LTCM Redux? Hedge Fund Treasury Trading and Funding Fragility*

Mathias S. Kruttli, Phillip J. Monin, Lubomir Petrasek, Sumudu W. Watugala†

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Abstract

During the March 2020 U.S. Treasury (UST) market turmoil, the average UST trading hedge fund saw significant losses and reductions in portfolio exposures, but bilateral repo lending relationships proved resilient sources of funding. Analyzing fund-creditor borrowing data reveals that more regulated dealers provided and more important clients received disproportionately more funding. Reduced hedge fund UST liquidity provision was related to fund-specific internal risk limits and expected future redemptions, rather than creditor regulatory constraints. Despite low contemporaneous outflows, hedge funds boosted cash and reduced portfolio size and illiquidity, suggesting precautionary liquidity management motives for reduced arbitrage activity.

JEL classification: G11, G23, G24, G01.

Keywords: Hedge funds, Treasury markets, relative value, arbitrage, liquidity, risk constraints, creditor constraints.

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†Kruttli: The Board of Governors of the Federal Reserve System. Email: mathias.s.kruttli@frb.gov. Monin: The Board of Governors of the Federal Reserve System. Email: phillip.monin@frb.gov. Petrasek: The Board of Governors of the Federal Reserve System. Email: lubomir.petrasek@frb.gov. Watugala: Kelley School of Business, Indiana University. Email: sumudu@iu.edu.

1 Introduction

Following unprecedented turmoil in U.S. Treasury (UST) markets in March 2020, there has been much debate in industry, policy, and academic circles regarding the role of hedge fund UST trading, which is thought to have grown since the global financial crisis (GFC) as bank-affiliated broker-dealers ceded some of their traditional activities in UST market arbitrage and liquidity provision to non-bank financial institutions.[1] While UST securities play a vital role in the global financial system, hedge funds' impact on UST market functioning is not well understood because they are less regulated than traditional broker-dealers and provide few disclosures. Further, hedge funds employ substantial leverage coupled with investment strategies that can be illiquid. Funding constraints are thought to hinder hedge fund arbitrage activity during crisis periods due to the intensification of intermediary capacity constraints (Adrian and Shin, 2014). In particular, there is debate on the resilience of repo funding—which hedge funds rely on to fund Treasury bond trades—during stress periods (see, for example, Gorton and Metrick (2012); Krishnamurthy, Nagel, and Orlov (2014)).

In this paper, we use a novel and comprehensive regulatory dataset to analyze UST-trading hedge funds' liquidity provision during a crisis.[2] In addition to fund-level data on hedge fund portfolio exposures, risk, and leverage, we harness hedge fund-creditor level borrowing data to investigate hedge fund borrowing relationships and their resilience. As we show, UST-trading hedge funds' repo borrowing is almost exclusively conducted via uncleared bilateral repo. Despite its implications for financial stability, previous studies were unable to empirically study this market due to a lack of data.[3]

[1]See, for example, the report of the Inter-Agency Working Group on Treasury Market Surveillance released on November 8, 2021: https://home.treasury.gov/news/press-releases/jy0470; Schrimpf, Shin, and Sushko (2020); He, Nagel, and Song (2022); *Revisiting the Ides of March, Parts I-III* (https://www.cfr.org/blog/revisiting-ides-march-part-i-thousand-year-flood); https://www.nytimes.com/2020/07/23/business/economy/hedge-fund-bailout-dodd-frank.html. Industry insiders and observers drew parallels between the 1998 Long-Term Capital Management (LTCM) episode and fixed income hedge funds during the March 2020 turmoil. LTCM—a common case study on liquidity risk and the risks inherent in "arbitrage" trading—was a hedge fund that predominantly traded in UST and other fixed income markets until a systematic shock caused massive losses that threatened systemic stability and led to a Fed-arranged broker takeover of the fund's positions (Edward, 1999; Jorion, 2000; Lowenstein, 2000; Duarte, Longstaff, and Yu, 2007).

[2]Our novel dataset is primarily constructed using Form PF, which large U.S. hedge funds are required to file starting in 2012, following its adoption as part of the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010. https://www.sec.gov/about/forms/formpf.pdf. For the first time, these data give a view on hedge fund UST long/short exposures, bilateral repo borrowing, collateral, funding terms, internal risk limits, liquidity, and leverage.

[3]To our knowledge, Form PF is the only dataset with a comprehensive view hedge fund uncleared bilateral repo activity. We observe repo borrowing amounts, maturities, collateral types, and haircuts. Using triparty or cleared repo in place of bilateral repo could lead to misleading conclusions because bilateral repo likely has distinct dynamics (Gorton, Metrick, and Ross, 2020).

At the time, even agencies overseeing financial markets were unable to determine whether hedge funds continued to provide liquidity through the March 2020 UST turmoil, and if not, why not. As investors around the world engaged in a flight to cash and liquidity amid a sudden economic shutdown, UST yields increased while equity and other markets collapsed, bringing into question the safe haven status of US Treasuries (Duffie, 2020). UST spreads that hedge funds generally bet will converge widened, representing profitable opportunities for UST arbitrage trading.[4] We show that the average hedge fund with UST exposures significantly reduced their gross exposures and arbitrage activity in UST markets, decreasing notional exposures on both the long and short sides by around 20%. At the end of March, funds had 20% higher cash holdings and smaller, more liquid portfolios. In aggregate, we do not find evidence that UST hedge funds provided liquidity during the market dislocation.

At first pass, these observations might suggest that hedge funds were unable to take advantage of arbitrage opportunities or even maintain their UST arbitrage activity levels due to investor redemptions and funding constraints. However, while the average UST hedge fund experienced a *monthly* return of around -7%, investor outflows in March 2020 remained relatively modest. This can be explained by the fact that the length of the share restrictions of the median hedge fund in our sample is such that the fund would have at least 30 days' notice before the first 1% of investor capital (net asset value) of the fund could be redeemed. In a short-lived market dislocation like the March 2020 turmoil, such long-duration share restrictions employed by hedge funds were likely stabilizing because hedge funds were not forced to engage in fire sales to meet large investor redemptions, in contrast to other asset managers like mutual funds (Ma, Xiao, and Zeng, 2020) and money market funds (Li, Li, Macchiavelli, and Zhou, 2021) during the same period.

Moreover, despite the fall in UST exposures, we find that borrowing levels, maturities, and collateral haircuts on bilateral repurchase agreements—the primary source of financing for hedge fund UST holdings—remained relatively unchanged in March 2020 for the average UST-trading hedge fund. This suggests that funding constraints might not have been the major driver of hedge funds stepping back from UST trading. We further analyze the borrowing constraints channel by testing specific mechanisms proposed in the existing literature on why hedge fund repo borrowing might be curtailed during a crisis.

[4] See the Online Appendix for an overview of fixed income arbitrage strategies that hedge funds engage in.

There has been much debate about whether post-GFC regulations impose constraints on bank-affiliated dealers' support of hedge fund arbitrage activity.[5] Hedge fund arbitrage trading implicitly depends on dealer balance sheets because it requires funding, which is typically provided by dealers. Dealer balance sheet and risk management constraints can therefore potentially limit the provision of arbitrage by hedge funds, particularly in times of stress. Even if aggregate borrowing remained unchanged, regulatory-constrained dealers might still have provided less funding than they would have otherwise. We test this hypothesis by examining the differences between funding provided by creditors constrained and unconstrained by enhanced regulations using data on borrowing amounts available at the hedge fund-creditor level and a within hedge fund-time methodology.[6] We use two different proxies for creditor regulatory constraints: the creditor's designation as a G-SIB and its proximity to the Basel III leverage ratio threshold. First, we find that G-SIBs—the largest dealers that are subject to enhanced regulations and are often taken as the dealer set more constrained by regulations—provided over 11-13% higher repo funding to their hedge fund counterparties during this period compared to other dealers. Second, we do not find evidence that a creditor bank's proximity to the minimum required Basel III leverage ratio threshold was a significant factor in the credit supplied to hedge funds during this episode.[7] These results are robust to controlling for time-invariant and time-varying hedge fund characteristics using hedge fund-time fixed effects, and relationship-specific factors using hedge fund-creditor fixed effects. In summary, we do not find evidence that the hedge fund sell-off in UST was driven by he regulatory constraints of dealer banks leading to a credit supply shock.

