S. swap spread allows us to directly measure how much the U.S. Treasury can borrow below the foreign risk-free rate in a foreign currency.[12] After this adjustment, we see that the average U.S. Treasury convenience yield relative to the foreign risk-free rate benchmark declined from 49.9 [=51.5 (USD Swap Spread) - 0.6 (Cross-Currency Basis)] basis points pre-crisis to 27.5 [= 13.0 (USD Swap Spread) - (-14.5) (Cross-Currency Basis)] basis points after the crisis. While this 22 basis point decline is smaller in magnitude than the decline as measured Libor interest rate swap alone, it remains sizable. Therefore, to the extent that swap spreads sheds light on Treasury convenience yield in each country, our results suggest that the decline in the U.S. Treasury Premium is largely

[12] By paying irs^{USD}_t, an investor pays fixed dollar cash flows and receives floating U.S. Libor. By paying $bs^{i/USD}_t$, an investor pays floating Libor in currency i and also receives U.S. Libor. Therefore, by paying $(irs^{USD}_t - bs^{i/USD}_t)$, an investor pays fixed dollar cash flows and receives floating Libor in currency i, and the floating U.S. Libor cash flows get canceled. Therefore, frictions with the U.S. Libor benchmark do not directly enter into the asset swap package.

driven by a decline in the convenience yield of the U.S. Treasuries, rather than an increase in the convenience yield of foreign government bonds. [13]

3.4 Using OIS as Alternative Risk-Free Rate

To this point, we have used the Libor interest rate swap rate as the risk-free rate proxy and measured swap market frictions as the deviation from CIP in this market. In this subsection, we show that the decline in the medium- to long-term U.S. Treasury Premium is robust to the choice of the Overnight Indexed Swap (OIS) rate as the risk-free rate. The OIS rate is indexed to the overnight rate, which contains very little credit risk, and is unaffected by frictions in the Libor rate. This section demonstrates that our results are robust to the use of an alternativemeasure of the hypothetical currency i risk-free rate $\tilde{y}_{it}$.

Similar to Equation 10, we can measure CIP deviations for OIS rates as follows:

$$\tau_{i,n,t}^{OIS} = (ois_{i,n,t} - ois_{USD,n,t}) - \rho_{i,n,t}$$

where $ois_{i,n,t}$ denotes the OIS rate for currency i at tenor n at time t. Then the premium adjusted for swap mispricing implied by the OIS rates then become

$$\begin{aligned} \Phi_{i,n,t} - \tau_{i,n,t}^{OIS} &= [(y_{i,n,t}^{Govt} - \rho_{i,n,t} - y_{USD,n,t}^{Govt})] - [(ois_{i,n,t} - ois_{USD,n,t}) - \rho_{i,n,t}] \\ &= (ois_{USD,n,t} - y_{USD,n,t}^{Govt}) - (ois_{i,n,t} - y_{i,n,t}^{Govt}). \end{aligned}$$

In other words, if we use the OIS as the risk-free rate in each currency, then the OIS-Treasury spread measures the convenience yield of the U.S. Treasury bond in each currency, assuming that any CIP deviation in OIS rates is evidence of FX swap market frictions. Under this assumption, the U.S. Treasury Premium adjusted for OIS CIP deviations is equal to the

[13] We plot the U.S. swap spread and the adjusted U.S. swap spread, together with the average foreign swap spread, in the internet appendix.

difference between OIS-Treasury spread in United States and country i, which is analogous to the Libor based measure expressed in Equation 7.

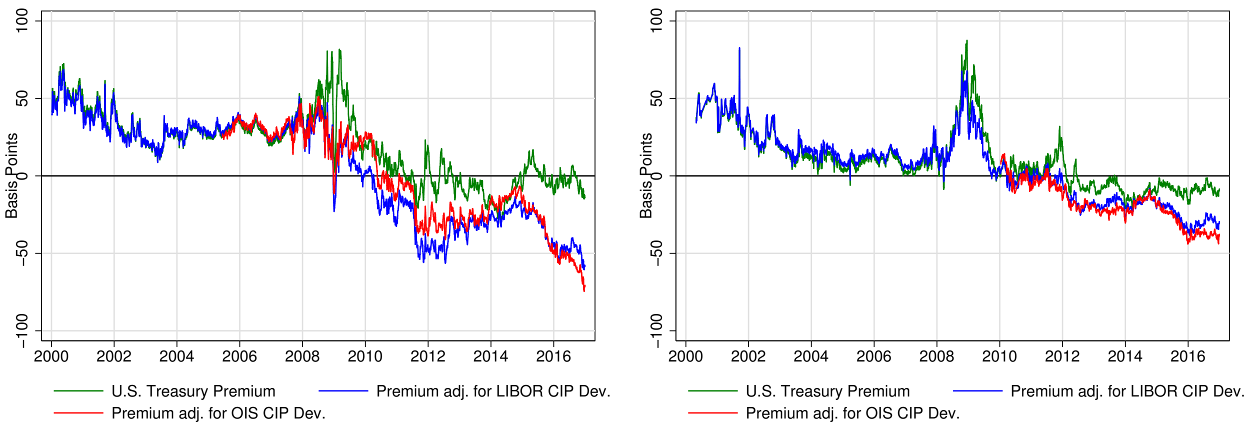
Prior to the crisis, the difference between Libor interest rate swaps and the OIS rates was negligible. Only the U.S. dollar and euro have separate long-term OIS quotes before 2007. The Libor-OIS spread widened significantly during the GFC for all currencies. Post-crisis, long-term OIS quotes become more widely available for other G10 currencies. In Figure 6(a), we first plot the U.S Treasury Premium vis-à-vis the German bund, and the premium adjusting for the mispricing measured by Libor and OIS respectively. Every version of the premium exhibits a secular decline after the global financial crisis. It is important to note here that all of these measures are essentially identical pre-crisis, as CIP holds pre-crisis for both Libor interest rate swaps and OIS rates. Post-crisis, we see that all of these measures follow a similar trend, demonstrating that our result on the secular decline of the U.S. Treasury Premium is not driven by our choice of the risk-free rate. Similarly, in Figure 6(b), we plot the average U.S Treasury Premium vis-à-vis the set of countries for which there exists a sufficiently long history of 5-year OIS rates,[14] and the premium adjusted for the mispricing measured by Libor and OIS. For the premium adjusted for OIS CIP deviations, we only start in 2008 due to the lack of data for most countries in the earlier period. Again, we see that post-crisis, the premium adjusted for Libor and OIS CIP deviations move in tandem.

While we may not be able to capture the exact magnitude of the hypothetical risk-free rate differential using observed data, different proxies of the risk-free rates point to a similar pattern: swap market mispricing after the GFC makes it more costly to swap foreign currency funding into dollar funding ($\tau_{i,n,t} > 0$) and correcting for these mispricings make the decline in the average U.S. Treasury Premium even more pronounced.

[14] All sample countries except for Denmark, Norway and Sweden all have sufficiently long historical data on 5-year OIS rates on Bloomberg post-crisis.

Figure 6: 5-Year U.S. Treasury Premium and Swap Market Mispricing

(a) Premia vis-à-vis EUR (b) Average Premia



Notes: Figure a plots the 5-year U.S. Treasury premium vis-à-vis the German bund in green, the premium adjusted for Libor CIP deviations in blue, the premium adjusted for OIS CIP deviations in red. Figure b plots the average, 5-year U.S. Treasury premium (in green), the average premium adjusted for Libor CIP deviations (in blue), the premium average adjusted for OIS CIP deviations (in red). Averages are over the panel of seven countries with long OIS data history: Australia, Canada, Switzerland, Germany, United Kingdom, Japan, and New Zealand. Series are seven-day moving averages.

3.5 G10 vs. EM Comparison

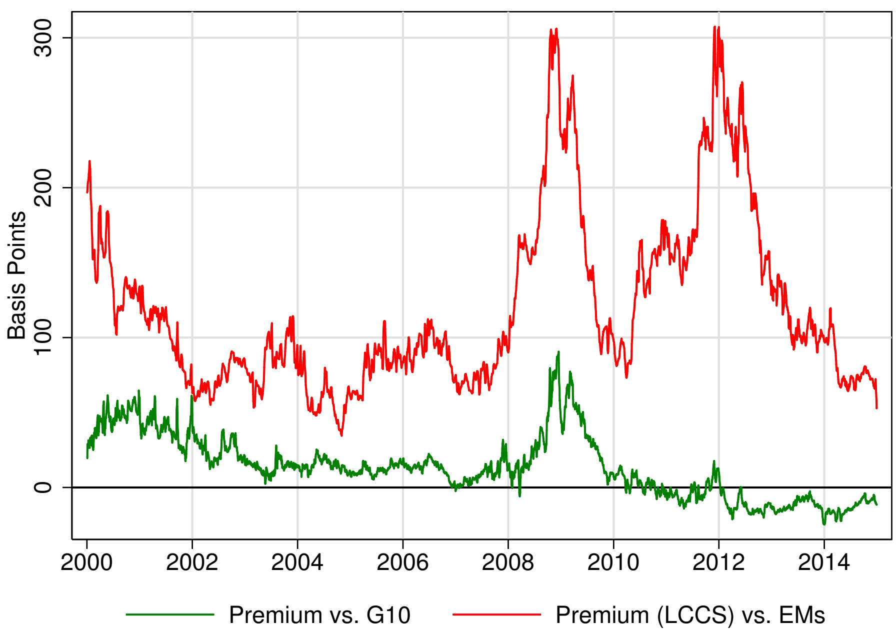
To better understand drivers of the U.S. Treasury Premium, we now compare the measure averaged across G10 currencies to the measure averaged across a set of 13 emerging markets (EMs). Figure 7 plots the U.S. Treasury Premium vis-à-vis G10 countries and the U.S. Treasury Premium vis-à-vis EMs. Unsurprisingly, the average U.S. Treasury Premium vis-à-vis G10 countries is significantly lower than the U.S. Treasury Premium vis-à-vis EMs.[15]

Du and Schreger (2016a) call the U.S. Treasury Premium the "Local Currency Credit Spread" because they argue that it constitutes a credit spread on local currency sovereign debt, and measures the risk that governments explicitly default on debt denominated in their own currency. The reason for this significantly different interpretation can be seen in Figure 8. The left panel plots the (unadjusted) mean U.S. Treasury Premium and CDS differential for G10 countries. Other than at the peak of the GFC, we see limited correlation between the

[15]The included countries are Brazil, Colombia, Hungary, Indonesia, Israel, Mexico, Malaysia, Peru, Poland, Thailand, Turkey South Africa, and South Korea.

measures.[16] Pre-GFC, the CDS differential is approximately zero for G10 countries, but the the U.S. Treasury Premium is positive and sizable. Post-GFC, the average CDS differential between G10 countries and the United States is positive, but the U.S. Treasury Premium is negative. By contrast, in the right panel, we make the same figure for a sample of emerging markets and see very strong co-movement between the unadjusted U.S. Treasury Premium and the CDS Differential, indicating that the premium is capturing fluctuations in default risk.

