

# U.S. Treasury Auctions: A High Frequency Identification of Supply Shocks\*

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June 2021

## Abstract

We identify Treasury supply shocks using auction data, interpreting changes in futures prices around announcements as shocks to expected supply. We isolate the component of futures price variations pertaining to U.S. Treasury announcements between 1998 and 2020. We study how supply affects financial markets through local projections, using shocks as instruments. We show that increases in Treasury supply cause an upward shift of the yield curve fueled partly by a higher term premium. Stock prices climb, volatility declines and corporate bond yields increase. The equity premium rises, the risk premium falls, inflation expectations soar and the liquidity premium decreases.

*JEL-Classification:* E44, E63, H63

*Keywords:* Treasury supply, high frequency identification, local projections, liquidity premium

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\*We are grateful to Kenza Benhima, Jean-Paul Renne, Samuel Reynard, Adrien Auclert, Yoann Della Croce, and University of Lausanne seminar participants for useful comments.

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# 1 Introduction

Following the outbreak of the COVID-19 crisis, OECD governments borrowed 18 trillion dollars from the markets in 2020.<sup>1</sup> This unprecedented 6.8 trillion dollar increase in debt securities with respect to 2019 has propelled debt-to-GDP ratios to record highs in many countries, including the United States. At the same time, ultra loose monetary policy combined with the general flight to safety have kept yields on these securities extremely low.

Still, amidst rising inflation expectations fuelled by rapid economic recovery, fears of monetary policy tightening have caused substantial financial market volatility. At the core of investors concerns lies the uncertainty as to how the debt burden will eventually affect financial markets.

Surely, the Ricardian equivalence hypothesis (Barro, 1974) posits that debt increases aimed at stimulating the economy are ineffective. As is well known, however, the presence of financial market imperfections—such as liquidity constraints—typically disprove its central implication. As a result, models of non-Ricardian agents usually attribute large welfare effects to debt management policies.<sup>2</sup>

In fact, there exists a body of empirical literature that relates changes in the supply of Treasury securities to several macro-financial outcomes. Although it is believed to crowd out private investment by raising real interest rates, Treasury supply is thought to provide liquidity services to firms and households thereby crowding in investment via better credit conditions.<sup>3</sup> Yet, estimating the relationship between the supply of Treasuries and the economy—let alone the financial markets—is a challenging task. Reduced-form coefficients from the regressions of interest rates onto debt at quarterly frequencies are, at best, correlations.

In this paper, we present a novel identification strategy of U.S. Treasury supply shocks based on Treasury auction data. After providing a quick

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<sup>1</sup>OECD Sovereign Borrowing Outlook 2021.

<sup>2</sup>See, e.g., Friedman (1978), Woodford (1990), Holmström and Tirole (1998), Caballero and Farhi (2018).

<sup>3</sup>See, e.g., Laubach (2009), Cecchetti et al. (2011), Checherita-Westphal and Rother (2012) for the crowding out effect, and Longstaff (2004), Krishnamurthy and Vissing-Jorgensen (2012) for the liquidity effect.

summary of the U.S Treasury auction process and the U.S Treasury futures market, we propose a conceptual framework to elicit expectations about debt supply based on futures data.

The working hypothesis formulates that changes in front-month Treasury futures prices around public announcements by the Treasury can be interpreted as shocks to the expected supply of debt securities by the U.S. government. This hypothesis rests upon the assumption that on announcement days (1) demand for public debt instruments is fixed and (2) markets are fed with no systematic innovation other than the announcement itself. Under these circumstances, a simple no-arbitrage condition fully identifies the relative shift in supply from the observed futures return: Ex-post price decreases (or yield increases) must stem from a downright shift of the expected supply curve.

Notwithstanding, because our futures data come at daily frequencies, and securities of given maturities tend to be auctioned on the same day of the week, one may be worried that other components affect Treasury futures contracts settlement prices (such as day-of-the-week effects). More importantly still, there are good reasons to believe that such variations in futures prices mirror changes in expectations about the future stance of monetary policy.

To cope with these concerns, we project linearly the futures returns on announcement days onto a set of controls as well as a market-based measure of expectations about monetary policy. By construction, the residuals from this regression are orthogonal to everything but the surprise component of the announcement pertaining to unexpected variations in Treasury supply. The resulting measures of supply shocks spans from July 1998 to March 2020 and covers auctions of 2-, 5- and 10-year T-notes; and 30-year T-bonds.

To investigate the financial consequences of surprise increases in the supply of U.S. debt securities, we estimate the impulse response functions (IRFs) of important financial variables at daily frequencies to shocks to the amount of securities offered by the U.S. Treasury (net of the amount of maturing securities) by means of local projections with instrumental variables (LP-

IV).

After shortly presenting the empirical framework, we argue that our four exogenous Treasury supply shock series ought to serve as reasonable instruments. The latter argument hinges upon the claim that our series are relevant (i.e., they explain a substantial share of the variance in the net amount of securities tendered by the U.S. Treasury on announcement days) and exogenous (i.e., they are orthogonal to innovations to the other variables in the system on announcement days).

We show that Treasury supply shocks have sizable and significant dynamic causal effects on financial markets. A one-billion-dollar net increase in supply of U.S. Treasury securities causes an upward shift in the yield curve that ranges from 1 to 2 basis points. The latter effect is only partly explained by an increase in the short rates. Instead, investors appear to command a yield in excess of the one predicted by short rates in order to hold the newly issued securities. Consequently, the term premium increases by about 1.5 basis point.

Furthermore, a one-billion-dollar net increase in Treasury supply is perceived as good news, as it drives stock prices up and leads to a decrease in market volatility. Corporate bonds yields increase by about 2 basis points, indicating a worsening in financing conditions for the corporate sector. The equity premium spikes (by 20 basis points) as a result of the simultaneous rise in stock prices and the fall in bond yields, and the risk premium falls (by roughly 0.5 basis point). Yet, because the sudden increase in the supply of debt instruments may signal an upcoming surge in fiscal deficits, long-term inflation expectations soar by about 1 basis point.

Moreover, a positive Treasury supply shock is associated with a significant decrease in the liquidity premium. Looking at two different measures of liquidity, namely Refcorp spreads (at maturities 2-, 5-, 10-, 20-year) and AAA as well as BAA spreads, we find that a one-billion-dollar increase in net supply of U.S. Treasury securities brings about a significant drop in these spreads of up to 1.5 basis points. This significant decrease in the liquidity services provided by U.S. Treasury securities is in line with predictions from the macro-financial literature.

To the best of our knowledge, this paper is the first to ever identify shocks to the supply of U.S. Treasury securities by systematically exploiting the auction process using high frequency data. Doing so makes it the first study to investigate closely and accurately the extent to which exogenous changes in debt supply immediately affect important financial outcomes.<sup>4</sup>

### 1.1 Literature review

Ever since Slutsky (1937) observed that business cycle fluctuations were driven by “random causes”—or shocks—macroeconomists have strived to find candidates therefor.<sup>5</sup> An outpouring of work has particularly focused on those shocks that are of policy nature, fiscal and monetary alike. However, up until Sims (1980) introduced vector autoregressions (VARs), fiscal and monetary policy shocks studied in large-scale econometric models were lacking credible identification. Yet, albeit extremely useful, VARs in their original form seemed to fail to account for the bulk of economic fluctuations, so much so that Cochrane (1994) feared we may never unravel their fundamental causes. As a result, most of the recent research has explored avenues for cleaner identification schemes.

One growing body of literature in particular—made possible by the big data—has exploited immediate changes on financial markets following policy announcements to extract the surprise component thereof. The idea is straightforward: Under the efficient market hypothesis (Malkiel and Fama, 1970) and provided the observer’s time window is tight, any such change must stem from a surprise triggered by the announcement.

This so-called high frequency identification (HFI) strategy was pioneered by Bagliano and Favero (1999) who used differences between target rates agreed upon in Federal Open Market Committee (FOMC) meetings and market-based measures of expectations thereof as shocks to monetary policy.<sup>6</sup> Kuttner (2001) later estimated how changes in the Federal Reserve’s

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<sup>4</sup>In a fashion akin to our methodology, Gorodnichenko and Ray (2017) exploit U.S. Treasury auction *results* to identify Treasury *demand* shocks.

<sup>5</sup>For a comprehensive review on the matter, see Ramey (2016).

<sup>6</sup>Following Söderlind and Svensson (1997), they used the spot yield curve on the day preceding the meeting to compute the forward rate for the day following the meeting and take the latter as measure of expectations.

policy affect interest rates by disentangling anticipated from unanticipated changes in the target rate using daily data on Fed funds futures. Faust, Swanson, and Wright (2004) then measured the impact of these unanticipated changes in monetary policy on the expected path of interest rates.