These results may seem surprising given discussions on how funding constraints during crisis periods impact market liquidity provision. During the March 2020 shock, the larger, bank-affiliated broker-dealers—subject to greater disclosures, periodic stress tests, and enhanced post-GFC regulations constraining their liquidity and risk-taking—were not exposed to significant concerns about solvency and run risk, unlike during previous crises. These dealers provided relatively stable funding to hedge fund clients through the stress period. Even with limited balance sheet capacity,

[5]See, for example Boyarchenko, Eisenbach, Gupta, Shachar, and Van Tassel (2020); Schrimpf, Shin, and Sushko (2020); He, Nagel, and Song (2022).

[6]Kruttli, Monin, and Watugala (2022) use Form PF data and a similar empirical strategy, adapted from Khwaja and Mian (2008), to examine the impact of idiosyncratic prime broker distress on hedge funds.

[7]The Basel III leverage ratio is a non-risk-weighted bank capital requirement that effectively constraints low-risk, high-volume activities such as uncleared Treasury repo. The U.S. banking agencies implementation of the Basel III leverage ratio is the Supplementary Leverage Ratio (SLR).

dealers did not significantly step back from repo funding provision to hedge funds. This is likely because relationships between creditors and large hedge fund borrowers tend to be sticky and hard to substitute (Kruttli, Monin, and Watugala, 2022). Illustrating the importance of relationships in bilateral uncleared repo, we find that dealers appear to favor clients with whom they do more business and likely bring in greater revenue via higher levels of activity in fixed income markets.

These findings are consistent with hedge funds' external funding constraints not being the major driver of the step back from UST liquidity provision. An alternate set of constraints can stem from a hedge fund's internal risk and liquidity management.

First, we analyze the relationship between a hedge fund's internal risk limits and its UST trading. Many hedge funds use Value-at-Risk (VaR) methods to measure and manage the risk of their portfolios, dynamically adjusting their portfolio exposures to avoid losses over pre-specified VaR limits. We use VaR information reported by hedge funds and find that funds with higher risk limits provided more liquidity during the March 2020 episode. This empirical evidence illustrates, for the first time, the importance of internal risk limits for hedge funds' ability and willingness to provide liquidity during a crisis period. The economic magnitude of the effect is substantial. A one standard deviation increase in the risk limit, predicts an increase in the UST arbitrage position of over 47%. While past papers like Adrian and Shin (2014) show that bank internal risk limits can impact their liquidity provision, prior studies on hedge funds often model them as risk-neutral agents on the theoretical side or are unable to test the effects of heterogeneity in risk-bearing capacity due to a lack of data on the empirical side. To our knowledge, this is the first paper to show the significant impact of hedge funds' internal risk limits on their trading.

Using the comprehensive coverage of share restrictions in our data, we next examine the role of redemption risk in the liquidity provision of levered arbitrageurs. While hedge funds experienced small outflows during the March 2020 turmoil itself, they may have received notices about future redemptions or, facing uncertainty about the duration and depth of the crisis, may have predicted greater expected volatility in future redemptions. There are contrasting predictions in the literature on whether redemption restrictions are stabilizing for hedge funds. Hombert and Thesmar (2014) show theoretically that contractual impediments to investor withdrawals can be stabilizing by enabling a fund to hold on to their arbitrage trades through a stress period. However, Ben-David, Franzoni, and Moussawi (2012)—in an examination of 13-F filings of long equity holdings during the GFC, a relatively long-lasting crisis—find that equity hedge funds were likely forced to delever to meet redemptions because hedge fund investors subject to share restrictions react quicker to adverse performance than mutual fund investors.[8] In contrast, our data allow us to observe both long *and* short exposures of fixed income hedge funds, in addition to granular information on fund cash, liquidity, and share restrictions. We find that, in general, the boost to liquidity holdings and the step back from UST arbitrage activity were less pronounced for funds with lower redemption risk due to longer (stricter) share restrictions including lock-ups, gates, and redemption notice periods. Funds with higher redemption risk (shorter share restrictions) traded out of and closed out more portfolio positions, and, in particular, cut their UST arbitrage exposures by more. Note that while heterogeneity in redemption risk had a significant impact, the impact of internal risk limits were of equal or greater magnitude on a fund's propensity to hold on to UST arbitrage trades.

Finally, we consider margin calls from exchanges, which can create an immediate need for cash that impacts UST hedge fund activity as a fund depletes their cash held for liquidity management purposes (Brunnermeier and Pedersen, 2009). Compared to other UST trading funds during the March 2020 turmoil, the subset of UST hedge funds that predominantly engaged in the cash-futures basis trade faced greater margin pressure stemming from their short futures positions, requiring immediate liquidity infusions or position liquidations (Schrimpf, Shin, and Sushko, 2020). Unlike with bilateral repo borrowing, trading derivatives on exchange is not subject to bespoke, stabilizing arrangements due the strength of a relationship. We find that basis trading funds faced worse repo terms—including shorter maturities and higher haircuts—compared to other UST hedge funds. Basis traders' cash positions including posted margin were substantially higher. Also, basis trading funds reduced the number of open positions in their portfolios by more than other hedge funds. These findings are consistent with basis traders facing greater immediate liquidity needs and funding pressures.

In the midst of a systemic stress period, asset managers face a trade-off: selling the more liquid assets first likely has a smaller price impact and mitigates current realized losses. However, such an approach to liquidity management makes the remaining portfolio less liquid, increasing the risk of fire sales should the crisis persist or worsen. On the other hand, selling illiquid assets earlier, while

[8] On the other hand, Jylhä, Rinne, and Suominen (2014) and Aragon, Spencer, and Shi (2019) find that share restrictions are beneficial for equity hedge fund liquidity provision.

potentially incurring greater current realized losses, improves the liquidity condition of the fund in the future, when the crisis might deepen.[9] The pecking order of liquidity risk management by hedge fund managers therefore has important implications for financial stability. However, little is known about the liquidity management behavior of the hedge fund sector in stressed conditions.[10] Jorion (2000) draws together press reports for a case study of the LTCM meltdown, describing the likely liquidity management choices at that hedge fund as it approached catastrophic failure. We find several contrasting findings in the March 2020 crisis for the liquidity management of the sample of UST hedge funds, who may have learned lessons from LTCM and other hedge fund meltdowns. The hedge funds in our sample significantly increased the liquidity of their portfolios by reducing the size of their portfolios and disproportionately scaling down relatively illiquid assets, in marked contrast to LTCM in crisis. This effect is stronger for hedge funds whose advisors were incepted prior to the 1998 LTCM crisis, suggesting that experiencing that episode affected a hedge fund's liquidity management.

