Online Appendix

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

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Appendix

A.1 Treasury Auction Schedule

Table A1 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).

Table A1. 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
2-year notes	Monthly	End of month
3-year notes	Monthly	Middle of month
5-year notes	Monthly	End of month
7-year notes	Monthly	End of month
10-year notes	Monthly	Middle of month
30-year bonds	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.

A.2 Treasury Futures Eligible Securities

Table A2 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.

Table A2. Treasury Futures Contracts

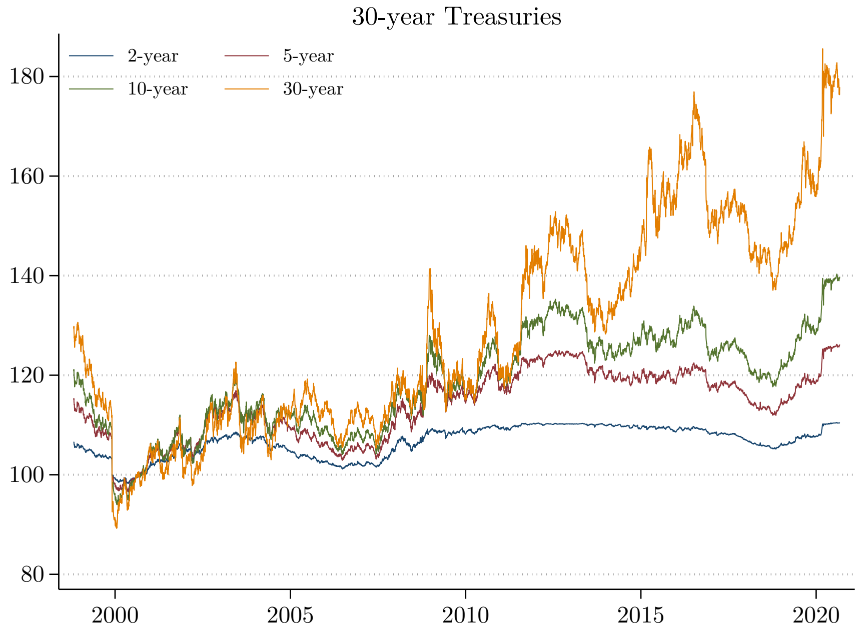
Futures	Deliverable
2-Year T-Note	Treasury notes. Original term to maturity: not more than 5 years 3 months. Remaining term to maturity: at least 1 year 9 months and not more than 2 years.
3-Year T-Note	Treasury notes. Original term to maturity: not more than 5 years 3 months. Remaining term to maturity: 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.

A.3 Treasury Futures Close Prices

Figure A1 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 A1 mimics an inverse yield curve. Note that the continuous futures series 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.

Figure A1. 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.

A.4 Treasury Demand Price Elasticity

To illustrate the role of Treasury demand price elasticity for our identification strategy, Figure A2 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.

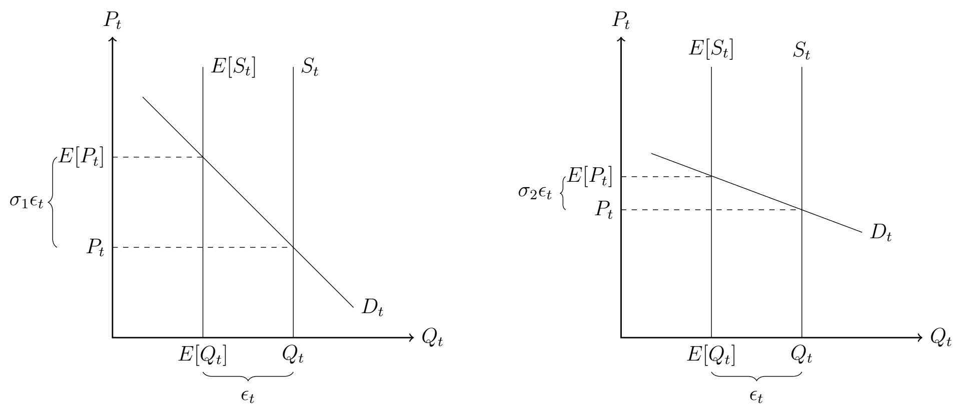
By definition, supply shocks $\epsilon_t = Q_t - E[Q_t]$ map into price changes proportionally to the coefficient of elasticity $\sigma_i < 0$, $i = 1, 2$. Although the two supply shocks depicted in Panel A and B of Figure A2 are identical, the price variation they trigger differs greatly. Because we 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.

