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# Prone to Contagion

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## Abstract

We examine how shocks to the supply of US Treasuries (UST) impact long-term foreign sovereign bond prices. Leveraging the suspension of 30-year Treasury bond auctions from 2002 to 2006 as a natural experiment, we employ a demand-driven term premium model incorporating limits to arbitrage. Our results indicate that reduced UST supply elevates UST prices and decreases foreign bond yields. The contagion effect intensifies with higher correlations between US and foreign short-term rates, reinforcing the limits-to-arbitrage framework in global markets.

*JEL classification:* E41, E44, E51, E58, G11, G22, G23

*Keywords:* Limits to arbitrage, safe assets, preferred habitat, contagion, foreign bonds, quantitative easing

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The literature now recognizes that shocks to the supply of US Treasuries (UST) affect the prices of long-term foreign sovereign bonds. Indeed, Backus and Wright (2007) and Greenspan (2005) point out that the prices of foreign sovereign bonds increased before the Great Financial Crisis when Global Savings Glut (GSG) countries were massively buying long-term UST. The prices of long-term foreign sovereign bonds have also increased with QE purchases (e.g., Bauer and Neely, 2014; Neely, 2015). The mechanism by which UST purchases affect the prices of foreign bonds is still unclear. In this paper, we empirically examine this mechanism using a targeted shock—the suspension of 30-year Treasury bond auctions announced on October 31, 2001. On May 4, 2005, the Treasury announced the possible resumption of 30-year Treasury auctions, which resumed in February 2006.

We formalize our empirical examination with a demand-driven model of the term premium. The model is a simple application of the quantity-driven model of the term premium of Greenwood, Hanson, Stein, and Sunderam (2023) (GHSS hereafter), which relies on limits-to-arbitrage. In the absence of limits to arbitrage, the supply of long-term bonds by arbitrageurs is perfectly elastic, resulting in the insensitivity of safe asset prices to demand fluctuations (Vayanos and Vila, 2021, VV hereafter). We posit that different financial assets are not perfect substitutes in the portfolios of some investors. These investors have a preference for long-term safe bonds denominated in their own currencies (habitat-preference). We also assume the presence of an arbitrageur (the global arbitrageur in GHSS and in Gourinchas, Ray, and Vayanos, 2022) that absorbs shocks related to the net supply for both US and foreign sovereign bonds. This arbitrageur, being risk-averse, requires a premium to arbitrage away the price disparities in long-term bonds caused by shocks to their net supply. As a result, the supply of US and foreign long-term bonds by the arbitrageur is not perfectly elastic.

The model proposition that we test is that a decrease in the net supply of Treasury bonds leads to a rise in the price of these bonds, which, in the presence of a global arbitrageur that mitigates supply shocks worldwide, causes a rise in the price of foreign bonds. Moreover, the rise in the price of foreign bonds increases with the correlation between the foreign and US short-term interest rates.

We examine whether these implications of the model are observed in the data with a

single targeted shock — the suspension of 30-year Treasury bond auctions from 2002 to 2006. We analyze the prices of Treasuries and foreign sovereign bonds.

We find strong support for the proposition that a decrease in the net supply of UST bonds leads to a rise in the price of these bonds and a decrease in the yields on long-term sovereign bonds. Similar to GHSS and Gourinchas, Ray, and Vayanos (2022), our model assumes that supply shock effects are disseminated across bonds from various countries due to a global arbitrageur who absorbs supply shocks globally. We observe a significant decrease in the yields of foreign bonds when the suspension is announced. Our results also indicate that the decrease in foreign bond yields increases with the correlation between the foreign and US short-term interest rates.

The literature addressing limits to arbitrage examines a wide array of subjects (e.g., Pontiff, 1996; Shleifer and Vishny, 1997; Gromb and Vayanos, 2010; He and Krishnamurthy, 2013). Our work augments the existing evidence that a limits-to-arbitrage framework in which risk-averse arbitrageurs absorb shocks to the excess demand for different securities (e.g., VV, Greenwood and Vayanos, 2010, 2014) helps explain a diverse and important collection of capital market phenomena. We achieve this by examining the various outcomes – such as the impact on prices of UST and foreign bonds resulting from a shock to the net supply of a particular safe asset, namely 30-year UST bonds.<sup>1</sup> GHSS demonstrate that the same limits-to-arbitrage framework addresses the relation between supply shocks and foreign exchange rates. Gourinchas, Ray, and Vayanos (2022) introduces a model in which the effects of monetary policy are transmitted internationally through global arbitrageurs who absorb excess demand shocks originating from habitat investors in different countries. In support of the mechanism proposed by GHSS and Gourinchas, Ray, and Vayanos (2022), we find an increase in the prices of foreign long-term bonds after the announcement of the suspension. Moreover, we show that certain countries are more prone to contagion because their macro economic policies are more correlated that U.S. policy.

We contribute to the literature that examines QE. Krishnamurthy and Vissing-Jorgensen

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<sup>1</sup>A few studies explore the same shock to the supply of long-term UST that we examine. Bernanke, Reinhart, and Sack (2004) and Dastidar (2009) show that the prices of UST bonds increased with the announcement of the suspension. Duarte and Umar (2024) analyze the effect of the suspension on the issuance, price, and acquisition of long-term PACs, which are bonds that substitute for long-term UST. In relation to these papers, we analyze the effect of the suspension on the price of foreign bonds.

(2011) examines the various channels through which QE affects the prices of different securities. Bauer and Neely (2014) and Neely (2015) explore the impact of QE on foreign bond yields, while D’Amico and King (2013) uses QE to examine VV theory. Despite the difference in the shock we analyze compared to QE, our findings support the mechanism in GHSS and Gourinchas, Ray, and Vayanos (2022) as an explanation for the yield changes observed across countries during the QE era.

To outline the next sections, Section 1 describes the model and its testable implications; Section 2 describes the data; Section 3 describes the empirics; and Section 4 concludes.

## 1 Model and Testable Implications

Our model adapts the framework presented in GHSS, to a three-period world. In the first period, the known short-term domestic (US) interest rate is  $r_1$ . The interest rate for the second period is  $r_2$  with mean  $\mu_r$  and variance  $\sigma_r^2$ . The foreign fixed income market mirrors the domestic market, with respective short-term rates and moments indicated by  $r_1^{ext}$ ,  $r_2^{ext}$ ,  $\mu_{r^{ext}}$ , and  $\sigma_{r^{ext}}^2$ . The correlation between domestic and foreign short-term interest rates is symbolized by  $\rho$ .