2 Background

2.1 Pre-crisis hedge fund UST activity

In the period leading up to the March 2020 COVID-19 shock, we show that hedge fund UST exposures doubled from early 2018 to February 2020, reaching \$1.4 trillion and \$0.9 trillion in long and short notional exposure, respectively, primarily driven by relative value arbitrage funds. Long UST securities positions are primarily financed via repurchase agreements (repo borrowing), while short UST securities positions are primarily sourced through reverse repo (repo lending). This reliance on repo is one of the major distinctions between hedge fund equity versus fixed income trading. Since 2018Q2, we find that there has been a significant increase in hedge fund repo

[9] There are contrasting findings on this trade-off in the asset management literature. Jiang, Li, and Wang (2021) find that the behavior of mutual funds during tranquil and stress periods are different: in tranquil periods, redemptions are met by selling liquid holdings, while mutual funds proportionally scale down liquid and illiquid holdings during periods of high aggregate uncertainty to preserve portfolio liquidity. In contrast, Ma, Xiao, and Zeng (2020) posit that in the March 2020 shock, corporate bond mutual funds sold more liquid bonds to meet investor redemptions.

[10] For example, several papers examine the liquidity management of mutual funds through stress periods. Chernenko and Sunderam (2016) find that mutual funds hold substantial cash positions to manage potential redemptions. Morris, Shim, and Shin (2017) find that cash hoarding by mutual funds is the rule rather than the exception, and that funds with more illiquid portfolios hold greater levels of precautionary cash. Chen, Goldstein, and Jiang (2010); Goldstein, Jiang, and Ng (2017) find that mutual fund fragility is impacted by portfolio liquidity.

borrowing, indicating a marked increase in long UST securities holdings. Until that point, aggregate hedge fund repo borrowing and lending exposures were generally matched, as one would observe with UST arbitrage strategies such as trading on-the-run/off-the-run spreads or yield spreads.[11] The divergence between hedge fund repo borrowing and lending is likely driven by a significant increase in recent years in UST cash-futures basis trading.[12] As with many other spread trades hedge funds engage in, these trades are primarily "short liquidity," and perform worst in states of the world in which liquidity is scarce.

2.2 Related literature

Several other papers have examined hedge fund activity during financial crises and periods of market stress. Examples include papers on equity hedge funds and their impact during the tech bubble (Brunnermeier and Nagel, 2004) and various episodes of the global financial crisis, including but not limited to Khandani and Lo (2011) on the quant fund crisis in August 2007, Aragon and Strahan (2012) on the Lehman bankruptcy in September 2008, and Ben-David, Franzoni, and Moussawi (2012) on equity-focused hedge funds and investor redemptions. Boyson, Stahel, and Stulz (2010) find there is contagion in hedge fund returns during adverse market shocks from 1990-2008. Compared to these crisis episodes, the March 2020 shock is unique, particularly in the speed at which extreme moves occurred and in its impact on otherwise safe and liquid markets such as the UST market. By analyzing the activity of hedge funds during this episode in U.S. Treasury markets and bilateral repo/reverse repo funding markets, this paper sheds light on how the characteristics and funding structures of hedge funds impact their trading in vital financial markets.

Due to data limitations, most prior papers focus on the trading of equity-oriented hedge funds for which snapshots of information exist based on regulatory filings of their equity positions on Form 13F and self-reported returns. We contribute to the literature by studying Treasury market activities of hedge funds before and during the March 2020 shock.

[11] We describe the cash flows and exposures for hedge funds involved with such fixed income arbitrage strategies in the Online Appendix.

[12] In this trading strategy, as described in the Online Appendix, a hedge fund goes long the (cheapest-to-deliver) Treasury security and goes short the corresponding Treasury futures contract. The futures leg does not require reverse repo, so the divergence between hedge fund repo borrowing and lending is consistent with reports of a significant increase in recent years in UST cash-futures basis trading. Typically, this is a low volatility, low yield convergence strategy that is operationally intensive and requires leverage to be worthwhile. The trade is profitable as long as the actual cost of carrying the cash position (the "repo rate" or the cost of repo borrowing for the hedge fund) is below the implied cost of carry on the futures (the "implied repo rate").

Our paper contributes to the literature on limits to arbitrage and liquidity management in asset management in general and hedge funds in particular. Arbitrageurs are constrained by internal limits, such as those based on leverage requirements and VaR (Shleifer and Vishny (1997); Gromb and Vayanos (2010); Hombert and Thesmar (2014)). Adrian and Shin (2014) document the important explanatory role of banks' disclosed VaR for credit supply fluctuations in the economy. There is a literature that links the balance sheet constraints of intermediaries like broker-dealers and investment banks to asset prices (e.g., He and Krishnamurthy (2013)) and show an association between the balance sheet of such intermediaries and market liquidity.[13] Kruttli, Patton, and Ramadorai (2015) show that constraints at hedge funds also impact asset prices given their intermediary role as arbitrageurs that provide liquidity to markets. Çötelioğlu, Franzoni, and Plazzi (2021) find that liquidity provision by hedge funds is particularly exposed to general financial conditions. In the post-GFC period, hedge funds are thought to have increased their role as quintessential arbitrageurs in the Treasury and other fixed income markets as more regulated financial institutions such as bank-affiliated dealers faced increasing regulatory- and non-regulatory constraints on their arbitrage activities (Boyarchenko, Eisenbach, Gupta, Shachar, and Van Tassel, 2020; He, Nagel, and Song, 2022). Hedge fund arbitrage implicitly depends on broker-dealer balance sheets since it requires funding, which is typically provided by dealers and prime brokers.[14] Dealer balance sheet and risk management constraints can therefore limit the provision of arbitrage by hedge funds, particularly in times of stress. We contribute to the literatures on limits to arbitrage and intermediary asset pricing by studying the behavior of hedge fund arbitrageurs under extreme market stress and analyzing the impact on their trading and liquidity provision from constraints to the external financing provided by dealers and investors, as well as internal risk management considerations.

Our paper significantly advances our understanding of hedge funds that engage in fixed income arbitrage in particular. Other work in this area has been limited by data or scope. Primarily using contemporaneous press reports, Edward (1999); Jorion (2000) give a view into the meltdown of LTCM, which famously engaged in several fixed income arbitrage strategies using substantial

[13] E.g., Adrian and Shin (2010); Acharya, Lochstoer, and Ramadorai (2013).

[14] Ang, Gorovyy, and Van Inwegen (2011) find that the leverage of hedge funds is counter-cyclical to the aggregate leverage of other financial intermediaries. Kruttli, Monin, and Watugala (2022) show that a prime broker who is liquidity constrained due to an idiosyncratic shock can be quick to significantly cut credit to its hedge fund clients, with significant consequences to the funding of connected funds who are only able to imperfectly substitute such creditor relationships quickly, even during tranquil market conditions.

leverage and potentially misspecified risk management metrics. Jorion (2000) points out that many of these different "arbitrage" strategies implicitly involve taking on correlated exposures on liquidity risk, volatility risk, and default risk, all of which tend to spike during periods of market stress. Duarte, Longstaff, and Yu (2007) replicate a range of common fixed income arbitrage strategies to analyze their potential returns and risks, and find that the risk-adjusted performance of these strategies is not simply "picking up nickels in front of a steamroller." Barth and Kahn (2021) use a model and aggregate sector-level data to analyze the mechanics of the cash-futures basis trade. Our paper differs in that we use granular data to conduct fund-level and fund-creditor-level analyses to gain a comprehensive view on the trading and funding of all major hedge funds that are active in UST markets, of which basis traders are a subset. Bilateral repo data at the hedge fund-creditor level enable us to analyze how dealer regulatory constraints impacted hedge fund borrowing. We use fund-level data to understand how heterogeneity across UST trading hedge funds is related to cross-sectional differences in hedge fund trading and liquidity management.