Figure 7: Premium vs. EM and G10 countries

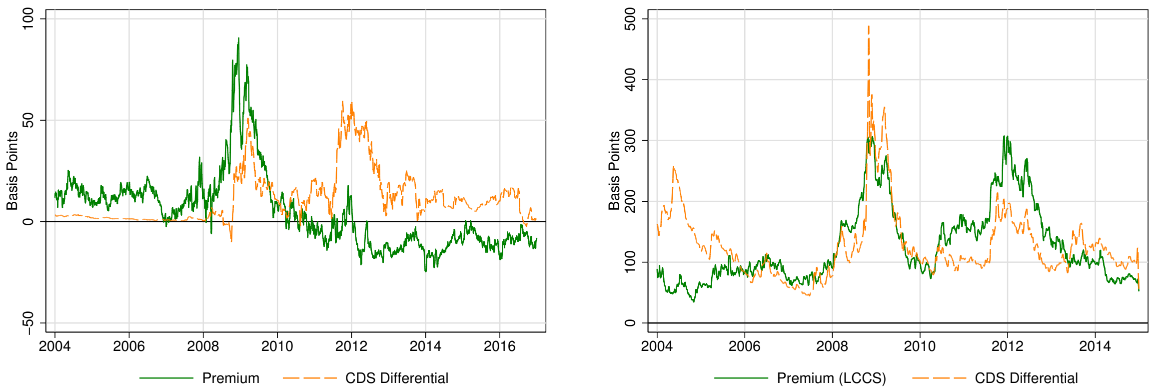


Notes: This figure plots the cross-sectional mean premium for 13 emerging markets (Brazil, Colombia, Hungary, Indonesia, Israel, Mexico, Malaysia, Peru, Poland, Thailand, Turkey, South Africa, and South Korea) (in red) and the mean premium for G10 countries (in green). Series are seven-day moving averages.

[16] Japan is an interesting exception, as can be seen in the internet appendix. The pattern of the strong comovement between the premium and the CDS differential is quite similar to the pattern documented for individual emerging markets in Du and Schreger (2016a). Notably, the credit rating of Japan is the lowest in our sample of sovereigns.

Figure 8: Components of the 5-Year Premium

(a) G10 (b) EM



Notes: This figure plots the premium (in solid green) and the CDS differential (in dashed orange) for G10s and EMs. Series are seven-day moving averages.

4 Relationship with Other Convenience Yield Measures

In this section, we examine the relationship between the U.S. Treasury Premium and existing measures of the safety and liquidity components of the convenience yield.

4.1 Short-term premium comparison

A conventional measure of convenience yield in the 3-month market for Treasuries is the General Collateral (GC) Repo-Treasury Bill spread, defined as the spread between the 3-month Treasury GC Repo rate and a 3-month T-Bill yield. Assuming that Treasuries themselves are default-free, a Treasury GC repo is free of credit risk as it is secured by Treasuries. However, repos are not as liquid as Treasury bills because the money is always lent for term (Nagel (2016)); thus, the GC Repo-Treasury Bill spread mainly captures the convenience premium of Treasury bills. Since our U.S. Treasury Premium is vis-à-vis another country, if it is being driven by a convenience component, that component should be a relative measure of the U.S. Treasury market vis-à-vis the Treasury market of a foreign sovereign. The closest approximation of this is the difference in the 3-month GC Repo rate-TBill spread for

United States Treasuries and foreign country's Treasuries. This motivates the following set of regressions to estimate the convenience component of the 3-month Treasury premium:[17]

$$\bar{\Phi}_{3M,t} = \alpha + \beta \cdot RT_{USD,3M,t} + \epsilon_t$$
$$\Phi_{i,3M,t} = \alpha + \beta \cdot RT_{USD,3M,t} + \gamma \cdot RT_{i,3M,t} + \epsilon_t,\ i \in \{EUR, JPY\},$$

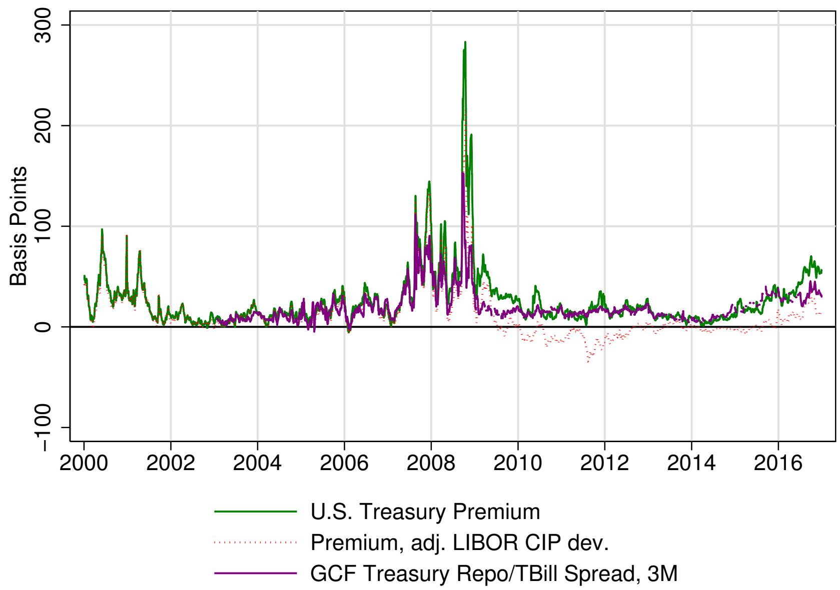
where $\bar{\Phi}_{3M,t}$ denotes the cross-country average of the 3-month U.S. Treasury Premium; $RT_{USD,3M}$ is the 3-month GC repo-TBill spread for the United States; $RT_{EUR,3M}$ is the 3-month GC repo-TBill spread for Germany ; $RT_{JPY,3M}$ is the 3-month GC repo-TBill spread for Japan. We run these regressions in levels and changes at the weekly frequency in Table 4 with changes denoted as Δ . This exercise is restricted to Germany and Japan because of lack of usable data on GC repo rates in other countries in our sample.

Regression results in levels are reported in the first three columns of Table 4 whereas regression results in differences are reported in the next three columns. In the first regression in levels, $RT_{USD,3M}$ enters with a highly significant coefficient of 1.726 and with the constant, explains 75% of the variation in the U.S. Treasury Premium. In the second and third regressions in levels, $RT_{USD,3M}$ enters with a highly significant coefficient of 1.635 and 2.362, respectively. This supports the hypothesis that when the liquidity benefit of U.S. Treasuries is high, so is the U.S. Treasury Premium. The country-specific convenience yield variables enter in as negative and insignificant in the levels regression for Japan and Germany. The regressions in first differences are broadly consistent with the regressions in levels, and supports the notion that our U.S. Treasury Premium is, at the 3-month horizon, a relative measure of the convenience yield on U.S. Treasury bills vis-à-vis foreign Treasury bills. When estimated in first differences, however, increases the EUR and JPY GC-Repo are associated with statistically significant declines in the bilateral U.S Treasury Premium.

[17] Throughout the paper, we follow Driscoll and Kraay (1998) and to calculate heteroskedasticity autocorrelation spatial correlation robust standard errors.

Figure 9 plots the average U.S. Treasury Premium and the GC-repo-Tbill spread at the three-month maturity to make clear just how closely the two measures co-move.

Figure 9: Three-month Average U.S. Treasury Premium vs. Repo-Tbill Spread



Notes: This figure plots the average three-month U.S. Treasury premium (in solid green), the average three-month premium adjusted for CIP deviations (in dotted red), and the three-month U.S. GCF Treasury repo and T-bill spread (in solid purple). Series are seven-day moving averages.

Table 4: The 3-month U.S. Treasury Premium and the GC repo-Tbill spread (Weekly Frequency, 2000-2016)

	(1)	(2)	(3)	(4)	(5)	(6)
	$\underline{\Phi}_{3M}$	$\Phi_{EUR,3M}$	$\Phi_{JPY,3M}$	$\Delta\underline{\Phi}_{3M}$	$\Delta\Phi_{EUR,3M}$	$\Delta\Phi_{JPY,3M}$
$RT_{USD,3M}$	1.726***	1.635***	2.362***			
	(0.229)	(0.156)	(0.249)			
$RT_{EUR,3M}$		-0.00290				
		(0.0835)				
$RT_{JPY,3M}$			-0.840			
			(0.523)			
$\Delta RT_{USD,3M}$				0.822***	0.916***	1.215***
				(0.238)	(0.295)	(0.219)
$\Delta RT_{EUR,3M}$					-0.198*	
					(0.117)	
$\Delta RT_{JPY,3M}$						-1.393**
						(0.551)
Constant	3.184	-6.201	7.573*	0.0121	-0.0805	0.0986
	(3.534)	(4.318)	(4.511)	(0.338)	(0.387)	(0.675)
Observations	631	444	384	582	395	335
R-squared	0.745	0.803	0.723	0.368	0.428	0.350

