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THE TREASURY MARKET IN SPRING 2020 AND THE RESPONSE OF THE FEDERAL RESERVE

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The Treasury Market in Spring 2020 and the Response of the Federal Reserve
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ABSTRACT

Treasury yields spiked during the initial phase of COVID. The 10-year yield increased by 64 bps from March 9 to 18, 2020, leading the Federal Reserve to purchase $1T of Treasuries in 2020Q1. Fed purchases were causal for reducing Treasury yields based on the timing of purchases (which increased on March 19), the timing of yield reversal and Fed purchases in the MBS market, and evidence against confounding factors. Treasury-QE worked more via purchases than announcements. The yield spike was driven by liquidity needs of mutual funds, foreign official agencies, and hedge funds that were unaffected by the March 15 Treasury-QE announcement.

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1. Introduction

In March 2020, as the COVID crisis intensified, stressed emerged in the market for Treasury securities. Treasury yields spiked sharply, leading the Federal Reserve to buy large amounts of Treasuries, over $1T in 2020Q1. I seek to contribute new facts and analysis to improve our understanding of this episode.

Figure 1, Panel A documents the fact that motivates this paper. It graphs the S&P500 index level and the 10-year nominal Treasury yield over the first half of 2020. Until March 9, the series move down together as news about the COVID crisis worsened. This is what one would expect if negative news about the economy leads bond investors to expect lower short rates or to reduce the term premium, fleeing to the safety and liquidity of Treasuries in crisis. The surprising part of the figure is the March 9 to March 18 period during which the 10-year yield spiked sharply by 64 basis points while the stock market kept falling. What caused the Treasury yield spike over the March 9-18 period? Was the intervention by the Federal Reserve central for bringing Treasury yields back down? What lessons does this episode provide for investors and for monetary policy?

I begin my analysis with an asset-pricing decomposition of Treasury yield movements to show that Treasury yields did not spike because of a loss of confidence in Treasury fundamentals in the sense of higher expected inflation or increased default risk. Based on market measures, inflation expectations fell as yields spiked, implying that real yields increase even more than nominal yields. The 10-year real (and default-adjusted) rate increased by about 100 bps over the March 9 to 18 period. While liquidity in the Treasury market deteriorated, I estimate that this can only account for a few basis points of the yield spike, given the price of liquidity (estimated from the cross-section of Treasuries) and the deterioration in liquidity over time.

With default risk, inflation and illiquidity unable to explain the increase in Treasury yields, the natural explanation is a negative demand shock for Treasuries, necessitating a fall in prices for

markets to clear. I document large sales of Treasury securities by foreigners, mutual funds, and the household sector (which includes hedge funds). Sales were large in historical terms, at $287B, $266B, and $196B respectively for the three groups in 2020Q1. Notably, neither of these sectors sold many Treasuries at the peak of the financial crisis 2008Q4.

A central part of my analysis is to study the Federal Reserve's intervention in the Treasury market in response to the yield spike. I document that Treasury yields started falling on March 19 and March 20, lining up well with a large increase in the Federal Reserve's daily Treasury purchases on March 19. This is unlike to be due to confounding stabilizing factors. Corporate yields increased on March 19-20 and the stock market fell. Furthermore, in the MBS market, the spike in yields started to reverse a day later than in the Treasury markets, and the Federal Reserve increased its daily MBS purchases a day later than in the Treasury market, consistent with a causal link from purchases to yields. This further rules out confounding factors since one would expect these to affect MBS and Treasury markets at the same time.

The Federal Reserve's Treasury purchases during the COVID crisis thus appear to have had large effects on asset prices at the time of purchase, as opposed to on announcement dates as the prior literature has found (e.g. Krishnamurthy and Vissing-Jorgensen (2011)). Large purchase effects suggest that Treasury sellers had immediate liquidity needs. If liquidity needs do not change as a result of Fed purchase announcements, then asset prices may not change fully until the announced purchases are implemented, especially in situations where arbitrage capital is limited (by prior losses and competing investment opportunities). I emphasize the "if liquidity needs do not change" part of the argument. In contrast to the importance of large purchases in the Treasury market, yields on corporate bonds fell (as measured by prices of exchange traded funds) on days with Federal Reserve corporate bond purchase announcements (Haddad, Moreira and Muir

(2020)).[3] This happened without immediate purchases and purchases have been delayed and modest ($14B, starting on May 12, 2020). Haddad et al (2020) show that the announcements reduced credit default spreads. Falato, Goldstein and Hortacsu (2021) argue that Fed announcements helped reverse outflows from mutual funds holding corporate bonds. Therefore, in the corporate market, announcements *did* change liquidity needs (of mutual funds in particular). Corporate announcements improved perceived corporate fundamentals enough to stop the selling and only a small amount of actual purchases were needed (if any).[4] By contrast, an announcement on March 15, 2020, that the Federal Reserve would buy at least $500B worth of Treasury securities was insufficient to stop the Treasury yield increase. The Treasury yield spike was not due to problems with Treasury fundamentals (credit risk, inflation) but rather driven by massive selling due to liquidity needs that remained important, Treasury purchase announcement or not. Only large purchases turned the Treasury market around.

I seek to understand drivers of selling by each of the sectors mentioned, in order to argue that urgent liquidity needs were relevant for selling by both mutual funds, foreign official agencies, and hedge funds. I document large outflows from bond mutual funds in 2020Q1 and link fund outflows and Treasury selling in the cross-section of bond funds. Increased holdings of Treasury securities by mutual funds since the financial crisis, especially for bond mutual funds, explain why funds did not sell Treasuries in 2008Q4, despite them having similar outflows measured in quarterly data and scaling flows by the size of fund assets. In terms of why investors pulled money out of bonds (during both crises), I hypothesize that as default risk increases, bond funds seize to satisfy the demand by unsophisticated investors for safe assets. This "safety effect" – investor

[3] Gilchrist, Yue, Wei and Zakrajsek (2020) also document announcement effects of Federal Reserve corporate bond interventions though these took several weeks after the announcements to fully emerge in the market for individual corporate bonds, presumably related to infrequent trading of corporate bonds. For identification, they exploit the maturity restriction on corporate bond eligibility for Fed purchase (bonds with up to 5 year maturity were eligible).
[4] This is similar to the "whatever it takes" comment of ECB President Draghi in 2012, which reversed European sovereign yields with no purchases ever made under the ECB's Outright Monetary Transactions (OMT) program.

willingness to pay more for low-risk assets than their default risk and the price of default risk for higher risk assets would imply – was proposed by Krishnamurthy and Vissing-Jorgensen (2012). I interpret bond fund outflows in crisis as a disappearance of the safety attribute and provide asset pricing evidence consistent with this idea. Importantly, the negative mutual fund demand shock for Treasuries ultimately came from disappearing safety of other riskier bonds (corporate bonds, MBS etc.). The spillover likely arose via funds using Treasuries for liquidity management.

Turning to foreigners, about 2/3 of Treasury sales by foreigners were from foreign official agencies (including governments and central banks), with the foreign private sector accounting for the rest. Foreign official agencies appear to have sold Treasuries both for immediate cash needs (having net sales of U.S. assets overall), in expectation of future cash needs (increasing holdings of currency and deposits), and for higher expected returns (buying agency debt, corporate bonds, as well as stocks and investment fund shares). Consistent with the first motive, in the cross-section of countries, foreign net purchases of Treasuries are positively related to the change in foreign reserves. Countries that are hedge fund domiciles sell more Treasuries, suggesting that hedge funds may be a driver of foreign private sales. I estimate of Treasury sales by U.S. and foreign domiciled hedge fund that report to the Securities and Exchange Commission of $183B in 2020Q1, enough to account for a the majority of Treasury sales by the foreign private and the U.S. household sector. Prior work link hedge fund Treasury selling to unwinding of the Treasury basis trade, see Barth and Kahn (2020) and Schrimpf, Shin and Sushko (2020).[5]

2. Decomposing Treasury yields

Figure 1, Panel B graphs Treasury yields for various maturities. The yield spike is stronger for longer maturities but visible even for the 2-year bond. To assess possible drivers of the yield spike,

[5] While I focus on Fed purchases and on sectors with large Treasury sales, others have emphasized the role of broker-dealers not increasing their balance sheets sufficiently, see He, Nagel and Song (2020) and Duffie (2020).

Figure 1, Panel C provides a yield decomposition. The nominal yield can be decomposed as

$$\text{Nominal yield} = \text{Real yield} + \text{expected inflation} + \text{credit risk} \quad (1)$$

I focus on the 10-year maturity. I proxy expected inflation by the rate on inflation swaps and use the credit default swap (CDS) rate to measure credit risk. The inflation swap rate dropped by 42 bps over the March 9-18 period, while there was little change in the CDS rate. The March yield spike in Treasury yields was therefore driven by an increase in the real yield. The real yield on 10-year Treasuries implied by the decomposition, increased by 103 bps from March 9 to 18. This increase is similar to that for (CDS-adjusted) Treasury inflation-protected securities.

For comparison, Figure 1, Panel D illustrates the same time series for the second half of 2008 during the financial crisis. There was no sudden spike in the Treasury yield as the stock market fell sharply in October 2008. A more slow-moving increase in the two measures of the riskless real yield is visible in the bottom left figure. However, this increase reversed before any purchases of Treasury securities by the Federal Reserve (announced on March 18, 2009).

During the COVID crisis, Treasury liquidity deteriorated during around the same time yields spiked, see Fleming and Ruela (2020) and Board of Governors of the Federal Reserve (May 2020). Deteriorating Treasury liquidity could by itself lead to increased Treasury yields. To quantify the illiquidity component of yields (part of the real yield in the decomposition), I estimate the price of liquidity in the cross-section of Treasury securities and multiply this price by the bid-ask spread for a given security.

To illustrate the link between liquidity and yields, Figure 2, Panel A, graphs the bid yield in percent and the bid-ask spread measured in $ per $100 face value across the term structure, as of March 12, 2020 (using data from Bloomberg). I use March 12 because it is the last day before the Federal Reserve started purchasing Treasuries but the cross-sectional price of liquidity estimate is similar if using March 9 or March 18 data. I use the bid-ask spread in dollars to avoid any

mechanical correlation between the bid yield and the bid-ask spread that could emerge if scaling the latter by the price. For readability, I graph Treasuries that have remaining maturities between 1 and 10 years and that are still in their original ``maturity bucket". Securities between 7 and 10 years in the graph were thus all issued as 10-year bonds and have at least 7 years of remaining life. In the >1 to 10 year range, the Treasury issues securities with initial maturities of 2, 3, 5, 7 and 10 years.[6] The label along the bid yield line indicates the age of the bond in its maturity bucket. The label 1 denotes the most recently issued security in the bucket (the ``on-the-run"), 2 is the second most recently issued security in the bucket (the ``first off-the-run"), and so on. The graph documents a lower bid-ask spread and lower bid yield for on-the-run bonds, and to a lesser extent for the first off-the-run bonds, relative to other bonds that are close in terms of remaining maturities. This makes the yield curve very unsmooth and indicates that investors were willing to pay a substantially higher price for more liquid bonds. This contrasts with Figure 2, Panel B which graphs the same series for January 6, 2020 (first Monday of the year) and showslower bid-ask spreads and a smoother yield curve.

To estimate the cross-sectional price of liquidity, I regress the bid yield on the bid-ask spread along with a cubic in the remaining time to maturity (results are similar using a Nelson-Siegel functional form to relate yields to remaining time to maturity). I also control for the coupon rate (which affects the duration, given the term). Table 1, column 1 estimates this relation for the sample of 76 bonds graphed in Figure 2, Panel A. The cross-sectional price of liquidity is 0.213 meaning that an increase in the dollar bid-ask spread of $0.1 translates into a bid yield that is 2.13

[6] For bonds issued with an initial term of 30 years, bid-ask spreads and yields are also lower for the on-the-run and first few off-the-run bonds than for slightly older issues. I exclude 30-year bonds from the liquidity analysis because they appear to have higher bid-ask spreads than other bonds even controlling for term and coupon, perhaps because many are held by buy-and-hold investors (including the Fed). I similarly do not include bonds with less that one year of remaining maturity. For terms close to zero, a given difference between bid and ask prices translates to a very large difference between bid and ask yields (very high bid yields and very low ask yields).

bps higher. The estimated cross-sectional price is a bit higher at 0.299 when I include all bonds with terms between 1 and 10 years (as opposed to only those still in their original maturity bucket). Columns 3 and 4 show that differences in liquidity appear to fully explain yield differences across on and off-the-run bonds. Column (3) includes dummies for being on-the-run, first off-the-run etc. The coefficient on the on-the-run dummy imply that on-the-run securities have 9 bps lower yields than securities older than the fourth off-the-run. This coefficient goes to approximately zero in column 4 when including the bid-ask spread as a regressor (I return to the remaining dummies in related to futures contracts below). Column 5 repeats the regression from column 1 using data from January 6, 2020. The cross-sectional price of liquidity is 0.235, similar to that in column (1). The much larger yield differences between on- and off-the-run securities in Figure 2, Panel A than Figure 2, Panel B is thus primarily driven by larger liquidity differences across securities in March than in January, not by a changing cross-sectional price of liquidity.

Figure 2, Panel C shows the estimated illiquidity component of bid yields on the on-the-run, first off-the-run and fourth off-the-run 10-year bonds over time. I estimate this component as 0.213 (the cross-sectional price of liquidity from Table 1, column 1) times the bid-ask spread (in $ per $100 face value). The illiquidity component of the on-the-run bond yield never exceeds more than few basis points. The illiquidity component is larger for the off-the-run bonds (consistent with the visible wiggles in Figure 2, Panel A), but does not exceed 10 bps for the first off-the-run and 20 bps for the fourth off-the-run bond. Furthermore, part of the increase in the illiquidity component for the first and fourth off-the-run bond take place before March 9. Relating back to the 64 bps yield spike in the 10-year yield in Figure 1, Panel A, the rise in the illiquidity component of bond yields can only explain a couple of basis points of this spike . The series in Figure 1, Panel A is from the Federal Reserve's FRED database and comes from the U.S. Department of the

Treasury. This curve is based on bid yields on on-the-run securities.[7]

3. Buyers and sellers of Treasuries in 2020Q1

A simple explanation for the yield spike would be a negative demand shock for Treasuries, necessitating an increase in yields to clear the market. In order for a demand shock to be reflected in equilibrium quantities, the shock needs to be heterogeneous across groups of investors so demand changes can be inferred from reallocation of ownership. I exploit data on group level holdings and transactions from the U.S. Financial Accounts.

Table 2 documents who owned Treasuries before the COVID crisis hit and how that changed over the first quarter of 2020. As of the end of 2019Q4, about $19T of Treasuries were outstanding. Column 4, which is based on the ``flow" table from the U.S. Financial Accounts, accounts for valuation changes in order to assess net changes in holdings due to purchases and sales (valuation changes are positive as Treasury yields fell for the quarter as a whole).

The Federal Reserve purchased $1.019T worth of Treasuries in 2020Q1 ($863B of notes and bonds, $156B of bills; this detail is not included in the table as it is only available for some sectors). The only other major buyer of Treasuries was money market funds who bought Treasuries worth $231B, mostly bills ($36B of notes and bonds, $195B of bills). Figure 3, Panel A illustrates the unprecedented nature of the Federal Reserve's Treasury purchases in 2020Q1. In just one quarter, they exceeded purchases under each of the QE1, QE2, and QE3 programs. The earlier programs are the three sets of positive bars visible in earlier years in the graph. Summing up quarterly data, purchases were $301B for QE1 (2009Q1-2009Q4), $808B for QE2 (2010Q4-2011Q2) and $817B for QE3 (2012Q4-2014Q4).

Accounting for valuation changes, foreigners (the rest of the world) sold $287B worth of

[7] https://www.treasury.gov/resource-center/data-chart-center/interest-rates/Pages/yieldmethod.aspx

Treasuries in 2020Q1, making them the sector with the largest sales. Foreign sales of notes and bonds were $300B, while foreigners purchased $13B worth of bills. The second largest sellers were U.S. mutual funds, with sales of $266B (of which notes and bonds $260B and bills $6B). The household sector, which includes domestic hedge funds, sold $196B worth of Treasuries. To compare sales in 2020Q1 to typical time series fluctuations, Figure 3, Panel B graphs time series of quarterly net purchases by sector back to 2000Q1. For foreigners and mutual funds, the 2020Q1 treasury sales exceeded sales in any prior quarter by large amounts. For the household sector, net purchases are more volatile, likely because this category is calculated as the residual in the U.S. Financial Accounts. Nonetheless, net sales by the household sector are also at their largest value in 2020Q1. Comparing COVID to the financial crisis, foreigners and households were net buyers of Treasuries in 2008Q4 (buying $278B and $75B worth, respectively) while mutual funds had close to zero net sales in 2008Q4 (selling $4B worth).