Both countries have preferred habitat investors. Preferred-habitat investors demand bonds maturing at  $t = 3$ . The demand of US preferred habitat investors for bonds maturing at  $t = 3$  net of the government supply of that bond is:

$$Z = \alpha [1/P - (1 + r_1)(1 + \mu_r)] - g \quad (1)$$

where  $\alpha \geq 0$ . The demand for long term bonds is decreasing in prices ( $P$ ) and increases on the excess return of long-term bonds  $[1/P - (1 + r_1)(1 + \mu_r)]$ . When  $\alpha = 0$ , US preferred-habitat investors demand is  $-g$ . In this case,  $g$  which is equal to the amount of bonds the UST issues minus the total demand from inelastic preferred habitat investors – the net supply of bonds with maturity at  $t = 3$ . A similar dynamic is observed in the foreign market, where the excess supply for long-term bonds is:

$$Z^{ext} = \alpha^{ext} [1/P^{ext} - (1 + r_1^{ext})(1 + \mu_r^{ext})] - g^{ext} \quad (2)$$

Drawing parallels to Gourinchas, Ray, and Vayanos (2022) and GHSS, our model incorporates a yield curve arbitrageur adept at capitalizing on arbitrage opportunities within the

yield curves of both countries. This term-structure arbitrageur addresses the excess demand for US long-term domestic bonds by selling long-term bonds at a price  $P$  and reallocating the proceeds at the short-term interest rate. Consequently, the excess return generated by this domestic yield-curve strategy is quantified as  $rx_3 = [(1 + r_1)(1 + r_2) - 1/P]$ . We assume that the arbitrageur sells  $\$h$  worth of these long-term bonds. In a similar vein, the arbitrageur allocates  $h^{ext}$  to the foreign yield curve strategy with the return given by  $rx_3^{ext} = [(1 + r_1^{ext})(1 + r_2^{ext}) - 1/P^{ext}]$ . In line with the approach described in GHSS, let  $\mathbf{h}'$  denote the vector representing the term-structure arbitrageur's holdings. Furthermore, the excess return for each of these strategies is encapsulated in the vector  $\mathbf{rx}_3$ .<sup>2</sup> To determine the optimal holdings, the arbitrageurs engage in the following maximization problem:

$$\max_{\mathbf{h}} \mathbf{h}' E[\mathbf{rx}_3] - \frac{1}{2\lambda} \mathbf{h}' Var[\mathbf{rx}_3] \mathbf{h} \quad (3)$$

Here,  $\lambda$  signifies the arbitrageur's tolerance for risk, and  $Var[\mathbf{rx}_3]$  is the covariance matrix of the excess returns of three arbitrageur's strategies.

The first-order condition of the arbitrageur's problem along with the market clearing conditions lead to the following expression for the expected return premium of the domestic long-term bond:

$$\frac{1}{P} - (1 + r_1)(1 + \mu_r) = \frac{(\alpha^{ext}(\eta_h \eta_h^{ext} - \eta_\rho^2) + \eta_h)g + \eta_\rho g^{ext}}{(1 + \alpha \eta_h)(1 + \alpha^{ext} \eta_h^{ext}) - \eta_\rho^2 \alpha \alpha^{ext}} \quad (4)$$

where  $\eta_h = (1 + r_1)^2 \sigma_r^2 / \lambda$  is the risk penalty of the domestic yield curve strategy,  $\eta_h^{ext} = (1 + r_1^{ext})^2 \sigma_{r^{ext}}^2 / \lambda$  is the risk penalty of the foreign yield curve strategy, and  $\eta_\rho = \rho \sigma_r \sigma_{r^{ext}} (1 + r_1)(1 + r_1^{ext}) / \lambda$  is the risk penalty related to the correlation of the returns of the international and domestic yield curve strategies ( $\rho$ ). The expected return premium of the foreign long-term bond is:

$$\frac{1}{P^{ext}} - (1 + r_1^{ext})(1 + \mu_{r^{ext}}) = \frac{\eta_\rho g + (\alpha(\eta_h \eta_h^{ext} - \eta_\rho^2) + \eta_h^{ext})g^{ext}}{(1 + \alpha \eta_h)(1 + \alpha^{ext} \eta_h^{ext}) - \eta_\rho^2 \alpha \alpha^{ext}} \quad (5)$$

It is interesting to compare the solution in Equations 4 to 5 with the implications in GHSS. Similar to GHSS, the price of the long-term bond in Equation 4 responds to shocks on its

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<sup>2</sup>The term-structure arbitrageur also has access to the currency strategy, involving short-term borrowing in domestic currency and short-term lending in foreign currency. For details, see Appendix A.1.

excess supply. This contrasts with models without any limits to arbitrage. For example, when the yield curve arbitrageur is risk neutral ( $\eta_h = 0$  and  $\eta_\rho = 0$ ) resulting in no limits to the yield curve arbitrage, the price of the long-term bond does not respond to shocks in  $g$  and  $g^{ext}$ .

The price of foreign long-term bonds in Equation 5 is sensitive to fluctuations in the excess supply of US bonds ( $g$ ) when  $\eta_\rho$  is different from zero. To understand the mechanism behind this relation, note that the global arbitrageur issues domestic and foreign long-term bonds and invests at short-term interest rates to meet the excess demand from US and foreign habitat-preference investors. Consequently, a variation in  $g$  impacts the arbitrageur's exposure to common fluctuations in both US and foreign short-term interest rates, thereby affecting the prices of US and foreign long-term bonds.

Equations 4 to 5 deliver the main propositions that we take to the data:

**Proposition 1** *Equation 4 and 5 indicate that when the arbitrageur is not risk neutral ( $\eta_h > 0$ ), the price of long-term government bonds increases in response to negative excess supply shocks. Moreover, when the short-term interest rates of the two countries exhibit a positive correlation, ( $\eta_\rho > 0$ ), the price of foreign long-term bonds rises with a decrease in the excess supply for US Treasuries ( $g$ ). This increase in foreign bond prices are not due preferred-habitat investors substituting from UST to foreign sovereign bonds.*

Our empirical analysis explores the suspension of the 30-year Treasury bond auction from 2002 to 2005 as a shock to the supply of long-term bonds. We map the bond with maturity at  $t = 3$  in our model to the real-world 30-year Treasury bond, deliberately excluding Treasury notes (times-to-maturity between 2 and 10 years) from our long-term bond category. This approach helps to cleanly identify the effects described in Proposition 1 by exploring the difference in the effect of the auction suspension between the treated group (time-to-maturity above 10 years) and the control group (time-to-maturity of two to 10 years).