Gürkaynak et al. (2005) argued that there are two factors underlying the response of futures prices to monetary policy: one that pertains to changes in the current target, and one that pertains to future path of monetary policy.<sup>7</sup>

Since then, the HFI scheme has been used for shocks other than monetary. For instance, Ferrara and Guérin (2018) identified shocks to the level of economic uncertainty using financial market responses to macroeconomic news releases. More recently, Känzig (2021) identified oil supply shocks using financial market reactions to OPEC announcements.<sup>8</sup> Yet, to the best of our knowledge, there has been no attempt to import HFI methods to the literature on debt supply.<sup>9</sup>

Our paper is not the first to track changes in financial outcomes around U.S. Treasury auctions. Fleming and Rosenberg (2008), Lou et al. (2013) and Fleming and Liu (2016) show that the price of Treasury securities tend to decrease prior to an auction and to increase thereafter (using respectively weekly, daily and intraday data). Moreover, Smales (2020) shows that auctions affect the prices, volumes and volatility of the 10-year Treasury futures, and Smales (2021) finds that U.S. Treasury auctions matter for the Treasury futures market in a way that is comparable to important macroeconomic news. Nonetheless, although these studies have looked into the relevance and the effects alike of U.S. Treasury *auctions*, none of them has exploited Treasury *announcements* to identify shocks to the supply of Treasuries.

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<sup>7</sup>More recent contributions to the identification of monetary policy shocks based on HFI techniques include Gertler and Karadi (2015), Altavilla et al. (2019), Caldara and Herbst (2019), Cieslak and Schrimpf (2019), Jarociński and Karadi (2020).

<sup>8</sup>Others contributions using financial market responses to oil events for identification include Cavallo et al. (2012), Anzuini et al. (2015).

<sup>9</sup>In the fiscal literature, some papers have used so-called *narrative* methods instead. For instance, Ramey and Shapiro (1998) and Ramey (2011) used newspaper articles to identify government purchases shocks, while Romer and Romer (2010) identified tax shocks based on presidential speeches and congressional reports.

Undoubtedly, the paper closest to ours is Gorodnichenko and Ray (2017), who use U.S. Treasury auction results to relate changes in the demand of Treasury securities to changes in yields and corporate borrowing rates. In a fashion akin to our methodology, they interpret high-frequency movements in the prices of Treasury futures following the release of new information by the U.S. Treasury as market surprises. Unlike our paper, however, they focus on auction *results* to identify shocks to the *demand* of Treasuries, in an attempt to better understand the effects of large-scale asset purchase programs (QE).

In the macro-financial literature, the supply of U.S. Treasury securities is thought as being strongly linked with several important variables. On the one hand, increases in debt supply, because they drives interest rates up, may discourage investment and lead to a lower level of economic activity. This so-called crowding out effect is notably documented by Laubach (2009), Cecchetti et al. (2011) and Checherita-Westphal and Rother (2012). On the other hand, increases in debt supply may provide liquidity services to firms and households, thereby stimulating investment and economic activity. Papers stressing this negative relationship between the liquidity premium and the supply of Treasuries include Longstaff (2004), Krishnamurthy and Vissing-Jorgensen (2012), Nagel (2016) and Du et al. (2018).

The contribution of our paper is twofold. First, it is the first to employ HFI methods in order to identify U.S. Treasury supply shocks using the auction process. Second, it provides clean estimates of how changes in U.S. Treasury supply affects a comprehensive set of financial outcomes, such as Treasury and corporate bond yields, stock prices, as well as various premia.

The remainder of this paper is as follows. Section 2 summarizes the U.S. Treasury auction process and describes our identification procedure of debt supply shocks from futures data. Section 3 studies the interaction between Treasury supply shocks and key financial variables at high frequencies. Section 4 concludes.

## 2 Identification of Treasury Supply Shocks

In this section, we present a novel identification of U.S. Treasury supply shocks based on Treasury auction data. After providing a quick summary of the U.S. Treasury auction process and the U.S. Treasury futures market, we propose a conceptual framework to elicit expectations about debt supply based on futures data. Finally, in order to back the claim that announcements by the U.S. Treasury are closely watched, we investigate the extent to which the auction process impacts the volatility and the volumes of the U.S. Treasury futures market

### *2.1 U.S. Treasury Auctions*

The U.S. government finances its debt by issuing Treasuries to individual and institutional investors. To sell and determine the yield of these securities, the U.S. Treasury holds public auctions. Any such auction is carried out in three steps:

1. Announcement,
2. Bidding,
3. Issuance.

The announcement first provides details on the auction date, the maturity date, and the issue date. Moreover, it discloses the amount being extended and any relevant information for bidders (such as the bidding close times and the terms and conditions). In general, announcements precede auctions by a few business days.

The bidding starts after the announcement is made and allows participants to submit bids. Bids are of two types: competitive and noncompetitive. Competitive bids specify an amount (up to 35% of the offering amount) and a yield deemed acceptable. Noncompetitive bids are engagements to purchase (up to \$5 millions per auction worth of) Treasuries at the yield determined at auction. Upon closing, noncompetitive bidders are awarded their securities; while competitive bidders are considered in ascending order of their posted yield until the offered amount is reached. The highest accepted bid will determine the yield received by all bidders.

Table 1. Treasury Auction Schedule

Security	Frequency	Auction
4-week bills	Weekly	Tuesdays
13-week bills	Weekly	Mondays
26-week bills	Weekly	Mondays
52-week bills	Every four weeks	Tuesdays
<b>2-year notes</b>	Monthly	End of month
3-year notes	Monthly	Middle of month
<b>5-year notes</b>	Monthly	End of month
7-year notes	Monthly	End of month
<b>10-year notes</b>	Monthly	Middle of month
<b>30-year bonds</b>	Monthly	Middle of month
5-year TIPS	Three times per year	Apr, Aug, Dec
10-year TIPS	Bimonthly	Jan, Mar, May, Jul, Sep, Nov
30-year TIPS	Three times per year	Feb, Jun, Oct
2-year FRN	Monthly	End of month

*Notes:* This Table displays, for each security, how often and when its auction usually takes place. Securities in boldface are the ones considered in this paper.

*Source:* Federal Reserve Bank of New York.

The issuance finally consists for the U.S. Treasury in delivering securities to awarded bidders in exchange for payments. Treasuries become tradable on so-called secondary markets. Treasury notes, bonds and TIPS have semiannual interest payments, while bills do not. At maturity, all securities are paid at par.

Table 1 displays the general auction schedule for all securities issued by the U.S. Treasury. Securities in boldface are the ones we consider in this paper. As shown in the Table, some securities are auctioned both at similar frequencies and at the same time (e.g. the 13- and 26-week bills; or the 10-year notes and 30-year bonds).

**Announcements.**—Since 1997, each announcement by the U.S. Treasury is summarized in a report published on the same day. In the case of the Treasury’s Quarterly Refunding statement, the report is released upon a press conference held by Treasury officials. Figure 1 is an excerpt of one such document, dated August 4, 1999.

Figure 1. U.S. Treasury Announcement on August 4, 1999 (excerpt)

FOR RELEASE WHEN AUTHORIZED AT PRESS CONFERENCE    CONTACT: Office of Financing  
August 4, 1999    202/691-3550

TREASURY AUGUST QUARTERLY FINANCING

The Treasury will auction \$15,000 million of 5-year notes, \$12,000 million of 10-year notes, and \$10,000 million of 30-year bonds to refund \$28,890 million of publicly held securities maturing August 15, 1999, and to raise about \$8,110 million of new cash.

*Notes:* Excerpt of the report published upon the Treasury’s Quarterly Refunding press conference on August 4, 1999. *Source:* Treasury Direct.

As can be seen from the excerpt, most of the information relevant to market participants is disclosed within the first lines of the document: the maturities and the volumes of the tendered securities, along with an estimate of the amount of maturing securities and the resulting net operation.

## 2.2 Treasury Futures Contracts

Futures contracts on U.S. Treasuries exist on the Chicago Board of Trade (CBOT) since 1977. Several underlying securities were introduced progressively and currently amount to the following ones: 2-, 3-, 5-, 10-year Treasury notes, and 30-year Treasury bonds.

These futures are quoted in a similar fashion as the underlying coupon-bearing securities, namely (and unlike other money-market instruments) as prices rather than yields. Each contract specifies a settlement price at which the buyer agrees to take delivery of eligible securities on settlement date. There are four settlement dates over the course of one year (so each contract is tradable for three months), namely March 21, June 21, September 21, December 21.

Table 2 displays for each futures the class of securities eligible for delivery. As can be seen from the Table, the range of deliverable securities for a given futures is broad. Because securities with different maturities are not worth the same, upon delivery, the invoice value is adjusted using “conversion factors” so as to reflect the pricing features (i.e., maturity and coupon) of the Treasury security being supplied.

If the conversion factors were perfect, all eligible securities would be equally

Table 2. Treasury Futures Contracts

Futures	Deliverable
2-Year T-Note	Treasury notes. Original term to maturity: not more than 5 years 3 months. Remaining term to maturity: at least 1 year 9 months and not more than 2 years.
3-Year T-Note	Treasury notes. Original term to maturity: not more than 5 years 3 months. Remaining term to maturity: at least 2 years 9 months and not more than 3 years.
5-Year T-Note	Treasury notes. Original term to maturity: not more than 5 years 3 months. Remaining term to maturity: at least 4 years 2 months.
10-Year T-Note	Treasury notes. Remaining term to maturity: at least 6 years 6 months and not more than 10 years.
Ultra 10-Year T-Note	Treasury notes. Remaining term to maturity: at least 9 years 5 months and not more than 10 years.
Classic T-Bond	Treasury bonds. Remaining term to maturity: at least 15 years and less than 25 years.
Ultra T-Bond	Treasury bonds. Remaining term to maturity: at least 25 years.

*Notes:* The Table displays for each futures the deliverable securities. *Source:* CME Group.