I next argue that Federal Reserve purchases were essential for reversing the yield spike and then seek to understand what drove the negative demand shocks for Treasuries for foreigners, mutual funds, and the household sector.

4. The role of Federal Reserve purchases in reversing the Treasury yield spike

As the COVID crisis intensified, the Federal Reserve took a series of steps to stabilize financial markets and the economy. Table 3 lists the main policy changes and programs announced during March and April of 2020. The Federal Reserve reduced the Federal funds target, the primary credit rate, and the rate on its dollar swap lines with five foreign central banks (Bank of Canada, Bank of England, Bank of Japan, ECB and the Swiss National Bank). It also restarted/introduced facilities to stabilize money and bond markets following outflows from prime money market funds

and bond funds.[8] In addition, a series of bond purchases was announced, covering Treasuries, MBS, corporate bonds, municipal bonds, and ABS. On March 15 at 5 p.m. (a Sunday before the open of futures markets), the Federal Reserve announced that it would buy at least $500B of Treasuries and at least $200B of mortgage-backed securities. On March 23 at 8 a.m., the Federal Reserve announced that it would "purchase Treasury securities and agency mortgage-backed securities in the amounts needed to support smooth market functioning and effective transmission of monetary policy to broader financial conditions and the economy". Furthermore, bond purchases were expanded to include investment grade corporate bonds. On April 9 at 8:30 a.m., it was announced that corporate bond facilities would be expanded in size and extended to fallen angels (bonds that were investment grade as of March 22, but were since downgraded below investment grade) and high yield ETFs with broad corporate bond market exposure. Purchases were also expanded to include municipal bonds.

4.1 Announcements do not line up with the yield spike reversal

Figure 4, Panel A, adds vertical lines to Figure 1, Panel A to indicate the three dates with bond purchase announcements. Since March 15 was a Sunday it is not possible to assess whether this announcement helped lower Treasury yields as markets reopened after the weekend. However, it is clear that the announcement was insufficient to stop the yield spike. The 10-year yield rose by 45 bps on March 17 and 18 combined. Then, on March 19 and 20, it dropped by 26 bps, dropping a further 16 bps on March 23. Evidence from Treasury futures markets, which were open around the 8 am announcement, suggest that the majority of the March 23 yield decline was not right at the announcement, see Appendix Figure 1, Panel A. This contrasts with experiences from earlier

[8] Prime money market funds invest in short-maturity assets (weighted average maturity of 60 days or less), including assets with credit risk such as commercial paper and certificates of deposits. See Baklanova, Kuznits and Tatum (2021) for analysis of prime money market fund outflows.

QE announcements where the literature has documented large yield changes following announcements. For Federal Reserve Treasury QE, the most dramatic announcement effect for the Treasury market occurred following the Federal Reserve's March 18, 2009 announcement which stated that Treasuries would be included in QE1. This episode is illustrated in Appendix Figure 1, Panel B which is taken from Krishnamurthy and Vissing-Jorgensen (2011). The 10-year Treasury yield drops over 30 basis points in the minutes after the announcement.

4.2 The yield spiked reversed as Fed purchases were sharply increased

These facts do not mean that the Federal Reserve's Treasury purchases were unimportant for reversing the Treasury yield spike. If some investors are selling due to immediate liquidity needs, an announcement of purchases by itself (the March 15, 2020 announcement) may have little effect on yields. An announcement effect on yields emerges if liquidity seeking investors stop selling, or others start buying, in expectation of later being able to sell the securities at a profit to the Federal Reserve. However, if liquidity needs are immediate and potential buyers are constrained (or see better opportunities elsewhere), the policy may only lower yields as announced purchases are implemented. Evidence from the cross-section of Treasury securities is consistent with strained balance sheet capacity in March 2020. In Table 1, I include dummy variable for securities being cheapest to deliver (CTD) into Treasury futures contracts (a given futures contract allows for delivery of one of a set of securities). On March 12, 2020, CTD securities trade at yields that are 10-20 bps lower than other securities, controlling for maturity, suggesting that the CTD securities were pushed up by high prices of Treasury futures contarcts.[9] Long Treasury futures positions allow buyers exposure to Treasury yields, without a need for balance sheet capacity (aside from margin posted). High futures prices – and therefore high CTD Treasury prices – are thus an

[9] I obtain information on which securities are cheapest to deliver from Bloomberg.

indicator of tight balances sheets.[10]

An alternative mechanism for yields to move at the time of Federal Reserve purchases is that the purchase turned out larger than expected based on prior announcements, with the purchase thus containing an unspoken announcement element. This may have played a role but probably only modestly so. The Federal Reserve was far from the initially announced $500B of Treasury purchases when it increased purchases on March 19 and the $500B was "at least", not "at most".

4.2.1 Exploiting time series variation in Fed Treasury purchases

To document how yields fell at the time of purchase, Figure 4, Panel B graphs the 10-year yield along with daily Treasury purchases by the Federal Reserve. I calculate daily Treasury purchases by summing purchases across Treasury auctions held on a given day, using data from the website of the Federal Reserve Bank of New York. The Federal Reserve's daily Treasury purchases were minor until March 13, then around $40B/day on March 13, 16, 17 and 18, before increasing to around $70B/day from March 19 to April 1. The increase in daily purchase amount on March 19 lines up perfectly with the yield spike starting to reverse and yields revert to almost their March 9 level by April 1. In total, $672B of the Federal Reserve's quarterly net purchases of $1.019T were purchased over 10 trading days from March 19 to April 1.

To argue that Federal Reserve Treasury purchases were causal for reversing the yield spike it is important to rule out potential confounding factors. Perhaps other events calmed the market. Counter to this possibility, across March 19 to 20, the yield on investment grade corporate bonds went up 53 bps, as illustrated in Figure 4, Panel C, while high yield corporate bond yields increased 78 bps, and the S&P500 index lost 3.9%.

Another central piece of evidence for arguing causality from the Fed's bond purchases to

[10] Fleckenstein and Longstaff (2020) argue that the Treasury futures market is way for balance-sheet constrained investors to effectively rent a Treasury security from the institution taking the short side of the futures trade (and buying the CTD Treasury security to hedge the short position).

yields is that in the MBS market, yields start falling and Fed purchases increase one day later than in the Treasury market. Facts about the MBS market are shown in Figure 5. Panel A shows the yield on the Bloomberg Barclays US MBS Index (for fixed-rate agency-backed MBS) and the corresponding option-adjusted spread (OAS), a measure of the risk-premium required by MBS investors. Both peak on March 19, a day later than the peak in the 10-year Treasury yield. Panel B lines up the reversal in MBS OAS (and yield) starting on March 20 with a sharp increase in daily MBS purchases by the Federal Reserve on March 20. The fact that yields fall and Fed purchases increase a day later in the MBS market provides one more example linking yield reversal to Fed purchases and suggests that confounding factors are not driving the Treasury and MBS yield reversal. Stabilizing factors would be expected to affect both the Treasury and MBS market on the same day.

Liquidity provided by the Fed's dollar swaps lines may have played a complementary role to the Fed's Treasury purchases in stemming market dislocations. The first auctions of dollar liquidity to foreign financial institutions via dollar swap lines with foreign central banks settled on March 19, as illustrated in Appendix Figure 2. A total of $162B was borrowed, of which $112B through the ECB. It is difficult to assess how many foreign Treasury sales may have been averted, by foreign financial institutions borrowing dollars rather than having to sell dollar-denominated assets. In terms of where the substantial foreign demand for dollars came from, it may relate to large outflows from prime money market funds in the US, who had net outflows of $139B in March 2020 (Table 5).[11]

4.2.2. Exploiting cross-sectional variation in Fed Treasury purchases

[11] The Federal Reserve was able to reduce its daily purchases on April 2 without yields rebounding. The Fed introduced a repo facility for foreign central banks (to prevent Treasuries selling to obtain dollars) on March 31 and removed Treasuries and reserves from leverage calculations under the Supplementary Leverage Ratio on April 1. It is difficult to assess how much these changes mattered as markets had already improved materially by March 31.

Exploiting cross-sectional variation in Fed Treasury purchases for identification is difficult. First, it is not clear how local purchase effects should be. Yields of bonds far from those purchased may be affected if purchases change in the price of duration risk. By contrast, if preferred habitat demand results in some degree of market segmentation across maturities one could see disproportionate impact on bonds with maturities close to that of bonds purchased. Second, there is little exogenous cross-sectional variation in Fed Treasury purchases. For a given day, the planned purchase amount for the day is announced along with a schedule of auctions stating the time and maturity range for each auction.[12] There is no set amount for each maturity range or security. Realized purchases are affected by which securities dealers' are more eager to sell.

Across notes and bonds, the Fed bought on average 4.3% of outstanding, with a range from 0 to 22%. The Fed generally does not buy "securities trading with heightened scarcity value in the repo market for specific collateral, newly issued nominal coupon securities, and securities that are cheapest to deliver into active Treasury futures contracts" though the latter were eligible for purchase between March 13 and April 17, 2020.[13] These exclusions do not provide good variation for documenting a causal effect of Fed purchases. For example, yields of on-the-run securities may move differently from yields on other Treasuries on for reasons unrelated to Fed purchase eligibility. Instead, I exploit an additional restriction in purchases: The maximum amount the Fed will purchase of a given security is 70%. As a result, the Fed was unable to buy some securities due to large purchases made in the past and may have been constrained in purchase amounts for securities with close to 70% Fed ownership.

Figure 6, Panel A shows the histogram of the percent of the nominal Treasury issues owned

[12] https://www.newyorkfed.org/markets/domestic-market-operations/monetary-policy-implementation/treasury-securities/treasury-securities-operational-details
[13] Federal Reserve Bank of New York, "FAQs: Treasury Purchases", April 29, 2020 https://web.archive.org/web/20200508071013/https://www.newyorkfed.org/markets/treasury-reinvestments-purchases-faq

by the Fed on March 18, 2020, the day before the Fed sharply increased its Treasury purchases. For 15 securities (of which 12 with remaining maturity above one year), the Fed is at the 70% maximum. These are all bonds issued with original maturity of 30 years ("30-year bonds" in what follows). Figure 6 Panel B focuses on 30-year bonds. The left figure shows the fraction owned by the Fed across the term structure, along with the fraction purchased during the period of the yield spike reversal from March 19 to April 1. Fed ownership is low for the longest bonds issued after then end of QE3 but high for most bonds in the 17-22 year remaining maturity range as well as for some of the shorter bonds. Purchases are highest (as a percent of outstanding) for bonds with 23-26 years of remaining maturity, perhaps to compensate for the lack of ability to buy aggressively (or at all) for bonds in the 17-22 year range.

Figure 6 Panel B (right) plots the series for the fraction owned on March 18 along with the yield change from March 18 to April 1. The two series appear positively related. Notably, the yield reduction over this period is smaller for bonds around the 20-year point than for bonds around the 10-year point or bonds around the 25-year point, consistent with high Fed ownership constraining Fed purchases in the 17-22 year range.[14] This evidence should only be viewed as suggestive. It is focused on 30-bonds only and it cannot be ruled out that the oddly shaped term structure of the yield decline could be driven by factors other than Fed purchases. That said, to put some magnitudes and t-statistics on the relation, Table 4, column (1) shows the result of regressing the yield change from March 18 to April 1, 2020, on a dummy for Fed ownership being at 70% and a dummy for Fed ownership being at or above 59% but below 70% intended to capture securities for which the Fed may be constrained it its buying (the Fed does not buy more than 1% of an issue in a given auction if initial ownership is above 59%). Both dummies enter with positive and significant signs.

[14] To focus on exogenous variation in Fed ownership and purchases, Figure 6 Panel B and Table 4 omit the two bonds that are cheapest to deliver into the 30-year and ultra 30-year future contracts. These bonds were hit by a negative demand shock due to the Treasury basis trade unwind, leading to large but not exogenous Fed purchases.

Yields decline 6 bps less for bonds with 70% initial Fed ownership.[15] Column 2 controls for the size of the March 9 to 18 yield spike. If Fed holdings were cross-sectionally correlated with the size of the spike and the spike reversed for reasons unrelated to Fed purchases, this could bias the estimated effect of Fed purchases. Adding this control results in smaller but still significant dummy variables. Column 3 and 4 takes an instrumental variables approach, regressing the March 18 to April 1 yield change on the fraction purchased by the Fed, instrumented with the two dummies. Column 3 (first stage) shows that the dummies have strong negative explanatory power for the fraction bought. Column 4 (second stage) shows a coefficent of -0.535 on the fraction bought, implying that an increase of 0.1 (buying 10% of supply) leads to a 5.35 bps larger decline in yields.

I next consider each of the three sectors selling large amount Treasuries. Bond mutual funds faced large outflows leaving them little choice but to liquidate securities (with Treasuries being among the most liquid ones). Foreign official holders faced immediate liquid needs from FX intervention (leading to reduced dollar reserves) and precautionary liquidation of Treasuries in case of future need for intervention. Foreign private holders include hedge funds who, like the domestic hedge funds included in the U.S. household sector, faced liquidity needs from the unwinding of trades related to the Treasury futures market.[16]

5. Drivers of mutual fund Treasury selling in 2020Q1

This section documents the extent of outflows from bond mutual funds in the first quarter of 2020, links Treasury selling to the outflows and lays out a possible reason behind the outflows.

5.1 Fund outflows

[15] I control for term, term squared and term cubed as well as coupon. Results are similar omitting term cubed. One cannot allow for a fully general term structure shape since the treatment varies mainly by maturity.

[16] MBS selling was driven by mortgage real estate investment trusts (REITs) who are levered investors using repo funding to invest in mortgage-related securities. They faced losses on their assets and sold $124B of agency & GSE backed securities in 2020Q1, reducing their repo funding accordingly. See U.S. Financial Accounts Table FU.129.m and Board of Governors of the Federal Reserve (2020).

Table 4 documents mutual fund flow using monthly data from the Investment Company Institute. The same data source is used for mutual funds in the U.S. Financial Accounts. Bond funds faced outflows in March 2020 of $257B, corresponding to 5.6% of total net assets (TNA). Outflows were also substantial for hybrid funds (investing in a mix of stocks and bonds), at 3.1% of TNA. Equity funds faced only modest fund outflows relative to their large size, with outflows of 0.4% of TNA. Within bond funds, all subsectors had outflows. The investment grade sector accounted for the largest dollar outflows at $89B. In contrast to mutual funds, money market funds saw large inflows of $688B, with prime funds the main exception. Figure 7 graphs the time series of fund flows to assess how abnormal March 2020 was. Panel A shows fund flows as a percent of total net assets, monthly back to 2000M1. The 5.6% outflows in March 2020 were the largest over this sample, but bond funds also faced outflows at the peak of the financial crisis, with outflows of 2.7% of TNA in October 2008. Accounting for events moving slower during the financial crisis, Figure 7, Panel B (left) shows that in quarterly data, bond fund outflows were similar as a percent of TNA in 2008Q4 and 2020Q1. For bond funds, what stood out in the COVID crisis was the speed of outflows. Figure 7, Panel B (right) shows in weekly data how the bond fund outflows during the COVID crisis were concentrated over just a couple of weeks, with outflows of $93B in the week ending March 18, 2020 and $91B in the following week.

5.2 Linking outflows to Treasury sales

The large bond fund outflows in the weeks ending March 18 and 25 line up with the period of the Treasury yield spike and large Fed intervention. However, as we have seen (Figure 3), mutual funds did not sell substantial amounts of Treasuries in 2008Q4, despite the fact that this was also a period of large fund outflows. Three simple arguments link outflows to Treasury sales in March 2020. First, funds facing outflows had many more Treasuries to sell than during the financial crisis. Second, the extent to which funds sold their Treasuries depended on outflows. Third, Treasury

sales by fixed income index funds were substantial and are mechanically linked to flows.