## 2 Data

Our empirical analysis spans from 1998 to 2007, concluding in 2007 to ensure that our findings are not influenced by the financial crisis.

To perform our empirical analysis, we gather data on US Treasury (UST) notes and bonds from the CRSP Treasury files. We gather data for all non-callable US Treasury bonds and notes trading between 1998 and 2007 from CRSP. CRSP data files contain information on each Treasury security, including CUSIP, the daily return, the total amount outstanding, the issuance date, the maturity date, and the daily yield-to-maturity (YTM). We convert CRSP daily yield-to-maturity (YTM) into bond-equivalent YTM to align our empirical analysis with market conventions.

Figure 1, Panel A shows the total amount of notes and bonds issued between 1998 and 2007. We divide all UST issuances into two categories based on the term of the Treasury securities: notes are medium-term (two to ten years to maturity) and bonds are long-term (with maturities greater than ten years). The issuance of notes increased during the event period from about \$0.4 trillion in 2002 to \$0.6 trillion in 2005. Bond issuance decreased from about \$16 billion in 2001 to zero dollars between 2002 and 2005. About \$26 billion worth of bonds were issued in 2006 with surprisingly strong demand. Figure 1, Panel B shows the issuance of bonds relative to the total issuance of Treasury bonds and notes. In 2001, the issuance of bonds was about 6% of the total issuance of bonds plus notes. Between 2002 and 2005, there was no issuance of US Treasury bonds. Bond issuance increased to approximately 4% of the total issuance of bonds plus notes in 2006.<sup>3</sup>

[Insert Figure 1 Here]

To evaluate the prediction that that a shock to the net supply of Treasuries affects the yields on foreign sovereign bonds, we follow GHSS procedures to create a daily series of zero coupon bond yields with one, three, five, ten, twenty and thirty years to maturity for the five foreign countries with traded 30-year bonds at the time of the event (Canada, Eurozone, Great Britain, Switzerland, and Japan).<sup>4</sup> We also use data on the zero coupon bond yield curve from Gürkaynak, Sack, and Wright (2007).<sup>5</sup>

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<sup>3</sup>See <https://home.treasury.gov/news/press-releases/po749> and <https://home.treasury.gov/news/press-releases/js2420> for the announcement of the suspension and the announcement of the possible resumption of 30-year Treasury bond auctions. See <https://www.nytimes.com/2006/02/09/business/30year-treasury-bond-returns-and-demand-is-strong.html> for evidence that the demand at resumption was surprisingly strong in Feb. 2006.

<sup>4</sup>The original data are from the central banks of each of these countries. Bond equivalent yields are calculated for Switzerland and Japan. For Japan, we bootstrap the constant maturity-par yields.

<sup>5</sup><https://www.federalreserve.gov/pubs/feds/2006/200628/200628abs.html>

## 3 Empirical Results

### 3.1 Treasury and Prices on the Announcement of the Suspension of 30-Year Treasury Bond Auctions

Proposition 1 predicts that a negative shock to the excess supply of long-term UST bonds causes an increase in the prices of long-term UST bonds. To examine this prediction, we investigate the daily returns of UST on Oct. 31, 2001, which is when the US Treasury announced the suspension of 30-year Treasury bond auctions. We also examine their returns when the US Treasury announced the possible reversal of the suspension on May 4, 2005. Eventually, 30-year UST bond issuances resumed in February 2006.

On Oct. 31, 2001 – the date the Treasury announced the suspension of Treasury bond auctions – the mean daily return of long-term 30-year Treasury bonds (with 25-30 years until maturity), weighted by the outstanding amount, minus the daily weighted return of medium-term Treasury notes (with 9 to 10 years to maturity), was approximately 2.1%.<sup>6</sup> This marks the highest positive daily return within the sample period from 1998 to 2007. This pronounced reaction suggests that the market was taken by surprise by the discontinuation of the 30-year bond issuance.<sup>7</sup> This significant announcement return is in line with the findings of Bernanke, Reinhart, and Sack (2004), which noted a 43 basis point drop in the yield of the constant maturity 30-year Treasury bond between October 30 and November 1, 2001. Furthermore, when the potential reversal of the suspension was announced on May 4, 2005, the returns of Treasury bonds relative to the returns of Treasury notes were approximately -1.2%, consistent with the limits to arbitrage mechanism proposed in our model.<sup>8</sup>

Table 1 evaluates the statistical significance of these market reactions. To do so, we calculate the distribution of the daily difference in the returns between long-term Treasury

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<sup>6</sup>We focus on Treasury bonds with 25 to 30 years of maturity to ensure that some Treasury bonds are trading during the four-year suspension period. The results are robust to using 29-30, but then there is a gap in the figure during the suspension period.

<sup>7</sup>Although Gary Gensler, the under secretary of the Treasury for domestic finance, hinted in February 2000 that the ten-year note might replace the thirty-year bond as the benchmark long-term security, the announcement’s coverage suggested the suspension was largely unexpected. Coverage of this “surprise move” can be found in the Wall Street Journal at <https://www.wsj.com/articles/SB1004548380881711360>, CNN at <https://money.cnn.com/2001/10/31/markets/longbond/>, and the Economist at <https://www.economist.com/finance-and-economics/2001/11/01/cut-short>.

<sup>8</sup>The figure also indicates the largest negative return occurred on September 21, 2001, the day markets reopened after the September 11, 2001 terrorist attacks.

bonds (with 25-30 years until maturity) and medium-term Treasury notes (with 9 to 10 years to maturity) in the period January 1, 1998 to August 30, 2001. This sample period precedes the announcement. Then, we compare the difference in returns on the announcement with the distribution of preceding returns. The t-statistic is 7.7 for US Treasury bonds on October 31, 2001 when the suspension is announced, and the t-statistic is -4.4 on May 4, 2005 when the possible reversal of the suspension is announced.