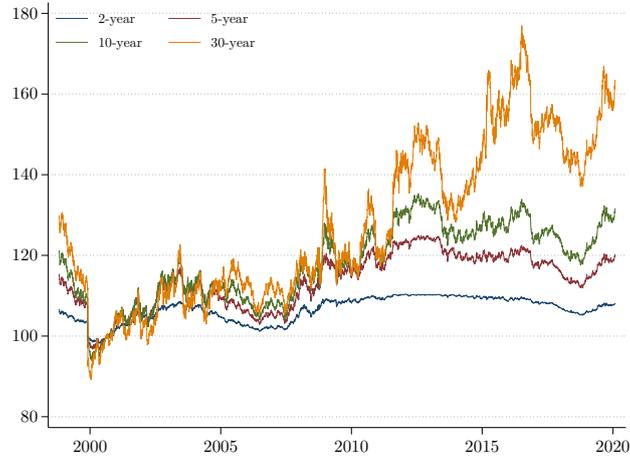
cost-effective to deliver. In practice however, due to so-called “cash market biases”, one security tends to emerge as “cheapest-to-deliver” (CTD). As a result, Treasury futures contracts are best thought of as highly liquid instruments tracking the expected price of the underlying CTD bond.

Because they do not bear coupon payments, these futures are typically acquired for speculative or hedging purposes—rather than as fixed income. Hence, they represent an ideal “synthetic” metrics to gauge market participants’ expectations about near-future U.S. Treasury prices, and consequently U.S. Treasury yields.<sup>10</sup>

Figure 2 plots the daily times series of the 2-, 5-, 10- and 30-year U.S. Treasury futures close prices. Recall that Treasury prices and Treasury yields move in opposite directions, so it is not surprising that Figure 2 mimics an inverse yield curve. Note that the continuous futures series

<sup>10</sup>By nature, Treasury futures prices are better at capturing short-term expectations than spot yields, as their settlement date is at most three month in the future. In contrast, spot yields reflect expectations over the entire life of the bond and are constructed to account for coupon payments. Moreover, there is empirical evidence that futures market lead cash markets when reacting to news (Li and Engle, 1998).

Figure 2. U.S. Treasury Futures Prices, 1998–2020



*Notes:* This Figure plots the series of U.S. Treasury futures prices at maturities 2, 5, 10, and 30 years between 1998 and 2020. U.S. Treasury futures are traded on the Chicago Board of Trade (CBOT) since 1977.

used in this paper track the price of the front-month contract (i.e., the one expiring the soonest) and make no adjustment on rollover days.

### 2.3 *Extracting Shocks from Treasury Announcements*

The announcement date and the auction date are two key moments for financial markets, for they respectively convey information on the supply of and demand for Treasuries at a given maturity.<sup>11</sup> As is common in the high frequency literature, the financial developments occurring within a short time window around these events can be assumed as being mostly due to the news release.

In this paper, we are after supply shocks of public debt instruments. While auction results allow for direct measures of excess demand (such as bid-to-cover ratios, i.e. the total bidden amount relative to the offered one), auction announcements do not provide fresh information beyond the amount

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<sup>11</sup>In Appendix A.1, we model the futures returns as a multivariate white-noise process allowing for ARCH(1) errors with multiplicative heteroskedasticity to assess the importance of Treasury announcements on futures returns' volatility relative to other macroeconomic news and FOMC announcements. We also measure how futures traded volumes change during the auction process. Our results indicate that Treasury announcements are under some level of scrutiny and do matter for financial markets.

being offered. The key challenge is to determine whether this amount falls above or below investors' expectations.

If there was a survey-based forecast of this variable, our job here would be done and forecast errors would serve our purpose as a natural estimator. However, in the absence of such data, we have to make assumptions so as to elicit a market-based expectations measure. In effect, one needs to assume that demand for public debt instruments is fixed within an announcement day.<sup>12</sup> Arguably, there is no reason to believe otherwise. This assumption together with the above-mentioned one (that no systematic changes occur within announcement days other than the news itself) allow us to state the formal relationship between a Treasury futures price (for a given maturity) and the expected supply of that Treasury.

Given the nature of Treasury futures contracts, as mentioned above, their price should reflect investors' expectations about the yield that will prevail by the end of settlement month (plus a risk premium). Consequently, on the approach of an auction, all information relevant to the expected end-of-auction yield (such as the demand for the said Treasury) is incorporated in its futures price. Hence a variation in the price of a futures contract occurring within a short time window around the announcement must originate from a surprise.<sup>13</sup> Because the only relevant figure published on Treasury announcement days is the offered amount, we can safely infer that this surprise reveals a shift to the expected supply of that Treasury.

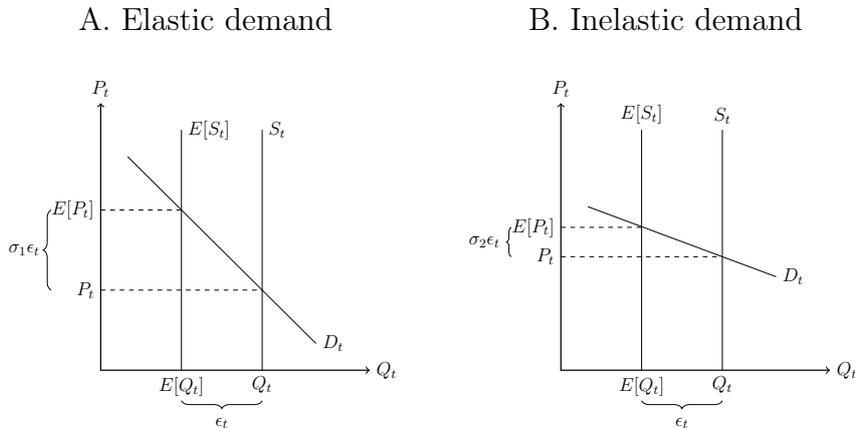
Whether the announcement comes as a positive or a negative surprise can then simply be deduced from plain economic analysis: A price decrease (i.e., a yield increase) reflects a higher-than-expected supply. But the latter informs us on the *sign* of the shock only: Its *magnitude* on the other hand depends on the price elasticity of demand of the Treasury security. To illustrate, Figure 3 represents a supply shock under two different elasticities: Panel A shows the case of an elastic demand, while Panel B that of an inelastic one.

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<sup>12</sup>A somewhat weaker assumption having similar implications is to say that demand for public debt instrument is fixed *on average*. In particular, there is no systematic shift in demand on announcement days.

<sup>13</sup>Note that we assume the risk premium to be constant within the window around the announcement, as in Känzig (2021).

Figure 3. U.S. Treasury Supply Shocks



By definition, supply shocks  $\epsilon_t = Q_t - E[Q_t]$  map into price changes proportionally to the coefficient of elasticity  $\sigma_i < 0$ ,  $i = 1, 2$ . Although the two supply shocks depicted in Panel A and B of Figure 3 are identical, the price variation they trigger differs greatly. Because we only observe futures price changes, we cannot compare the magnitude of shocks happening at different points in time unless the coefficient of elasticity is fixed over time. Consequently, another assumption that needs to be made is that the price elasticity of demand be constant over the period under study. This ensures that changes in Treasury futures prices on announcement days can be compared across periods.<sup>14</sup>

We compute the intraday returns of Treasury futures prices on announcement days between July 1998 and March 2020, by considering only the futures whose underlying bond are being issued.<sup>15</sup> This means, for instance, that during the announcement that took place on August 4, 1999 (cf. Figure 1), we only look at the returns of the 5-, 10-, and 30-year Treasury futures.

Let  $\Delta F_{t,t-1}^{TS,k}$  denote the log-difference in settlement price from  $t-1$  to  $t$  of a

<sup>14</sup>Alternatively, a sufficient condition for validity of our empirical approach is to let the coefficient of elasticity be variable but assume it to be unrelated to characteristics affecting supply beyond what is expected by market participants. If any, variations in elasticity will simply add noise to our measurements.

<sup>15</sup>The data on announcement dates come from [TreasuryDirect.com](http://TreasuryDirect.com) (an official website managed by the U.S. Department of the Treasury Bureau of the Fiscal Service), while those on futures prices come from Thomson Reuters Datasream.

$k$ -year U.S. Treasury front-month futures contract. Because we have more than one maturity, i.e.,  $k \in \{1, \dots, K\}$ , we normalize these returns (by individually subtracting their sample mean and dividing by their standard deviation) and denote the result  $\Delta f_{t,t-1}^{TS,k}$ . The resulting four series are reasonable series of shocks to the supply of U.S. Treasury securities.

#### 2.4 Disentangling Supply-, Monetary- and Financially-Driven Shocks

Arguably, a full trading day is a long time by any financial metric. Albeit empirically sound on average, the *ceteris paribus* assumption high-frequency studies typically make may hold systematically less on some days than others. In particular, on those days when other relevant information—such as monetary policy decisions—is being released to the public, our futures returns  $\Delta f_{t,t-1}^{TS,k}$  might be driven thereby rather than by the Treasury announcement.