Providing more detail, Figure 8 shows mutual fund holdings of Treasuries and other bonds over time. The left graph illustrates dollar amounts and documents a large increase in mutual fund holdings of corporate bonds, Treasury bonds, and municipal bonds after the financial crisis. Over this period, the supply of corporate bonds and especially of Treasuries grew dramatically (middle graph). The right graph illustrates mutual fund holdings as a percent of supply, showing sharp increases for corporate bonds, Treasury bonds, and municipal bonds. Falato, Goldstein and Hortacsu (2020) document the increase in total bond fund assets relative to the size of the corporate market. Figure 8 expands on that fact by showing that increased bond fund assets led to increased holding not only of corporate bonds but also of Treasuries, a central fact for Treasury market dislocations in March 2020. By the end of 2019, funds had Treasury holdings of $1.311T, more than five times the holdings of just $173B at the end of 2008Q2 going into the financial crisis.

Linking mutual fund Treasury sales in 2020Q1 to fund outflows, Table 6 studies the relation between Treasury selling, initial Treasury holdings, and fund flows. I use data from the CRSP Survivor-Bias-Free US Mutual Fund Database. I aggregate different share classes for a given fund into one and perform the analysis at the level of a fund.[17] I manually code whether a given fund holding is a Treasury security based on security names and include STRIPS securities (but not long positions in Treasury futures since these do not represent ownership of any particular security). I omit exchange-traded funds since the prior analysis reveals large Treasury sales by mutual funds but not ETFs. Panel A documents Treasury holdings and selling in this database. Total Treasury holdings at the end of 2019 were $1.085T, somewhat lower than the $1.311T in the U.S. Financial Accounts.[18] Net sales of Treasuries by mutual funds of $132B in 2020Q1 in the

[17] The CRSP data uses "funds" for share classes and "portfolios" for funds. I use more standard terminology here.
[18] Total fund outflows are fairly similar across datasets with outflows of $347B in the CRSP data and $290B in the ICI data (that underlie the US Financial Accounts) in 2020Q1.

CRSP data are lower than sales of $266B in the U.S. Financial Accounts. With that qualifier, Panel B decomposes mutual fund Treasury selling in 2020Q1. Consistent with outflows driving Treasury selling, funds with inflows were overall buyers of Treasuries while funds with outflows had net sales of $140B of Treasuries. As noted, while Treasuries were less liquid than usual during this time, they were likely still more liquid than most other securities funds held. For funds with outflows, Treasury sales not in excess of outflows amounted to $103B. If funds sold Treasuries first to meet outflows, most Treasury sales may thus have been directly flow-driven.[19] For funds with outflows, even the $54B Treasury sales in excess of the outflows could indirectly be due to outflows since funds may sell to prepare for potential future outflows. Schrimpf, Shim and Shin (2021) document a negative relation between investor flows and funds' change in cash holdings (in percent of total net assets) in March 2020 and argue that this is due to managers anticipating possible future outflows. Panel C takes a regression approach to link fund Treasury sales to flows. Focusing on funds with positive Treasury holdings at the end of 2019, I estimate this relation:

$$\begin{aligned} Net\ purchase\ of\ Treasuries_f^{2020Q1} &= \beta_0 + \beta_1 * \left(Treasury\ holdings_f^{2019Q4}\right) * \left(D\left[Outflows_f^{2020Q1}\right]\right) \\ &+\beta_2 * \left(Treasury\ holdings_f^{2019Q4}\right) + \beta_3 * \left(D\left[Outflows_f^{2020Q1}\right]\right) + \varepsilon_f \end{aligned} \quad (2)$$

where $D\left[Outflows_f^{2020Q1}\right]$ equals one for funds with outflows and f denotes a given fund. The coefficient of interest is β_1. It measures whether funds with outflows were more or less likely to sell their Treasuries than funds without outflows. In the baseline in column 1, β_1 is significant and estimated to be -0.18 meaning that funds facing outflows sold 18 cents more of Treasury securities per dollar of initial Treasury holdings than funds with similar Treasury holdings that did not face outflows. Column 2 shows that the coefficient on the interaction term is similar when weighting observations by funds' initial Treasury holdings (to understand how the typical mutual fund

[19] See Ma, Xiao and Zeng (2021) for an analysis of funds' liquidation preferences.

Treasury dollar reacted, as opposed the typical mutual fund). Column 3-5 show that the negative coefficient on the interaction term is present for bond funds (taxable), hybrid funds and equity funds, though not for a smaller set of various other funds in column 6 (these account for only $27B of initial Treasury holdings). These regressions fund flows and Treasury sales. For index funds, this link is even clearer, as funds have little flexibility in what they sell in response to outflows. In the CRSP database, Treasury sales by bond index funds (taxable) in 2020Q1 amount to $25B.

5.3 Who sold bond funds and why?

According to the U.S. Financial Accounts (Table FU.122), mutual fund outflows were $290B in 2020Q1 (a bit smaller than the $350B outflow for March 2020 in Table 5 due to inflows earlier in the quarter). Households accounted for most of these outflows, withdrawing a total of $280B from mutual funds in 2020Q1.[20] Separate data by fund type are not available, but based on Investment Company Institute (2020, Table 60), households own over 90% of both equity funds, hybrid funds and bond funds, making it likely that most bond fund outflows were also from households.

It is unlikely that households sold bond funds mainly because of liquidity needs (even though their fund sales of course led to liquidity needs for the funds). Household increased their investment in money market funds by $214B over the quarter 2020Q1 in addition to increasing holdings of time and savings deposits by $346B (U.S. Financial Accounts, Table FU.101). Household sales of mutual funds in 2020Q1 thus appears to be part of a reallocation to safe, short-maturity assets as opposed to a liquidity crunch. What is puzzling is that this de-risking involved disproportionate sales of bond funds compared to stock funds.

A possible explanation is what I label a “disappearing safety effect”. Krishnamurthy and Vissing-Jorgensen (2012) argue that investors are willing to pay extra for very safe and liquid

[20] The $280B is comprised of redemptions of $236B from mutual funds held outside retirement accounts (FU.101) and $46B from mutual funds held in defined contribution retirement plans (tables FU.118.c, FU.120.c).

assets. Figure 9, Panel A illustrates the idea. The security price is a decreasing function of default risk but with a higher slope for very low risk, as illustrated by the curved segment from A and B. The safety effect addresses yield spreads between similar-maturity bonds with different credit risk. Krishnamurthy and Vissing-Jorgensen (2012) documented this effect for Treasuries, showing that yield spreads between Aaa-rated corporate bonds and Treasuries tend to be large, despite Aaa's having only slightly higher default risk. Furthermore, changes in Treasury supply are negatively related to the Aaa-Treasury yield spread, thus effectively tracing out a demand curve for the safety/liquidity of Treasuries. The safety effect appears to be present to some extent also for Aaa corporate bonds, since the spread between Baa and Aaa-rate corporate bonds also relates negatively to Treasury supply (a liquidity price premium is less relevant for corporate bonds which all tend to be much less liquid than Treasuries). For households, a willingness to accept lower yields (higher prices) on low-risk bonds (beyond what their low credit risk and credit risk pricing for riskier securities would imply) could stem from saved information costs. For example, investing in a bond mutual fund with low initial risk and daily liquidity does not require a sophisticated understanding of credit risk.

A possible explanation for large household redemptions from bond funds in 2020Q1 is that these funds initially had safety attributes but (temporarily) lost these as their risk increased. I have illustrated this hypothesis in Figure 9 Panel A with a bond fund sliding down the price-risk curve from point 1 to 2. The framework applies to the COVID crisis to the extent that the bond funds with withdrawals were funds with low but increasing credit risk. From Table 5, about half of bond mutual funds (by total net assets) are investment-grade funds and these account for 35% of outflows. Multisector, world and municipal bond funds are harder to classify in terms of credit risk as are government funds which hold Treasuries but also MBS. Less than 10% of bond mutual funds are high-yield funds that are unlikely to have any safety attributes.

Testing the disappearing safety hypothesis based on flows is difficult. While a disappearing safety attribute may be one reason for mutual fund withdrawals, households may also reallocate funds out of bonds that had lost their safety attribute even before COVID (high-yield funds). Instead, I provide evidence from asset prices that is consistent with the nonlinearity in the price-credit risk relation. Figure 9, Panel B graphs corporate bond yield spreads over 5-year Treasury yields and 5-year corporate credit defaults swap rates. The yield spread for investment grade bonds increases more than one-for-one with the investment-grade CDS rate, consistent with the nonlinearity of the safety demand framework. By contrast, for high yield bonds, the yield spread and CDS rates move by similar amounts, consistent with such bonds not having a safety attribute.[21] Table 7 presents results from regressing corporate bond yield spreads on CDS rates. For 2020H1, the regression coefficient for investment grade bonds is 2.6, much above one and thus consistent with such bonds sliding down the steep part of the price-default risk curve describing the safety effect. By contrast, the regression coefficient is close to one for high yield bonds. Results are similar for a longer period going back to 2013 (with the sample determined by data availability).

6. Drivers of Treasury selling by foreigners in 2020Q1

Turning to sales by the rest of the world, I decompose these into foreign official sales and private sales and study drivers of Treasury sales by each of these groups.

6.1 Foreign official and foreign private Treasury sales

Foreigners sold $287B of Treasuries in 2020Q1 thus exceeding even the large Treasury sales by mutual funds. Table 8 uses data from the Bureau of Economic Analysis (BEA) to decompose foreign sales into sales by foreign official agencies (including foreign central banks and governments) and foreign private sales.[22] About 2/3 of Treasury sales were from foreign official

[21] Haddad et al. (2020) also document corporate spreads and CDS rates but do not link these to the safety effect.
[22] I thank Carol Bertaut from the Board of Governors of the Federal Reserve for help with this table.

agencies and 1/3 from the foreign private sector. The BEA calculates foreign net purchases of US securities from changes in holdings (using Treasury International Capital (TIC) data), combined with assumptions about returns earned on the asset category. The assumed return is based on market indices, weighted to account for the portfolio composition of foreign holdings (known from reporting in the TIC data, including information about maturity structure).[23] Exploiting higher frequency data, Figure 10 Panel A graphs a proxy for weekly foreign official selling of Treasury securities: The weekly change (Wednesday data) in the face value of U.S. Treasury securities owned by foreign official and international accounts and held in custody at the Fed.[24] The two largest reductions are for the weeks ending March 18 and 25, exactly as for mutual fund flows and lining up well with the yield spike and subsequent period of large Fed Treasury purchases.

6.2 Foreign official agencies' holdings and portfolio changes

Focusing on foreign official agencies, Table 9 Panel A documents how their portfolio of U.S. holdings changed from just before the financial crisis to just before the COVID crisis. Like mutual funds, foreign official agencies increased their reliance on Treasuries. Their total U.S. holdings increased by about $3T of which $2.1T was an increase in Treasury holdings. The portfolio weight for Treasuries increased from 45% to 56%.[25] Equity and investment fund shares increased by $0.9T, likely via sovereign wealth fund investments since most central banks do not hold stocks. Table 9, Panel B documents net purchases of U.S. assets overall and by asset class. In 2020Q1,

[23] Calculating foreign net purchases from TIC holdings data and returns is preferable to using TIC data on transactions. As described by Bertaut and Judson (2014), TIC transactions data are recorded according to the country of the first cross-border counterparty, not the country of the ultimate buyer or seller of the security. This leads to a bias toward financial centers in the transactions data and the TIC transactions data gives the opposite (and incorrect) conclusion about the relative importance of foreign official and foreign private sales.

[24] The majority of foreign official Treasury holdings are held at the Fed. From my Table 9 Panel A, foreign official Treasury holdings of notes, bonds and bills were $4.077T at the end of 2019. From the FRED database, custody holdings of Treasuries were $2.957T as of January 1, 2020, implying that 72.5% was held in custody at the Fed.

[25] As a percent of total Treasuries outstanding, the foreign official agency share decreases since Treasury supply increased by a factor of three over this period.

foreign official agencies had net sales of $51B overall, suggesting that their sales of Treasuries was partly motivated by a need for dollars for foreign exchange intervention. Currency and deposits increase by $60B, likely in expectation of possible future need for cash. Of the total Treasury sales by foreign official agencies of $182B, the $111B ($51B plus $60B) are thus likely due to liquidity needs. A smaller part was used to reallocate portfolios toward higher yielding assets, with purchases of $43B of mortgage-related securities and corporate bonds and purchases of $36B worth of equities and investment fund shares.

As described above, foreigners did not sell Treasuries at the peak of the financial crisis in 2008Q4. In fact, they purchased $278B worth of Treasuries in that quarter driven mainly by purchases of $214B of Treasuries by foreign official holders, almost all Treasury bills (Table 9, Panel B). This was funded by sales of long and short-term agency securities for a total of $174B. The contrast between foreign official Treasury purchases in 2008Q4 and foreign Treasury sales in 2020Q1 thus appears to be driven by a four factors: (1) a larger cash need in 2020Q1, leading to net sales of U.S. holdings overall, (2) increased reliance on Treasuries in foreign portfolios, resulting in sales of Treasuries rather than mortgage-related securities in the face of liquidity needs, (3) “precautionary” reallocations going into currency and deposits in 2020Q1 rather than Treasury bills in 2008Q4, and (4) Treasury sales for return-seeking purposes in 2020Q1.

6.3 Insights into foreign private sales from the cross-section of countries

To gain insights into the $105B of foreign private Treasury sales, it is informative to study the cross-section of countries. In Appendix Table 1 documents Treasury holdings and net purchases by country for foreign and private holders combined (country-level data does not distinguish). I calculate net purchase of Treasuries in 2020Q1 from the change in holdings from 2019Q4 to 2020Q1 and assumed returns. The table is based on Treasury International Capital (TIC) data, which divides Treasury holdings into securities with below one year maturity and securities above

one year maturity. I use the return on Bloomberg Barclays Treasury Indices for these two maturity groups for 2020Q1.[26] Appendix Table 1 also tabulates the changes to currency reserves using IMF data. The largest seller is China, selling $75.9B, partly driven by a $42.4B reduction in reserves. Brazil and Saudi Arabia also have large sales and large reductions in reserves. The Cayman Islands, Ireland and Luxembourg have large Treasury sales, despite changes in reserves close to zero. These three countries are domiciles for a large part of the world's hedge funds. According to U.S. Securities and Exchange Commission (2020), 51.4% of US hedge fund assets were domiciled in the US at the end of 2019, while 34.6% were domiciled in the Cayman Islands, 4.6% in Ireland, 3.2% in Luxembourg, and just above 1% in each of British Virgin Islands and Bermuda. For European hedge funds, Preqin (2017) states that 56% of European hedge funds are domiciled in Luxembourg and 26% in Ireland. Large sales from hedge fund domiciles suggest that hedge fund Treasury selling was a driver of the $105B of foreign private Treasury sales. Figure 10 shows a cross-country scatter plot of foreign net purchase of Treasuries in 2020Q1 against the change in reserves in 2020Q1. The relation is positive, consistent with FX intervention being one motive for foreign official Treasury sales, but the large sales by the Cayman Island, Ireland and Luxembourg are also visible.[27] Table 10 takes a regression approach to assess magnitudes and statistical significance, regressing net purchases on the change in reserves and a dummy for hedge fund domiciles. Both are significant with changes in reserves translating about one-for-one to net purchases of Treasuries and hedge fund domiciles selling about $17B more each, on average.

7. Hedge fund Treasury sales

Barth and Kahn (2020) and Schrimpf, Shin and Sushko (2020) discuss the unwind of levered hedge

[26] The return is 0.84% for securities with below one year maturity (Bloomberg variable LT12TRUU) and 8.20% for securities with above one year maturity (Bloomberg variable LUATTRUU).
[27] The UK is an outlier with purchases of $49.7B despite little change in reserves. UK purchases are driven by purchases in January 2020, prior to the Brexit date of January 31, 2020 and thus unrelated to the COVID crisis.

fund trades in March 2020. The trade most discussed is the Treasury basis trade. The trade seeks to profit from price difference between Treasury securities ("cash" Treasuries) and Treasury futures. When futures are expensive relative to cash Treasuries, the basis trade consists of a short position in the Treasury future (promising delivery of one of the eligible Treasury securities in return for cash) and a long position in a Treasury security that can be delivered into the futures contract (the cheapest to deliver among those eligible). The long position is typically financed using repo financing. The trade is often highly levered to increase returns. Barth and Kahn (2020) document the increased popularity of this trade especially since 2018 and the unwind of the trade in the COVID crisis. As the COVID crisis intensified in March, the difference between futures and cash prices widened, with futures becoming even more expensive relative to cash Treasuries than before the COVID crisis. That led to losses on the basis trade and a need for increased margin to be posted. As a result, many hedge funds unwound their basis trades. This would be expected to lead to a sale of Treasury securities to close out the repo borrowing.