[Insert Table 1 Here]

Proposition 1 also predicts that a negative shock to the excess supply of US long-term bonds causes an increase in the prices of long-term foreign bonds. The effect on foreign bond prices occurs even though the model assumes that habitat investors only demand domestic bonds. Moreover, the model predicts that the degree to which foreign bond prices change depends on the correlation between US and foreign sovereign bonds (see equation 5).

Consistent with Proposition 1, Figure 2, Panel A plots the 30-year zero coupon YTM over time for the five foreign countries with 30-year bonds trading at the time of suspension. The vertical red line marks the suspension date, and one can see that the YTM on 30-year bonds in the Eurozone, Canada, and the United Kingdom fell on announcement. The effect is visibly absent in Japan and Switzerland. Panel B of Figure 2 plots the changes in the yield to maturity (YTM) of U.S. and foreign zero-coupon bonds on the day the suspension was announced. It shows that the YTM of bonds with maturities of less than 30 years declined globally. This is consistent with the models presented in Gourinchas, Ray, and Vayanos (2022), Greenwood, Hanson, Stein, and Sunderam (2023), and Vayanos and Vila (2021), which suggest that a shock to the supply of a bond affects the prices of bonds with different maturities by altering the price of interest rate risk.

[Insert Figure 2 Here]

Table 2, Panel A shows the significance of these declines. We calculate the t-statistic in column (2) by comparing the effect on the announcement day to the distribution of daily changes in the YTM measure by country during the period January 1, 1998 to August 30, 2001 before the announcement of the suspension. We find that the most significant change

is in Canada with a drop of 44 basis points (t-statistic -13.1); however, because of a market holiday in Canada on October 31, 2001, this change is from October 30 to November 1. The next most significant change is in the Eurozone (Germany) with a drop of 36 basis points (t-statistic -10.9), followed by Great Britain with a drop of 10 basis points (t-statistic -2.9). There is no significant change in Japan and Switzerland. We carefully consider time zone differences when examining these price effects. In columns (3) and (4), we observe a significant decline in the spread between the YTM on 30-year zero coupon bonds and the YTM on 10-year zero coupon bonds for both Canada and the Eurozone.

[Insert Table 2 Here]

Furthermore, consistent with Proposition 1, column (5) of Table 2 shows that the significance of the effect appears to increase with the correlation of short rates between the US and the foreign country. We proxy the correlation of short rates with the correlation of monthly changes in the 1-year YTM in the United States and the foreign country. To precisely determine the correlation of the short-term interest rate, we first remove the influence of changes in the YTM of medium- and long-term bonds from changes in the 1-year YTM for each country. To do so, we regress changes in short-term rates on the changes in the YTM for 5-, 10-, 20-, and 30-year zero-coupon bonds. The  $R^2$  is approximately 85% in the US. We then calculate the residual short rate. We then compute the correlation of these adjusted short-term rates between countries. This method refines our empirical analysis, aligning it more closely with the theoretical model. It minimizes the likelihood that variations in the YTM of medium- and long-term bonds are misconstrued as driving forces behind changes in the short-term rate.

Lastly, we take advantage of our single shock to a specific maturity (the 30 year bond) to examine whether the announced suspension had spillover effects on the prices of foreign bonds of shorter maturities, as predicted by Gourinchas, Ray, and Vayanos (2022) because of the presence of a global arbitrageur. By contrast, identifying spillover effects across maturities is more challenging to execute in a setting such as Quantitative Easing (QE) because in the QE setting, the shocks to bond supply are across the maturity spectrum and QE was happening concurrently in other countries. Using data from the central banks of

the five foreign countries with 30 year bonds trading during the event period, we estimate the following regression:

$$\Delta YTM_{m,j} = \beta_1 \times \rho_j + \beta_2 \times \text{Duration}_{m,j} + \beta_3 \times \rho_j \times \text{Duration}_{m,j} + \epsilon_{m,j}. \quad (6)$$

The outcome variable is the change on the day of the announcement in the YTM of the zero coupon bond with maturity  $m$  in the country  $j$ .  $\rho_j$  is the correlation of the adjusted monthly changes in the YTM of 1-year government bonds in country  $j$  with the adjusted changes in the YTM of 1-year government bonds in the US.  $\beta_2$  multiples the duration of the zero coupon bonds with maturities of 1, 3, 5, 10, 20, and 30 years.  $\beta_3$  multiples the interaction of  $\rho_j$  and the bond's duration.

Table 2, Panel B column (1) shows, for the five countries with traded 30 year bonds, that the negative effect of the suspension of 30-year US Treasury bonds is significantly stronger for bonds with higher short rate correlations with the US. A one standard deviation increase in the short rate correlation is related to a 7bps larger drop in yields on announcement. Column (2) shows that the yields on bonds with longer durations decreased significantly more. The adjusted- $R^2$  of column (2) shows that when accounting for the duration of bonds and the correlation of short rates, the regression model explains 55.9% of the variation in yields between countries and maturities on the day of suspension. More interestingly, in column (3), we interact the duration with the short rate correlation and find that the effects are concentrated in the countries with higher short rate correlations. Also, importantly, the adjusted- $R^2$  increases to 76.1%, indicating that accounting for the interactions of maturity and short rate correlations is important to explain the cross-sectional variation in yield changes on the day of the announcement.

The fact that a large component of the shock to 30 year US bonds transmitted across maturities and countries, in line with the short rate correlations, is consistent with the VV framework and the presence of a global arbitrageur as in Gourinchas, Ray, and Vayanos (2022) and GHSS. In other words, we are seeing the shock on the 30 year US bond affecting the yields on 5 year bonds around the world (column 3). It is unlikely that habitat investors requiring 30 year safe assets are substituting towards 5 year bonds in other countries.

GHSS proxy the short rate with the yield of sovereign bonds with one year until maturity.

Table 3 repeats Table 2 using the un-adjusted short rate correlations. The results are similar to those in Table 2.

## 4 Conclusion

We provide direct evidence that Treasury and foreign sovereign bond prices increased in response to a suspension of 30-year bond auctions in 2002. We show that the prices of foreign government bonds rose significantly on the announcement of the suspension of US bond auctions. This observation aligns with the presence of a global arbitrageur who mitigates supply shocks in the bond market worldwide. Our setting capitalizes on the targeted suspension of Treasury bond auctions (and its reversal).