Finally, we contribute to a growing literature examining aspects of the COVID-19 shock in fixed income markets including its implications for financial stability and market design. These include papers examining the investor outflows and fire sales of corporate bond mutual funds (see, for example, Falato, Goldstein, and Hortaçsu (2021); Ma, Xiao, and Zeng (2020) and money market funds (Li, Li, Macchiavelli, and Zhou, 2021) and dealer liquidity provision in MBS markets (Chen, Liu, Sarkar, and Song, 2020). Duffie (2020); Schrimpf, Shin, and Sushko (2020) describe the stress to UST markets and present suggestions for market reform. He, Nagel, and Song (2022) present a theoretical model that shows how regulatory constraints of dealer banks could potentially exacerbate the destabilizing effects of a UST supply shock. There are several papers focused on corporate bond markets during this episode including Haddad, Moreira, and Muir (2021); Kargar, Lester, Lindsay, Liu, Weill, and Zúñiga (2021); O'Hara and Zhou (2020).

3 Data and summary statistics

The hedge fund data used in this paper are primarily from Form PF. In our analysis, we use the set of qualifying hedge funds (QHFs) that file this form quarterly,[15] and follow the data cleaning and

[15]These quarterly filings include the intra-quarter *monthly* values for most key variables of interest including asset and repo exposures, returns, cash levels, portfolio size, and number of positions, etc.

validation procedure outlined in Kruttli, Monin, and Watugala (2022). Table 1 presents summary statistics for the key variables of interest. Our sample consists of the set of hedge funds with gross UST exposure of at least \$1 million on average during Q4 2019.[16] We apply this threshold for two reasons. On the one hand, we want to ensure that the estimates of our regression models are not affected by changes in very small UST exposures. On the other hand, the threshold should be sufficiently low that we capture potential hedge funds that had small UST trading positions before March 2020 but then substantially increased their UST trading during the crisis. A summary reference of variable definitions is included as the last table in this paper in Table 13.

Panel A of Table 1 reports the hedge fund characteristics. The average hedge fund has \$2.8 billion in net asset value (NAV) and a leverage ratio of 2.5. The next three variables measure different dimensions of fund liquidity, including portfolio liquidity ($PortIlliq_{h,t}$), investor liquidity as measured by share restrictions ($ShareRes_{h,t}$), and the funding liquidity measured as the weighted average maturity of a fund's borrowing ($FinDur_{h,t}$). Form PF asks for the percentage of a hedge fund's assets, excluding cash, that can be liquidated within particular time horizons (within $\leq$1, 2-7, 8-30, 31-90, 91-180, 181-365, and >365 days) using a given periods' market conditions. We compute the weighted average liquidation time to obtain the measure $PortIlliq_{h,t}$. The average $PortIlliq_{h,t}$ is 33.1 days in our sample and the median is 7.2 days. $ShareRes_{h,t}$ is a measure of the expected weighted average time it would take for a hedge fund's investors to withdraw the fund's equity. This variable quantifies the restrictions faced by a fund's investors, such as lock-up, redemption, and redemption notice periods. The average $ShareRes_{h,t}$ is 125.8 days. The weighted average time to maturity of a fund's borrowing is denoted $FinDur_{h,t}$. On average, the financing duration is 37.1 days for our sample of hedge funds with a median of 10.7 days. Panel A further provides summary statistics for monthly and quarterly returns as well as quarterly flows.

The variable $RiskLimit_{h,t}$ is based on the hedge fund's value at risk, VaR. The VaR shows for each fund and month the potential loss (as a percent of NAV) over a one-month horizon with a probability of 5%.[17] A detailed description of the VaR measure is given in the Online Appendix. We construct two measures based on the monthly VaR observations. The first measure proxies for

[16]Our findings are robust to either smaller or larger cutoffs for UST exposure.

[17]Not every fund in our baseline sample reports its VaR in Form PF. Only funds that regularly calculate VaR for their risk management report it. Around 60% of the funds in our sample report the VaR.

a fund's typical risk limit and is the VaR averaged over a rolling 12-month window, given by

$$RiskLimit_{h,t} = \frac{1}{12} \sum_{n=t-11}^{t} VaR_n. \tag{1}$$

The average $RiskLimit_{h,t}$ is 4.7%, which implies that the average fund expects to lose 4.7% of its NAV in a month 5% of the time.

Form PF data contain granular information on a hedge fund's cash positions. The variable $FreeCashEq_{h,t}$ measures unencumbered cash that is held for liquidity management purposes, including U.S. Treasuries that are not posted as collateral. The variable $Cash_{h,t}$ on the other hand only includes "pure" cash and not U.S. Treasuries. The two measures, normalized by NAV, are on average 26.8% and 30.6%, respectively. Panel A also provides information on the number of a hedge fund's open positions, gross notional exposure (GNE), and portfolio GNE. The difference between the GNE and the portfolio GNE is that portfolio GNE does not include free cash.

We obtain data on hedge fund UST exposures from Question 30 of Form PF, which requires hedge funds to report the month-end values of long and short portfolio exposures in a range of asset classes. Fixed income holdings are reported both as notional exposures and on a risk-adjusted basis.[18] Panel B of Table 1 provides summary statistics on the hedge funds' UST exposure. The gross notional UST exposure for hedge fund h in month t, $UST\_Gross_{h,t}$, is on average \$2.8 billion. Importantly, this measure includes exposure to UST through derivatives and futures, as well as physical exposures. The $UST\_Gross_{h,t}$ is the sum of the long and short UST exposure, which we observe separately and are named $UST\_Long_{h,t}$ and $UST\_Short_{h,t}$, respectively. The net UST exposure is given by the difference of the two and named $UST\_Net_{h,t}$. On average, the $UST\_Net_{h,t}$ is positive with \$846.0 million, indicating that the average long exposure is larger than the short exposure.

The variable $USTArbitrage_{h,t}$ captures the part of the UST GNE that is long-short balanced and is used as a proxy for the UST arbitrage activity of a fund. Explicitly, we set $USTArbitrage = 2 \times min(UST\_Long_{h,t}, UST\_Short_{h,t})$.[19] This definition will capture prominent UST arbitrage trades like the on-the-run/off-the-run and the cash-future basis trade. On the other hand, the

[18] The risk-adjustment is either based on duration, weighted average tenor, or 10-year equivalent. Where we use risk-adjusted exposures, we convert the reported values to the same units, as described further in the Online Appendix.

[19] We multiply the minimum by two to ensure comparability to the GNE.

variable $USTDirectional_{h,t}$ captures the unbalanced directional UST exposure and is set equal to $abs(UST\_Net_{h,t})$. The arbitrage and directional exposure are related to the $UST\_Gross_{h,t}$ as

$$UST\_Gross_{h,t} = USTDirectional_{h,t} + USTArbitrage_{h,t}. \tag{2}$$

The duration of a hedge fund's long and short UST exposure are provided separately, $UST\_Long\_Drtn_{h,t}$ and $UST\_Short\_Drtn_{h,t}$, with an average value of 4.2 and 4.3 years, respectively. The duration of the net exposure, $UST\_Net\_Drtn_{h,t}$, is on average 4.6 years.

Panel C describes the borrowing data. Repo borrowing is on average \$3.6 billion, and the average repo lending is \$2.7 billion. The terms for the repo borrowing and lending, $RepoBrrwTerm_{h,t}$ and $RepoLendTerm_{h,t}$, are on average 25.7 and 12.2 days, respectively. Repo borrowing is over-collateralized, with the average ratio of total collateral to borrowing of 118%. On average, 85% of the collateral supporting repo is securities collateral, although cash collateral is also sometimes posted. Most of hedge fund repo is transacted bilaterally, with only 13.7% of the repo centrally cleared.