In Table 11, I estimate Treasury sales by hedge funds of $183B in 2020Q1. This number covers hedge funds that report to the Security Exchange Commission (SEC) whether foreign domiciled or domiciled in the U.S. Hedge funds with at least $150 million in private fund assets under management must report to the SEC on Form PF. Funds domiciled abroad must report if they have U.S. investors. Form PF asks filers for total long and short Treasury exposure, combining exposure form cash Treasuries and derivatives (including futures). The Form PF data are not publicly available but total long Treasury exposure can be extracted from Figure 61 of Office for Financial Research (2020) and is stated in the first row in Table 11. Futures positions are available from the CFTC's Commitment of Traders reports. Subtracting long futures positions from total long exposure, I estimate that hedge funds held Treasuries worth $991B and the end of 2019Q4 and $889B at the end of 2020Q1. Assuming a return equal to that on the Bloomberg Barclays

Treasury Indices for Treasury securities with >1 year remaining maturity (8.20% for 2020Q1), hedge fund net purchases of Treasuries were 991-1.082*889=-$183B in 2020Q1. Hedge funds sales by domestic and foreign funds reporting to the SEC are thus large enough to account for around 60% of the combined sales by the foreign private sector $105 and the US household (including US hedge fund) sector of $194B. Since only hedge funds selling to US investors report to the SEC, total hedge fund selling is likely larger than the $183B. The $183B estimated Treasury sales are larger than the reduction in short Treasury futures positions of $127B, suggesting that levered trades other that the Treasury basis trade may have been relevant, perhaps related to risk-parity trades (see European Central Bank (2020)).[28]

Barth and Kahn (2020) (and my Table 1) show that yields of the securities that were cheapest to deliver (CTD) into futures contracts were abnormally *low* at the peak of the COVID crisis in March, the opposite of what one may expect from large-scale liquidation of these particular securities. However, hedge fund Treasury sales likely contributed to the spike in Treasury yields form March 9 to 18, despite the CTDs securities having low yields. To the extent that the Treasury market remained an integrated market, as opposed each security trading in a segmented market, hedge fund Treasury selling added to the negative demand shock from mutual funds and foreign official agencies. Lower yields on CTD Treasury securities reflect their extra value above other Treasuries for arbitrageurs with short futures positions.

8. Policy discussion and conclusion

The paper has studied the spike in Treasury yields in March 2020. It was not driven by higher expected inflation or government credit risk but rather a negative demand shock from three groups of investors with urgent liquidity needs: Mutual funds facing outflow, foreign official agencies

[28] Weekly changes in short futures positions of levered investors (hedge funds) are graphed in Appendix Figure 2. Large negative changes start in February and remain large until the week ending April 7. They are thus more spread out around the yield spike than mutual fund outflows and foreign official Treasury selling.

needing to reduce their currency reserves and reallocate them toward cash in preparation for additional future cash needs, and hedge funds unwinding levered trades. In hindsight, it should not come as a surprise that some holders of Treasuries want to sell in crisis. Treasuries are more liquid than other bonds and mutual funds and foreign official holders buy them partly for this reason.

The Federal Reserve's purchases of Treasury securities were central for reversing the yield spike and appear to have affected asset prices upon purchase more than upon announcement. The March 15 purchase announcement had little effect on the liquidity needs of sectors that were heave sellers of Treasuries. As a result, it took large actual purchases to stabilize the Treasury market. This contrasts with the Fed's corporate bond purchases programs during COVID where announcements stemmed outflows from mutual funds and thus reduced liquidity needs, resulting in few actual purchases being necessary. Should the Fed stand ready to support the Treasury market on demand, effectively doing maturity transformation on a grand scale when investors want cash rather than bonds? As a tax payer one may be tempted to say yes, to keep government borrowing costs low. Furthermore, the Treasury market is sufficiently important for financial markets – including for the pricing of corporate and household debt -- that supporting it is likely to have broader economy-wide effects. However, market interventions create moral hazard, not just higher hedge fund leverage but also a risk of excessive government debt accumulation.

Given the pros and cons of Fed Treasury purchases, various ideas have been put forward to reduce the need for Fed intervention. Duffie (2020) argues for central clearing to reduce the need for dealer (and Fed) balance sheet space. Liang and Parkinson (2020) propose removing reserves permanently from the supplementary leverage ratio to increase banks' ability to buy assets. To reduce mutual fund selling in crisis, Falato et al (2020) mention the use of swing pricing to reduce run dynamics at mutual funds by penalizing investors for withdrawing when many others withdraw. Other possibilities include making the repo facility for foreign central banks permanent,

introducing a repo facility with broad access (G30 (2021)), or addressing high hedge fund leverage.

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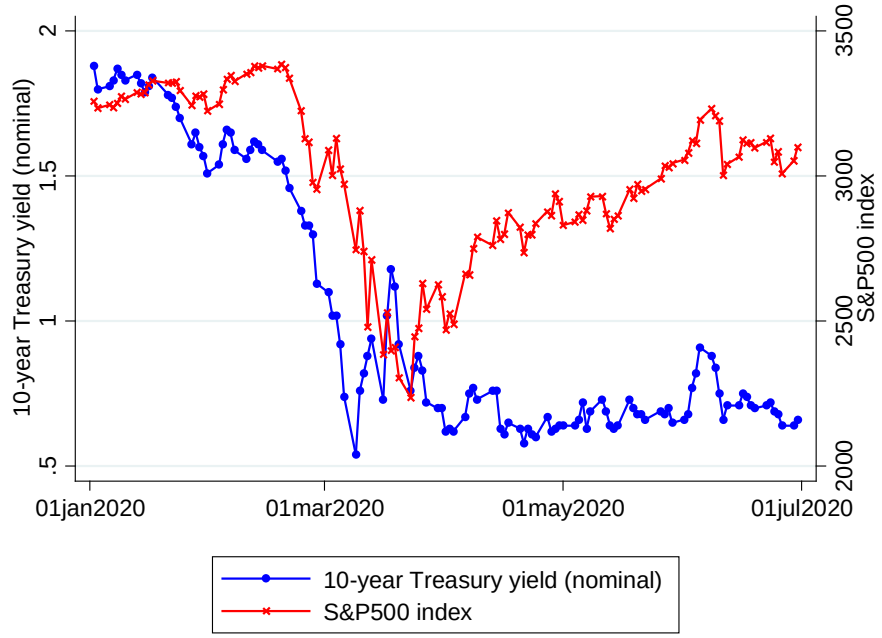
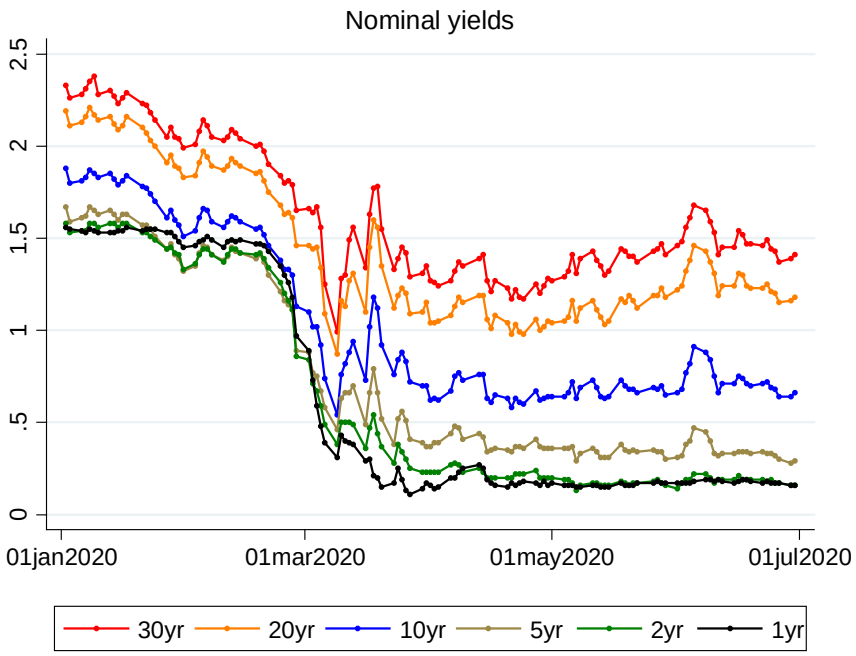
Figure 1. Treasury yields

Treasury yields and the S&P500 index are from the Federal Reserve's FRED database. The inflation swap series is from Bloomberg and the credit default swap rate from Datastream. All yields are in percent.

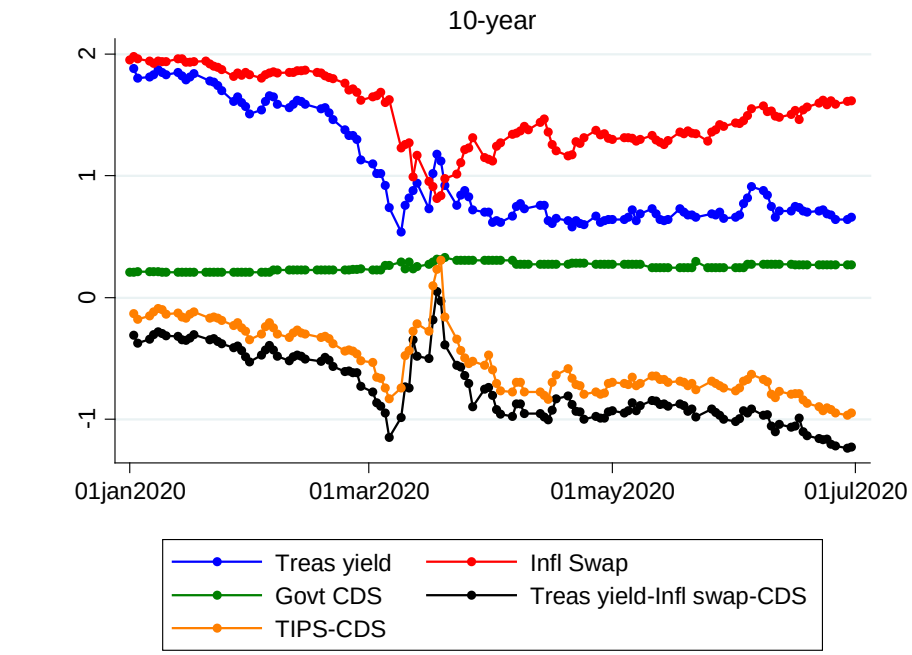
Panel A. Treasury yields spiked in mid-March as the S&P500 index kept falling



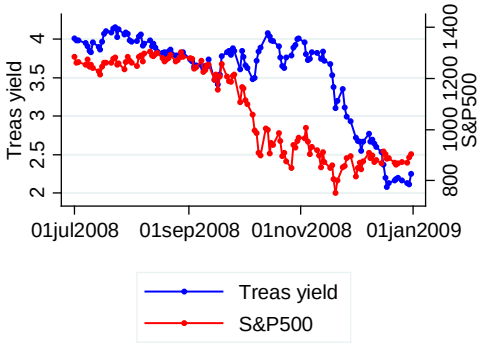
Panel B. Treasury dislocations were mostly in longer yields

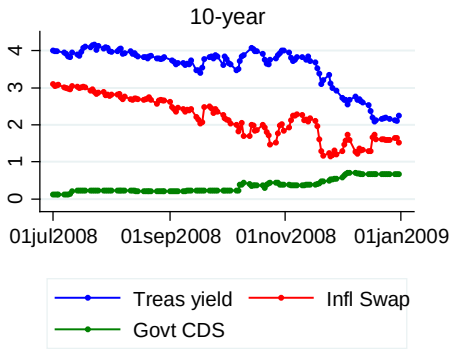


Panel C. Yield spike driven by higher real yield, not expected inflation or credit risk



Panel D. Comparison to 2008





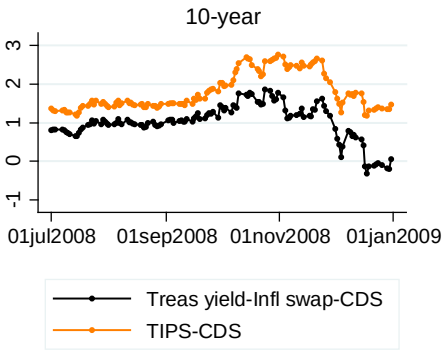
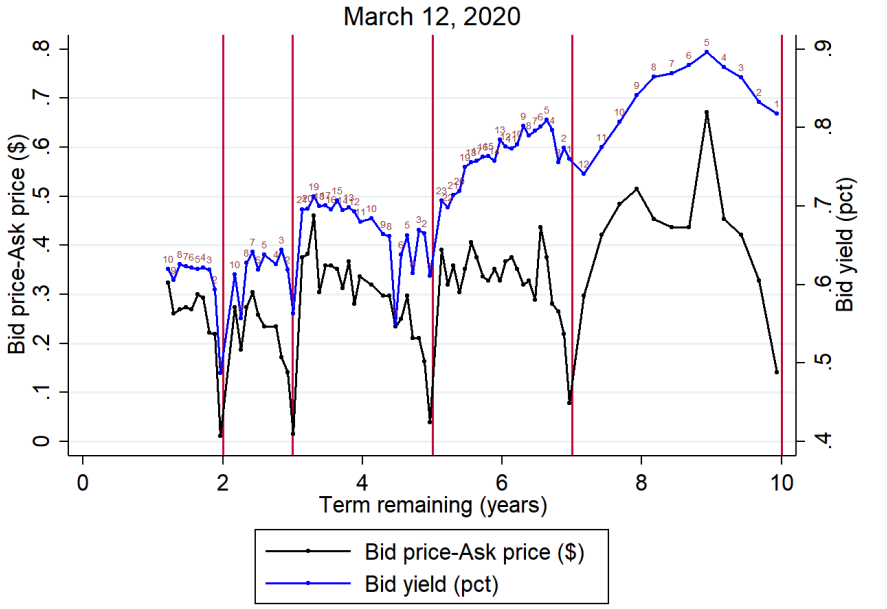


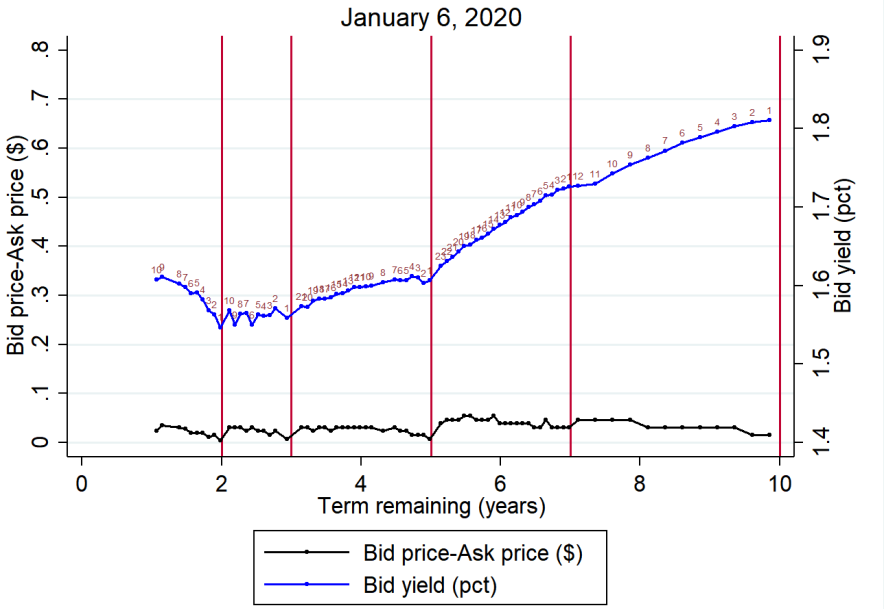
Figure 2. Cross section of Treasury yields and bid-ask spreads

The figure is based on data from Bloomberg. Sample graphed: Bonds with 1 to 10 year maturity that are still in the same maturity bucket they were issued in (e.g., 10-year bonds with remaining term of at least 7 years). Blue line label: Age rank within maturity bucket, 1=on-the-run, 2=first off-the-run etc.