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Figure 1: **Total amount of Treasury Notes and Bonds Issued by Year.** Panel A shows the total amount of Treasury notes and bonds issued by year. Treasury notes have a maturity of 1.98 to 10 years. Treasury bonds have a maturity of 10.1 or more years. Panel B shows the dollar amount of bonds issued per year as a fraction of the total amount of notes and bonds issued each year. No Treasury bonds were issued between 2002 and 2005.

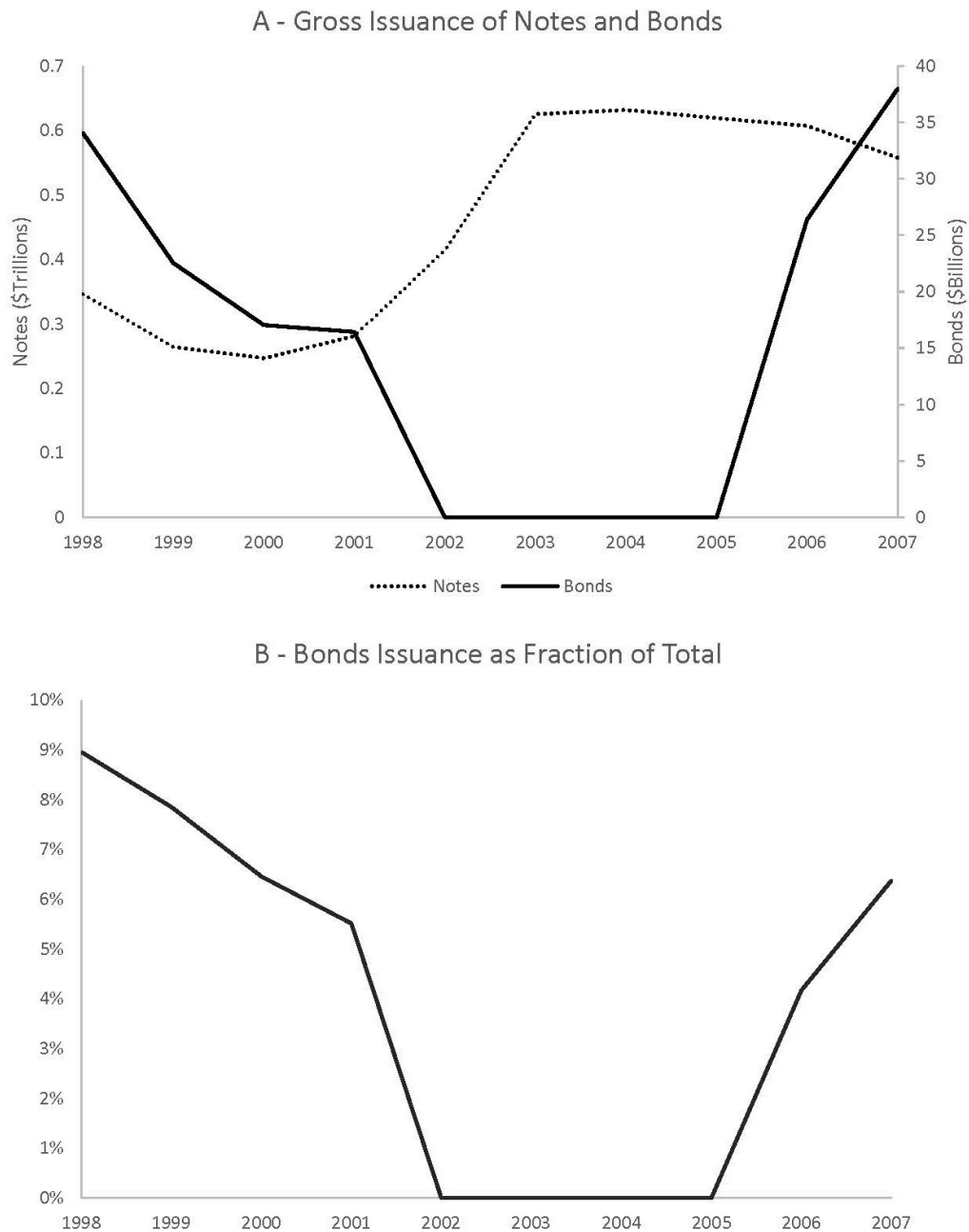
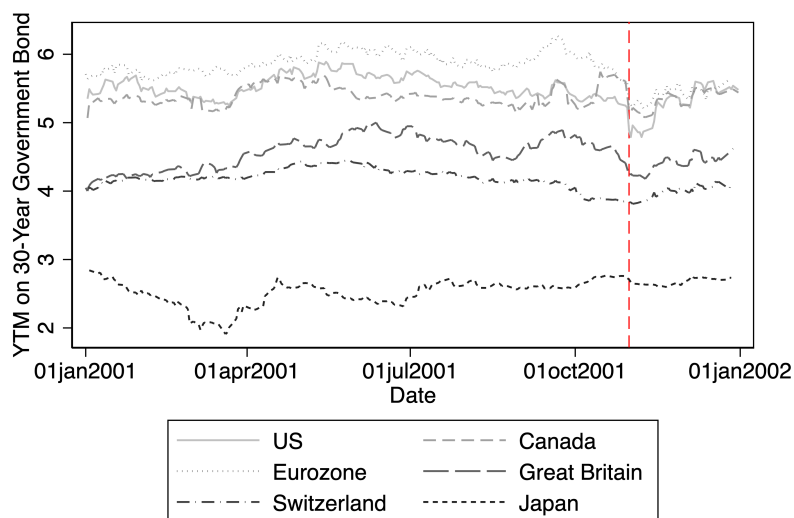
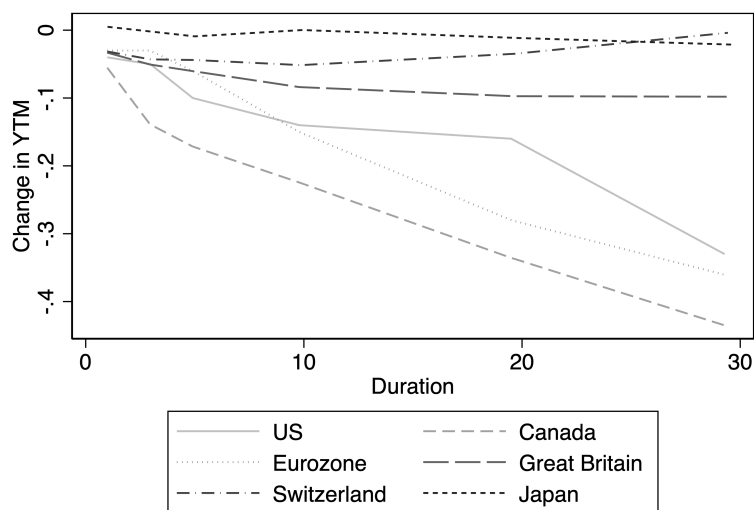


Figure 2: **Effect of the Suspension Announcement on the YTM of 30-Year Zero Coupon Bonds.** This figure plots the YTM on 30-year zero coupon bonds for the six countries with 30 year bonds at the time of the announcement of the suspension on October 31, 2001 (marked with a red vertical line). Panel A plots the time series of the YTM for the year 2001, with a red vertical line denoting the day the suspension of the 30-year US Treasury bond was announced. Panel B plots the change in the YTM of foreign zero-coupon bonds on the announcement date against the modified duration.