Significance levels: * p<0.10 ** p<0.05 *** p<0.01

Notes: This table reports the regression results of the level of the 3-month U.S. Treasury Premium on convenience yield measures of the country's and United States' 3-month treasury bills. Standard errors are heteroskedasticity autocorrelation spatial correlation robust with a 13 week lag. The first column reports on the regression of the 3-month, U.S. Treasury Premium averaged across countries $\underline{\Phi}$ on our measure of the convenience yield on U.S. Treasuries at the 3-month horizon $RT^{Repo/Tbill}_{USD,3M}$, which is the spread between a 3-month Treasury repo and the 3-month U.S. T- bill. The same regression in differences is reported in the fourth column. The second column reports on the regression of the 3-month U.S. Treasury Premium vis-à-vis Germany $\Phi_{EUR,3M}$ on the measures of the convenience yield on U.S. treasuries at the 3-month horizon $RT^{Repo/Tbill}_{USD,3M}$ and German treasuries at the 3-month horizon $RT^{Repo/Tbill}_{EUR,3M}$, which is the spread between the 3-month repo rate on German treasuries and the rate on a German T-bill. The same regression in differences is reported in the fifth column. The third column reports on the regression of the 3-month U.S. Treasury Premium vis-à-vis Japan $\Phi_{JPY,3M}$ on the measure of convenience yield on U.S. treasuries at the 3-month horizon and Japanese treasuries at the 3-month horizon $RT^{Repo/Tbill}_{JPY,3M}$, which is the spread between the 3-month repo rate on Japanese treasuries and the rate on a Japanese T-Bill. The same regression in differences is reported in the sixth column. All data are at the weekly frequency and span 2000-2016. The U.S. Treasury Premium is from the authors' calculations using data from Bloomberg. The convenience yield measures $RT^{Repo/Tbill}_{USD,3M}$, $RT^{Repo/Tbill}_{EUR,3M}$, $RT^{Repo/Tbill}_{JPY,3M}$ were computed by the authors. Three-month GCF rates are from Thomson Reuters Eikon.

4.2 Long-term Premium

At medium to long maturities, a conventional measure of the convenience yield of government bonds is the spread between yields on near risk-free agency paper and Treasuries denominated in the same currency. Some well-known examples include the spread between the yields on Refcorp and Treasury bonds, which are both guaranteed by the U.S. government and subject to the same taxation (Negro et al., 2017; Fleckenstein et al., 2014), and the spread between yield on the euro-denominated KfW bonds and German bunds, which are both guaranteed by the German government (Schwartz (2015)).

We can also measure the Treasury convenience yield differential as the difference in these conventional convenience measures across countries. However, if we allow the agency benchmark to differ by country, cross-country differences in the agency credit, the degree of the government guarantee, and the liquidity of the paper they issue will potentially drive our relative Treasury convenience result. To avoid this problem, we keep the agency fixed. We pick KfW as our benchmark risk-free agency, because it issues bonds in different currencies with an annual issuance volume of \$60-80 billion. To mitigate problems of differential liquidity between KfW bonds denominated in different currencies, we focus on the euro and dollar comparison, the two most important issuance currencies for KfW. The euro and the dollar each account for about 40% of the annual issuance volume.

We measure the 5-year convenience yield of a German bund relative to KfW ($KT_{EUR,5Y,t}$) as the difference between the euro-denominated KfW yield ($y^{KfW}_{EUR,5Y,t}$) and the German bund yield ($y^{Govt}_{EUR,5Y,t}$):

$$KT_{EUR,5Y,t} = y^{KfW}_{EUR,5Y,t} - y^{Govt}_{EUR,5Y,t}.$$

Similarly, we measure the 5-year convenience yield of the U.S. Treasury bond relative to KfW ($KT_{USD,5Y,t}$) as the difference between the yield on the dollar-denominated KfW yield ($y^{KfW,}_{USD,5Y,t}$) and the yield on the U.S. Treasury:

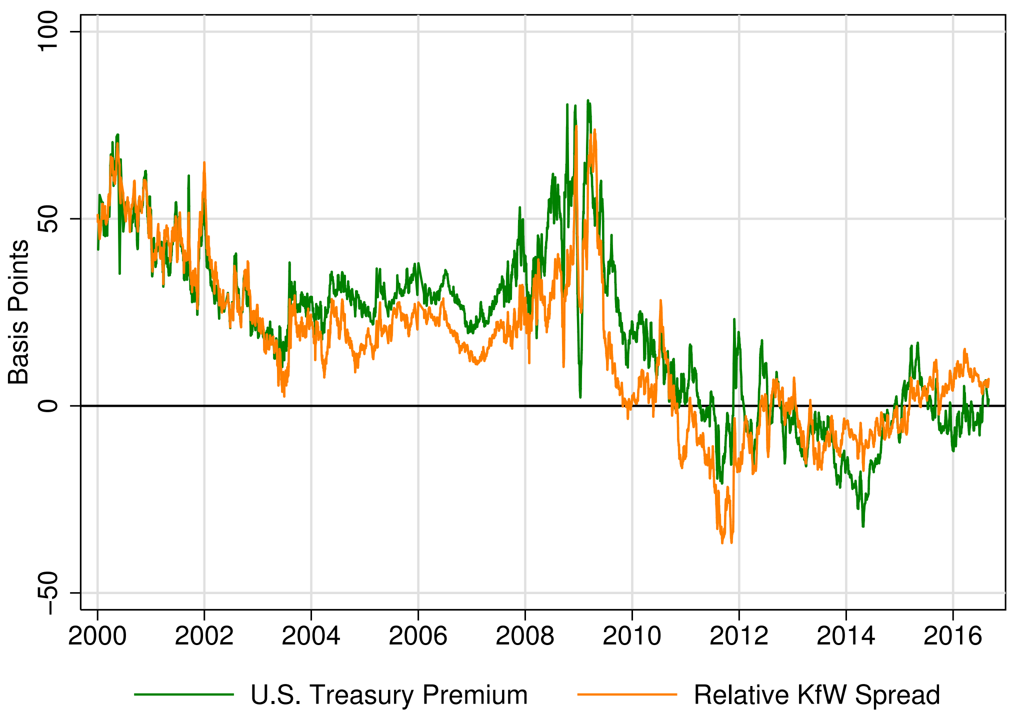
$$KT_{USD,t} = y^{KfW}_{USD,t} - y^{Govt}_{USD,t}.$$

We can therefore construct a new relative convenience yield measure between the U.S. Treasury and the German bund as the difference between the spreads each government earns relative to KfW in each currency as:

$$\Phi^{KfW}_{EUR,5Y,t} \equiv KT_{USD,5Y,t} - KT_{EUR,5Y,t} = (y^{KfW}_{USD,5Y,t} - y^{Govt}_{USD,5Y,t}) - (y^{KfW}_{EUR,5Y,t} - y^{Govt}_{EUR,5Y,t}).$$

As shown in Figure 10, this relative Treasury convenience measure based on KfW bond yields (shown in orange) strongly comoves with our U.S. Treasury Premium (shown in green) defined vis-à-vis the German bund and declines notably after the GFC. Since no swaps are used in the construction of $\Phi^{KfW}_{EUR,5Y,t}$, frictions in the swap market cannot explain the decline.

Figure 10: Five-Year Average U.S. Treasury Premium vs. KfW Based Relative Convenience Yield Measure



Notes: This figure plots the average 5-year U.S. Treasury Premium vis-à-vis Germany (in solid green) and the KfW based relative convenience yield measure of U.S. Treasuries vis-à-vis German Treasuries (in dashed orange), which is defined as the difference in the yield spread between a 5-year KfW bond denominated in U.S. dollars and a U.S. Treasury bond and the yield spread between a 5-year KfW bond denominated in euros and a German Treasury bond. Series are seven-day moving averages.

Conducting an exercise similar to the Repo-Tbill regressions at the 3-month tenor but at the 5-year horizon, we run the following set of regressions:

$$\bar{\Phi}_{5Y,t} = \alpha + \beta \cdot KT_{USD,5Y,t} + \epsilon_t$$

$$\Phi_{EUR,5Y,t} = \alpha + \beta \cdot KT_{USD,5Y,t} + \gamma \cdot KT_{EUR,5Y,t} + \epsilon_t$$

where $\bar{\Phi}_{5Y,t}$ denotes the cross-country average of the 5-year unadjusted premium.

We run the specifications in both levels and first differences, using Δ to indicate weekly changes. Table 5 presents the results. In Columns 1 and 3, the regression results in levels and differences both suggest that a higher $KT_{USD,5Y,t}$ is associated with a higher average U.S. Treasury Premium. The results also show that $KT_{USD,5Y,t}$ and the constant can jointly explain approximately 50% of the variation in the average U.S. Treasury Premium. As reported in Columns 2 and 4, the euro-specific regressions in levels and differences both show that a 1 basis point increase in the $KT_{USD,5Y,t}$ spread is associated with a close to 1 basis point increase in the our U.S. Treasury premium vis-à-vis Germany, and a 1 basis point increase $KT_{EUR,5Y,t}$ spread is associated with a close to 1 basis point decrease in the premium. The two components of the alternative relative convenience yield measure, $KT_{USD,5Y,t}$ and $KT_{EUR,5Y,t}$, explain 81% and 60% of the variation in the premia in the levels and difference regressions, respectively. Overall, the results provide strong support that our long-term U.S. Treasury Premium is also related to conventional convenience yield measures.