Panel A. March 12, 2020



Panel B. January 6, 2020



Panel C. Illiquidity component of yields implied by cross-sectional price of illiquidity and time series of bid-ask spreads

The illiquidity component of the bid yield is in percent. It is estimated as 0.213 times the bid-ask spread (in $ per $100 face value). The factor 0.213 is from Table 1, column 1. The vertical lines indicate March 9 and March 18, 2020.

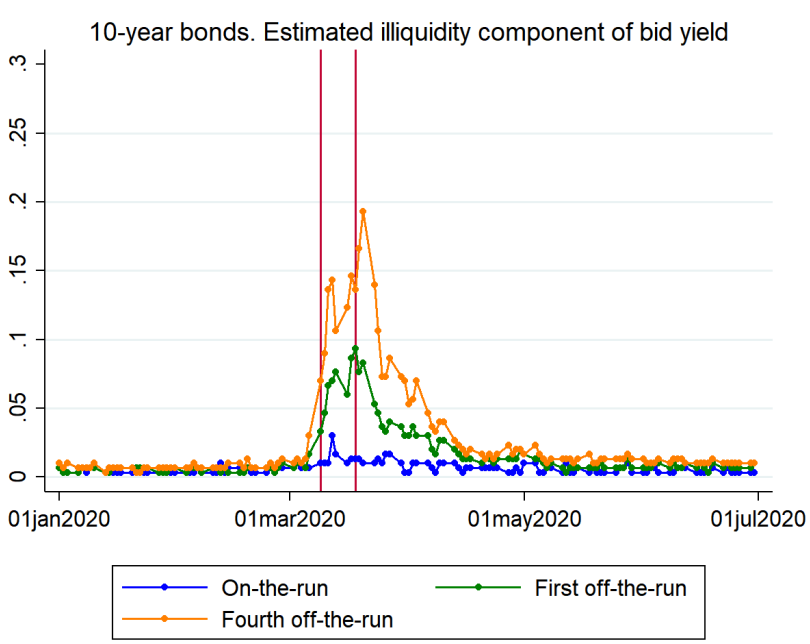
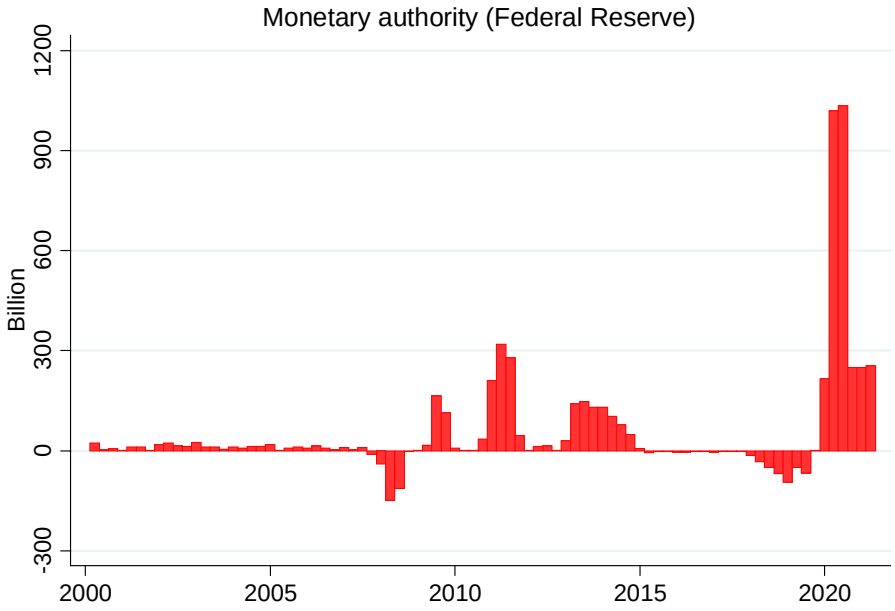


Figure 3. Quarterly net purchases of Treasuries, 2000Q1-2021Q1, U.S. Financial Accounts

Source: U.S. Financial Accounts, Table FU.210 (not seasonally adjusted), June 2021 data release.

Panel A. Net purchases by the Federal Reserve

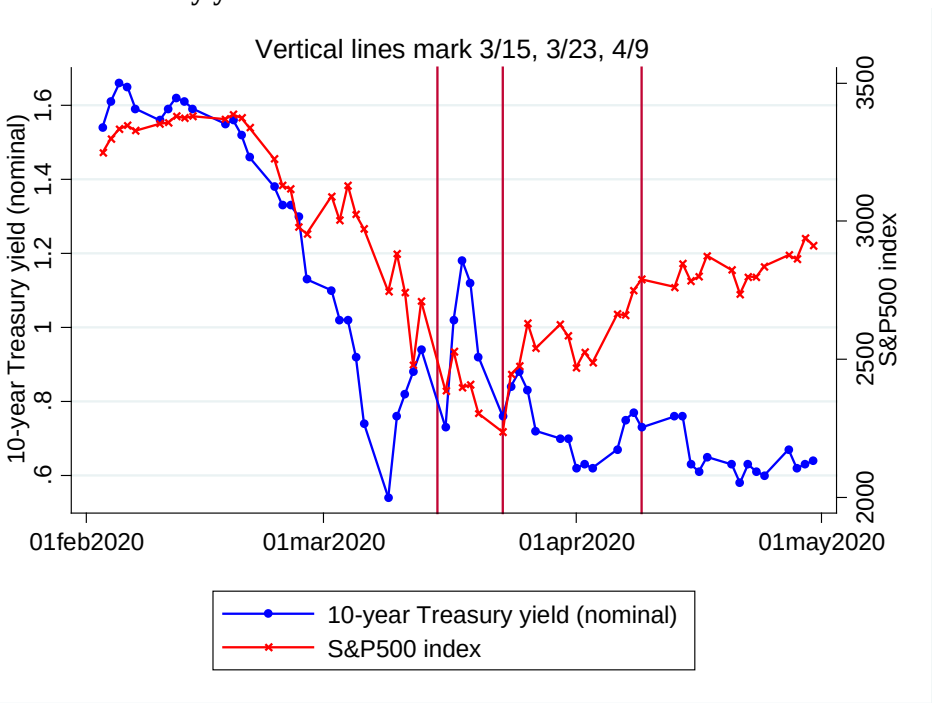


Panel B. Net purchases by the sectors with the largest sales in 2020Q1

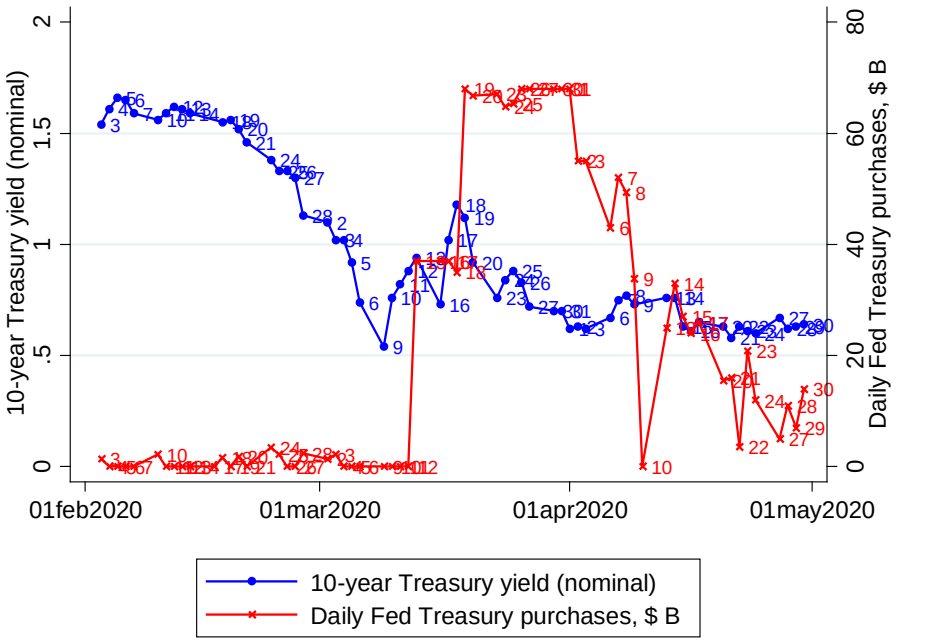
Figure 4. Federal Reserve purchase effects on the Treasury market

Panel A is similar to Figure 1, Panel A, but adds vertical lines to indicate the three Federal Reserve bond purchase announcements during the COVID crisis. Panel B lines up the timing of the Treasury yield reversal to the size of Federal Reserve Treasury purchases, using data from the Federal Reserve Bank of New York. Panel C graphs the 10-year Treasury yield and the yield on investment grade corporate bonds.

Panel A. Treasury yields and S&P500



Panel B. Daily Fed Treasury purchases and 10-year Treasury yield



Panel C. Treasury yields and investment grade corporate bond yields

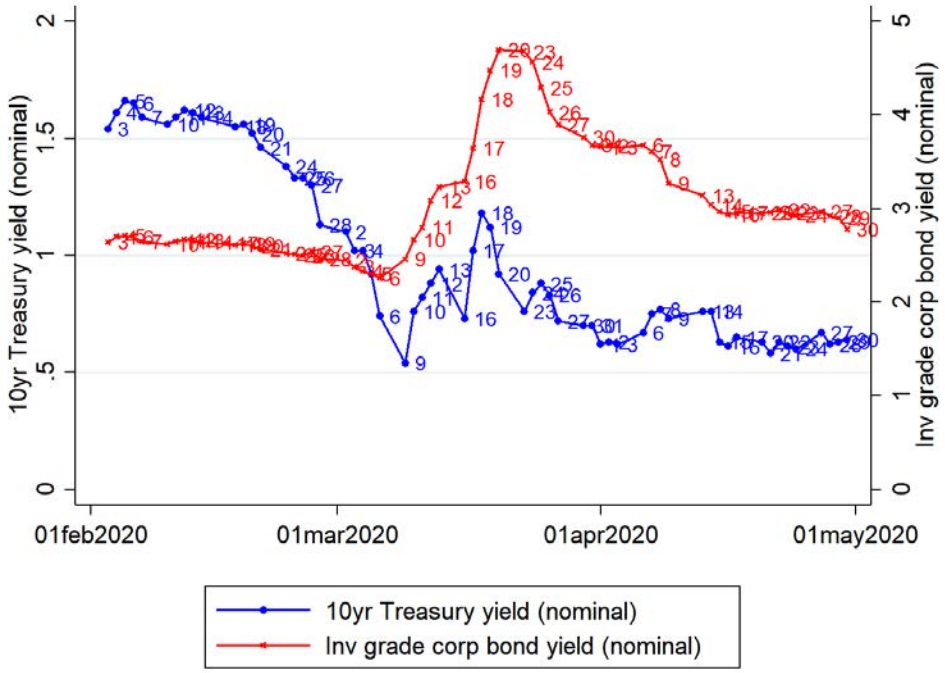
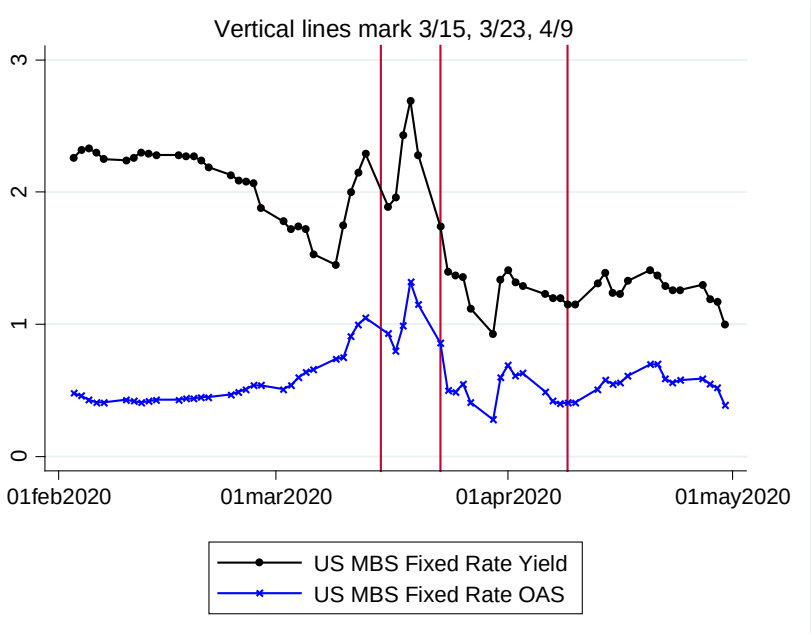


Figure 5. Federal Reserve purchase effects on the MBS market

Panel A graphs the MBS yield and OAS using data from Bloomberg. Panel B lines up the timing of the MBS yield and OAS reversals to the size of Federal Reserve MBS purchases, using data from the Federal Reserve Bank of New York.

Panel A. MBS yield and option-adjusted spread



Panel B. Daily Fed MBS purchases and MBS option-adjusted spread

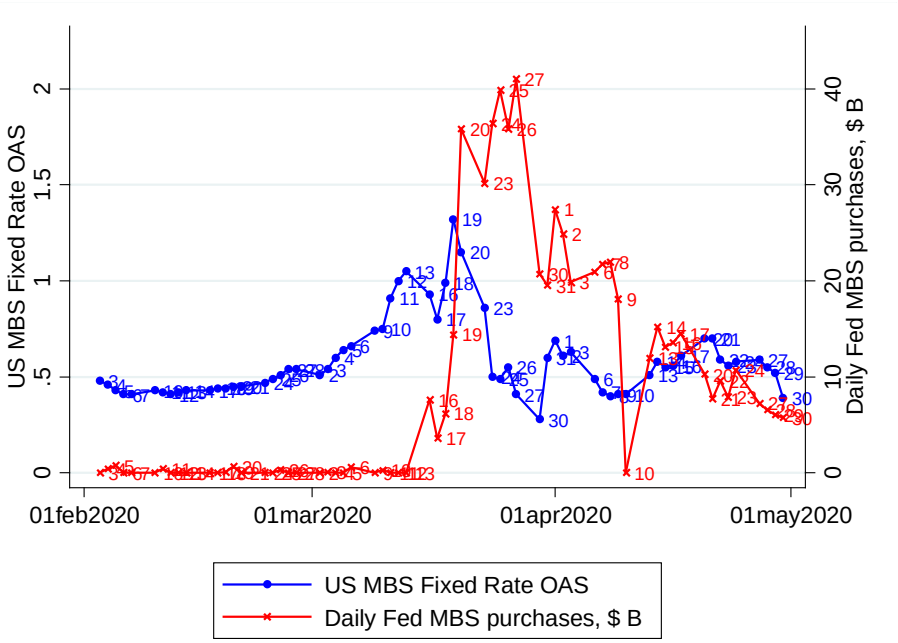
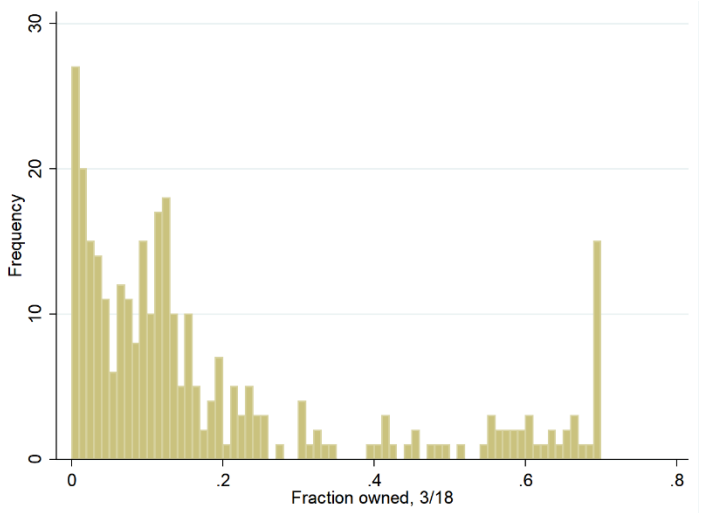


Figure 6. The cross-section of Federal Reserve Treasury holdings and purchases

Panel A is based on all 312 notes and bonds outstanding on March 18, 2020 (TIPS excluded). Panel B is based on 70 bonds with 30-year maturity at issue and remaining term of at least one year. It omits the two bonds that are cheapest to deliver into the 30-year and ultra 30-year futures contracts.