(a) YTM of 30-Year Zero Coupon Bonds



(b) Effect of Suspension on the YTM of Zero Coupon Bond by Duration

Table 1: **Halted UST Bond Auctions & the Returns of Bonds and PACs.**

This table examines the returns of UST bonds, PAC CMOs, and fed funds futures contracts around the U.S. Treasury's Oct. 31, 2001 announcement suspending 30-year Treasury bond auctions. Daily on-the-run UST returns for bonds and notes are sourced from CRSP, monthly PAC returns are obtained from the ICE Bank of America Merrill Lynch CMO Indices, daily fed fund futures prices come from Bloomberg, and the yields of the on-the-run USTs are from Federal Reserve Economic Data (FRED). UST returns are calculated as the price change plus accrued and paid interest, divided by the previous day's price plus accrued interest (TDRETNUA in CRSP). Panel A reports the daily return of the on-the-run 30-year UST bond, while Panel B presents the change in yield. Panel C analyzes the daily changes in the prices of 30-day fed funds futures (FF1, FF6, and FF9) from Bloomberg, which mature in one, six, and nine months, respectively. Futures contracts with longer maturities are unavailable for this sample period. Column (2) displays the t-statistic relative to the prior distribution (January 1, 1997, to August 30, 2001). Columns (3) and (4) report the return difference and t-statistic for the potential reversal announcement on May 4, 2005. \*\*\*, \*\*, and \* denote statistical significance at 1%, 5%, and 10%, respectively.

|                                        | Suspension<br>Announced<br>(Oct 31, 2001)<br>Effect    t-stat<br>(1)        (2) |      | Possible Reversal<br>Announced<br>(May 4, 2005)<br>Effect    t-stat<br>(3)        (4) |      |
|----------------------------------------|---------------------------------------------------------------------------------|------|---------------------------------------------------------------------------------------|------|
| Panel A: Daily Returns                 |                                                                                 |      |                                                                                       |      |
| Treasury Bond Returns                  | 5.10***                                                                         | 8.6  | -1.53**                                                                               | -2.6 |
| Treasury Bond Less Note Returns        | 3.72***                                                                         | 13.7 | -1.37***                                                                              | -5.0 |
| Panel B: Daily Yield Changes           |                                                                                 |      |                                                                                       |      |
| Treasury Bond                          | -0.33***                                                                        | -6.0 | 0.11**                                                                                | 2.0  |
| Treasury Bond Less Note                | -0.19***                                                                        | -9.3 | 0.12***                                                                               | 5.9  |
| Panel C: Daily Fed Fund Futures Prices |                                                                                 |      |                                                                                       |      |
| Fed Fund Futures, $t + 1$              | 0.00                                                                            | -0.1 | 0.00                                                                                  | -0.1 |
| Fed Fund Futures, $t + 6$              | -0.02                                                                           | -0.6 | 0.04                                                                                  | 1.2  |
| Fed Fund Futures, $t + 9$              | 0.01                                                                            | 0.2  | 0.05                                                                                  | 1.4  |

Table 2: **Foreign Bond Yields and the Suspension of Treasury Bond Auctions**

This table examines whether foreign 30-year bond yields responded to the US Treasury's announced suspension of 30-year Treasury bond auctions. The sample includes countries with 30-year sovereign bonds during the event period. Panel A column (1) reports the change in the 30-year zero-coupon bond yield for each country on the announcement day. Column (2) reports the t-statistic for the change, relative to the distribution of the measure from January 1, 1998 to August 30, 2001. Column (3) reports the change in the 30-year zero coupon bond yield less the change in the 10-year zero coupon bond yield for each country on the announcement day. Column (4) reports the t-statistic. Column (5) shows the adjusted correlation between the monthly changes of 1-year yields in the US and the changes of 1-year yields in other countries from January 1, 1998 to August 30, 2001. For each country, we regress changes in the 1-year short rate on changes in the 5, 10, 20, and 30 year YTM's and keep the residuals. We correlate these adjusted short rates. Panel B examines whether this effect differed for these five countries based on the duration of the foreign bonds and the correlation of the one-year short rate between the US and the foreign country. The outcome variable is the announcement day's daily change in the yield to maturity for zero coupon bonds with maturities of 1, 3, 5, 10, 20, and 30 years.  $\rho$  is the adjusted correlation of the monthly changes in the 1-year yields between the US and each foreign country. *Duration* is the modified duration of the zero coupon bond. We report heteroskedasticity robust standard errors. \*\*\*, \*\*, and \* denote statistical significance at levels 1%, 5%, and 10%, respectively.

Panel A: Effect of suspension on long-term yields

| Country            | Announcement Effect on<br>30YR YTM |               | Announcement Effect on<br>30-10YR YTM |               | Correlation of<br>Short Rates |
|--------------------|------------------------------------|---------------|---------------------------------------|---------------|-------------------------------|
|                    | Effect<br>(1)                      | t-stat<br>(2) | Effect<br>(3)                         | t-stat<br>(4) | $\rho$<br>(5)                 |
| United States      | -0.33***                           | -7.5          | 1.00                                  |               |                               |
| Canada             | -0.44***                           | -13.1         | -0.21***                              | -14.9         | 0.38                          |
| Eurozone (Germany) | -0.36***                           | -10.9         | -0.21***                              | -14.9         | 0.25                          |
| Great Britain      | -0.10***                           | -2.9          | -0.01                                 | -1.0          | 0.22                          |
| Japan              | -0.02                              | -0.6          | -0.02                                 | -1.5          | 0.14                          |
| Switzerland        | -0.00                              | -0.1          | 0.05***                               | 3.4           | -0.00                         |