Table 5: Regressions of the 5-year U.S. Treasury Premium on the KfW-Sovereign Spread (Weekly Frequency, 2000-2016)

	(1)	(2)	(3)	(4)
	$\underline{\Phi}_{5Y,t}$	$\Phi_{EUR,5Y}$	$\Delta\bar{\Phi}_{5YR}$	$\Delta\Phi_{EUR,5Y}$
$KT_{USD,5Y}$	0.557***	0.973***		
	(0.0602)	(0.0455)		
$KT_{EUR,5Y}$		-0.837***		
		(0.0603)		
$\Delta KT_{USD,5Y}$			0.956***	1.041***
			(0.0592)	(0.0657)
$\Delta KT_{EUR,5Y}$				-0.719***
				(0.0755)
Constant	-5.669	0.870	0.0502	0.0331
	(3.448)	(2.072)	(0.129)	(0.0967)
Observations	851	851	840	840
R-squared	0.491	0.809	0.495	0.601

Significance levels: * p<0.10 ** p<0.05 *** p<0.01

Notes: This table reports regression results of the level of 5-year U.S. Treasury Premium $\Phi_{i,5Y}$ on the 5-year KfW based convenience yield measures of German and United States' treasuries. Standard errors are heteroskedasticity autocorrelation spatial correlation robust with a 13 week lag. The first column reports on the regression of the 5-year U.S. Treasury Premium averaged across countries $\underline{\Phi}_{5Y,t}$ on our KfW based convenience yield measure of a 5-year U.S. Treasury bond $KT_{USD,5Y}$, which is the yield spread between a 5-year KfW zero-coupon bond denominated in dollars and a 5-year U.S. Treasury zero-coupon bond. The same regression in differences is reported in the third column. The second column reports on the regression of the 5-year U.S. Treasury Premium vis-à-vis Germany $\Phi_{EUR,5Y}$ on the KfW based convenience yield measure of a 5-year U.S. Treasury $KT_{USD,5Y}$ and a German Treasury $KT_{EUR,5Y}$, which we defineas the yield spread between the 5-year KfW zero-coupon bond denominated in euros and a 5-year, zero-coupon German treasury. The same regression in differences is reported in the fourth column. All data are at the weekly frequency and span 2000-2016. The U.S. Treasury Premium is from the authors' calculations using data from Bloomberg; $KT_{USD,5Y}$, $KT_{EUR,5Y}$, are from the authors' calculations.

5 Bond Supply and the U.S. Treasury Premium

In this section, we test for a relationship between the U.S. Treasury Premium and the relative scarcity of sovereign debt in the U.S. vis-à-vis the other countries in the sample. We proxy for the scarcity of sovereign debt by taking the ratio of the quantity of outstanding federal debt excluding central bank holdings to seasonally-adjusted nominal GDP.[18] This analysis

[18]We conduct the same analysis without netting out central bank holdings in the internet appendix and find similar results.

builds on the work of Krishnamurthy and Vissing-Jorgensen (2012) that finds that the U.S. public debt to GDP ratio is inversely related to the convenience yield on U.S. Treasuries. Because the measure is intended to capture the relative premium of U.S. Treasuries relative to other safe sovereign debt, we will look at the supply of debt for both the U.S. and other countries.

Our general regression framework is given by:

$$\Phi_{i,n,t} = \alpha + \beta \cdot \log\left(\frac{debt}{GDP}\right)_{USD,t} + \gamma \cdot \log\left(\frac{debt}{GDP}\right)_{i,t} + \zeta \cdot X_{i,t} + \epsilon_{i,t}, \tag{13}$$

where $\log\left(\frac{debt}{GDP}\right)_{USD,t}$ is the log of the U.S. debt to GDP ratio at time t, $\log\left(\frac{debt}{GDP}\right)_{i,t}$ is the log of country i's debt to GDP ratio at time t, and $X_{i,t}$ is a set of additional covariates motivated by Nagel (2016). In particular, $X_{i,t}$ includes the U.S. Policy Rate (the Federal Funds rate), the country i's policy rate, and the VIX, which is the CBOE Volatility Index and measures the market expectation of 30-day volatility in the S&P 500. In columns 1-4, we estimate the regressions in levels, and in columns 5-8 we estimate the regressions in changes at the quarterly frequency. In the even numbered columns, we include country fixed effects and in the odd number columns we omit these fixed effects. Given the short sample period, these results should be interpreted conservatively.

In column 1 of Table 6, we omit country fixed effects and any controls and include only the debt variables. We find that a 1 log point increase in the U.S. debt to GDP ratio is associated with a 0.72 basis point fall in the U.S. Treasury Premium. By contrast, a 1 log point increase in the foreign country debt-to-GDP ratio is associated with a 0.29 basis point higher U.S. Treasury Premium. Therefore, the initial specification is consistent with the idea that the relative supply of government debt affects the U.S. Treasury Premium. In column 2, we include country fixed effects and the effect of the individual country debt/GDP ratio disappears. In other words, the coefficient in column 1 is driven by differences in between country means. In columns 3 and 4, we rerun the regressions in columns 1 and 2 but include the additional covariates. The U.S. policy rate and VIX enter statistically significantly–the latter result being consistent with "flight to safety" to U.S. Treasuries during times of high global risk aversion. The coefficient on the U.S. Debt-to-GDP ratio is quantitatively similar across specifications. In columns 5-8, we estimate the same regressions in first differences and examine whether changes in the Debt-to-GDP levels are associated with changes in the U.S. Treasury Premium. One potential concern with these regressions is that quarterly changes in debt ratios can be quite noisy. Indeed, the results of these regression are qualitatively similar to columns 1-4, but the standard errors are much larger and many of the coefficients lose statistical significance.

Taken together, these regressions show that the U.S. Treasury Premium co-moves with the relative supply of government debt. This is consistent with the the story that when the supply of U.S. Treasuries becomes higher or the supply of foreign government bonds becomes lower, the value that investors assign to the liquidity and safety premia of U.S. Treasuries relative to foreign bonds decreases. However, our results should be interpreted cautiously given the short sample period. In addition, the Debt-to-GDP ratio we use is of total outstanding federal debt to nominal GDP, and is not maturity specific. We do not find a significant effect of the relative bond supply on the 3-month Treasury Premium.

Table 6: Effects of Government Bond Supply on the U.S. Treasury Premium, Net Central Bank QE Purchases (Quarterly Frequency, 2000-2016)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Φ_{5Y}	Φ_{5Y}	Φ_{5Y}	Φ_{5Y}	$\Delta\Phi_{5Y}$	$\Delta\Phi_{5Y}$	$\Delta\Phi_{5Y}$	$\Delta\Phi_{5Y}$
$\log\left(\frac{debt}{GDP}\right)_{USD}$	-71.76***	-64.28***	-75.18***	-51.15***				
	(8.966)	(9.458)	(13.17)	(12.11)				
$\log\left(\frac{debt}{GDP}\right)_{i}$	29.06***	1.735	17.51***	2.616				
	(2.905)	(6.549)	(3.043)	(4.820)				
Policy Rate			-0.0801***	-0.0160				
			(0.0120)	(0.0164)				
U.S. Policy Rate			0.0465***	0.0238*				
			(0.00947)	(0.0123)				
VIX			0.0139***	0.0117***				
			(0.00315)	(0.00312)				
$\Delta\log\left(\frac{debt}{GDP}\right)_{USD}$					-64.00	-64.20	-104.6*	-104.9*
					(62.92)	(62.94)	(54.74)	(54.82)
$\Delta\log\left(\frac{debt}{GDP}\right)_{i}$					18.02**	18.28**	11.10	11.17
					(7.867)	(8.140)	(8.215)	(8.528)
Δ Policy Rate							-0.0544***	-0.0547***
							(0.0120)	(0.0121)
Δ U.S. Policy Rate							-4.38e-05	4.37e-05
							(0.0169)	(0.0168)
Δ VIX							0.00490***	0.00491***
							(0.00173)	(0.00173)
Constant	19.21***	-41.70***	-11.75*	-57.50***	-0.193	-0.908	-0.101	-0.763
	(3.865)	(11.99)	(6.640)	(11.59)	(0.735)	(1.071)	(0.773)	(1.045)
Observations	670	670	670	670	660	660	660	660
R-squared	0.383	0.633	0.552	0.690	0.008	0.009	0.075	0.075
Country FE	No	Yes	No	Yes	No	Yes	No	Yes

Significance levels: * $p<0.10$ ** $p<0.05$ *** $p<0.01$

Notes: The table reports panel regression results of the level and differences of the 5-year U.S. Treasury Premium on country level and U.S. variables that proxy for the scarcity of government bonds. Heteroskedasticity autocorrelation spatial correlation robust standard errors were used with a 8 quarter lag. The variable $\log\left(\frac{debt}{GDP}\right)_i$ is the ratio of the country's federal debt, net central bank holdings, to nominal GDP and the variable $\log\left(\frac{debt}{GDP}\right)^{USD}$ is the ratio of the United States' federal debt, net central bank holdings, to nominal GDP. The variable Policy Rate is the country-specific policy rate, the variable U.S. Policy Rate is the U.S. policy rate–the Federal Funds rate, and the VIX is the CBOE Volatility Index. All data are at the quarterly frequency and span 2000-2016. The U.S. Treasury Premium is from the authors' calculations using data from Bloomberg. Data on federal debt and nominal GDP are from Haver Analytics; data on central bank holdings of domestic debt are from national websites; data on policy rates and the VIX are from Bloomberg.

6 Conclusion

We construct a new measure of the convenience yield of developed country government bonds relative to U.S. Treasuries. We find that prior to the Global Financial Crisis, U.S. Treasuries earned a significant convenience yield relative to other government bonds. Following the crisis, medium and long-term U.S. Treasuries lost their specialness relative to the government bonds of sovereigns of comparable credit while short-term U.S. Treasury bills remain special.

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Internet Appendix (not for publication)

The appendix contains a decomposition of the U.S. Treasury Premium (A), the Bloomberg and Thomson Reuters tickers used in the data analysis (Section B), supplementary charts and summary statistics (Section C), an extension of the bond supply regression (Section D), and regression and reduced form VAR results that comment on the explanatory power of different components in explaining variations in the U.S. Treasury Premium (Section E)

A Decomposition of the U.S. Treasury Premium

In this section, we provide a simple theoretical decomposition of the U.S. Treasury Premium into three components: convenience yield, credit risk, and swap market mispricing. The underlying assumption is that government bond markets and FX markets are integrated and priced by a global investor, which is a reasonable assumption for G10 countries. In this framework, the U.S. Treasury premium can exist for three reasons: convenience yield differentials, credit risk differentials, and swap market frictions.