Panel A. Histogram of fraction of issue owned by the Federal Reserve on March 18, 2020



Panel B. Relating fraction owned to fraction purchased and yield curve changes, 30-year bonds only

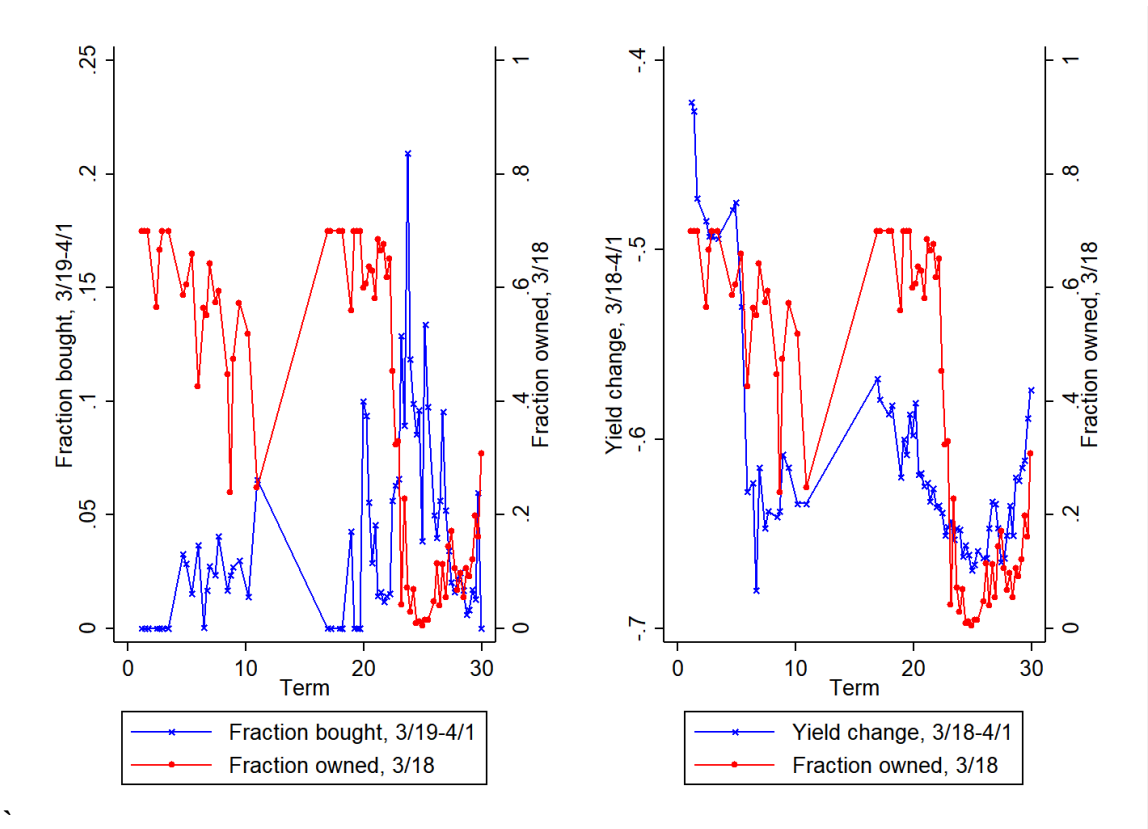
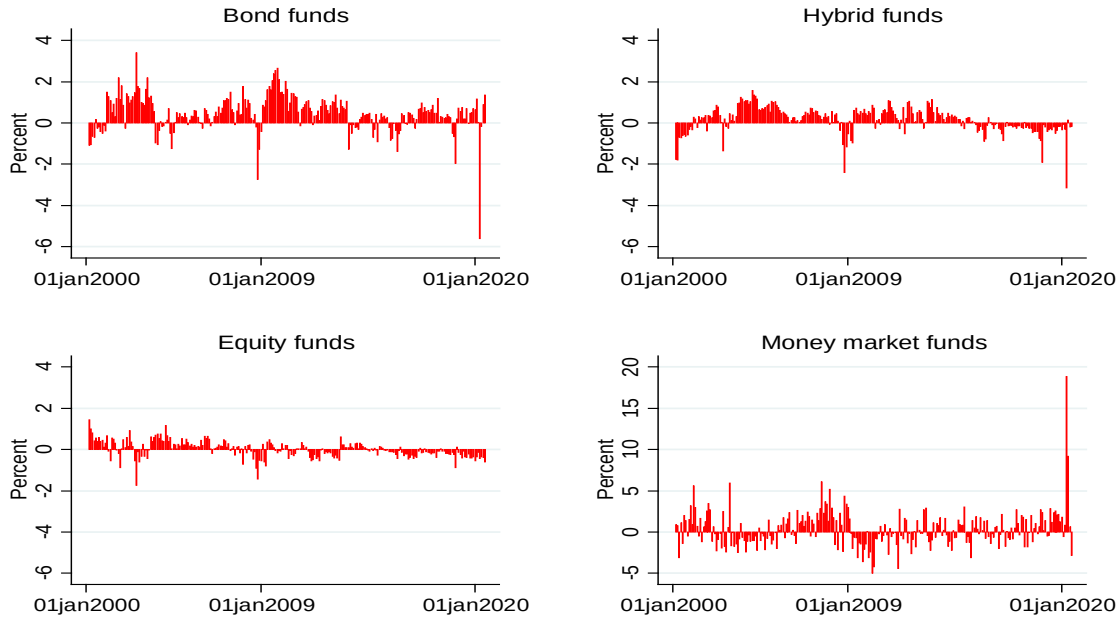


Figure 7. Mutual fund flows

Source: Investment Company Institute data downloaded from Bloomberg. Flow (net new cash flow) is defined as new fund sales less redemptions plus net exchanges. Panel B (right) is based on Wednesday data. The dashed vertical line indicates March 18, 2020, the peak of the Treasury yield spike.

Panel A. Mutual fund flows as percent of total net assets, monthly, 2000M1-2020M6



Panel B. Measures of bond fund flows

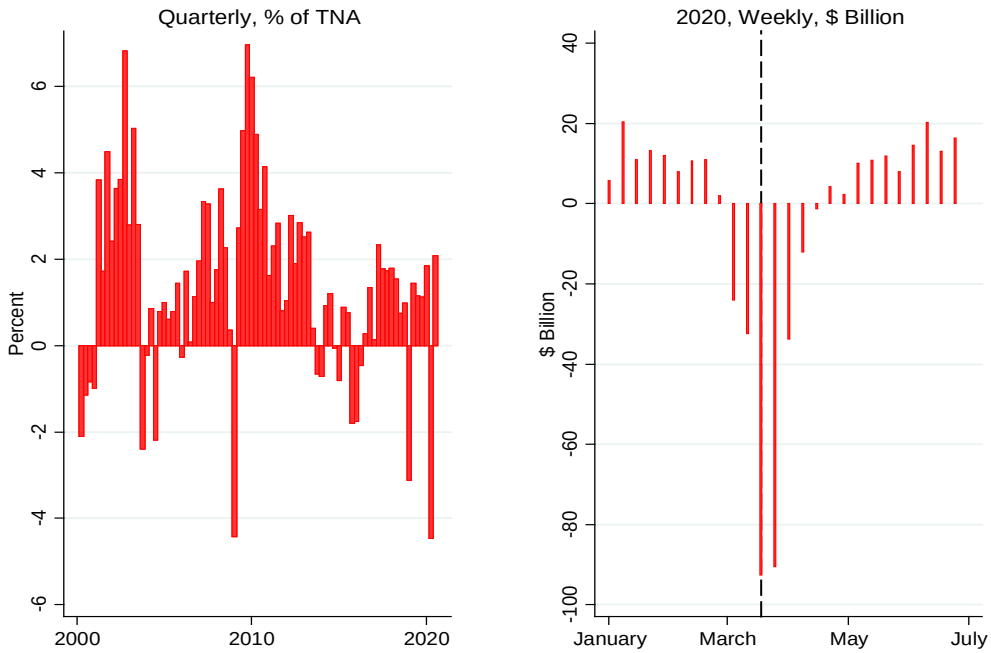


Figure 8. Mutual fund bond holdings

Data are from the U.S. Financial Accounts, Table L.122 and L.208.

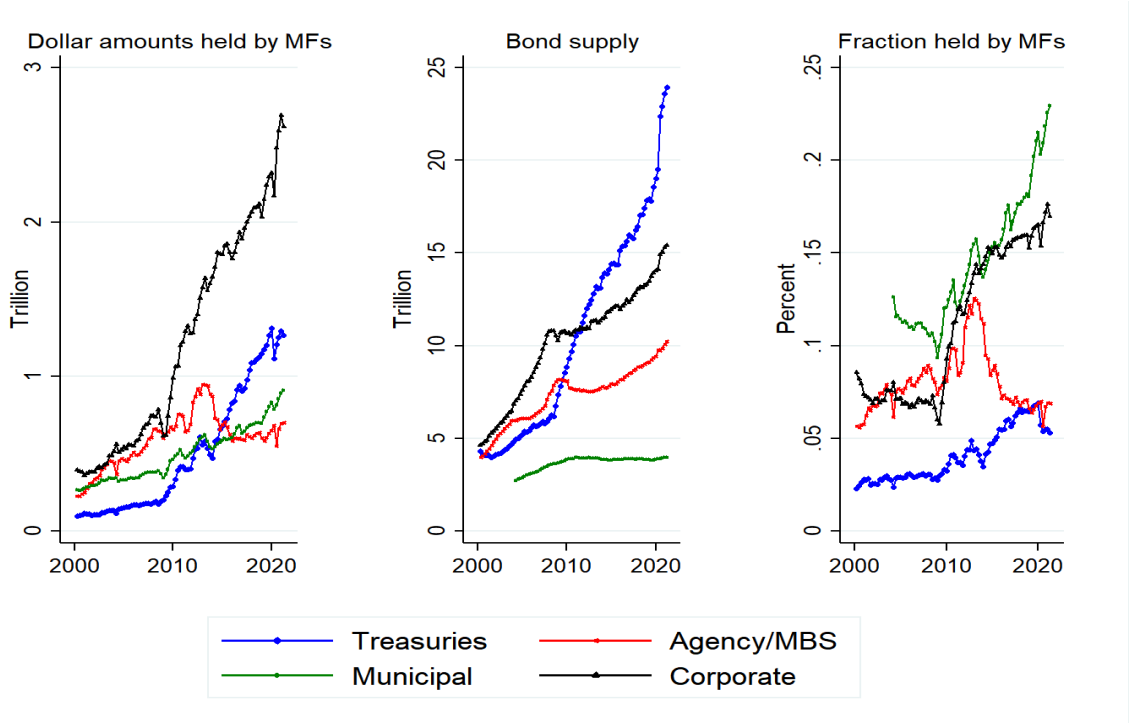
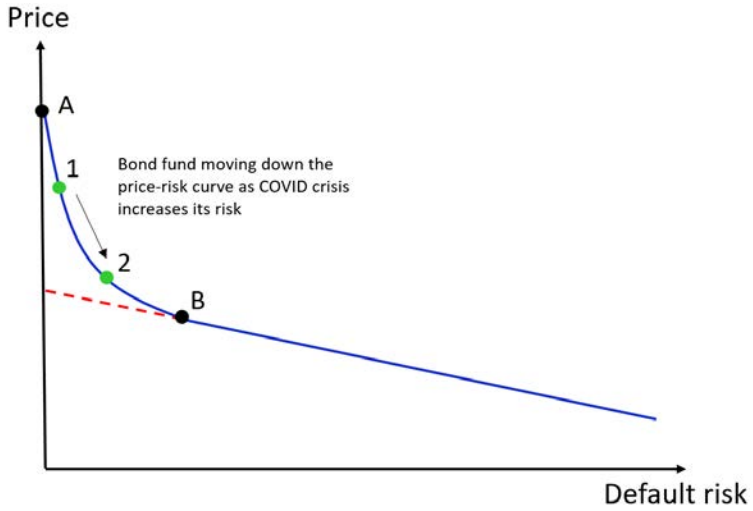


Figure 9. Safety effects

Panel A. The safety effect of Krishnamurthy and Vissing-Jorgensen (2012)



Panel B. Corporate bond yield spreads and CDS rates

The figure shows yield spreads of corporate bond yields over Treasuries to credit default swap (CDS) rates on corporate bonds. Data for the investment grade and high yield corporate bond indices are from the Federal Reserve's FRED database as are Treasury yields (I use the 5-year Treasury yield to approximately match the duration of the corporate bond indices). CDS rates are from Bloomberg and refer to the 5-year maturity.

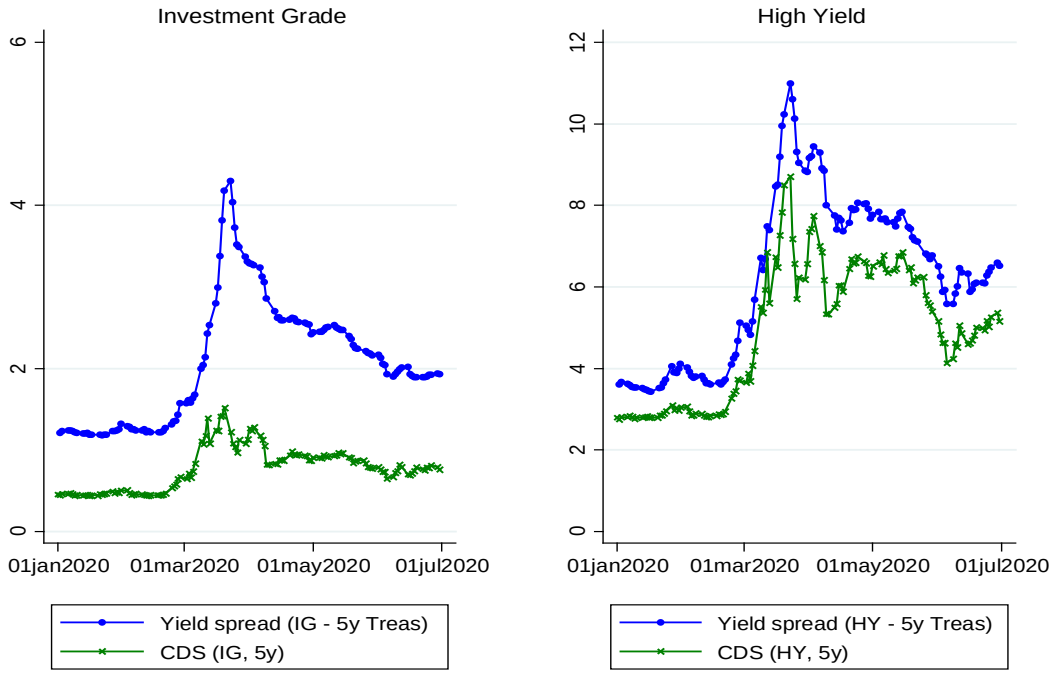
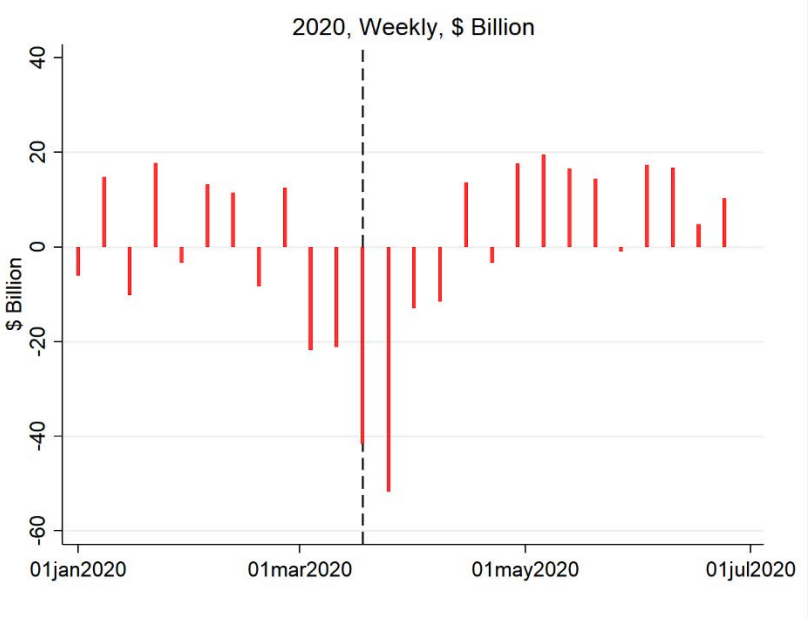


Figure 10. Timing and drivers of foreign Treasury sales

Panel A graphs the weekly change (Wednesday data) in the face value of U.S. Treasury securities held in custody by the Fed for foreign official and international accounts (data are from FRED). The dashed vertical line indicates March 18, 2020, the peak of the Treasury yield spike. Panel B uses quarterly data and graphs net purchases by country (official and private) against the change in reserves (data sources are as for Appendix Table 1). Some country labels are omitted for readability.