Panel D presents data on a hedge fund's borrowing from major creditors at the counterparty level. The total amount of borrowing, $TotalMCBorrowing_{h,t}$, is the sum of borrowing across all major counterparties reported in Question 47 of Form PF as of the end of a given quarter. It includes borrowing from repo as well as other sources such as margin loans. The number of creditors from which a hedge fund borrowed as of the end of a given quarter, $NumCrdtrsPerHF_{h,t}$, is on average 4.5. The average amount borrowed from a specific creditor is $HF\_Ctpty\_Credit_{h,p,t}$ is \$1.3 billion. In about half of the cases, a hedge fund's creditor is also its prime broker and custodian.

4 Hedge funds and the COVID-19 Treasury market shock

We first analyze the changes to hedge fund UST portfolios, performance, liquidity and leverage management, and (repo) financing during the March 2020 Treasury market shock. Figures 1 to 6 give an indication of the aggregate changes to the Treasury market activity of hedge funds. To provide a fund-level view of the changes that occurred during March 2020, while separating out differences due to different hedge fund characteristics and fund-specific effects, we estimate panel regressions of changes in different measures of hedge fund Treasury activities on the March 2020 dummy variable and control variables. The baseline regressions take the form,

$$\Delta y_{h,t} = \beta_1 D_t + \gamma Z_{h,t-1} + \mu_h + \epsilon_{h,t}, \tag{3}$$

where $\Delta y_{h,t}$ is the outcome of interest and is a change variable. D_t is 1 for March 2020 and 0 otherwise. $Z_{h,t-1}$ is the set of lagged controls ($LogNAV$, $NetRet$, $NetFlows$, $PortIlliq$, $ShareRes$, $FinDur$, $MgrStake$, and $Leverage$). μ_h denote fund fixed effects. Standard errors are double clustered by fund and time. The data are monthly from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least \$1 million on average during Q4 2019.

4.1 Changes to U.S. Treasury exposure

Table 2 presents regression results with dependent variables capturing different aspects of a hedge fund's UST exposure. Panel A analyzes changes to the notional exposure—both gross notional exposures and long and short exposures separately—measured either in dollar terms or as a fraction of NAV. The coefficient on $March2020$ is significant and negative for all outcome variables. The first three columns show that, in March 2020, hedge funds reduced UST exposure by around 20%, on both the long and the short sides. The last three columns show that this change is significant even when UST exposures are normalized by a fund's NAV. UST exposure as a fraction of NAV went down by about 8% on the long and short side. Total (gross) UST exposure as a fraction of NAV went down by about 15% in March. These results provide robust evidence of a significant, abnormal decline in hedge funds' Treasury exposures in March 2020. Despite the widening of spreads during the Treasury market turmoil, hedge funds refrained from providing liquidity. In fact, they consumed liquidity by reducing their gross, long, and short exposures.

Among the control variables, flows are positively related to UST exposure: the first three columns show a positive and significant coefficient on $NetFlows$ indicating that funds adjust their portfolios in response to investor inflows and outflows. As expected, flows do no change UST allocations as a fraction of a fund's NAV. Most other variables are not significantly related to Treasury exposures after controlling for fund fixed effects.

Table 2 Panel B examines the directional exposure and arbitrage activity in UST portfolios.

As discussed in Section 3, *USTArbitrage* captures the part of a hedge fund's UST portfolio that is long-short balanced. The regression in column 1 indicates that purely directional exposures, *USTDirectional* dropped by close to 15%. Column 2 shows that following the March 2020 shock, hedge funds reduced their UST arbitrage portfolios by around 25%. The next column confirms that long-short balanced exposures declined disproportionately more than directional exposures in UST hedge fund portfolios. Columns 4 to 7 show changes to arbitrage exposures for the set of UST hedge funds that had "medium" or "large" arbitrage exposures in 2019:Q4.[20]

While these drops in notional UST exposure are based on end-of-month Treasury securities valuations, we estimate valuation-adjusted UST exposures in the Online Appendix and use them as dependent variables. This adjustment has little effect on the coefficient estimates. Further, in the Online Appendix, we show robustness to including time series controls, namely the Bank of America / Merrill Lynch Option Volatility Estimate (MOVE1), the yield slope, and the Hu, Pan, and Wang (2013) noise measure (HPW).[21]

The data that we use are the most comprehensive that we are aware of across regulatory and commercial datasets to view hedge fund UST activity in March 2020. We estimate that in March 2020, hedge funds sold $173 billion in UST securities after accounting for valuation changes (see also Banegas, Monin, and Petrasek (2021) for more discussion). He, Nagel, and Song (2022) use publicly available quarterly Flow of Funds data published by the Federal Reserve—which covers only the subset of the hedge funds in Form PF domiciled in the US and excludes offshore funds—and find that this subset sold $30 billion in 2020Q1. Our estimate is in line with Vissing-Jorgensen (2021) who estimates that hedge funds had at least $183 billion in Treasury sales during 2020Q1 using publicly available private fund statistics from the SEC and Treasury futures data from the CFTC.

4.2 Repo activity

Having found notable declines in hedge funds' UST exposures following the March 2020 shock, we analyze whether hedge funds were forced to reduce their exposure because their access to repo funding decreased. Previously, very little was known about hedge funds' repo activity because it is

[20]The medium (large) set is defined as the UST arbitrage hedge funds with above 25^{th} (50^{th}) percentile *USTArbitrage* on average in 2019:Q4 and captures the set of hedge funds with significant long-short UST exposures, excluding those with only directional positions, prior to the UST turmoil.

[21]The yield slope is computed as the Treasury 10-year constant maturity rate minus 2-year constant maturity rate.

largely conducted on a bilateral, uncleared basis, in what is considered the most opaque segment of the repo market (Gorton, Metrick, and Ross, 2020). Form PF data provides a unique view into hedge funds' bilateral repo activity and its resilience under stress. The summary statistics for $RepoBilateral_{h,t}$ and $RepoClearedCCP_{h,t}$ in Table 1 Panel C show that hedge fund repo borrowing is predominantly (around 80%) bilateral and uncleared.

Table 3 presents results from analyzing hedge funds' repo activity. The table shows the hedge funds' repo borrowing was surprisingly resilient during the March 2020 sell-off in Treasury markets. The results in column 1 show that borrowing levels on repurchase agreements—the primary source of financing for hedge fund long UST holdings—remained relatively unchanged in March 2020.

In contrast to repo borrowing, column 5 shows that hedge fund repo lending or "reverse repo" decreased in March 2020 by around 25% for the average fund. When trading Treasury securities, UST short bond positions are typically sourced through reverse repo, with the hedge fund obtaining the security as collateral from the borrower in exchange for lending cash. A reduction in repo lending is therefore consistent with the decline in short UST exposures shown in Table 2 Panel A, as well as with hedge funds conserving their cash holdings during the crisis.

These unchanged repo exposures fail to support the hypothesis that a tightening of hedge funds' repo borrowing caused hedge funds to sell their UST positions. However, this result still leaves the possibility that while the amounts of repo borrowing were unchanged, the terms of the bilateral repo transactions changed. To our knowledge, there is no dataset that contains information on the repo rate of the uncleared bilateral repo market that hedge funds predominantly use either in the aggregate or at the fund level. However, Form PF allows us to observe two important terms of repo transactions at the fund level: the maturity and the collateral haircut.

Columns 2 and 6 in Panel A show that changes to repo and reverse repo maturities in March 2020. The maturity of hedge funds' repo borrowing increased in March by about 3 days, which is a considerable increase as the average and median repo maturity is 26 and 9 days, respectively. This result is again consistent with hedge funds having unconstrained access to repo borrowing in March 2020.