To cope with this, we estimate the following regression model (on announcement days, one per Treasury maturity):<sup>16</sup>

$$\Delta f_{t,t-1}^{TS,k} = \mu^k + \beta^k \Delta f_{t,t-1}^{FF} + \Gamma^k X_t' + \eta_t^k \quad (1)$$

where  $\Delta f_{t,t-1}^{TS,k}$  is the ( $k$ -maturity) front-month Treasury futures normalized return,  $\Delta f_{t,t-1}^{FF}$  is the front-month Fed funds futures daily yield change,  $X_t'$  is a set of controls,  $\mu^k$  is a constant,  $\beta^k$ ,  $\Gamma^k$  are coefficients, and  $\eta_t^k$  is an i.i.d. zero-mean error term.<sup>17</sup>

Table 3 below shows the estimated coefficients of Equation 1. Model A (columns 1 to 4) takes the Fed funds futures yield change as sole regressor, while Model B (columns 5 to 8) includes a set of controls. Those are day-of-week fixed effects as well as announcement-number fixed effects.

Increases in the Fed funds futures yield on announcement days are associated on average—if anything—with negative returns in the Treasury

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<sup>16</sup>This approach is similar to the one Romer and Romer (2004) perform in the context of monetary policy.

<sup>17</sup>In practice, Fed funds futures returns need to be adjusted to account for their structure. Following Kuttner (2001), we weight them according to the remaining number of days until settlement date.

futures. In other words, on announcement days that trigger an expected monetary policy tightening, Treasury futures tend to experience lower returns than on days that did not cause such a shift in expected monetary policy.

This is especially true in the benchmark for the 2- and 5-year securities, for which a one-basis point increase in the Fed Funds futures yield brings about a statistically significant change in the futures prices of -0.05 and -0.03 standard deviations respectively. When controlling for other variables, these relationships hold true.

Admittedly, there is little or no interest in interpreting these coefficients beyond their meaningfulness for announcement-day changes in U.S. Treasury futures prices. Accordingly, we perform F-tests of overall significance and report the results in the last row of Table 3. Out of the four specifications in Model B, we reject the joint null hypothesis at the 10% level for two maturities. The returns on the 10-year and 30-year T-note futures seem to be jointly unaffected by changes in expected monetary policy and the controls.

Looking at the  $R^2$  tells us a similar story. Ranging from roughly 0% to 6%, they indicate that—albeit statistically relevant at times—our explanatory variables generally leave unexplained a substantial share of Treasury futures’ prices variability on announcement days. The latter observation is not a concern, for we seek a measure of Treasury supply shocks. Rather, this uniqueness reinforces the view that changes in Treasury futures on announcement days mirror unexpected changes in Treasury supply.

By construction, the residuals  $\hat{\eta}_t^k$  from these regressions are orthogonal to everything *but* the surprise component of the announcement pertaining to unexpected variations in Treasury supply. They qualify therefore as a clean high-frequency measure of Treasury supply shocks.

Note that a one-unit increase in  $\hat{\eta}_t^k$  is a one-standard deviation *increase* in the return of the  $k$ -maturity front-month U.S. Treasury futures contract. However, as argued earlier, positive unexpected returns are associated with supply *decreases*. Therefore, for we are interested in a metrics that correlates positively with supply, we use the inverse of the residuals  $-\eta_t^k = \hat{\xi}_t^k$

Table 3. Regression of Supply Shocks on Monetary Policy and Controls

	Model A: Benchmark				Model B: Controls			
	2-year	5-year	10-year	30-year	2-year	5-year	10-year	30-year
$\Delta f_{t,t-1}^{FF}$	-0.048 (0.01)	-0.029 (0.02)	0.007 (0.02)	-0.028 (0.02)	-0.047 (0.01)	-0.028 (0.02)	0.008 (0.02)	-0.026 (0.02)
Day-of-week F.E.	No	No	No	No	Yes	Yes	Yes	Yes
Ann. Number F.E.	No	No	No	No	Yes	Yes	Yes	Yes
Observations	255	217	197	146	255	217	197	146
$R^2$	0.04	0.02	0.00	0.01	0.07	0.06	0.04	0.03
F-stat	11.4	3.5	0.1	1.4	2.9	2.0	1.3	1.3
Prob. > F	0.001	0.061	0.702	0.234	0.009	0.060	0.270	0.276

*Notes:* This Table shows the estimates of our regression of daily supply shocks (on announcement days) onto expectations about monetary policy over the sample 1998–2020. Model A only includes the front-month Fed funds futures daily yield change ( $\Delta f_{t,t-1}^{FF}$ ), whereas Model B includes day-of-week fixed effects and announcement number fixed effects. Standard errors in parentheses.

as our supply shocks.<sup>18</sup>

## 2.5 U.S. Treasury Supply Shocks: 1998–2020

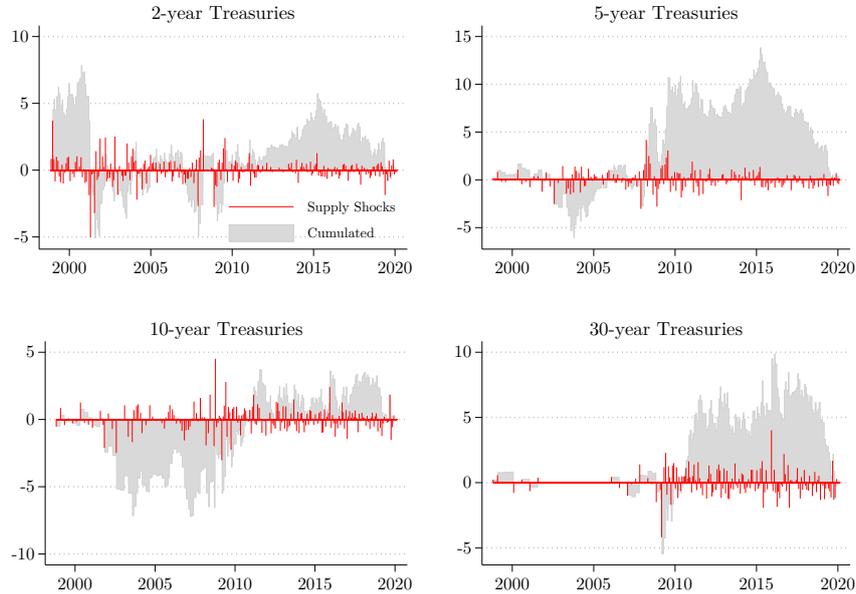
**Historical Shock Series.**—Figure 4 plots the resulting series of supply shocks  $\hat{\xi}_t^k$  for  $k = 2, 5, 10, 30$  years. The solid red spikes show the residuals  $\hat{\xi}_t^k$ , while the shaded areas show the (running) cumulated series of these residuals  $\sum_{s=1}^t \hat{\xi}_s^k$ . By construction, each of these supply shocks series has a zero mean, and therefore sums to zero.

Taken at face values, these series of shocks give only little information as to the stance of public debt management (and, by extension, fiscal policy). In this respect, the cumulated series plotted in Figure 4 offer a better picture.

Notwithstanding, to verify that our series of shocks correctly recount the various fiscal episodes in recent U.S. economic history, Figure 5 plots the the cumulated series of supply shocks summed across maturities, i.e.,  $\sum_k \sum_{s=1}^t \hat{\xi}_s^k$  (shaded area, left-hand-side axis) against detrended U.S. debt-to-GDP (blue solid line, right-hand-side axis), between 1998 and 2020. Because debt-to-GDP is a quarterly variable, we interpolate it linearly at daily fre-

<sup>18</sup>Note that all our results are robust to using changes in Treasury futures prices on announcement days  $\Delta f_{t,t-1}^{FF}$  directly as measures of supply shocks, rather than the residuals in Equation (1).

Figure 4. Supply Shocks  $\hat{\xi}_t^k$ , 1998–2020



*Notes:* This Figure plots the series of supply shocks  $\hat{\xi}_t^k$  at maturities  $k = 2, 5, 10, 30$  years. The solid red spikes show the residuals  $\hat{\xi}_t^k$ , while the shaded areas show the running cumulated series of these residuals  $\sum_{s=1}^t \hat{\xi}_s^k$ .

quencies. Clearly, our supply shocks series account extremely well for the evolution of the debt supply in the U.S. throughout the sample.

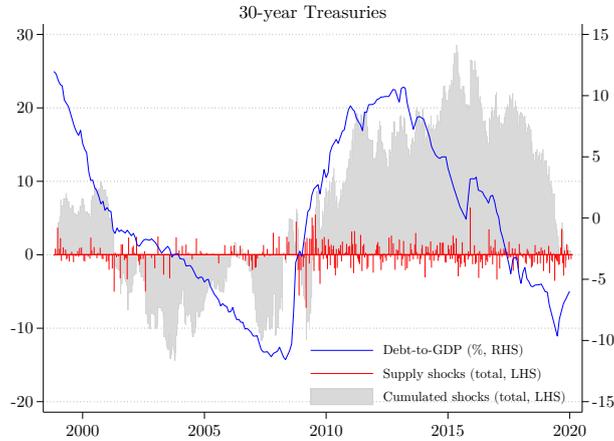
This serves us as strong evidence that our methodology is well suited to identify structural shocks to the supply of U.S. Treasury securities, and thereby to the level of debt-to-GDP.<sup>19</sup>

**Shock Densities.**— An additional sanity check that our shock series truly captures surprises in the supply of U.S. Treasuries can be performed by inspecting their respective empirical probability density functions.

In this regard, the solid red lines from Figure 6 plot the densities of U.S. Treasury supply shocks  $\hat{\xi}_t^k$  at maturities  $k = 2, 5, 10, 30$  years on different types of days, estimated using Epanechnikov kernels. Additionally, Table 4 provides summary statistics of the four series of shocks.