Panel A. Change in the face value of U.S. Treasuries held in custody by the Fed



Panel B. Relating foreign Treasury sales to currency reserves

Table 1. The cross-section of Treasury yields

This table is based on data from Bloomberg. Sample used: Bonds with 1 to 10 year maturity. CTD stands for cheapest to deliver. t statistics in parentheses, * p<0.10, ** p<0.05, *** p<0.01.

	Dept. var.: Bid yield (pct)				
	March 12, 2020				January 6, 2020
	(1)	(1)	(2)	(3)	(4)
Bid-ask spread ($ per $100 face value)	0.213***	0.299***		0.269***	0.235*
	(4.42)	(11.03)		(8.98)	(1.70)
D(On the run)			-0.0919***	-0.00876	
			(-6.52)	(-0.59)	
D(1st off the run)			-0.0349**	0.00539	
			(-2.44)	(0.43)	
D(2nd off the run)			-0.0266**	0.00369	
			(-2.05)	(0.33)	
D(3rd off the run)			-0.0269**	-0.00669	
			(-2.10)	(-0.62)	
D(4th off the run)			-0.00525	-0.00762	
			(-0.41)	(-0.72)	
D(CTD in 2yr futures contract)			-0.194***	-0.167***	
			(-7.07)	(-7.30)	
D(CTD in 5yr futures contract)			-0.142***	-0.120***	
			(-5.13)	(-5.19)	
D(CTD in 10yr futures contract)			-0.101***	-0.0811***	
			(-3.64)	(-3.52)	
D(CTD in ultra 10yr futures contract)			-0.0376	-0.0277	
			(-1.10)	(-0.98)	
Coupon	0.0173**	0.00124	0.00686	0.00166	0.0007
	(2.13)	(0.28)	(1.49)	(0.43)	(0.28)
Constant, Term, $Term^2$, $Term^3$ included	Yes	Yes	Yes	Yes	Yes
N (securities)	76	186	186	186	76
R-squared	0.908	0.855	0.862	0.906	0.989

Table 2. Ownership of US Treasuries, US Financial Accounts

Column 1-3 shows amounts held based on table L.210 in the U.S. Financial Accounts. Column 4 shows ownership changes (flows) and is based on table FU.210. Data is from the June 2021 release of the U.S. Financial Accounts.

	(1) Holdings 2019Q4	(2) Holdings 2020Q1	(3) Holdings change 2020Q1-2019Q4	(4) Net purchase 2020Q1
			$B	
Total liabilities	19,019	19,518	500	500
Total assets	19,422	20,737	1,314	500
Discrepancy	403	1,218	815	0
Sectors buying Treasuries in 2020Q1				
Monetary authority	2,541	3,757	1,217	1,019
Money market funds	1,037	1,268	231	231
Nonfinancial corporate business	64	92	29	23
Exchange traded funds	214	263	49	21
Private pension funds	421	472	52	17
State and local governments	850	912	63	10
Federal government retirement funds	2,151	2,158	7	5
U.S. chartered depository institutions	704	724	20	3
Government sponsored enterprises	176	195	19	2
Property casualty insurance companies	153	163	10	1
Sectors selling Treasuries in 2020Q1				
Rest of the world	6,691	6,950	259	-287
Mutual funds	1,311	1,114	-197	-266
Household sector, incl. hedge funds	1,963	1,500	-463	-196
State and local govt retirement funds	341	334	-7	-36
Foreign banking offices in U.S.	121	116	-5	-15
Brokers and dealers	230	266	36	-12
Holding companies	58	54	-4	-9
Nonfinancial noncorporate business	74	77	2	-4
Banks in U.S. affiliated areas	17	15	-2	-3
Credit unions	38	39	1	-2
Life insurance companies	215	233	18	-2
ABS issuers	33	32	-1	-1
Closed end funds	3	3	-1	-1

Table 3. Federal Reserve announcements in March and April, 2020

Date	Announcement	Detail
3/3, 10 a.m.	Federal funds target lowered 50 bps to 1-1.25%	
3/15, 5 p.m.	**At least: $500B Treasury purchases, $200B MBS purchases**	
	Federal funds target lowered 100 bps to 0-0.25%	
	Primary credit rate lowered 150 bps to 0.25%	Discount window borrowing encouraged
	Rate on dollar swap lines lowered 25 bps to OIS+0.25%	BoC/BoE/BoJ/ECB/SNB are counterparties
3/17, 10:45 a.m.	Commercial Paper Funding Facility (CPFF) restarted	Buying 3-month A1/P1 commercial paper $10B credit protection from Treasury
3/17, 6 p.m.	Primary Dealer Credit Facility (PDCF) restarted	Up to 90 day borrowing at primary credit rate
3/18, 11:30 p.m.	Money Market Mutual Fund Liquidity Facility (MMLF)	Lends funds to banks to buy assets from prime money market funds $10B credit protection from Treasury
3/19, 9 a.m.	Temporary dollar liquidity arrangements w/other central banks	
3/20, 10 a.m.	Dollar swap lines goes from weekly to daily operations	
3/20, 11 a.m.	MMLF expanded to municipal bonds	
3/23, 8 a.m.	**Unlimited Treasury and MBS purchases**	Agency CMBS now included in MBS purchases
	$300B in lending via:	$30B credit protection from Treasury
	1. Primary market (PMCCF), secondary market (SMCCF) corporate bond facilities	Corporate bond purchases: Investment grade issuers only
	2. Term Asset-Backed Securities Loan Facility (TALF)	Fed lending against asset-backed securities
	3. CPFF, MMLF expanded with more muni debt	
	4. Main Street Lending Program (MSLP), details to be announced	
3/31, 8:30 a.m.	Repo facility for foreign and international monetary authorities	Objective is to support Treasury (and other) markets
4/1, 4:45 p.m.	Temporary change to Supplementary Leverage Ratio (SLR) for banks	Treasuries and reserves excluded from SLR
4/6, 2 p.m.	Fed will provide term financing backed by PPP loans	
4/9, 8:30 a.m.	**Corporate bond purchases (plus TALF) expanded**	Up to $850B, $85B credit protection. Fallen angels added.
	Main Street Lending Program	Up to $600B, $75B credit protection
	Municipal Liquidity Facility (MLF)	Up to $500B, $35B credit protection
4/27, 4/30	Term sheets updated for MLF, MSLP, PPPLF	

Table 4. The cross-section of Federal Reserve Treasury purchases: Effects on yields, 30-year bonds only

	Reduced form		1st stage	2nd stage
Dept. var.	Yield on 4/1 - Yield on 3/18	Yield on 4/1 - Yield on 3/18	Fraction bought from 3/19 to 4/1	Yield on 4/1 - Yield on 3/18
	(1)	(2)	(3)	(4)
D(Fraction owned on 3/18 = 0.7)	0.0634***	0.0396***	-0.0733***	
	(5.71)	(5.33)	(-5.46)	
D($0.59 \leq$ Fraction owned on 3/18 < 0.7)	0.0330***	0.0175***	-0.0359***	
	(3.42)	(2.77)	(-3.15)	
Fraction bought from 3/19 to 4/1				-0.535***
				(-4.09)
Controls:				
Coupon	0.0164**	0.0109**	0.00679	0.0144**
	(2.15)	(2.25)	(0.77)	(2.34)
Yield on 3/18 - Yield on 3/9		-0.661***	-0.0967	-0.711***
		(-9.80)	(-0.79)	(-8.45)
Constant, Term, $Term^2$, $Term^3$ included	Yes	Yes	Yes	Yes
N (securities)	70	70	70	70
R-squared	0.811	0.926	0.474	0.872

t-statistics in parentheses, * p<0.10, ** p<0.05, *** p<0.01.

Table 5. Mutual fund and money market fund flows, by fund type

The table is based on data from the Investment Company Institute (via Bloomberg). Flow is net new cash flow, defined as new fund sales less redemptions plus net exchanges. Monthly data frequency.

Type of fund	Total net assets (TNA), end of Feb 2020, $B	Net new cash flow, March 2020	
		$B	% of Feb 2020 TNA
Equity mutual funds	**10,381**	**-46**	**-0.4**
Hybrid mutual funds	**1,500**	**-47**	**-3.1**
Bond mutual funds	**4,581**	**-257**	**-5.6**
Inv. grade (govt, MBS, corp, ABS etc.)	2,258	-89	-3.9
High yield	328	-22	-6.6
Government (incl MBS)	364	-16	-4.5
Multisector	519	-42	-8.1
World	556	-44	-7.9
Municipal	859	-42	-4.9
Money market funds	**3,647**	**688**	**18.9**
Treasury & Repo	794	327	41.2
Treasury & Agency	1,927	507	26.3
Prime	791	-139	-17.6
Tax-Exempt	135	-6	-4.8

Table 6. Mutual fund selling of Treasuries in the CRSP mutual fund data

The table uses data from the CRSP mutual fund database (excluding ETFs). All share classes for a given fund are aggregated into one observation. Panel A and B are based on all 9,234 mutual funds in the database as of the end of 2019. Panel C is based on the 2307 mutual funds with positive Treasury holdings at the end of 2019.

Panel A. Summary statistics on Treasury holdings and selling

	End of 2019, $B		2020Q1, $B	
Type of fund	Total net assets (TNA)	Treasury holdings	Net new cash flow	Net purchase of Treasuries
Equity	13,668	64	-111	-9
Hybrid	2,170	105	-56	-22
Bond, taxable	3,815	889	-132	-99
Of which core bond funds	1,558	465	-50	-72
Bond, municipal	807	0	-22	0
Other (MBS, currency funds)	405	27	-26	-4
Sum	20,865	1,085	-347	-132

Panel B. By fund in/outflow status in 2020Q1

	End of 2019, $B		2020Q1, $B	
Type of fund	Total net assets (TNA)	Treasury holdings	Net new cash flow	Net purchase of Treasuries
Funds with outflows	14,273	767	-615	-140
Funds selling Treasuries	3663	672	-204	-157
Treasuries sold up to outflow				-103
Treasuries sold in excess of outflow				-54
Funds buying Treasuries	10,609	95	-410	16
Funds with inflows	6,592	318	267	8
	20,865	1,085	-347	-132

Note: Sales are indicated with negative sign and purchases with positive signs.

Panel C. Drivers of Treasury buying/selling by mutual funds

	Dependent variable: Net purchase of Treasuries, 2020Q1, $B					
	(1)	(2)	(3)	(4)	(5)	(6)
	All funds	All funds	Bond funds, taxable	Hybrid funds	Equity funds	Other funds
Treasury holdings (end of 2019)	-0.180***	-0.208***	-0.212***	-0.273***	-0.285***	0.220*
*D(Outflows in 2020Q1)	(-30.32)	(-64.06)	(-42.51)	(-4.04)	(-11.56)	(1.67)
Treasury holdings (end of 2019)	-0.00335	0.0143***	0.0158***	0.0118	-0.0588**	-0.424***
	(-0.78)	(6.69)	(4.80)	(0.17)	(-2.39)	(-3.28)
D(Outflows in 2020Q1)	-0.0121	0.871***	1.231***	-0.0181	-0.0520*	0.200**
	(-0.57)	(5.78)	(4.95)	(-0.14)	(-1.82)	(1.26)
Constant	0.0114	-0.670***	-0.811***	0.0352	0.0781***	0.0720
	(0.65)	(-5.19)	(-3.86)	(0.29)	(3.05)	(0.52)
Weighted by Treasury holdings (end of 2019)	No	Yes	Yes	Yes	Yes	Yes
N (funds)	2307	2307	1032	364	722	189
R^2	0.470	0.754	0.753	0.904	0.992	0.332

t-statistics in parentheses, * p<0.10, ** p<0.05, *** p<0.01.

Table 7. The disappearing safety effect

Daily data frequency. Data sources are as for Figure 9. Yield spreads are relative to the 5-year Treasury yield. Coefficients are estimated by OLS. Standard errors account for AR(1) autocorrelation and are estimated using the bootstrap after bootstrap approach of Krishnamurthy and Vissing-Jorgensen (2015).

	Dependent variable: Yield spread			
	2020H1		2013-2020H1	
	IG	HY	IG	HY
Investment grade CDS index	2.626***		2.325***	
	(5.89)		(13.78)	
High yield CDS index		1.205***		1.486***
		(13.08)		(14.18)
Constant	0.0398	0.281	-0.0101	-0.851*
	(0.11)	(0.59)	(-0.08)	(-2.11)
N (days)	125	125	1868	1868
R-squared	0.832	0.943	0.770	0.819

Note: Yield spreads are corporate yields minus 5-year Treasury yields.
t statistics in parentheses. * p<0.05, **p<0.01, *** p<0.001.

Table 8. Foreign holdings and net purchases of Treasuries

The table is based on data from the Bureau of Economics Analysis (BEA) International Data (March 2021 release), which relies on the same underlying data as the U.S. Financial Accounts. Data for all foreigners are from BEA Table Table 1.2 (U.S. Net International Investment Position at the End of the Period, Expanded Detail) for holdings and Table 7.1 (U.S. International Financial Transactions for Portfolio Investment) for net purchases. Data for foreign official agencies are from BEA Table 3.1 (U.S. International Investment Position for Liabilities to Foreign Official Agencies) for holdings and Table 9.1 (U.S. International Financial Transactions for Liabilities to Foreign Official Agencies) for net purchases. I calculate data for the foreign private sector as the difference between values for all foreigners and foreign official agencies. The BEA calculates the net purchase based on the change in holdings combined with an assumed return.

	HOLDINGS ($B)			NET PURCHASES ($B)
	2019Q4	2020Q1	Pct change	2020Q1
All foreigners				
Treasuries in total	**6,691**	**6,950**	**3.9**	**-287**
Notes/bonds	5,985	6,220	3.9	-301
Bills	706	730	3.3	13
Foreign official				
Treasuries in total	**4,077**	**4,118**	**1.0**	**-182**
Notes/bonds	3,808	3,835	0.7	-196
Bills	269	283	5.4	15
Foreign private				
Treasuries in total	**2,614**	**2,832**	**8.3**	**-105**
Notes/bonds	2,176	2,385	9.6	-104
Bills	438	446	2.0	-1

Table 9. U.S. liabilities to foreign official agencies

The table is based on data from the Bureau of Economic Analysis (BEA) International Data (March 2021 release). Panel A is based on Table 3.1 (U.S. International Investment Position for Liabilities to Foreign Official Agencies) and Panel B on Table 9.1 (U.S. International Financial Transactions for Liabilities to Foreign Official Agencies). The category "other" refers to loans, trade credit and advances and special drawing rights allocations. The table underlying Panel A does not separately identify agency debt and corporate bonds within the other long-term securities category.

Panel A. Foreign official agency holdings

	$B		Percent	
	2008Q2	2019Q4	2008Q2	2019Q4
Total U.S. liabilities to foreign official agencies	**3,751**	**6,763**	**100.0**	**100.0**
Long term debt securities				
Treasury bonds and notes	**1,690**	**3,808**	**45.0**	**56.3**
Other long-term securities (agency debt and corporate bonds)	1,073	848	28.6	12.5
Short term debt securities				
Treasury bills and certificates	**228**	**269**	**6.1**	**4.0**
Other short-term securities	150	32	4.0	0.5
Equity and investment fund shares	363	1,216	9.7	18.0
Currency and deposits	100	391	2.7	5.8
Other	149	200	4.0	2.9

Panel B. Foreign official agency net purchases

$B	2008Q4	2020Q1
Net U.S. incurrence of liabilities to foreign official agencies	**15**	**-51**
Long term debt securities		
Treasury bonds and notes	**20**	**-196**
Federally sponsored agency securities	-107	31
Corporate bonds and notes	3	12
Short term debt securities		
Treasury bills and certificates	**194**	**15**
Federally sponsored agency securities	-67	0
Negotiable certificates of deposit	-6	2
Commercial paper and other securities	-6	2
Equity and investment fund shares	11	36
Currency and deposits	12	60
Other	-38	-13

Note: Corporate bonds and notes include a small amount of transactions in state and local government securities and negotiable CDs.