Table 3 columns 5 and 6 examine the collateral and collateral haircuts on repo financing. Surprisingly, we do not find evidence that repo haircuts became significantly more onerous for hedge funds during this stress period. In fact, the total collateral as a fraction of repo borrowing,

$\frac{RepoTotalCollateral}{RepoBorrowing}$, shows a statistically significant decrease of around 0.7 percentage points.

Because the previous results use end-of-month data, it could be that some crucial intra-month fluctuations of the repo market are missing. The March turmoil dampened following the Fed intervention on March 23, 2020, in the latter part of the month. Form PF yields a comprehensive view on the state of funds soon after, on March 31, 2020. However, we obtain the daily time series of bilateral repo lending by the top 10 G-SIB dealers from the regulatory dataset FR2052a. Figure 7 shows that repo funding provision also stayed relatively unchanged intra-month.

Overall, these baseline results on repo amounts, maturity, and collateral haircuts do not support the view that repo funding volumes and terms became significantly tighter for hedge funds that invest in Treasuries following the March 2020 shock. However, although the average hedge fund did not experience a funding shock, it is possible that some lending counterparties tightened their provision of credit to hedge funds more than others. We conduct further analysis on hedge fund repo borrowing in Section 5.1 using hedge fund-creditor (fund-dealer) level data, specifically focusing on whether dealers subject to enhanced regulations passed on funding supply shocks to connected hedge funds.

5 Constraints on hedge fund UST liquidity provision

5.1 Dealer regulatory constraints and bilateral repo lending

We examine the role of dealer regulatory constraints in affecting hedge fund trading through dealers' differential provision of funding in March 2020.

Using data on borrowing amounts available at the hedge fund-creditor level, we conduct a granular analysis to identify the impact of creditor supply shocks on hedge fund repo borrowing. We use a within hedge fund-time methodology to test for differences between funding provided by creditors that are constrained and those that are not, allowing us to compare hedge funds' borrowing from different creditors while controlling for unobserved time-varying hedge fund characteristics.[22]

[22] This identification strategy is similar to Khwaja and Mian (2008), Kruttli, Monin, and Watugala (2022), and many others that use borrower-creditor data to isolate credit supply effects.

The panel regressions take the form,

$$\Delta \log HF\_Crdtr\_Credit_{h,p,t} = \gamma_1 DealerConstraint_{p,t} + \gamma_2 DealerConstraint_{p,t} \times D_t + \phi Z_{h,p,t-1} + \mu_h + \theta_t + \psi_p + \epsilon_{h,p,t}, \tag{4}$$

$$\Delta \log HF\_Crdtr\_Credit_{h,p,t} = \gamma_1 DealerConstraint_{p,t} + \gamma_2 DealerConstraint_{p,t} \times D_t + \nu_{h,t} + \psi_p + \epsilon_{h,p,t}, \tag{5}$$

$$\Delta \log HF\_Crdtr\_Credit_{h,p,t} = \gamma_1 DealerConstraint_{p,t} + \gamma_2 DealerConstraint_{p,t} \times D_t + \nu_{h,t} + \xi_{h,p} + \epsilon_{h,p,t}, \tag{6}$$

where D_t is 1 for March 2020, 0 otherwise. $DealerConstraint_{p,t}$ is a measure that captures heterogeneity across dealers in terms of potential constraints to their intermediary role in repo markets. Equation (4) includes hedge fund (μ_h), creditor (ψ_p), and time (θ_t) fixed effects. Equation (5) includes creditor fixed effects and hedge fund-time fixed effects ($\nu_{h,t}$). Fund-time fixed effects control for all time invariant and time-varying fund characteristics, absorbing fund-level borrower demand shocks, which allows for better identification of dealer-specific supply effects. Equation 6 includes both fund-time and fund-creditor ($\xi_{h,p}$) fixed effects, with the latter allowing us to control for relationship-specific factors. Standard errors are clustered at the dealer and quarter level. Since Treasury positions are typically financed by repo, we limit the sample for this analysis to hedge funds that primarily borrow via repo (50% or more of their borrowing is via repo) on average during Q4 2019. A requirement of the within fund-time analysis is that the sample includes only hedge funds that borrow simultaneously from at least two creditors. The vast majority of the hedge funds in our sample borrow from multiple creditors simultaneously. The methodology is illustrated with an example hedge fund-dealer network in Figure 8.

First, we use a dealer's status as a global systemically important financial institution (G-SIB) as the $DealerConstraint_{p,t}$ measure.[23] G-SIBs are the largest, most interconnected institutions and face enhanced regulations in the post-GFC period — including the U.S. enhanced supplementary leverage ratio based on the total size of their balance sheet and off-balance sheet exposures — and are therefore subject to the most stringent regulatory constraints. However, the findings reported in

[23]See the Online Appendix for the list of primary dealer and G-SIB institutions, including the timeline of G-SIB classifications.

Table 4 are inconsistent with these constraints limiting dealers' funding provision during the March 2020 UST sell-off. Interestingly, G-SIBs provided disproportionately *higher* funding during the crisis to hedge funds engaged in repo borrowing. Relative to other dealers, G-SIBs increased repo lending to hedge funds by 11-13% in March 2020. These results suggest that larger, more regulated G-SIB dealers were better able to provide stable, more resilient funding during the March 2020 sell-off than smaller dealers. The findings also imply that hedge funds connected to G-SIB dealers had access to disproportionately greater funding during the March sell-off. In the Online Appendix, we present additional results. The Online Appendix shows results when the same set of regressions are run on all hedge funds that primarily borrow via repo, regardless of their UST exposures. The results are qualitatively similar.

Next, we explicitly use the distance between a bank's leverage ratio and its minimum required leverage ratio threshold (LRT), $DistanceToLRT_{p,t}$, as the $DealerConstraint_{p,t}$ measure. The Basel Committee on Banking Supervision introduced the leverage ratio to constrain the build-up of leverage and supplement risk-based capital requirements. The leverage ratio measure compares a bank's capital to total exposures, including some held off balance sheet. The Basel III accords recommended that leverage ratios be disclosed by Q1 2015 and a minimum LRT of 3% with add-ons for G-SIBs. The minimum requirement was implemented by legislation and rulemaking across different jurisdictions with a variety of effective dates and calculation methods. We hand-collect the leverage ratios, (time-varying) minimum requirements, and relevant dates for all banks in our sample to construct $DistanceToLRT_{p,t}$.[24] A bank closer to its minimum LRT would have a smaller $DistanceToLRT_{p,t}$, and hence, likely be more constrained by the leverage ratio requirement.

Table 5 shows the results. In Panel A, the sample consists of US G-SIBs only and the indicator variable $PostJanuary2018_t$ controls for the effective date of the leverage ratio requirement in the US. In Panel B, the sample consists of all US and foreign banks. The indicator variable $PostEffectiveDate_{p,t}$ is included to control for the effective date of the leverage ratio requirement for each bank, which can differ across countries and institutions. If the leverage ratio requirement was a binding constraint on the funding provided to hedge funds by bank-affiliated broker-dealers in March 2020, we expect the coefficient on $March2020_t \times DistancetoLRT_{p,t-1}$ to be positive and

[24] In the US, this regulation is the Supplementary Leverage Ratio (SLR) rule, which was finalized in September 2014 and mandated disclosure starting in January 2015 with the minimum capital requirement effective from January 2018. US banks subject to the SLR have an LRT of 3%, while US G-SIBs are subject to an enhanced SLR of 5%.

significant. However, the coefficients are insignificant. We do not find evidence that the distance to the leverage ratio threshold was a significant factor in the credit supplied to hedge funds during this episode.