<sup>19</sup>To lose so little information as possible, we use the four series from Figure 4 as distinct instruments rather than the summarized information shown in Figure 5 when we perform the local projections in Section 3.

Figure 5. Debt-to-GDP & Supply Shocks



*Notes:* This Figure plots the series of supply shocks summed across maturities, i.e.,  $\sum_k \hat{\xi}_t^k$  (red spikes, left-hand-side axis) as well as their cumulated series  $\sum_k \sum_{s=1}^t \hat{\xi}_s^k$  (shaded area, left-hand-side axis) against U.S. debt-to-GDP (blue solid line, right-hand-side axis), between 1998 and 2020. The debt-to-GDP is expressed in deviations from trend.

The appearance of these densities conveys a comforting general message, in that they do not display symptoms of ill-suited methodology. Because they are the residuals from Equation (1), these four series are centered around zero. Although not perfectly symmetric, they have a skewness close to zero.<sup>20</sup> Moreover, their leptokurtic shape (i.e., their positive excess kurtosis) indicates fat tails: Rare events have a relatively high probability of occurring, a common property in financial time series (Lucas and Klaassen, 1998).

Yet, a natural question that emerges at this point is how do these densities compare with “normal” days. To address this question, we re-estimate Equation (1) for each maturity but on days when no particular event relevant to financial market participants occurs.<sup>21</sup> Comparing our series of

<sup>20</sup>In fact, we cannot reject the null hypothesis that they are normally distributed at the 99% level solely based on their skewness.

<sup>21</sup>Akin to our ARCH(1) approach in Appendix A.1, we take as “normal” those days when there is no FOMC publication, no macroeconomic news, no recession, no Treasury announcement nor auction. The macroeconomic news are average hourly earnings, business inventories, capacity utilization, Chicago PMI, Conference Board CCI, construction spending, consumer credit, core CPI, CPI, factory orders, GDP (advance and final), ISM manufacturing index, personal consumption, Philadelphia Fed index, retail sales (includ-

Table 4. Supply Shocks Summary Statistics

	2-year	5-year	10-year	30-year
Mean	0	0	0	0
Standard Deviation	0.89	0.89	0.91	1.01
Skewness	-0.29	0.36	0.42	0.07
Kurtosis	9.78	6.15	6.30	5.35
Observations	255	217	197	146

supply shocks with the resulting series of residuals is a good placebo test for our methodology.

The grey shaded area shown in Figure 6 corresponds to the empirical probability density functions of the placebo residuals. It appears that our supply shocks series are more volatile and recount more occurrences of rare events than their respective placebo counterparts. This can be deduced from the probability mass they exhibit in excess of that of the placebo, away from the center. The latter holds especially true for the 2-, 5- and 10-year shocks, and somewhat less so for the 30-year shocks.

The variance ratio as well as the p-value for the test that variance on announcement days exceeds that on placebo days is displayed on each subplot. Accordingly, we reject the null hypothesis of equal variance at the 99% level for all maturities and thus conclude that our series of U.S. Treasury supply shocks do reflect abnormally high market reactions.

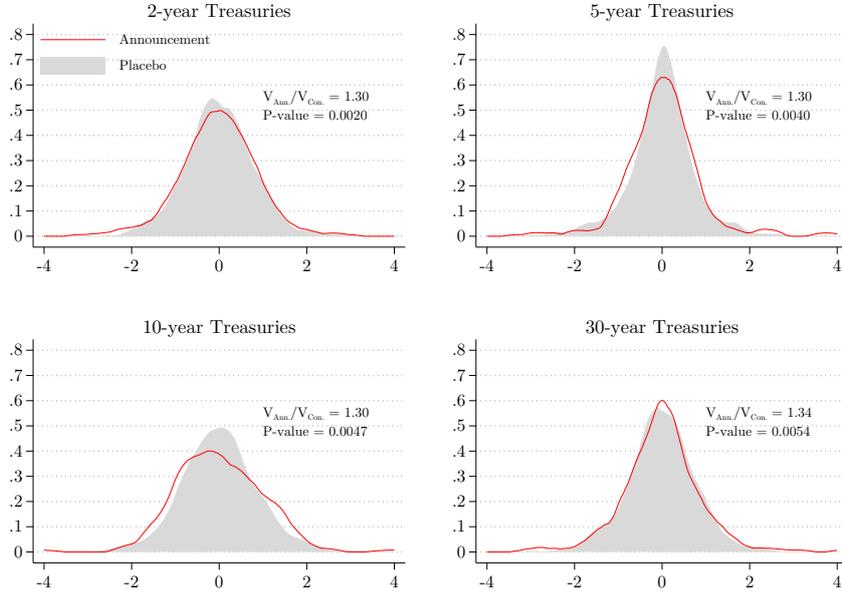
***Shock Correlations.***— Another interesting statistics to consider is the correlation between supply shocks of different maturities on simultaneous-announcement days. Table 5 displays the set of pairwise Pearson correlations between the four series as well as the number of observations for each pair.

As can be seen from the table, on days when multiple maturities are being announced, the surprise triggered by the announcement is consistent across maturities. In particular, simultaneously announced securities tend to produce market reactions that correlate by 61% to 94%, with the latter relationship being a negative function of the maturity differential.

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ing and excluding autos), trade balance, University of Michigan CCI (preliminary and final).

Figure 6. Supply Shocks  $\hat{\xi}_t^k$ , Probability Density Functions



*Notes:* This Figure plots the empirical probability density functions of U.S. Treasury supply shocks at maturities  $k = 2, 5, 10, 30$  years on different types of days, estimated using Epanechnikov kernel. The solid red line stems from announcement days, whereas the grey shaded area corresponds to placebo days. The  $x$ -axis is expressed in standard deviations from the mean. The variance ratio and the p-value for the test that variance on announcement days exceeds that on placebo days is displayed on each subplot.

This result is in line with the preferred habitat theory which posits that different investors value maturities differently, thus asking for a premium to hold bonds outside their maturity preference (Modigliani and Sutch, 1966, Vayanos and Vila, 2009). Indeed, following a surprise change in the supply of Treasury securities of a given maturity, the resulting yield change might make it optimal for investors with a preferred habitat to hold more or less of the neighboring maturities.

As a result, potentially all maturities are subject to this substitution effect and the shock travels across the yield curve. But due to the heterogeneity in investors preferences, the yield change will occur more strongly for maturities relatively closer to the newly issued ones.

Table 5. Supply Shocks Correlations

	2-year	5-year	10-year	30-year
2-year	1.00 (255)	0.85 (167)		
5-year	0.85 (167)	1.00 (217)	0.94 (39)	0.61 (7)
10-year		0.94 (39)	1.00 (197)	0.89 (146)
30-year		0.61 (7)	0.89 (146)	1.00 (146)

*Notes:* Each cell displays the pairwise Pearson correlations between the row and the column variable. The number of observations for each pair is displayed in brackets under the correlation coefficient. Empty cells refer to pairs with no observation.

### 3 Financial Effects of Treasury Supply Shocks

In this section, we study the interaction between Treasury supply and the financial markets. To do so, we estimate the impulse response functions (IRFs) of several financial variables to shocks to the total amount of securities offered by the U.S. Treasury by means of local projections with instrumental variables (LP-IV).<sup>22</sup> We initially present the empirical framework and argue that the Treasury supply shock series computed in Section 2 are valid instruments, and we then show the results for several financial variables. In particular, we look at variations in Treasury yields, stock prices, corporate bond indices, several measures of risk, inflation expectations, as well as the liquidity premium.

#### 3.1 Methodology

***Infinite Moving Average Representation.*** — Let  $\varepsilon_t$  be a  $n$ -dimensional vector of structural shocks, and  $y_t$  be  $n$ -dimensional vector of observables. By definition of structural shocks, the components of  $\varepsilon_t$  are serially and mutually independent, zero-mean and unit-variance processes. The elements of  $y_t$  are stationary processes driven by  $\varepsilon_t$ .

<sup>22</sup>See, among others, Jordà (2005), Jordà et al. (2015), Ramey and Zubairy (2018), Stock and Watson (2018), Jordà et al. (2020).

If  $\varepsilon_t$  affects  $y_t$  linearly, then  $y_t$  admits an infinite MA representation:

$$y_t = \mu + \sum_{h=0}^{\infty} \phi_h \varepsilon_{t-h}, \quad (2)$$

where  $\mu$  is a  $n$ -dimensional vector of constants, and  $\phi_h$  are  $(n \times n)$ -dimensional matrices of coefficients. The elements of  $\phi_h$  are the IRFs. Indeed, the  $i, j$ -th element of  $\phi_h$  is the effect of a one-unit shock to  $\varepsilon_{i,j}$  on  $y_{i,t+h}$ :  $\phi_{i,j,h} = E[y_{i,t+h} | \varepsilon_{j,t} = 1] - E[y_{i,t+h}]$ .

Without loss of generality, let us assume that the first element in  $y_t$  (i.e.,  $y_{1,t}$ ) is the supply of U.S. Treasury securities, and thus  $\varepsilon_{1,t}$  is the structural shock thereto. What we are after in this paper is therefore only the first column of the  $\phi_h$ 's, that is,  $\phi_{i,1,h}$ .