Table 10. The cross-section foreign Treasury sales across countries

Reserve data are from the IMF. Other data is as for Table 8. The table shows country-level regressions of net purchase of Treasuries regressed against the change in reserve, a dummy for being a hedge fund domicile (and a UK dummy to capture UK Treasury purchases prior to Brexit).

	Dept. variable: Net purchase of Treasuries, 2020Q1 ($B)		
Change in reserves, 2020Q1 ($B)	0.934***	0.941***	0.970***
	(5.40)	(5.79)	(7.30)
D(Hedge fund domicile)		-17.77**	-16.83***
		(-3.09)	(-3.58)
D(United Kingdom)			58.04***
			(5.70)
Constant	-5.506**	-4.157*	-5.094***
	(-3.40)	(-2.62)	(-3.91)
N (countries)	66	66	66
R^2	0.31	0.40	0.61

Table 11. Hedge fund selling

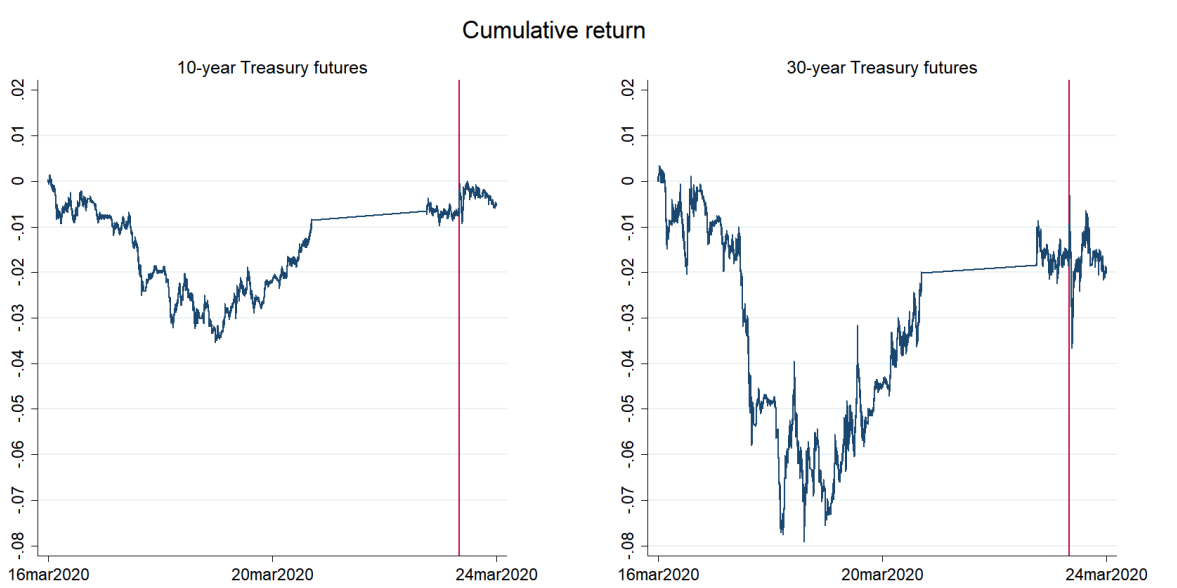
Total long Treasury exposure is from hedge fund Form PF reporting to the Securities and Exchange Commission, extracted from Figure 61 in Office of Financial Research (2020). Long and short positions in Treasury note and bond futures are from the CFTC's Commitment of Traders reports. To estimate net Treasury purchases from holdings changes I assume a return equal to that on the Bloomberg Barclays Treasury Indices for Treasury securities with >1 year remaining maturity (8.20% for 2020Q1).

$B	2019Q4	2020Q1
Total long Treasury exposure	1297	1164
Long positions in Treasury note/bond futures	306	275
Estimated Treasury holdings	991	889
Estimated net purchase of Treasuries		**-183**
Short positions in Treasury note/bond futures	746	618
Change in short positions in Treasury note/bond futures		-127

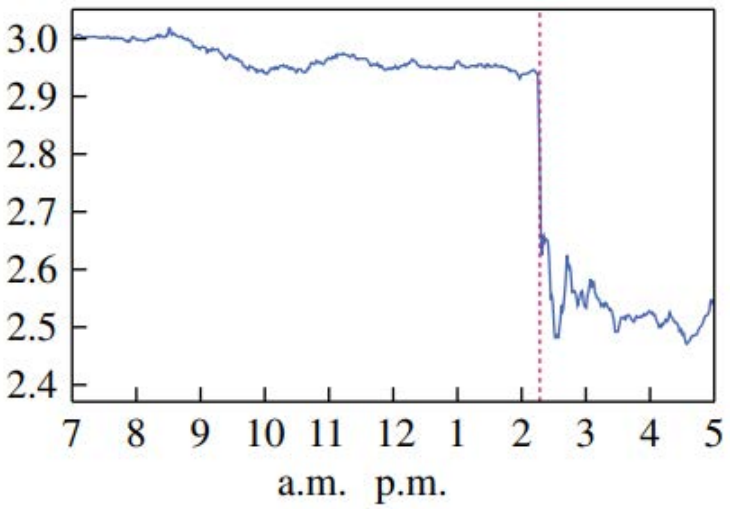
Appendix Figure 1. Intraday QE announcement effects on yields

Panel A graphs the cumulative return on 10-year and 30-year Treasury futures (with data from kibot.com) from March 16 to 23, measured from the start of the day on March 16. The vertical lines indicate the March 23, 8 a.m. Federal Reserve announcement. A yield spike corresponds to a futures return trough. The figure shows the reversal of the return trough on March 19 and 20, with only a modest positive return on the 10-year future around the March 23 announcement and only a short-lived positive return spike on the 30-year future around that announcement. Panel B graphs the 10-year Treasury yield around the March 18, 2009 Federal Reserve QE announcement (the figure source is Krishnamurthy and Vissing-Jorgensen (2011)).

Panel A. Treasury futures, minute-level data, March 16 to March 23, 2020

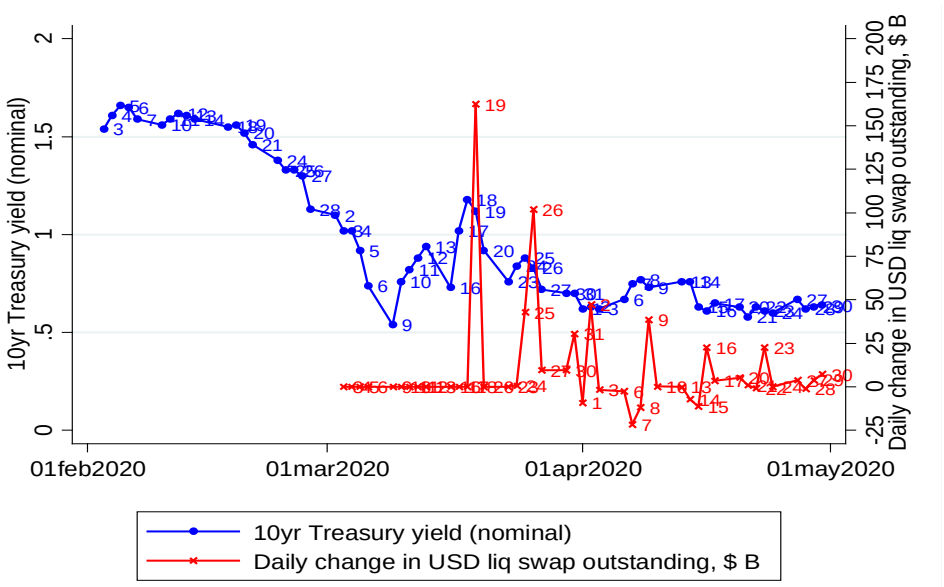


Panel B. 10-year Treasury yield around March 18, 2009 QE announcement



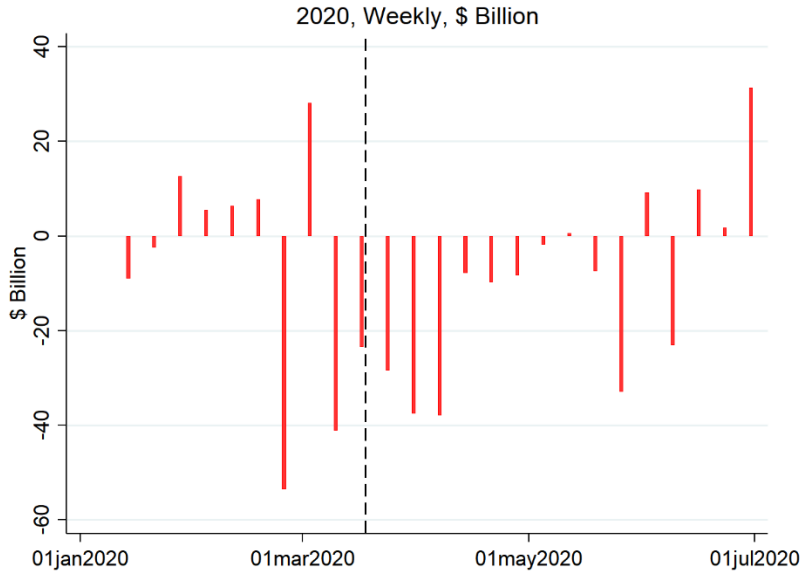
Appendix Figure 2. Dollar swap lines

The figure illustrates the 10-year Treasury yield and the daily change in the amount outstanding on dollar liquidity swap lines with foreign central banks.



Appendix Figure 3. Weekly change in short Treasury futures positions of levered investors

Data are weekly (Tuesday) from the CFTC and aggregated across all Treasury futures contracts. The dashed vertical line indicated March 18, 2020, the peak of the Treasury yield spike.



Appendix Table 1. Treasury holdings, Treasury net purchases and change in currency reserves, by country

Net purchases by country are for both official and private holders. I calculate them from Treasury International Capital data on holdings combined with assumptions about returns based on Bloomberg Barclays Treasury Indices for securities with >1 and <1 year remaining maturity. Data on currency reserves are from the IMF. I classify the Cayman Islands, British Virgin Island, Bermuda, Ireland, Luxembourg, and Belgium as hedge fund domiciles. See text for detail. I set reserves to zero for Bermuda and British Virgin Islands who both use the US dollar.

Country	Abbre-viation	Holdings ($B)			Net purchase of Treasuries ($B)	Change in reserves ($B)	Hedge fund domicile
		2019Q4	2020Q1	Pct change	2020Q1	2020Q1	
China	CHN	1069.9	1081.6	1.1	-75.9	-42.4	
Cayman Islands	CYM	238.2	209.4	-12.1	-41.2	0.0	Yes
Brazil	BRA	281.8	264.4	-6.2	-40.3	-13.7	
Saudi Arabia	SAU	179.8	159.1	-11.5	-32.2	-26.2	
Ireland	IRL	281.9	271.6	-3.6	-29.4	0.1	Yes
Luxembourg	LUX	254.6	246.1	-3.3	-25.6	0.0	Yes
Canada	CAN	143.3	131.5	-8.2	-22.2	0.8	
South Korea	KOR	121.9	110.8	-9.1	-20.8	-8.7	
India	IND	162.0	156.5	-3.4	-18.5	17.9	
Belgium	BEL	207.4	206.1	-0.6	-16.8	0.7	
United Arab Emirates	ARE	40.7	28.0	-31.2	-15.0	-1.1	
Thailand	THA	90.5	81.8	-9.6	-14.9	2.1	
Sweden	SWE	48.7	39.5	-19.0	-13.2	0.0	
Hong Kong	HKG	249.7	256.0	2.5	-13.0	-3.7	
Indonesia	IDN	32.2	23.3	-27.7	-11.4	-8.2	
Bermuda	BMU	71.3	64.2	-9.9	-11.3	0	Yes
Spain	ESP	50.4	43.8	-13.2	-10.6	-0.2	
Switzerland	CHE	237.5	244.6	3.0	-10.0	-4.1	
Singapore	SGP	147.9	151.5	2.4	-7.9	-0.3	
Mexico	MEX	45.3	40.9	-9.8	-7.7	6.8	
Germany	DEU	78.3	77.3	-1.3	-6.8	10.3	
Russia	RUS	10.0	3.9	-61.4	-6.5	9.1	
Kuwait	KWT	43.3	40.1	-7.4	-6.3	-0.4	
Israel	ISR	43.1	41.1	-4.7	-5.2	-0.1	
Colombia	COL	31.4	29.3	-6.6	-4.6	0.2	
Taiwan	TWN	193.1	205.0	6.2	-3.8	2.2	
Italy	ITA	45.3	44.8	-1.0	-3.8	7.2	
Iraq	IRQ	32.9	30.7	-6.7	-3.6	-0.2	
Kazakhstan	KAZ	8.7	5.7	-35.2	-3.2	0.8	
Chile	CHL	30.8	30.1	-2.0	-2.8	-2.7	
Malaysia	MYS	14.3	13.2	-7.9	-2.3	-1.9	
British Virgin Islands	VGB	39.2	40.0	1.8	-2.0	0	Yes
Bahamas	BHS	8.9	7.4	-17.5	-2.0	0.3	
Finland	FIN	6.6	5.6	-14.5	-1.5	-0.3	
Denmark	DNK	16.9	16.8	-0.2	-1.4	-11.7	
Oman	OMN	7.1	6.4	-9.8	-1.3	-0.3	
Netherlands	NLD	65.1	69.1	6.2	-1.2	1.6	
Peru	PER	19.3	19.9	3.2	-0.9	no data	

Guatemala	GTM	6.9	6.5	-5.3	-0.9	0.5
Morocco	MAR	4.7	4.3	-9.1	-0.8	-0.7
Argentina	ARG	6.6	6.0	-9.8	-0.8	-1.4
Portugal	PRT	5.3	5.0	-4.8	-0.7	2.1
Panama	PAN	3.6	3.2	-10.8	-0.5	-0.7
Barbados	BRB	2.1	1.7	-19.0	-0.5	0.0
Costa Rica	CRI	1.9	1.7	-13.2	-0.4	-0.9
Austria	AUT	4.6	4.6	0.0	-0.3	2.3
Trinidad & Tobago	TTO	3.2	3.2	2.2	-0.1	-0.3
Bolivia	BOL	0.3	0.2	-24.4	-0.1	-0.4
Venezuela	VEN	0.3	0.3	-10.7	0.0	no data
Jamaica	JAM	0.7	0.7	3.9	0.0	0.1
Haiti	HTI	0.3	0.2	-2.0	0.0	no data
Algeria	DZA	0.7	0.7	0.0	0.0	-3.8
Liberia	LBR	0.1	0.1	5.2	0.0	0.0
Ecuador	ECU	0.3	0.3	6.6	0.0	-1.4
New Zealand	NZL	7.1	7.6	7.7	0.0	5.7
Cyprus	CYP	0.2	0.3	26.1	0.0	0.1
Bahrain	BHR	1.3	1.5	15.2	0.2	-1.8
Uruguay	URY	9.3	10.1	8.2	0.3	0.8
Turkey	TUR	2.0	2.5	25.9	0.4	-13.5
Norway	NOR	90.1	98.0	8.8	0.5	4.1
Honduras	HND	1.8	2.4	39.4	0.5	0.3
Paraguay	PRY	0.6	1.2	105.0	0.6	0.2
Australia	AUS	41.8	46.3	10.9	1.5	-2.8
South Africa	ZAF	13.8	16.5	19.4	1.6	-2.6
Dominican Republic	DOM	0.4	3.3	771.5	2.9	0.5
Philippines	PHL	34.8	43.1	24.0	5.6	1.0
France	FRA	127.7	156.0	22.2	19.0	9.8
Japan	JPN	1155.2	1272.6	10.2	27.3	42.4
United Kingdom	GBR	392.1	469.7	19.8	49.7	-3.4