A natural question is whether the frequency of the repo data used in the regression analysis misses any crucial intramonth fluctuations. The fund-level aggregate borrowing data available from Form PF are at a monthly frequency and the hedge fund-creditor-time borrowing data are at a quarterly frequency. However, as discussed previously, the daily time series of repo lending by the top 10 G-SIB dealers obtained from a different regulatory dataset (FR2052a) also does not show any pull back in repo supply (see Figure 7).

There has been much debate about the impact of post-GFC regulations on bank affiliated broker-dealers on Treasury and other fixed income market liquidity,[25] and the impact of dealer regulatory constraints on hedge fund arbitrage activity (e.g., Boyarchenko, Eisenbach, Gupta, Shachar, and Van Tassel (2020)) including specifically during the March 2020 UST market turmoil (e.g., Schrimpf, Shin, and Sushko (2020); He, Nagel, and Song (2022)).

We find that broker-dealers affiliated to banks subject to enhanced regulations were able to disproportionately increase repo funding to connected hedge funds in March 2020. There are several possible reasons why. These larger dealers may have greater economies of scale and risk-bearing capacity. Their regulated status can give greater access to cheaper funding, which is further augmented during crisis periods via Fed facilities like the Primary Dealer Credit Facility (PCDF).[26] Temporary exemption of UST securities from leverage ratio charges is also likely to have boosted G-SIB dealers' liquidity provision in UST markets in particular. During the COVID-19 shock, these institutions—subject to enhanced regulations constraining their liquidity and risk-taking, greater disclosures, and periodic stress tests conducted by the Federal Reserve post-GFC—were not exposed to significant concerns about solvency and run risk, unlike during the GFC.[27] This may have mitigated precautionary liquidity hoarding behavior by bank-dealers.

[25]See discussions on the potential impact of post-GFC regulatory constraints of bank dealers on intermediation, for example, in UST markets (Duffie, 2020; Infante and Saravay, 2021; Yadav and Yadav, 2021) and corporate bonds (Bao, O'Hara, and Zhou, 2018; Allahrakha, Cetina, Munyan, and Watugala, 2021).

[26]As shown in the Online Appendix, the set of primary dealers' parent companies overlaps significantly with the set of G-SIB institutions.

[27]For example, Gorton and Metrick (2012) find that, during the GFC, concerns about bank insolvency and counterparty risk effectively led to a run on repo.

5.2 Portfolio risk limits

A large share of hedge funds employ VaR to manage the risk of their portfolio. Our data allow us for the first time to analyze risk management metrics of hedge funds and investigate how these metrics affect their trading during a crisis period.

A priori, how a fund's internal risk limits affect trading during a crisis period is unclear. On the one hand, an ex-ante high risk limit is indicative of a high risk-bearing capacity. Arbitrage spreads generally widen further during crisis periods, representing greater profit-making opportunities for those with the capacity to bear the risk. Therefore, a hedge fund with a ex-ante high risk bearing capacity could be better placed to hold onto its trades or even double down and put "risk on" during a crisis. On the one hand, funds that enter a crisis period already holding higher levels of risk due to higher risk limits, may have to sell more of their positions because greater losses and increases in volatility pushes them closer to liquidation or default.

As described in Section 3, funds that use VaR for their risk management are required to report their portfolio VaR at a monthly frequency on Form PF. The VaR shows for each fund and month the potential loss (as a % of NAV) over a one-month horizon with a probability of 5%. We use this information to create the variable $RiskLimit_{h,t}$, which is the rolling 12-month average VaR (as a % of NAV). The more risk the hedge fund is willing to take, the higher the $RiskLimit_{h,t-1}$.

We first estimate the panel regression model where we condition the trading in March 2020 on the risk limit:

$$\begin{aligned} \Delta y_{h,t} = \beta_1 RiskLimit_{h,t-1} + \beta_2 D_t \times RiskLimit_{h,t-1} \\ + \gamma_1 Z_{h,t-1} + \gamma_2 D_t \times Z_{h,t-1} + \mu_h + \theta_t + \epsilon_{h,t}, \end{aligned} \tag{7}$$

where $\Delta y_{h,t}$ is the portfolio change of interest. Again, D_t is 1 for March 2020 and 0 otherwise. $Z_{h,t-1}$ is the same set of controls as in equation (3) and are also included in the regression interacted with D_t. The regression is run with just fund fixed effects (not shown) or both fund and time fixed effects, with qualitatively similar results. β_2 is again the coefficient of interest and captures the differential effect between funds with a high and low risk limit.

The results are reported in Table 7. Across the different dependent variables, the estimates show that funds with a high risk limit were less likely to reduce their UST positions than funds with a low risk limit. The effect of the risk limit is economically large as can be directly seen as the independent variables are standardized. For example, a one standard deviation increase in $RiskLimit_{h,t}$ allowed funds to hold on to 47.2% more of their arbitrage positions. Interestingly, the economic effect of the risk limit on the arbitrage positions in columns (5) through (7) are larger or comparable to the effects of the share restrictions shown in Table 8, even though both effects remain significant when included in the same regression.[28]

5.3 Redemption restrictions and investor runs

We next examine the role of redemption risk. Specifically, we ask whether existing share restrictions made a difference in hedge funds' step back from UST markets and had an impact on their liquidity management. We estimate the following panel regression,

$$\begin{aligned}\Delta y_{h,t} = {} & \beta_1 ShareRes_{h,t-1} + \beta_2 D_t \times ShareRes_{h,t-1} \\ & + \gamma_1 Z_{h,t-1} + \gamma_2 D_t \times Z_{h,t-1} + \mu_h + \theta_t + \epsilon_{h,t},\end{aligned} \tag{8}$$

where $\Delta y_{h,t}$ is the portfolio change of interest. Again, D_t is 1 for March 2020 and 0 otherwise. $Z_{h,t-1}$ is the same set of controls as in equation (3) and are also included in the regression interacted with D_t. The regression is run with just fund fixed effects (not shown) or both fund and time fixed effects, with qualitatively similar results. β_2 is the coefficient of interest and captures the differential effect between funds with long and short share restrictions.

Table 8 shows funds with higher redemption risk sold off more of their UST arbitrage portfolios. Hombert and Thesmar (2014) show theoretically that share restrictions are an effective tool for hedge funds to ensure that they can hold on to arbitrage trades even if the trade temporarily goes against them. However, hedge funds with short share restrictions are more likely forced to sell arbitrage positions before convergence occurs. Interestingly, the empirical findings on share restrictions and liquidity provision, particularly during crisis periods are mixed. Ben-David, Franzoni, and Moussawi (2012) find that equity hedge funds were forced to delever during the GFC to meet redemptions because hedge fund investors subject to share restrictions react quickly to

[28] Share restrictions are included as controls in Table 7 (not shown).

adverse performance. In contrast, Aragon, Spencer, and Shi (2019) find that lock-up periods were beneficial for hedge funds during stock market boom and crisis periods. Both of these papers make use of long equity holdings reported in 13-F filings.[29] Because 13-F does not include short equity positions, it is challenging to derive an empirical measure of arbitrage positions as present in the model of Hombert and Thesmar (2014).

Our empirical approach and setting are distinct in a number of ways. The March 2020 turmoil was an abrupt, extreme, but (in hindsight) short-lived crisis, whereas the Dot-com boom and GFC spanned multiple years. We analyze UST-trading hedge funds which have distinct funding sources and structures to equity hedge funds, e.g., the former extensively use repo funding while the latter do not.