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.

Figure A2. U.S. Treasury Supply Shocks

A. Elastic demand B. Inelastic demand

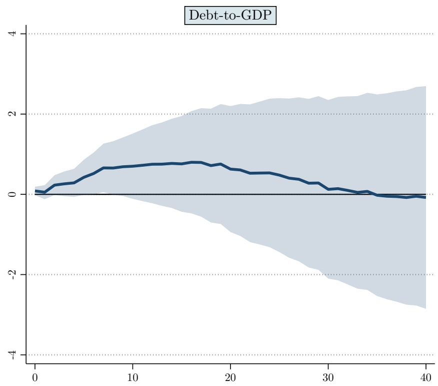


A.5 Treasury Supply Shocks and Debt-to-GDP

Figure 3 in the paper plots the the cumulated series of supply shocks summed across maturities against detrended U.S. debt-to-GDP between 1998 and 2020 in an attempt to provide 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.

One way to formalize this link is to apply the LP-IV approach to debt-to-GDP. However, recall that the federal debt held by the public is measured monthly, while GDP is measured quarterly, and both variables are interpolated at the daily level. Because the longer-term relationship between Treasury supply shocks and debt-to-GDP may involve additional factors, the results are to be interpreted with caution.

Figure A3. IRFs to U.S. Treasury Supply Shocks of Treasury Bond Yields



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

With that in mind, Figure A3 shows the IRF to a 1-billion-dollar increase in the supply of U.S. Treasury securities of the debt-to-GDP ratio. The blue shaded areas are the CI's at the 90% and 95% level computed using Newey-West standard errors. The x-axis represents business days from impact. All variables are expressed in basis points.

We find that debt-to-GDP increases by approximately 0.8 basis points following the shock, that this effect is significant at the 90% level about two weeks from impact, and that it lasts for about eight weeks. The magnitude of the effect is particularly interesting, as the average federal debt held by the public between October 1998 and January 2020 sample was around \$12.5 trillion. Assuming that GDP is constant over eight weeks, a 0.8 basis point increase in this debt level would correspond to an increase of \$1 billion, which matches exactly the original scale of the shock.

This finding provides further evidence that the Treasury supply shocks identified in this study have implications for the evolution of the debt-to-GDP ratio. Although analysis of lower-frequency data would require additional assumptions and falls outside the scope of this paper, this piece of evidence supports the notion that this paper sets the stage for future research on the implications of government debt management policy for the macroeconomy.

A.6 Diagnostic Tests

Granger Causality Tests.—We estimate a VARX(p) that treats both z_t and y_t as endogenous, and the other controls as exogenous. We then test the null hypothesis that the coefficients on the lagged values of y_t and z_t are jointly zero in the equations of z_t.

Table A3 collects the p-values for the test that the row variable Granger-cause the column shock. The results support the lead-lag exogeneity assumption, as we can reject the null hypothesis at the 95% level in the vast majority of cases.[1]

Table A3. Granger Causality Tests

	2-year	5-year	10-year	30-year
2-year shock		1.00	1.00	0.99
5-year shock	0.98		0.89	0.76
10-year shock	0.99	0.88		0.86
30-year shock	0.97	0.97	0.98	
3-month rate	0.19	0.14	0.27	0.70
1-year rate	0.30	0.04	0.20	0.55
2-year rate	0.81	0.41	0.83	0.85
5-year rate	0.99	0.95	1.00	0.66
10-year rate	0.92	0.90	0.99	0.75
30-year rate	0.81	0.94	0.91	0.73
S&P 500	0.08	0.03	0.07	0.11
VIX	0.04	0.02	0.08	0.27
Moody's AAA yield	0.80	0.61	0.79	0.91
Moody's BAA yield	0.93	0.69	0.97	1.00
Equity premium	0.07	0.80	0.42	0.23
2y Refcorp spread	0.29	0.27	0.16	0.12
5y Refcorp spread	0.38	0.44	0.21	0.55
10y Refcorp spread	0.68	0.23	0.18	0.68
20y Refcorp spread	0.57	0.10	0.05	0.16
2-year term premium	0.45	0.71	0.51	0.32
5-year term premium	0.29	0.71	0.79	0.17
10-year term premium	0.76	0.81	0.93	0.40
All	0.19	0.44	0.55	0.59

Notes: Each cell displays the p-values for the test that the row variable Granger-causes the column shock.

[1]Because the probability of making at least one Type I error among the 24 tests is 72%, we do not interpret the few rejections as alarming.

A.7 Data Citations

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