**Local Projections with Instrumental Variables.**—The idea of local projections with instrumental variables is to estimate the  $\phi_{i,1,h}$ 's in Equation (2) directly through the two-stage least-squares (2SLS) estimation of

$$y_{i,t+h} = \alpha_i + \phi_{i,1,h} y_{1,t} + \nu_{i,t+h}, \quad (3)$$

using  $z_t$  as an instrument for  $y_{1,t}$ . For the  $z_t$  to be a valid instrument, three assumptions are needed:

$$\begin{aligned} E[z_t \varepsilon_{1,t}] &\neq 0, && \text{(Relevance condition)} \\ E[z_t \varepsilon_{j,t}] &= 0 \text{ for } j > 1, && \text{(Exogeneity condition)} \\ E[z_t \varepsilon_{j,t+h}] &= 0 \text{ for } h \neq 0. && \text{(Lead-lag exogeneity)} \end{aligned}$$

Under these assumptions, the  $\nu_{i,t+h}$ 's are uncorrelated to  $z_t$ . However, for  $h > 0$ , the  $\nu_{i,t+h}$ 's are serially correlated. One thus needs to compute Newey-West standard errors in order to account for heteroskedasticity.<sup>23</sup>

As argued in Section 2, the residuals from the regression of changes in Treasury futures prices on announcement days onto a set of controls and a measure of monetary policy expectations (see Equation (1)) can be interpreted as surprises to the supply of Treasury securities.

Because they most certainly correlate with the offering amount of Treasuries, and because there are likely exogenous to both (i) the structural

<sup>23</sup>Following Andrews (1991), we use a Bartlett kernel with a truncation lag of  $0.75T^{1/3} - 1$ .

innovations to other variables in the system and (ii) the structural innovations to Treasury supply in the few following days, these four series of shocks qualify as valid instruments.

### 3.2 Data

As shown in Figure 1, announcements by the U.S. Treasury disclose the maturities and the volumes of the tendered securities, along with an estimate of the amount of maturing securities and the resulting net operation. Arguably, what is likely to matter most for financial market participants is the offering amount *net* of the maturing amount, i.e., the amount of cash that is being raised (or paid down). Note that this measure sums volumes across the four maturities, so it is unidimensional.

In practice, both the amount offered by the U.S. Treasury and the surprises they trigger are observed on announcements days only. In order to study the implications of an increase in the *total* net supply of debt securities, we set them to zero on days when no announcement occurs. In terms of Equation (3),  $y_{1,t}$  is then the change in the cumulated series of Treasury offerings, and  $z_t$  is the matrix of the four supply shocks series depicted in Figure 4, i.e.,  $\hat{\xi}_t^k$ .

The other elements in the dependent variable ( $y_{i,t}$ ,  $i > 1$ ) are various financial variables of interest retrieved from the Federal Reserve Economic Data (FRED), from Yahoo Finance or from Bloomberg:<sup>24</sup>

- **Treasury bond yields:** We use the 3-month, 1-, 2-, 5-,10- and 30-year Treasury constant maturity rates.
- **Stock prices and volatility:** We include the S&P 500 index and VIX,<sup>25</sup>
- **Corporate bond yields:** We use Moody’s AAA and BAA corporate bond yields;
- **Inflation expectations:** We use 5- and 10-year break even inflation rates;

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<sup>24</sup>Some variables have up to 30 gaps in the daily data relative to the S&P 500 index series over the entire sample. We interpolate them linearly when needed, though all results shown are robust to not interpolating.

<sup>25</sup>To improve comparability, we min-max normalize the S&P 500 index and the VIX.

- **Equity premium:** We use the year-on-year return of the 5000 Wilshire index minus the 10-year Treasury constant maturity rate;<sup>26</sup>
- **Term premium:** We use the 2-, 5- and 10-year Treasury term premium as well as the average expected target rate 2-, 5- and 10- years ahead.<sup>27</sup>
- **Risk premium:** We use the spread between Moody’s AAA and BAA corporate bond yields;
- **Liquidity premium:** We use the spreads between Resolution Funding Corporation (Refcorp) bonds yields and Treasury zero-coupon bonds yields at various maturities.<sup>28</sup> Alternatively, we use the spreads between the Moody’s AAA (or the Moody’s BAA) corporate bond yields and the 10-year Treasury constant maturity rate.<sup>29</sup>

As is common in the related literature, we add some controls to the 2SLS estimation of Equation (3).<sup>30</sup> These are the two first lags of  $y_t$  (as suggested by the Schwarz selection criterion), day-of-week fixed effects, dummies for bidding and auction days, and a time trend.

Our baseline sample starts on October 28, 1998 and ends on January 31 2020, providing 5343 observations. Due to data availability, estimations involving inflation expectations (i.e., the 5- and 10-year break even inflation rates) use a sample starting on January 2, 2003 (4300 observations).

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<sup>26</sup>Alternatively, using the year-on-year return of the 5000 Wilshire index minus the ICE BofA BBB corporate bond yields similar results. Note that we fill a few gaps in the 5000 Wilshire index through linear interpolation.

<sup>27</sup>These measures come from the three-factor model derived in Christensen et al. (2011) and is available on San Francisco Fed’s website. Using the measure by Kim and Wright (2005) instead yields similar results.

<sup>28</sup>As argued by Longstaff (2004), Refcorp bonds are special because their principal is fully collateralized by Treasury bonds. Thus, Refcorp bonds hold the same credit risk as Treasury bonds. Since Treasury bonds are more liquid, comparing their prices with those of Refcorp bonds provides an ideal measure of liquidity premia.

<sup>29</sup>These measures of liquidity are inspired by Krishnamurthy and Vissing-Jorgensen (2012).

<sup>30</sup>Adding controls can improve the fit substantially, as it (i) helps strengthen instruments in the first stage, (ii) deals with potential instrument endogeneity (conditional on observables). See Stock and Watson (2018) for details.

### 3.3 Results

**First Stage.**—Our empirical framework relies on the assumption that our instruments are relevant and exogenous. Albeit heuristically sound, the relevance assumption—and the extent to which it translates into strong instruments—can be tested. This is important because inference becomes unreliable when instruments are weakly correlated with the endogenous regressor (Andrews et al., 2019).

We compute the robust F-statistic proposed by Olea and Pflueger (2013), together with the critical values for the effective F-statistic at the 95% confidence level under the null hypothesis that the Nagar (1959) bias of the 2SLS estimation is greater than 10% of the benchmark.

We find a robust F-statistic of 10.38, which exceeds the critical value 10.25 and therefore allows us to reject the null hypothesis of weak instruments.<sup>31</sup>

**Treasury Bonds & Term Structure of the Yield Curve.**—The first set of financial variables we study consists of U.S. Treasury yields, thereby fulfilling two purposes. On the one hand, making sure that Treasury yields, following changes in supply, go in directions suggested by theory is a useful sanity check. On the other hand, comparing the response of shorter-term and longer-term yields allows to investigate the resulting changes in the term structure of the yield curve.

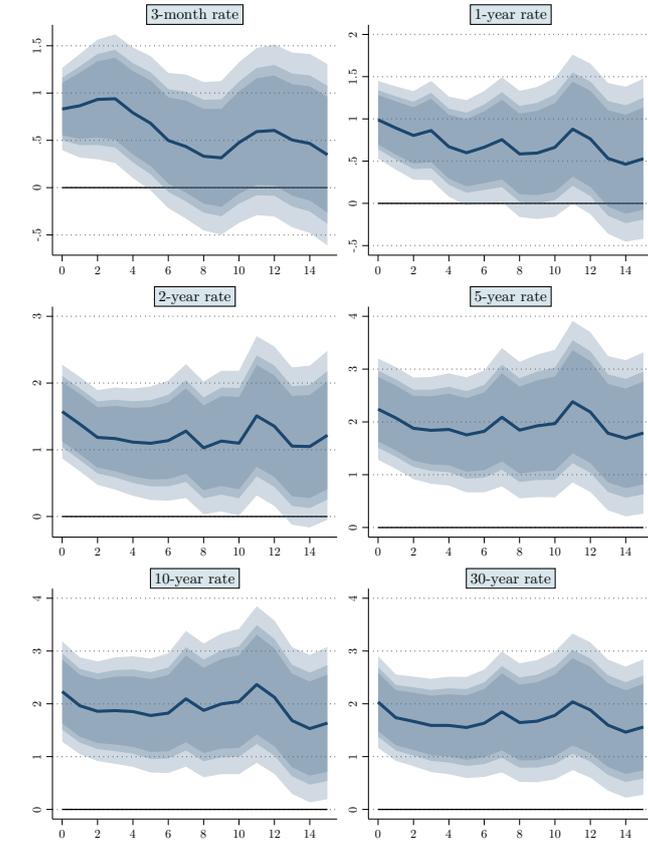
Figure 7 plots the IRFs of Treasury bond yields to Treasury supply shocks. In particular, each subplot shows the IRF to a 1-billion-dollar increase in the supply of U.S. Treasury securities of the above-mentioned variable. The blue shaded areas are the CI's at the 90%, 95% and 99% level computed using Newey-West standard errors. The horizontal axis represents the number of business days following the impact.

Unsurprisingly, when the U.S. Treasury issues more securities than expected, the price of U.S. Treasury bonds decreases at all maturities. As shown in Figure 7, a 1-billion-dollar increase in Treasury supply leads to a rise in the yields of the 3-month, 1-, 2-, 5-, 10- and 30-year bonds. The

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<sup>31</sup>On the smaller sample that includes inflations expectations, the robust F-statistic is 10.94, leading to the same conclusions.