A.1 Price of a U.S. Treasury Bond

Given a U.S. Treasury bond, let $\Lambda_{USD,t+1}$ denote the convenience benefit and $L_{USD,t+1}$ denote the default loss at time $t+1$. $\mathbb{E}_t^{USD}$ denotes the risk-neutral expectation at time t using the U.S. dollar numeraire. Then the price of a one-period U.S. Treasury bond is given by

$$P_{USD,t} = \exp(-y^{rf}_{USD,t})\mathbb{E}_t^{USD}[(1+\Lambda_{USD,t+1})(1-L_{USD,t+1})],$$

and the yield on the U.S. Treasury is

$$
\begin{aligned}
y^{Govt}_{USD,t} &= y^{rf}_{USD,t} - \ln \mathbb{E}^{USD}_t[(1+\Lambda_{USD,t+1})(1-L_{USD,t+1})] \\
&= y^{rf}_{USD,t} - \ln[\mathbb{E}^{USD}_t(1+\Lambda_{USD,t+1})\mathbb{E}^{USD}_t(1-L_{USD,t+1}) + Cov^{USD}_t(1+\Lambda_{USD,t+1}, 1-L_{USD,t+1})] \\
&= y^{rf}_{USD,t} - \ln \mathbb{E}^{USD}_t(1+\Lambda_{USD,t+1}) - \ln \mathbb{E}^{USD}_t(1-L_{USD,t+1}) \\
&\quad - \ln\left[1 + \frac{Cov^{USD}_t(1+\Lambda_{USD,t+1}, 1-L_{USD,t+1})}{\mathbb{E}^{USD}_t(1+\Lambda_{USD,t+1})\mathbb{E}^{USD}_t(1-L_{USD,t+1})}\right] \qquad \text{(A14)} \\
&= y^{rf}_{USD,t} - \lambda_{USD,t} + l_{USD,t} - \xi_{USD,t}, \qquad \text{(A15)}
\end{aligned}
$$

where $y^{rf}_{USD,t}$ is the hypothetical dollar risk-free rate, $\lambda_{USD,t}$ is the convenience premium, $l_{USD,t}$ is the default premium, and $\xi_{USD,t}$ is the covariance between convenience and default risk.

If the U.S. Treasury bond is default-free, we have $l_{USD,t} = 0$ and $\xi_{USD,t} = 0$, and then $y^{Govt}_{USD,t} = y^{rf}_{USD,t} - \lambda_{USD,t}$. In other words, the Treasury yield can be lower than the hypothetical dollar risk-free rate if the Treasury obligation earns a convenience yield over the private, risk-free obligation.

A.2 Price of a Foreign Government Bond

Now we price a one-period foreign government bond in an analogous way. Let $L_{i,t+1}$ denote the default loss at $t+1$ on a government bond of country i, and $\Lambda_{i,t+1}$ be the convenience benefit at $t+1$ for holding the bond. Let $y^{rf}_{i,t}$ be the hypothetical risk-free rate for currency i.

$$P_{i,t} = \exp(-y^{rf}_{i,t})\mathbb{E}_t[(1+\Lambda_{i,t+1})(1-L_{i,t+1})]$$

Based on the derivation for the U.S. Treasury yield, we have

$$y^{Govt}_{i,t} = y^{rf}_{i,t} - \lambda_{i,t} + l_{i,t} - \xi_{i,t}.$$

The hypothetical risk-free rate in currency i, $y_{i,t}^{rf}$, is connected to the hypothetical U.S. risk-free rate as follows

$$y_{i,t}^{rf} = y_{USD,t}^{rf} + \tilde{\rho}_{i,t}, \tag{A16}$$

where $\tilde{\rho}_{i,t}$ is the hypothetical forward premium in a frictionless market given by the CIP relationship for the risk-free rates $y_{i,t}^{rf}$ and $y_{USD,t}^{rf}$.

Therefore, we can write the foreign bond yield as

$$y_{i,t}^{Govt} = y_{USD,t}^{rf} + \tilde{\rho}_{i,t} - \lambda_{i,t} + l_{i,t} - \xi_{i,t}. \tag{A17}$$

Once again, if the foreign government bond is default-free, we have $l_{i,t} = 0$ and $\xi_{i,t} = 0$, so $y_{i,t}^{Govt} = y_{USD,t}^{rf} + \tilde{\rho}_{i,t} - \lambda_{i,t}$. The foreign yield can differ from the dollar risk-free rate due to currency risk and the convenience benefit.

We let the hypothetical forward premium in a frictionless market $\tilde{\rho}_{i,t}$ be the sum of the observed $\rho_{i,t}$ and a wedge due to swap market frictions, $\tau_{i,t}$:

$$\tilde{\rho}_{i,t} = \rho_{i,t} + \tau_{i,t}. \tag{A18}$$

By substituting Equation A18 into Equation A17, we can write the foreign government bond yield as[19]

$$y_{i,t}^{Govt} = y_{USD,t}^{rf} + (\rho_{i,t} + \tau_{i,t}) - \lambda_{i,t} + l_{i,t} - \xi_{i,t}. \tag{A19}$$

[19]Our theoretical decomposition focuses on the pricing of one-period bonds. We assume the intermediate spread $\tau_{i,t}$ is known ex ante and do not consider the covariance between the $\tau_{i,t}$ and $\lambda_{i,t}$ entering the spread. However, once we extend to multi-period bond, the covariance between $\tau_{i,t}$ and $\lambda_{i,t}$ could matter for bond pricing.

A.3 Components of the U.S. Treasury Premium

Using Equations A17 and A19, the U.S. Treasury Premium, denoted by Φ, is then given by:

$$
\begin{aligned}
\Phi_{i,t} &\equiv y_{i,t}^{Govt} - \rho_{i,t} - y_{USD,t}^{Govt} \\
&= [y_{USD,t}^{rf} + \tilde{\rho}_{i,t} - \lambda_{i,t} + l_{i,t} - \xi_{i,t}] - \rho_{i,t} - (y_{USD,t}^{rf} - \lambda_{USD,t} + l_{USD,t} - \xi_{USD,t}) \\
&= \hat{\lambda}_{i,t} + \tau_{i,t} - \hat{l}_{i,t} + \hat{\xi}_{i,t} \\
&\approx \hat{\lambda}_{i,t} + \tau_{i,t} - \hat{l}_{i,t},
\end{aligned}
\tag{A20}
$$

where $\hat{x}_{i,t} \equiv x_{USD,t} - x_{i,t}$. We assume that the difference in the covariances between currency and the convenience yield is negligible, i.e., $\hat{\xi}_{i,t} = 0$. Therefore, the U.S. Treasury Premium can be decomposed into (1) the difference in convenience premia, (2) an intermediation spread arising from frictions in the swap market, and (3) the difference in default risk..

B Bloomberg and Thomson Reuters Tickers

In this section, we list the Bloomberg and Thomson Reuters tickers used in the data analysis.

Table A2: Bloomberg and Thomson Reuters Eikon Tickers For Convenience Yield Measures

	Series		
	GC Repo Rate	BFV Agency Yield	Government Yields
USD	US3MRP=	C0915Y Index	C0795Y Index
EUR	EUR3MRP=	C9325Y Index	C9105Y Index
JPY	JPY3MRP=	C2215Y Index	C1055Y Index

Notes: This table lists the Bloomberg and Thomson Reuters Eikon tickers for the repo rate, agency yields, and government yields. Column 1 lists the Thomson Reuters Eikon Tickers for 3-month Treasury GC repo rates in their respective countries. Columns 2-3 list the Bloomberg Tickers for 5-year BFV Agency and Government par yields in their respective countries. EUR denotes Germany.

Table A1: Bloomberg Tickers: IRS, Basis Swaps, Government Yields, Policy Rates, OIS Swap Rates

	Series				
Currency	IRS	Basis Swaps	Government Yields	Policy Rates	OIS Swap Rates
USD	USSW## Curncy		C082##Y Index	FEDL01 Index	USSO## Curncy
EUR	EUSW##V3, EUSA## Curncy	EUBS## Curncy	C910##Y Index	EUORMARG Index	EUSWE## Curncy
GBP	BPSW##V3, BPSW## Curncy	BPBS## Curncy	C110##Y Index	UKBRBASE Index	BPSWS## Curncy
CHF	SFSW##V3, SFSW## Curncy	SFBS## Curncy	C256##Y Index	SZLTTR Index	SFSWT## Curncy
JPY	JYSW## Curncy, JYBC## Curncy	JYBS## Curncy	C105##Y Index	MUTKCALM Index	JYSO## Curncy
AUD	ADSWAP## Curncy	ADBS## Curncy	C127##Y Index	RBACOR Index	ADSO## Curncy
CAD	CDSW## Curncy	CDBS## Curncy	C101##Y Index	CABROVER Index	CDSO## Curncy
NZD	NDSWAP## Curncy	NDBS## Curncy	C250##Y Index	NZOCR Index	NDSO10## Curncy
NOK	NKSW## Curncy, NKBFV## Curncy	NKBS## Curncy	C266##Y Index	NOBRDEP Index	
SEK	SKSW## Curncy	SKBS## Curncy	C259##Y Index	SWBRDEP Index	
DKK	DKSW## Curncy	DKBS## Curncy	C267##Y Index	DEBRDISC Index	

Notes: This table lists the Bloomberg tickers used to construct the U.S. Treasury Premium for each country. The ## denotes the maturity of the contract. EUR denotes Germany.

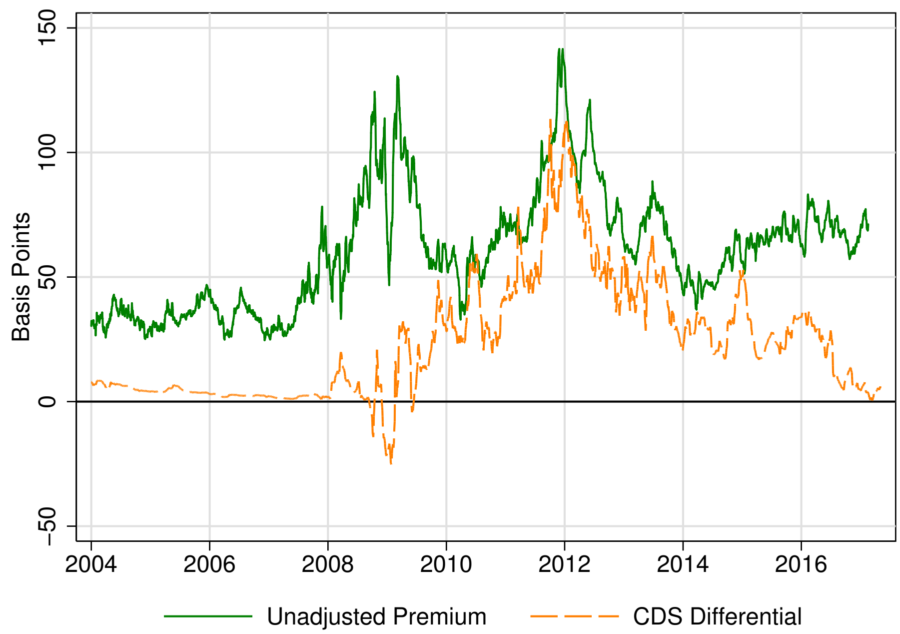
C Supplementary Charts and Regressions

In this section, we show supplementary charts and regression results: a chart of the U.S. Treasury Premium and the CDS differential vis-à-vis Japan may be found in Section C1, summary statistics of the 5-year premium adjusted for CIP deviations in LIBOR, and the 5-year premium adjusted for CIP deviations in LIBOR and credit differentials by country may be found in Section C2, a chart of the swap spread decomposition in Section C3, and a chart of showing the five-year swap spreads in the United States and foreign countries in Section C4.