Panel B: Effect by duration and correlation

|                           | $\Delta_t$ YTM (%)   |                      |                      |
|---------------------------|----------------------|----------------------|----------------------|
|                           | (1)                  | (2)                  | (3)                  |
| $\rho$                    | -0.553***<br>(0.142) | -0.555***<br>(0.121) | -0.107<br>(0.087)    |
| Duration                  |                      | -0.005***<br>(0.002) | 0.003<br>(0.002)     |
| $\rho \times$ Duration    |                      |                      | -0.040***<br>(0.007) |
| Constant                  | 0.011<br>(0.022)     | 0.071**<br>(0.034)   | -0.017<br>(0.021)    |
| % Adjusted R <sup>2</sup> | 35.04                | 55.89                | 76.11                |
| # Observations            | 30                   | 30                   | 30                   |

Table 3: **Foreign Bond Yields and the Suspension of Treasury Bond Auctions (Using un-adjusted short rate correlations)**

The table examines whether foreign 30-year bond yields responded to the US Treasury's announced suspension of 30-year Treasury bond auctions. The sample includes countries with 30-year sovereign bonds during the event period. Panel A column (1) reports the change in the 30-year zero-coupon bond yield for each country on the announcement day. Column (2) reports the t-statistic for the change, relative to the distribution of the measure from January 1, 1998 to August 30, 2001. Column (3) reports the change in the 30-year zero coupon bond yield less the change in the 10-year zero coupon bond yield for each country on the announcement day. Column (4) reports the t-statistic. Column (5) shows the correlation between the monthly changes of 1-year yields in the US and the changes of 1-year yields in other countries from January 1, 1998 to August 30, 2001. Column (6) reports the beta of a regression of changes of 1-year yields in other countries on the changes in 1-year US yields. Panel B examines whether this effect differed for these five countries based on the duration of the foreign bonds and the correlation of the one-year short rate between the US and the foreign country. The outcome variable is the announcement day's daily change in the yield to maturity for zero coupon bonds with maturities of 1, 3, 5, 10, 20, and 30 years.  $\rho$  is the correlation of the monthly changes in the 1-year yields between the US and each foreign country. *Duration* is the modified duration of the zero coupon bond. We report heteroskedasticity robust standard errors. \*\*\*, \*\*, and \* denote statistical significance at levels 1%, 5%, and 10%, respectively.

Panel A: Effect of suspension on long-term yields

| Country            | Annc. Effect on<br>30YR YTM |               | Annc. Effect on<br>30-10YR YTM |               | Correlation of<br>Short Rates | Beta of<br>Short Rates |
|--------------------|-----------------------------|---------------|--------------------------------|---------------|-------------------------------|------------------------|
|                    | Effect<br>(1)               | t-stat<br>(2) | Effect<br>(3)                  | t-stat<br>(4) | $\rho$<br>(5)                 | $\beta$<br>(6)         |
| United States      | -0.33***                    | -9.9          | -0.19***                       | -11.1         | 1.00                          |                        |
| Canada             | -0.44***                    | -13.1         | -0.21***                       | -12.3         | 0.75                          | 0.74                   |
| Eurozone (Germany) | -0.36***                    | -10.9         | -0.21***                       | -12.2         | 0.59                          | 0.48                   |
| Great Britain      | -0.10***                    | -2.9          | -0.01                          | -0.8          | 0.44                          | 0.45                   |
| Japan              | -0.02                       | -0.6          | -0.02                          | -1.2          | 0.19                          | 0.06                   |
| Switzerland        | -0.00                       | -0.1          | 0.05***                        | 2.8           | 0.36                          | 0.40                   |

Panel B: Effect by duration and correlation

|                           | $\Delta_t$ YTM (%)   |                      |                      |
|---------------------------|----------------------|----------------------|----------------------|
| $\rho$                    | -0.412***<br>(0.092) | -0.414***<br>(0.066) | -0.114**<br>(0.042)  |
| Duration                  |                      | -0.005***<br>(0.002) | 0.007**<br>(0.003)   |
| $\rho \times$ Duration    |                      |                      | -0.027***<br>(0.005) |
| Constant                  | 0.094***<br>(0.030)  | 0.154***<br>(0.034)  | 0.015<br>(0.019)     |
| % Adjusted R <sup>2</sup> | 45.76                | 67.15                | 88.48                |
| # Observations            | 30                   | 30                   | 30                   |

# Internet Appendix to Prone to Contagion

This Internet Appendix contains supplementary analyses. These include the following:

1. Appendix A.1 contains model details

## A.1 Model Details

Our model adapts the framework presented in GHSS to a three-period world. In the first period, the known short-term domestic (US) interest rate is  $r_1$ . The interest rate for the second period is  $r_2$  with mean  $\mu_r$  and variance  $\sigma_r^2$ . The foreign fixed income market mirrors the domestic market, with respective short-term rates and moments indicated by  $r_1^{ext}$ ,  $r_2^{ext}$ ,  $\mu_{r^{ext}}$ , and  $\sigma_{r^{ext}}^2$ . The correlation between domestic and foreign short-term interest rates is symbolized by  $\rho$ . Both countries have preferred habitat investors.

Drawing parallels to Greenwood, Hanson, Stein, and Sunderam (2023), our model incorporates a yield curve arbitrageur adept in capitalizing on arbitrage opportunities within the yield curves of both countries. This term-structure arbitrageur addresses the excess demand for U.S. long-term domestic bonds by selling long-term bonds at a price  $P$  and reallocating the proceeds at the short-term interest rate. This approach is termed the domestic yield-curve strategy. Let's assume the arbitrageur sells  $\$h$  worth of these long-term bonds. Consequently, the excess return generated by this domestic strategy is quantified as  $rx_3 = [(1 + r_1)(1 + r_2) - 1/P]$ . In a similar vein, the arbitrageur allocates  $h^{ext}$  to the foreign yield curve strategy with return given by  $rx_3^{ext} = [(1 + r_1^{ext})(1 + r_2^{ext}) - 1/P^{ext}]$ .

Moreover, the term-structure arbitrageur also has access to the currency strategy, involving short-term borrowing in domestic currency and short-term lending in foreign currency. The arbitrageur allocates  $h^q$  to this strategy with profitability:  $rx_3^q = -Q_1(1 + r_1)(1 + r_2) + Q_3(1 + r_1^{ext})(1 + r_2^{ext})$ , where  $Q_t$  is the dollar price of one unit of the foreign currency at  $t$ .