Figure 7. IRFs to U.S. Treasury Supply Shocks of Treasury Bond Yields



*Notes:* Each subplot shows the IRF to a 1-billion-dollar increase in the supply of U.S. Treasury securities of the above-mentioned variable. The blue shaded areas are the CI's at the 90%, 95% and 99% level computed using Newey-West standard errors. The  $x$ -axis represents business days from impact. All variables are expressed in basis points.

magnitude of the effect ranges roughly from 1 to 2 basis points depending on the maturity.

Noticeably, this increase is significant on impact for all maturities, but more persistent for longer maturities. Indeed, both the 3-month and 1-year Treasury yields return to their original level about one week after the shock, whereas the 2-, 5-, 10- and 30-year Treasury yields stay higher for about three weeks.

In light of this uniform upward shift in the yield curve, an interesting question to ask is how much of this shift is due to an increase in the short-term rates, as opposed to an increase in the term premium. Under the pure ex-

pectation hypothesis of the yield curve, equilibrium long-term yields ought to reflect expected future short-term rates. In practice, however, long-term yields tend to compensate investors more than suggested by short-term yields, and therefore pay a term premium.

The observed departure from this hypothesis is usually explained by the so-called preferred habitat theory (Modigliani and Sutch, 1966, Vayanos and Vila, 2009), whereby investors have heterogenous preferences over the maturities they are willing to hold. Under this view, investors acquire bonds outside their preferred habitat only in exchange for a term premium. Accordingly, an increase in the supply of long-term Treasuries will tend to raise the premium since investors must be compensated for exiting their habitat (Modigliani and Sutch, 1967, Greenwood and Vayanos, 2014).

Figure 8 plots the IRFs to Treasury supply shocks of both the average expected target rate 2-, 5- and 10- years ahead, and the 2-, 5- and 10-year Treasury term premium. As before, each subplot shows the IRF to a 1-billion-dollar increase in the supply of U.S. Treasury securities of the above-mentioned variable.

The results are in line with the above-mentioned theoretical mechanism. On the one hand, the increase in Treasury supply causes an immediate significant (about 1 basis point) yet short-lived (two days) increase in the average expected target rate several years ahead. On the other hand, the term premium slowly increases (by roughly 1.5 basis point), and remains higher for a relatively long time (almost three weeks).<sup>32</sup>

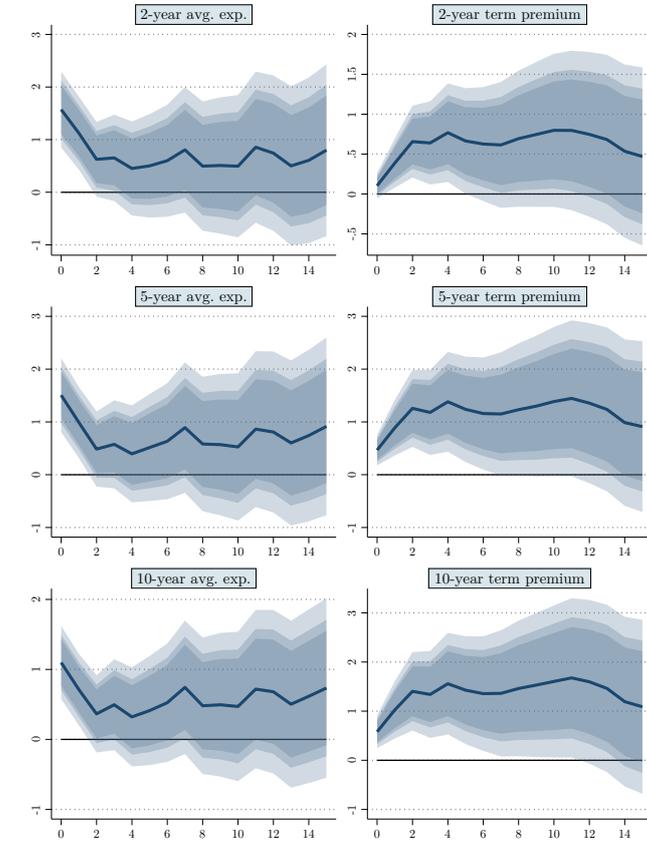
Overall, we find evidence that surprise increases in the supply of 2-, 5-, 10- and 30-year debt securities cause a significant upward shift in the yield curve at all maturities, the latter effect being only partly explained by an increase in the short rates. Instead, investors appear to command a yield in excess of the one predicted by short rates in order to hold the newly issued securities, thereby commanding a higher term premium.

***Stocks, Volatility & Corporate Bonds.***—The second set of variables under study in this section relates to the markets of stocks and corporate

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<sup>32</sup>Our results are also consistent with the empirical findings by Laubach (2011), who conversely show that fiscal surplus shocks cause yields decreases that are exacerbated by changes in the term premium.

Figure 8. IRFs to U.S. Treasury Supply Shocks of the Term Premium

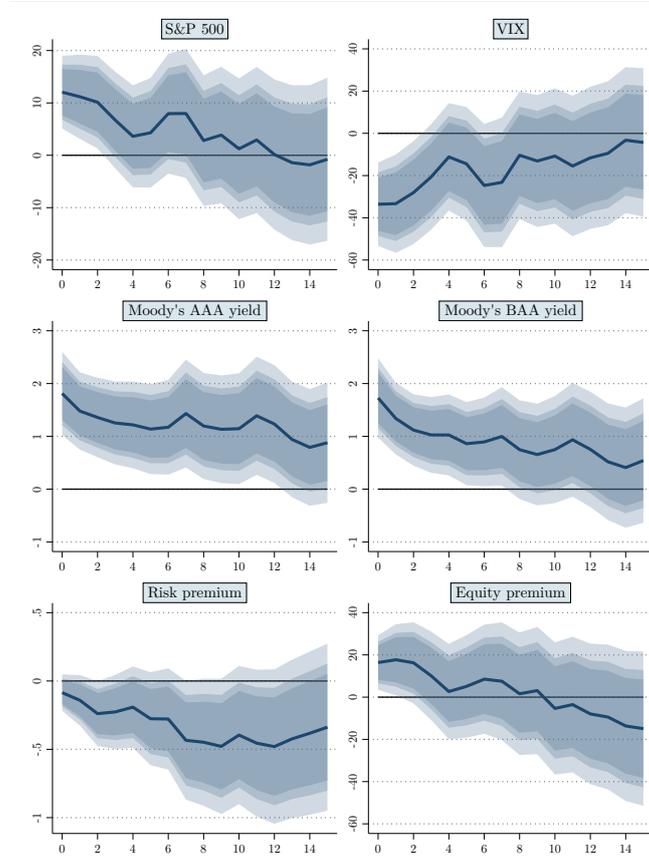


*Notes:* Each subplot shows the IRF to a 1-billion-dollar increase in the supply of U.S. Treasury securities of the above-mentioned variable. The blue shaded areas are the CI's at the 90%, 95% and 99% level computed using Newey-West standard errors. The  $x$ -axis represents business days from impact. All variables are expressed in basis points.

bonds. Here, we investigate whether Treasury supply shocks are perceived as good news by looking at stock prices and volatility. We also address how these shocks affect borrowing costs of the corporate sector and the level of perceived risk thereof. Finally, we estimate whether changes in Treasury supply bring about an outperformance of stocks with respect to safe bonds.

To this end, Figure 9 plots the IRFs of stock prices and volatility, corporate bond yields, the risk premium and the equity premium to Treasury supply shocks. As before, each subplot shows the IRF to a 1-billion-dollar increase in the supply of U.S. Treasury securities of the above-mentioned variable. The blue shaded areas are the CI's at the 90%, 95% and 99% level com-

Figure 9. IRFs to U.S. Treasury Supply Shocks of Stocks, Volatility & Corporate Bonds



*Notes:* Each subplot shows the IRF to a 1-billion-dollar increase in the supply of U.S. Treasury securities of the above-mentioned variable. The blue shaded areas are the CI's at the 90%, 95% and 99% level computed using Newey-West standard errors. The  $x$ -axis represents business days from impact. All variables are expressed in basis points.

puted using Newey-West standard errors. The horizontal axis represents the number of business days following the impact.

A one-billion-dollar increase in the supply of U.S. Treasury securities is perceived as good news for the stock market, as it drives stock prices up by about 10 basis points on impact, and leads to a decrease in market volatility of about 30 basis points. Both effects are statistically significant on impact at the 99% level and last for about three to four days following the shock, before returning to zero.

Moreover, corporate bonds yields increase by about 2 basis points. The

effect is significant at the 99% level on impact, and lasts for two to three weeks. This surge in bond yields indicates a worsening in financing conditions for the corporate sector stemming from the surprise increase in Treasury supply. At the same time, in accordance with the response of the VIX, the risk premium decreases by about 0.5 basis point, and significantly so for almost three weeks.

Unsurprisingly, as a result of the simultaneous rise in stock prices and the fall in bond yields, the equity premium spikes (significantly at the 99% level) on impact, but vanishes quickly. The magnitude of the effect represents an annualized outperformance of stocks returns over bonds yields that is about 20 basis points higher due to the shock.