C.1 Treasury Premia and CDS Differentials

A1 shows the U.S. Treasury Premium vis-à-vis Japan versus the Japan-U.S. sovereign CDS differential. Of our sample, Japan's Treasury has the lowest credit rating and the U.S. Treasury Premium defined vis-à-vis Japan displays moderate co-movement with the CDS differential, similar to the pattern we document for emerging markets in (Du and Schreger, 2016).

Figure A1: Japan: U.S. Treasury Premium vs. CDS Differential



Notes: This figure plots seven-day moving averages of the U.S. Treasury Premium against Japan (in solid green) and the Japan-U.S. sovereign CDS differential (in dashed orange). Series are seven-day moving averages.

C.2 Summary Statistics for Adjusted U.S. Treasury Premium

The secular decline in the U.S. Treasury Premium not only holds when the premium is adjusted for swap frictions and sovereign credit spread differentials, but also is more pronounced.

A3 reports the summary statistics of the 5-year premium adjusted for CIP deviations in LIBOR, and A4 reports the summary statistics of the 5-year premium adjusted for CIP deviations in LIBOR and credit differentials. Compared to the 5-year U.S. Treasury Premium, both series declined more sharply over our sample. The premia adjusted for CIP deviations in LIBOR trended down 44 basis points from 2000-2016, declining from a pre-crisis average of 22.0 basis points before the GFC to -22.4 basis points. post-GFC. The premia adjusted for CIP deviations in LIBOR and credit differentials trended down 51 basis points from 2000-2016, declining from a pre-crisis average of 13.1 basis points to -38.0 basis points.

Table A3: Summary Statistics of the 5-year Premium Adjusted for CIP Deviations in LIBOR, Φ^{CIP}

		Full Sample	2000-2006	2007-2009	2010-2016
AUD	Mean	-9.2***	14.6***	-6.6	-33.8***
	Std. Error	(3.2)	(2.9)	(5.0)	(2.5)
	N	4406	1797	783	1826
CAD	Mean	14.8***	34.9***	40.3***	-13.9***
	Std. Error	(3.9)	(2.7)	(7.9)	(3.7)
	N	4215	1609	782	1824
CHF	Mean	8.4***	26.4***	27.5***	-15.6***
	Std. Error	(3.1)	(2.8)	(5.1)	(2.1)
	N	4186	1603	770	1813
DKK	Mean	-1.8	29.1***	26.3***	-40.8***
	Std. Error	(4.3)	(1.9)	(2.8)	(2.2)
	N	4201	1599	776	1826
EUR	Mean	3.5	32.0***	23.4***	-31.4***
	Std. Error	(3.9)	(1.5)	(3.4)	(2.4)
	N	4287	1692	770	1825
GBP	Mean	0.8	12.2***	4.7	-11.7***
	Std. Error	(1.9)	(1.4)	(5.0)	(2.2)
	N	4220	1665	775	1780
JPY	Mean	30.6***	45.2***	51.3***	7.3**
	Std. Error	(3.1)	(3.5)	(5.1)	(2.9)
	N	4397	1787	784	1826
NOK	Mean	-15.7***	10.3***	-2.6	-43.8***
	Std. Error	(3.9)	(2.1)	(3.9)	(5.1)
	N	4110	1545	772	1793
NZD	Mean	-9.2***	-11.4***	-7.9	-8.1*
	Std. Error	(3.4)	(4.0)	(11.1)	(4.7)
	N	3912	1307	780	1825
SEK	Mean	-3.7	17.8***	17.6***	-31.9***
	Std.Dev.	(3.3)	(1.6)	(2.1)	(2.8)
	N	4235	1630	779	1826
Total	Mean	2.0*	22.0***	17.4***	-22.4***
	Std. Error	(1.2)	(1.2)	(2.5)	(1.4)
	N	42169	16234	7771	18164

Significance levels: * $p<0.10$ ** $p<0.05$ *** $p<0.01$

Notes: This figure table reports the mean, standard error of the mean based on Newey-West standard errors with a 91-day lag, and number of observations of the 5-year premium adjusted for CIP deviations by LIBOR by country, and period (pre-GFC (2000-2006), GFC (2007-2009), post-GFC (2010-2016)). EUR denotes Germany.

Table A4: Summary Statistics of the 5-Year Premium Adjusted for CIP Deviations in LIBOR and CDS Differentials, $\Phi^{CIP,CDS}$

		Full Sample	2000-2006	2007-2009	2010-2016
AUD	Mean	-34.5***	-1.2	-21.2***	-55.3***
	Std. Error	(4.1)	(1.2)	(4.9)	(4.4)
	N	3345	790	782	1773
CAD	Mean	-2.3	22.6***	32.3***	-23.8***
	Std. Error	(4.7)	(1.1)	(12.4)	(3.5)
	N	2944	711	541	1692
CHF	Mean	-25.4***		-19.9***	-26.2***
	Std. Error	(2.1)		(7.2)	(2.2)
	N	2013		253	1760
DKK	Mean	-21.5***	23.8***	17.2***	-57.4***
	Std. Error	(6.4)	(1.3)	(4.1)	(6.4)
	N	3288	740	776	1772
EUR	Mean	-10.1*	29.1***	26.6***	-43.6***
	Std. Error	(5.7)	(1.)	(3.1)	(5.2)
	N	3341	798	770	1773
GBP	Mean	-24.2***	11.5***	-13	-32.4***
	Std. Error	(-3.7)	(2.0)	(8.4)	(3.2)
	N	2657	153	775	1729
JPY	Mean	-0.5	28.5***	44***	-33.0***
	Std. Error	(5.2)	(1.4)	(6.9)	(2.4)
	N	3342	785	784	1773
NOK	Mean	-18.3***	7.7***	4.1	-39.9***
	Std. Error	(4.5)	(-1.8)	(5.9)	(-5.4)
	N	3290	778	772	1740
NZD	Mean	-33.2***	-32.6***	-33.1***	-33.5***
	Std. Error	(2.9)	(3.2)	(5.5)	(4.3)
	N	3114	569	773	1772
SEK	Mean	-15.1***	16.9***	4.6	-34.7***
	Std.Dev.	(4.)	(1.5)	(4.5)	(-4.1)
	N	3156	604	779	1773
Total	Mean	-18.2***	13.1***	5.0	-38.0***
	Std. Error	(1.6)	(1.9)	(3.1)	(1.5)
	N	30490	5928	7005	17557

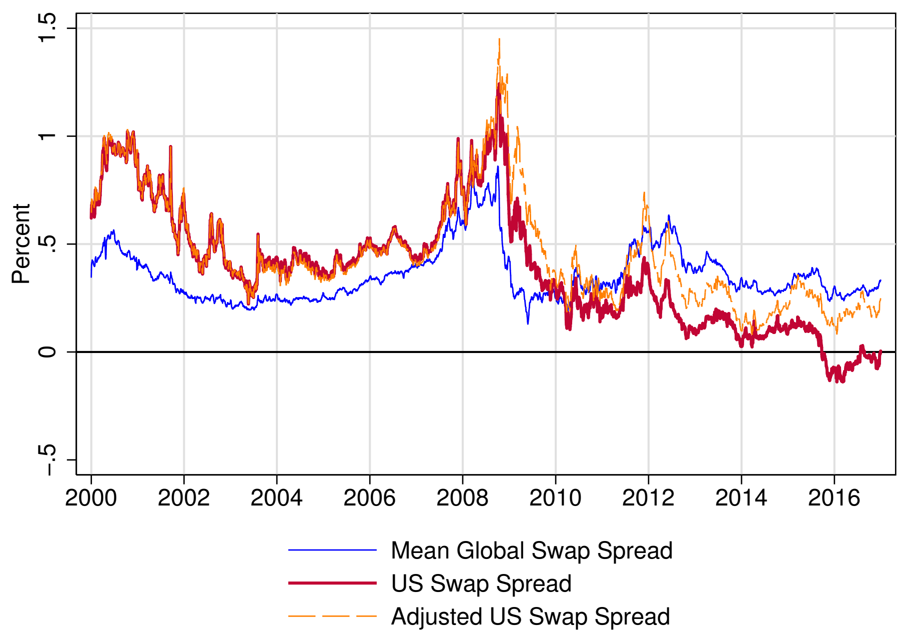
Significance levels: * $p<0.10$ ** $p<0.05$ *** $p<0.01$

Notes: This figure table reports the mean, standard error of the mean based on Newey-West standard errors with a 91-day lag, and number of observations of the 5-year premium adjusted for CIP deviations in LIBOR and CDS differentials by country, and period (pre-GFC (2000-2006), GFC (2007-2009), post-GFC (2010-2016)). Statistics are not reported for Switzerland (CHF) for 2000-2006 because of the lack of data on CDS spreads. EUR denotes Germany.

C.3 Swap Spread Decomposition

As discussed in Section 3.3, A2 plots five-year U.S. swap spread between the U.S. Libor interest rate swap rate and the U.S. Treasury yield in red, the average U.S. adjusted U.S. swap spread between the foreign interest rate swap rate and the swapped U.S. Treasury yield in orange, and the average foreign swap spread between the foreign interest rate swap rate and the foreign Treasury yield. We can see a notable decline in the two U.S. swap spread measures.