Let us denote  $\mathbf{h} = [h, h^{ext}, h^q]'$  as the vector representing the term-structure arbitrageur's holdings in both the domestic and foreign yield-curve strategies, as well as in the currency strategy. Furthermore, the excess return for each of these strategies is encapsulated in the vector  $\mathbf{rx}_3 = [rx_3, rx_3^{ext}, rx_3^q]'$ . To determine the optimal holdings, the arbitrageurs engage in the following maximization problem:

$$\max_{\mathbf{h}} \mathbf{h}' E[\mathbf{rx}_3] - \frac{1}{2\lambda} \mathbf{h}' Var[\mathbf{rx}_3] \mathbf{h} \quad (7)$$

Here,  $\lambda$  signifies the arbitrageur's tolerance for risk, and  $Var[\mathbf{rx}_3]$  is the covariance matrix

of the excess returns of three arbitrageur's strategies:

$$Var[\mathbf{r}\mathbf{x}_3] = \begin{bmatrix} \sigma_r^2 (r_1 + 1)^2 & \rho\sigma_r\sigma_{r^{ext}} (r_1 + 1) (r_1^{ext} + 1) & Cov(rx_3^q, rx_3) \\ \rho\sigma_r\sigma_{r^{ext}} (r_1 + 1) (r_1^{ext} + 1) & (\sigma_{r^{ext}})^2 (r_1^{ext} + 1)^2 & Cov(rx_3^q, rx_3^{ext}) \\ Cov(rx_3^q, rx_3) & Cov(rx_3^q, rx_3^{ext}) & \sigma_Q^2 \end{bmatrix} \quad (8)$$

The first-order condition of this problem leads to the following:

$$E[\mathbf{r}\mathbf{x}_3] = \frac{1}{\lambda} Var[\mathbf{r}\mathbf{x}_3] \mathbf{h} \quad (9)$$

Preferred-habitat investors demand bonds maturing at  $t = 3$ . The demand of US preferred habitat investors for bonds maturing at  $t = 3$  net of the government supply of that bond is:

$$Z = \alpha [1/P - (1 + r_1)(1 + \mu_r)] - g \quad (10)$$

where  $\alpha \geq 0$ . The demand for long term bonds is decreasing in prices and increases on the excess return of long-term bonds  $[1/P - (1 + r_1)(1 + \mu_r)]$ . When  $\alpha = 0$ , US preferred-habitat investors demand is  $-g$ . In this case,  $g$  which is equal to the amount of bonds the UST issues minus the total demand from inelastic preferred habitat investors – the net supply of bonds with maturity at  $t = 3$ . A similar dynamic is observed in the foreign market, where the excess supply for long-term bonds is:

$$Z^{ext} = \alpha^{ext} [1/P^{ext} - (1 + r_1^{ext})(1 + \mu_r^{ext})] - g^{ext} \quad (11)$$

Consider the vector  $\mathbf{Z} = [Z, Z^{ext}, 0]'$ , which encapsulates the excess demand for domestic bonds, for foreign bonds, and a zero value for the currency, reflecting our assumption of no excess supply for foreign currency for simplicity. The market equilibrium for domestic bonds is expressed by the equation ( $h = Z$ ). Consequently, combining the first-order conditions of the arbitrageur with the market equilibrium conditions, we arrive at the following equation:

$$E[\mathbf{r}\mathbf{x}_3] = \frac{1}{\lambda} Var[\mathbf{r}\mathbf{x}_3] \mathbf{Z} \quad (12)$$

This equation is solved to determine the values of  $1/P$ ,  $1/P^{ext}$ , and  $Q_1$ . To streamline the solution, we define a risk penalty matrix:

$$\frac{Var[\mathbf{r}\mathbf{x}_3]}{\lambda} = \begin{bmatrix} \eta_h & \eta_\rho & \eta_{YQ} \\ \eta_\rho & \eta_{h^{ext}} & \eta_{Y^{ext}Q} \\ \eta_{YQ} & \eta_{Y^{ext}Q} & \eta_Q \end{bmatrix} \quad (13)$$

The yield of the domestic long-term bond is:

$$\frac{1}{P} - (1 + r_1)(1 + \mu_r) = \frac{(\alpha^{ext}\eta_h^{ext}(1 - \rho^2) + 1)\eta_h g + \eta_\rho g^{ext}}{1 + \alpha\eta_h + \alpha^{ext}\eta_h^{ext} + (1 - \rho^2)\alpha\eta_h\alpha^{ext}\eta_h^{ext}} \quad (14)$$

The yield of the foreign long-term bond is:

$$\frac{1}{P^{ext}} - (1 + r_1^{ext})(1 + \mu_{r^{ext}}) = \frac{\eta_\rho g + (\alpha\eta_h(1 - \rho^2) + 1)\eta_h^{ext}g^{ext}}{(1 + \alpha\eta_h)(1 + \alpha^{ext}\eta_h^{ext}) - \eta_\rho^2\alpha\alpha^{ext}} \quad (15)$$

The suspension of the 30-year bond auction does not signify a change in the volume of Treasuries sold, but rather a shift in their time-to-maturity (Bernanke, Reinhart, and Sack, 2004). Consequently, the auction suspension does not yield clear-cut implications for the foreign exchange rate. Nonetheless, for the sake of completeness, we note that the model implies the dollar price of one unit of foreign currency as follows:

$$Q_1 = \frac{E[Q_3](1 + r_1^{ext})(1 + \mu_{r^{ext}})}{(1 + r_1)(1 + \mu_r)} + \eta_{YQ} \frac{g(\alpha^{ext}[\eta_h^{ext} + \eta_\rho] + 1) - g^{ext}(\alpha[\eta_\rho + \eta_h] + 1)}{(1 + r_1)(1 + \mu_r)[(1 + \alpha\eta_h)(1 + \alpha^{ext}\eta_h^{ext}) - \eta_\rho^2\alpha\alpha^{ext}]} \quad (16)$$

It is worth noting that Equation 16 shares similarities with the foreign exchange rate discussed in Greenwood, Hanson, Stein, and Sunderam (2023). Specifically, the first term on the right-hand side of Equation 16 is akin to the uncovered interest rate parity.