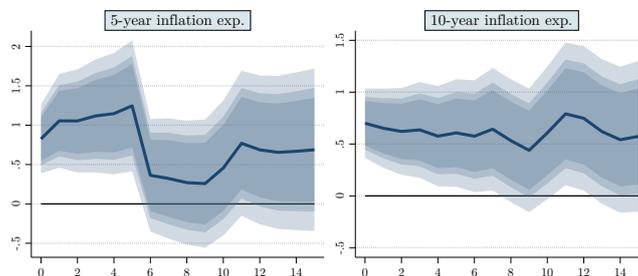
All in all, the results from the local projections represented in Figure 9 provide strong evidence that shocks to the supply of U.S. Treasury bring about sizable and significant consequences on the financial markets. With higher stocks and lower volatility, these shocks appear to be relatively good news for market participants. Yet, they trigger an increase in borrowing costs of the corporate sector but a decrease in the risk premium, and the outperformance of stocks that they generate translate into a higher equity premium.

***Inflation Expectations.***—The third set of variables of interest applies to inflation expectations, which we measure using 5- and 10-year break even inflation rates. Those are the inflation rates that—if they materialize—make the return on an investment into an inflation-indexed Treasury security equivalent to the return on an investment into a regular Treasury security. Since it is in investors' best interest to price inflation correctly, break-even inflation rates are good measures of inflation expectations.

Recall however that due to data availability, the estimates shown here use a smaller sample than in the other specifications. In fact, our measures of inflation expectations are observable starting on January 2, 2003 only.

Figure 10 plots the IRFs of inflation expectations to Treasury supply shocks. As usual, each subplot shows the IRF to a 1-billion-dollar increase in the supply of U.S. Treasury securities of the above-mentioned variable. The blue shaded areas are the CI's at the 90%, 95% and 99% level computed

Figure 10. IRFs to U.S. Treasury Supply Shocks of Inflation Expectations



*Notes:* Each subplot shows the IRF to a 1-billion-dollar increase in the supply of U.S. Treasury securities of the above-mentioned variable. The blue shaded areas are the CI's at the 90%, 95% and 99% level computed using Newey-West standard errors. The  $x$ -axis represents business days from impact. All variables are expressed in basis points.

using Newey-West standard errors. The horizontal axis represents the number of business days following the impact.

We find that inflations expectations as measured by 5- and 10-year break-even inflation rates soar subsequent to a one-billion-dollar surprise increase in the supply of U.S. Treasury securities. In particular, the inflation rate expected to prevail five (ten) years following the shock increases by 0.75 basis point (1 basis point). Albeit significant at the 99% level on impact, this effect dissipates one to two weeks after the shock.

Our finding is in line with the theoretical framework developed by Bhattarai et al. (2014) under the non-Ricardian regime of passive monetary policy and active fiscal policy, which predicts that public debt is inflationary through household wealth effects.

This result is also consistent with the classic view that when it increases, *ceteris paribus*, the level government debt gives rise to higher fiscal deficits, which eventually urges seigniorage and raises inflation (Sargent and Wallace, 1981). Accordingly, positive Treasury supply shocks, for they might signal weaker fiscal discipline, elevate anticipated prices at large horizons.

***Liquidity Premium.***—The final variable whose response to Treasury supply shocks is estimated in this paper is the liquidity premium. The liquidity premium is defined as the difference in yield between two equally risky bonds of similar maturity whose liquidity differ. It is the return

investors are willing to forego in exchange for an asset of superior liquidity, and it is usually decreasing in the supply of the asset.<sup>33</sup>

U.S. Treasury bonds are thought to carry safety and liquidity attributes which command a convenience yield over corporate bonds, giving rise to a safety and a liquidity premium. There is consensus in the macro-financial literature—both theoretical and empirical—that the liquidity premium is decreasing in the supply of Treasuries, at least in the short run (Longstaff, 2004, Krishnamurthy and Vissing-Jorgensen, 2012, Nagel, 2016, Du et al., 2018). Arguably, our methodology offers a cleaner way than previous studies to estimate this relationship.

For this purpose, Figure 11 plots the IRFs of the liquidity premium to Treasury supply shocks. As earlier, each subplot shows the IRF to a 1-billion-dollar increase in the supply of U.S. Treasury securities of the above-mentioned variable. The blue shaded areas are the CI's at the 90%, 95% and 99% level computed using Newey-West standard errors. The horizontal axis represents the number of business days following the impact.

Looking at our first measure of liquidity premium, namely the Refcorp spreads at various maturities, indicates a drop in the price of liquidity of 0.25 basis points. Though sometimes non-significant on impact, the effect 2-, 5-year and 10- and 20-year spreads is globally significant at least at the 90% level.

Turning to our second measure of liquidity, i.e., the AAA and BAA spreads, allows us to confirm the above evidence. Indeed, both spreads experience a significant decrease of half a basis point on impact, followed by a persistent decrease that reaches 1 basis point for the AAA spread and 1.5 basis point for the BAA spread. The effect lasts for more than three weeks.

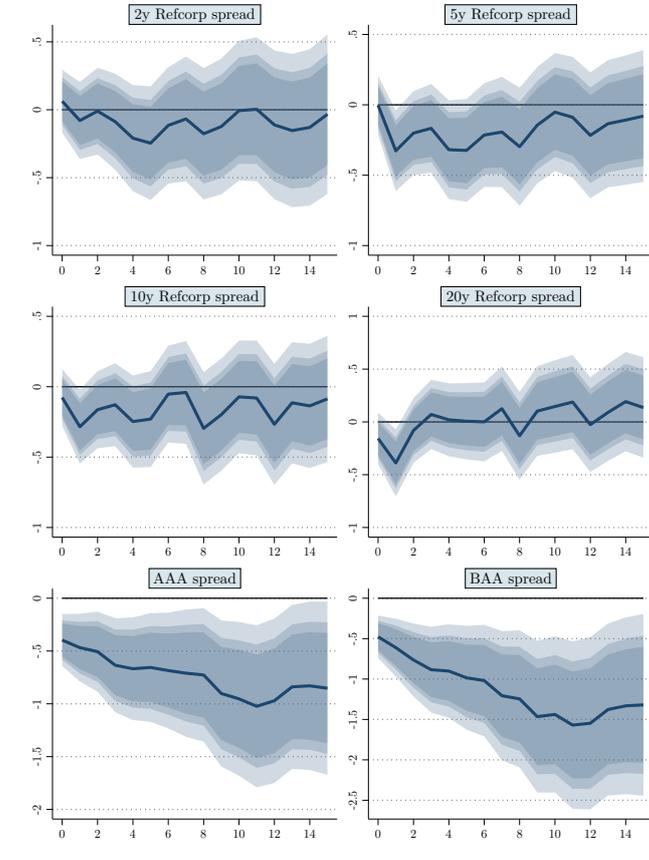
To sum up, the significant drop in the liquidity services provided by U.S. Treasury securities as a result of a positive shock to the supply thereof is in line with the aforementioned literature.<sup>34</sup>

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<sup>33</sup>This is because the marginal liquidity services provided by a given asset are decreasing in its holding (Vayanos and Vila, 1999).

<sup>34</sup>Note that the spread between the 3-month general collateral repurchase agreement rate and the 3-month Treasury constant maturity rate, a liquidity measure suggested by Nagel (2016), moves very similarly to the AAA spread following Treasury supply shocks. However, because including the variable leads to weaker instruments (robust F-stat of

Figure 11. IRFs to U.S. Treasury Supply Shocks of the Liquidity Premium



*Notes:* Each subplot shows the IRF to a 1-billion-dollar increase in the supply of U.S. Treasury securities of the above-mentioned variable (in basis points). The blue shaded areas are the CIs at the 90%, 95% and 99% level computed using Newey-West standard errors. The  $x$ -axis represents business days from impact. All variables are expressed in basis points.

## 4 Conclusions

We present a novel identification strategy of U.S. Treasury supply shocks based on Treasury auction data. We interpret changes in front-month Treasury futures prices around public announcements by the Treasury as shocks to expected supply of debt securities by the U.S. government. After briefly describing the theoretical mechanism between Treasury futures prices and expected debt supply, we isolate the component of price variation in futures pertaining to Treasury announcements between 1998 and 2020.

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9.74), we exclude it from our main specification.

We then study how Treasury supply affects financial markets by means of local projections, using our series of shocks as instrumental variables. In particular, we look at Treasury rates and the term structure of the yield curve, stock prices and volatility, corporate bond yields, the risk premium, the equity premium, as well as the liquidity premium.

We show that Treasury supply shocks have sizable and significant effects on financial markets. A positive surprise in Treasury supply causes an upward shift in the yield curve, the latter being only partly induced by an increase in the short rates. Rather, investors command a higher term premium to hold the newly issued securities.

At the same time, a positive supply shock is good news for market participants, though it increases borrowing costs of the corporate sector: Stock prices and the equity premium go up, volatility and the risk premium go down, and corporate bond yields increase. Yet, for it might signal higher future fiscal deficits, inflation expectations soar. Finally, the liquidity premium decrease following the shock, confirming previous findings that the liquidity services provided by Treasury securities are a negative function of the supply thereof.

Our paper, we believe, sets the stage for exciting further research at least on two grounds. First, it provides an ideal measure of shocks to the supply of U.S. Treasuries that—if taken at monthly frequencies—could be used to test empirically the theoretical predictions of the Ricardian equivalence. Second, if the shocks to the supply of debt securities that we identify in this paper constitute an accurate prediction of future government deficits—as the evidence regarding inflation expectations might suggest—an aggregation thereof could even serve as a sensible instrument to evaluate the macroeconomic dynamic causal effects of fiscal policy.

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