Figure A2: Five-Year Swap Spreads



Notes: This figure plots the mean 5-year foreign swap spread (in solid blue), the five-year U.S. swap spread over the U.S. Libor interest rate swap (in solid red), and the mean adjusted U.S. swap spread over the foreign interest rate swap (in dashed orange). Series are seven-day moving averages.

C.4 Supplementary Analysis on Effects of Government Bond Supply on the U.S. Treasury Premium

In this section, we report results on a version of the bond supply regressions where bond supply is defined as the log of the ratio of federal debt (including central bank purchases) and nominal GDP. As noted in the main text, our general regression framework is given by:

$$\Phi_{i,n,t} = \alpha + \beta \cdot \log\left(\frac{debt}{GDP}\right)_{USD,t} + \gamma \cdot \log\left(\frac{debt}{GDP}\right)_{it} + \zeta \cdot X_{i,t} + \epsilon_{i,t}, \tag{A21}$$

where $\log\left(\frac{debt}{GDP}\right)_{USD,t}$ is the log of the U.S. debt to GDP ratio at time t, $\log\left(\frac{debt}{GDP}\right)_{i,t}$ is the log of country i's debt to GDP ratio at time t, and $X_{i,t}$ is a set of additional covariates motivated by Nagel (2016). In particular, $X_{i,t}$ includes the U.S. Policy Rate (the Federal Funds rate), the country i policy rate, and the VIX, which is the CBOE Volatility Index and measures the market expectation of 30-day volatility in the S&P 500. In columns 1-4, we estimate the regressions in levels, and in columns 5-8 we estimate the regressions in changes at the quarterly frequency from 2000-2016. In the even numbered columns, we include country fixed effects and in the odd number columns we omit these fixed effects. As we noted in our interpretation of the baseline model, given the short sample period, the results should be interpreted conservatively.

The results correspond in magnitude, sign, and significance with the results obtained when the measure of bond supply netted out central bank purchases.

Table A5: Effects of Government Bond Supply on the U.S. Treasury Premium (Quarterly Frequency, 2000-2016)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Φ_{5Y}	Φ_{5Y}	Φ_{5Y}	Φ_{5Y}	$\Delta\Phi_{5Y}$	$\Delta\Phi_{5Y}$	$\Delta\Phi_{5Y}$	$\Delta\Phi_{5Y}$
$\log\left(\frac{debt}{GDP}\right)_t^{USD}$	-67.94***	-60.28***	-70.52***	-48.00***				
	(7.844)	(8.365)	(11.73)	(10.98)				
$\log\left(\frac{debt}{GDP}\right)_{it}$	27.74***	4.302	16.80***	5.268				
	(2.601)	(5.705)	(2.566)	(4.123)				
Policy Rate$_t$			-0.0807***	-0.0153				
			(0.0123)	(0.0162)				
U.S. Policy Rate$_t$			0.0462***	0.0234*				
			(0.00962)	(0.0124)				
VIX$_t$			0.0136***	0.0115***				
			(0.00300)	(0.00303)				
$\Delta\log\left(\frac{debt}{GDP}\right)_t^{USD}$					-67.68	-67.81	-113.2*	-113.4*
					(72.78)	(72.81)	(64.55)	(64.66)
$\Delta\log\left(\frac{debt}{GDP}\right)_{it}$					15.45*	15.61*	9.165	9.079
					(8.576)	(8.912)	(9.003)	(9.375)
Δ Policy Rate$_t$							-0.0559***	-0.0563***
							(0.0128)	(0.0129)
Δ U.S. Policy Rate$_t$							-0.000237	-0.000141
							(0.0171)	(0.0170)
Δ VIX$_t$							0.00492***	0.00493***
							(0.00172)	(0.00172)
Constant	19.71***	-35.27***	-9.324	-51.23***	-0.125	-0.797	0.0430	-0.590
	(3.243)	(10.82)	(6.244)	(10.26)	(0.761)	(1.133)	(0.849)	(1.132)
Observations	670	670	670	670	660	660	660	660
R-squared	0.387	0.638	0.555	0.693	0.007	0.008	0.075	0.075
Country FE	No	Yes	No	Yes	No	Yes	No	Yes

Significance levels: * p<0.10 ** p<0.05 *** p<0.01

Notes: The table reports panel regression results of the level and differences of the 5-year U.S. Treasury Premium on country level and U.S. variables that proxy for the scarcity of government bonds. Heteroskedasticity autocorrelation spatial correlation robust standard errors were used with a 8 quarter lag. The variable $\log\left(\frac{debt}{GDP}\right)_{it}$ is the ratio of the country's federal debt to nominal GDP and the variable $\log\left(\frac{debt}{GDP}\right)_t^{USD}$ is the ratio of the United States' federal debt to nominal GDP. The debt/GDP measures include central bank purchases. The variable Policy Rate is the country-specific policy rate, the variable Policy Rate$_{USD}$ is the U.S. policy rate, and the VIX is the CBOE Volatility Index. All data are at the quarterly frequency and span 2000-2016. The U.S. Treasury Premium is from the authors' calculations using data from Bloomberg. Data on federal debt and nominal GDP are from Haver Analytics.

D Variance Analysis of the U.S. Treasury Premium

In this section, we examine the explanatory power of credit differentials, swap market frictions, and the residual convenience yield factor in explaining the total variation in the U.S. Treasury Premium. Table A6 shows panel regression results of changes in the U.S. Treasury Premium on changes in swap market frictions and changes in the CDS differential at the daily, weekly, and monthly frequency. The coefficient on the swap market friction, as measured by CIP deviations for the interbank rates, is very close to 1. However, the coefficient on the CDS differential is small and slightly negative, which suggests CDS differentials have a limited role in driving the U.S. Treasury Premium. The R^2 of the regressions with both CIP deviations and the CDS spread is 5% at the daily frequency and 25% at the monthly frequency. This implies a large fraction of total variations in the U.S. Treasury Premium can be attributed to the residual convenience yield factor.

Table A6: Panel Regression of Changes in the 5-Year Unadjusted U.S. Treasury Premium (Varying Frequencies, 2000-2016)

	(1) $\Delta\Phi_{5Y}$	(2) $\Delta\Phi_{5Y}$	(3) $\Delta\Phi_{5Y}$
$\Delta\tau$	0.983***	1.185***	1.170***
	(0.0581)	(0.0708)	(0.109)
$\Delta\hat{l}_i$	-0.0501***	0.00319	-0.105*
	(0.0191)	(0.0288)	(0.0601)
Constant	-0.00729	-0.0964	-0.502*
	(0.0113)	(0.0636)	(0.282)
Observations	29,004	4,459	1,037
R-squared	0.039	0.188	0.247
Frequency	Daily	Weekly	Monthly

Significance levels: * p<0.10 ** p<0.05 *** p<0.01

Notes: The table reports results from panel regressions of changes in the 5-year U.S. Treasury Premium on changes in the LIBOR CIP deviation, defined as the difference between the swapped foreign interbank rate and the U.S. Libor rate and the CDS differential at the daily, weekly, and monthly frequency. Heteroskedasticity autocorrelation spatial correlation robust standard errors were used with 65 lags at the daily frequency, 13 lags at the weekly frequency, and 3 lags at the monthly frequency. The variable $\Delta\tau$ is changes in LIBOR CIP deviations; and the variable $\Delta\hat{l}_i$ is changes in the CDS differential, defined as the foreign sovereign's CDS spread on a 5-year senior, unsecured contract. Data range from 2005-2016. The U.S. Treasury Premium is from the authors' calculations using data from Bloomberg. Data on CIP deviations are from Bloomberg; data on CDS differentials are from Mark.it.

To take into account dynamic interactions among these factors, we present results from individual country vector autoregressions (VAR). For each country in our sample, we estimate a dynamic system based on quarterly time series for three variables: the CDS differential, CIP deviations, and the U.S. Treasury Premium, in that order.

$$\begin{bmatrix} \hat{l}_{i,t-l} \\ \tau_{i,t-l} \\ \Phi_{5Y,i,t-l} \end{bmatrix} = A_1(L) \begin{bmatrix} \hat{l}_{i,t-1} \\ \tau_{i,t-1} \\ \Phi_{5Y,i,t-1} \end{bmatrix} + A_2(L) \begin{bmatrix} \hat{l}_{i,t-2} \\ \tau_{i,t-2} \\ \Phi_{5Y,i,t-2} \end{bmatrix} + A_3(L) \begin{bmatrix} \hat{l}_{i,t-3} \\ \tau_{i,t-3} \\ \Phi_{5Y,i,t-3} \end{bmatrix} +$$

$$A_4(L) \begin{bmatrix} \hat{l}_{i,t-4} \\ \tau_{i,t-4} \\ \Phi_{5Y,i,t-4} \end{bmatrix} + B \begin{bmatrix} u_{i,t} \\ \epsilon_{i,t} \\ \xi_{i,t} \end{bmatrix}$$

Formal lag selection procedures (the Akaike information criterion (AIC), the Hannan and Quinn criterion, (HQ) and the Schwarz Criterion (SC)) suggest one to four lags. Given our relatively small sample of quarterly observations (34 to 53 quarters), we used the Edgerton and Shukur test to test the null hypothesis of residual autocorrelation. Across currencies, only a model with four lags rejects the null hypothesis for all currencies. We therefore choose four lags. For model stability, we want eigenvalues to be less than one; a formal test confirms all eigenvalues lie inside a unit circle. We triangularize the shocks using an upper triangular Cholesky decomposition, calling the first shock a CDS shock; the second, a CIP shock; and the third, a residual convenience yield shock. We then use the estimated VAR system to analyze the dynamic effect of the shocks via a historical decomposition and variance decomposition.

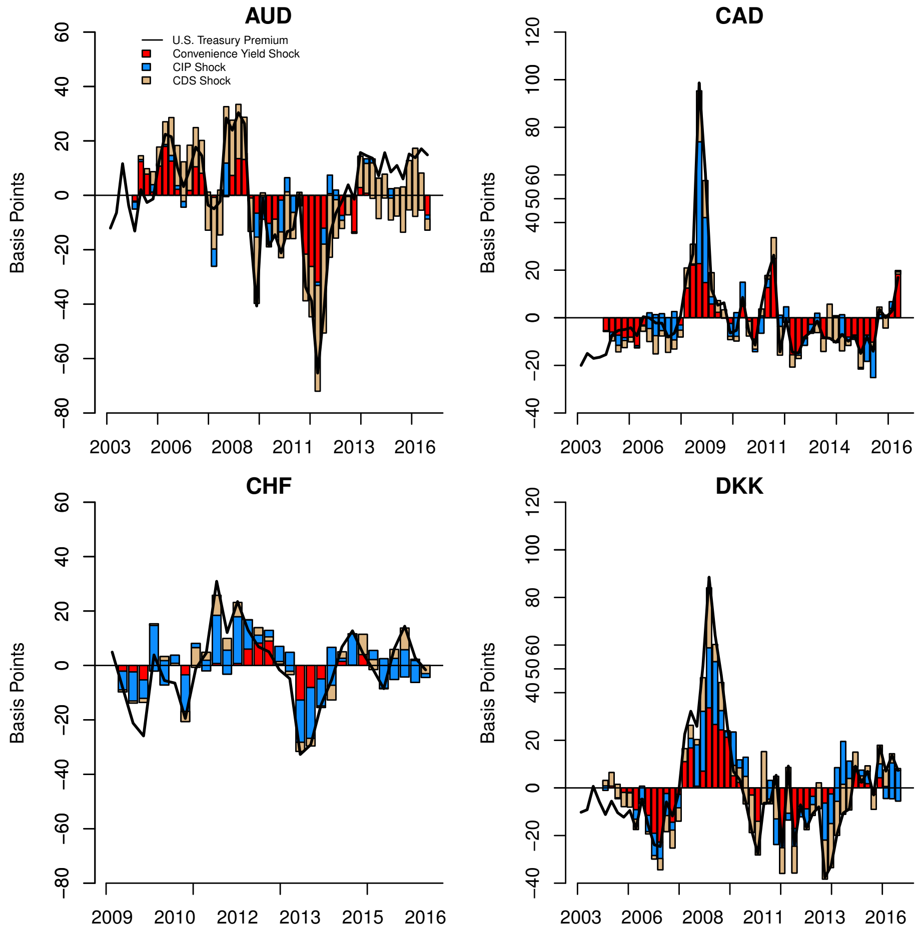
We find the contribution of the convenience yield shock to the forecast error to be sizable across countries despite some variation in the exact percentage. Table A7 shows variance decomposition results based on the 8-quarter forecasting horizon. The average contribution across countries is 20% for the CDS shock, 33% for the CIP shock, and 47% for the residual convenience yield shock. The historical decompositions of the five-year U.S. Treasury Premium by country are shown in Figure A3. We can see that the residual convenience yield shocks (in red) play an important role in all countries, especially in Denmark, Europe, Norway, and Germany.

Table A7: Proportion of Forecast Error 8 Quarters Ahead Produced By Each Innovation: 5-Year U.S. Treasury Premium (Quarterly Frequency, 2000-2016)

	Triangularized innovation		
	CDS Shock	CIP Shock	Convenience Yield Shock
AUD	0.58	0.05	0.37
CAD	0.13	0.41	0.47
CHF	0.12	0.66	0.22
DKK	0.21	0.25	0.54
EUR	0.06	0.26	0.68
GBP	0.19	0.37	0.44
JPY	0.39	0.35	0.26
NOK	0.19	0.21	0.59
NZD	0.06	0.02	0.92
SEK	0.07	0.67	0.26
Avg.	0.20	0.33	0.47
Std. Dev.	0.16	0.21	0.21

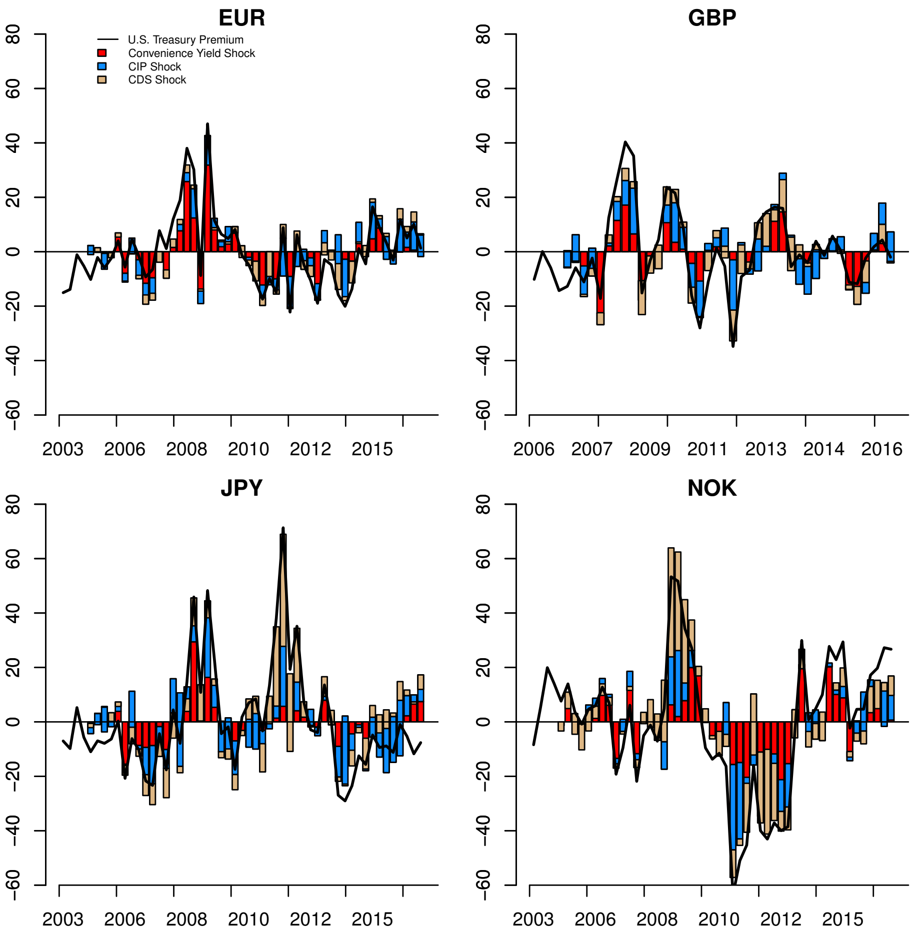
Notes: This table reports the variance decomposition of the 5-year U.S. Treasury Premium from a four-lag reduced form VAR of three variables: the CDS differential, CIP deviations, and the 5-year U.S. Treasury Premium, in that order. Orthogonalized shocks were obtained by taking the upper triangular Cholesky decomposition of residuals. EUR denotes Germany.

Figure A3: Historical Decomposition of the 5-Year Unadjusted U.S. Treasury Premium (Quarterly Frequency, 2000-2016)



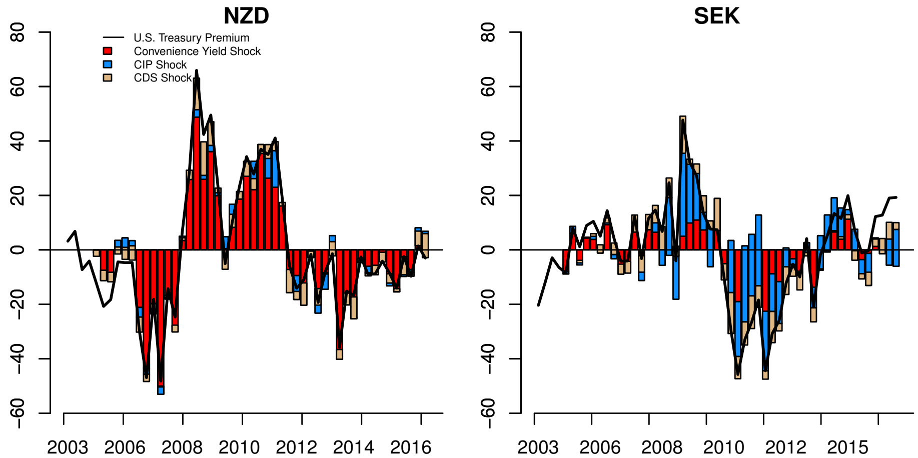
Notes: This figure plots the cumulative contribution of each structural shock to the evolution of the 5-year U.S. Treasury Premium over time. Structural shocks were obtained by taking the upper triangular Cholesky decomposition of residuals from a four-lag, reduced form VAR of three variables: the CDS differential, CIP deviations, and the 5-year U.S. Treasury Premium, in that order. Bars in red represent the contribution of a convenience yield shock; bars in blue, a CIP shock; bars in gold, a CDS shock. The black line is the demeaned, and detrended U.S. Treasury Premium.

Figure A3: (Continued) Historical Decomposition of the 5-Year U.S. Treasury Premium (Quarterly Frequency, 2000-2016)



Notes: This figure plots the cumulative contribution of each structural shock to the evolution of the 5-year U.S. Treasury Premium (demeaned and detrended) over time. Structural shocks were obtained by taking the upper triangular Cholesky decomposition of residuals from a four-lag, reduced form VAR of three variables: the CDS differential, CIP deviations, and the 5-year U.S. Treasury Premium, in that order. Bars in red represent the contribution of a convenience yield shock; bars in blue, a CIP shock; bars in gold, a CDS shock. The black line is the demeaned, and detrended U.S. Treasury Premium. EUR denotes Germany.

Figure A3: (Continued) Historical Decomposition of the 5-Year U.S. Treasury Premium (Quarterly Frequency, 2000-2016)



Notes: This figure plots the cumulative contribution of each structural shock to the evolution of the 5-year U.S. Treasury Premium (demeaned and detrended) over time. Structural shocks were obtained by taking the upper triangular Cholesky decomposition of residuals from a four-lag reduced form VAR of three variables: the CDS differential, CIP deviations, and the 5-year U.S. Treasury Premium, in that order. Bars in red represent the contribution of a convenience yield shock; bars in blue, a CIP shock; bars in gold, a CDS shock. The black line is the demeaned, and detrended U.S. Treasury Premium.