Further, our data allow us to observe the long and short UST positions of a hedge fund. Therefore, we can explicitly test the effect of share restrictions and arbitrage positions, which involve long and short positions, during a crisis period. Table 8 presents the results for UST arbitrage positions. Columns (5) to (7) show the results for subsamples of funds with medium and large arbitrage positions, where medium (large) arbitrage positions is defined as funds above the 25^{th} (50^{th}) percentile in our arbitrage position measure.

The coefficient estimate on the interaction term $March2020 \times ShareRes$ is positive and strongly significant for all but one specification. Further, the magnitude of the estimates increase for the subsamples with larger arbitrage positions and they are economically significant. This result demonstrates that share restrictions allow hedge funds to hold on to fixed income arbitrage trades for longer during the crisis period.

Further, our findings illustrate a crisis episode during which the funding structure of a hedge fund was potentially less destabilizing than that of a mutual fund or a money market fund (MMF), even with the higher illiquidity, leverage, and concentrations typical for a hedge fund. Chen, Goldstein, and Jiang (2010) show that strategic complementarities among investors of mutual funds–especially in funds with relatively more illiquid assets–amplify run risk. Ma, Xiao, and Zeng (2020) find that bond mutual funds were indeed subject to large outflows during the March 2020 turmoil and that these funds responded by selling the relatively liquid assets in their portfolios first,

[29] Similarly, Agarwal, Aragon, and Shi (2019) examine the mismatch between the asset portfolio liquidity of a set of fund of hedge funds and the liquidity offered to their investors and conclude that the extent of liquidity transformation a fund of hedge funds provides is positively associated with greater exposure to investor runs.

meaning that their remaining portfolios were significantly more illiquid when the Fed intervened to stabilize bond markets towards the end of March 2020. In contrast, we show that hedge funds, while experiencing large losses in March, experienced relatively low outflows and shored up the liquidity of their holdings. Their use of long share restrictions were largely stabilizing.

5.4 Basis trading and margin pressure

Unlike UST hedge funds predominantly engaged in fixed income arbitrage strategies that involve simultaneously going long and short bonds—funded via repo borrowing and lending, respectively—hedge funds predominantly engaged in the cash-futures basis trade likely faced greater margin calls requiring immediate liquidity infusions or position liquidations stemming from their short futures positions during the March 2020 turmoil.[30,31] At the inception of the March turmoil, while UST securities declined in value, UST futures *appreciated* in value, exposing the basis risk of this trade as it went against hedge fund positions. We take the set of hedge funds that predominantly engage in the cash-futures basis trade as the hedge funds that faced greater margin pressure and examine the differential impact of such immediate liquidity needs on hedge fund UST market activities.

We classify a hedge fund as a UST cash-futures "basis trader" based on its UST exposures and whether the short exposures are obtained through repo or futures. The classification recognizes that a basis trade has broadly balanced long and short UST notional exposures, with the long "cash" side being a physical bond while the short "futures" side is a derivative. As such, only the long side is funded via repo, while the short side is obtained through futures. This generally contrasts with other UST arbitrage strategies such as on-the-run/off-the-run spread trading where both the long and short side of the trade is supported through repo borrowing *and* lending. We identify the hedge funds that show a strong correlation between their balanced UST position, $USTArbitrage$, and *net* repo exposure, $RepoBorrowing - RepoLending$, as funds that predominantly engage in the basis trade.[32]

Figure 6 presents the times series of UST exposures, repo borrowing and lending, equity and assets, separately for hedge funds that predominantly engage in the basis trade and for hedge funds

[30] See Figure 9 and the Online Appendix for an overview of both types of fixed income arbitrage strategies.

[31] For example, initial and maintenance margin requirements on UST futures contracts traded on CME rose by 30–210% during March 2020, depending on the contract maturity.

[32] The Online Appendix provides a detailed explanation of the methodology.

that predominantly engage in other UST trading strategies. The basis trader fund set represents roughly a half of the aggregate UST notional exposure of the hedge funds in our sample, with a similar share of the aggregate repo exposures. The bottom two panels of the figure show that in aggregate, the total assets under management are substantially larger for non-basis traders, but basis traders on average use much more leverage.

We analyze differences in how basis traders fared during the March 2020 shock compared to other UST traders. We estimate the following panel regression:

$$\begin{aligned} \Delta y_{h,t} = {} & \beta_1 BasisTrader_h + \beta_2 D_t \times BasisTrader_h \\ & + \gamma Z_{h,t-1} + \mu_h + \theta_t + \epsilon_{h,t}, \end{aligned} \tag{9}$$

where $\Delta y_{h,t}$ is the portfolio change of interest. Again, D_t is 1 for March 2020 and 0 otherwise. $Z_{h,t-1}$ is the same set of controls as in equation (3) and are also included in the regression interacted with D_t. The regression is run with just fund fixed effects (not shown) or both fund and time fixed effects, with qualitatively similar results. β_2 is again the coefficient of interest and captures the differential effect between basis traders and other UST traders.

Table 10 Panel A examines changes to UST exposures. The estimates of β_2, the coefficients on $March2020 \times BasisTrader$, show that, after controlling for fund characteristics such as size and leverage, basis trading hedge funds did not change their UST notional exposures significantly more than other hedge funds. However, they predominantly reduced their directional exposure sin favor of retaining their arbitrage positions. As a result, they held more balanced portfolios in terms of long-short UST notional exposure at the end of March 2020.

Table 10 Panel B shows the differences for basis traders in repo borrowing and lending, repo terms, and the ratio of total collateral posted to total repo borrowing—a measure of haircuts or capital required to support repo borrowing. The terms of borrowing appear to have worsened for basis traders. The maturity of repo borrowing declined by 3.4 days for basis traders compared to other UST traders, a substantial decline considering the median repo borrowing term is 8.7 days and the mean is 25.7 days. Finally, we find that basis traders posted more collateral to their repo counterparties with their ratio of total repo collateral to borrowing increasing by around 1.4 percentage points.

In Table 10 Panel C, the regression results in columns 1 and 2 show that compared to other hedge funds, basis traders have significantly less unencumbered cash (including UST bonds) held for liquidity management at the end of March 2020. However, columns 3 and 4 show that their "pure" cash position—including both unencumbered cash *and* cash already posted as margin/collateral, but excluding UST securities held for liquidity purposes—was significantly higher than that of other UST hedge funds. We further find that basis traders close out more positions and have comparatively more *illiquid* portfolio positions at the end of March 2020. Finally, column 8 shows that basis trader hedge funds delevered more in March 2020.

Overall, these findings show that hedge funds engaged in the UST cash-futures basis trade faced greater margin pressure, and thus, contributed more to the reduction in UST exposures than other UST trading hedge funds, and their lenders tightened the financing terms for these hedge funds while they gave more accommodative terms for other hedge fund counterparties. However, the results also suggest that the major reasons for the decline in hedge funds' UST exposures were not specific to the basis trade as other hedge funds also saw large declines in UST exposures.

5.5 Cash, liquidity, and leverage

The final set of regressions giving a baseline overview of the March 2020 shock captures hedge fund outcomes related to liquidity and leverage. Table 12 Panels A and B show that, by the end of March 2020, funds held significantly higher cash and smaller, more liquid portfolios than at the beginning of the month. Panel A shows changes to four different measures of cash holdings as the outcome variable. $FreeCashEq$ refers to unencumbered "cash and cash equivalents" (e.g., bank deposits, certificates of deposits, money market fund investments, U.S. Treasury and agency securities) held for the purposes of liquidity management (see variable definitions in Table 13). $FreeCashEq$ increased by 26% in March 2020. $Cash$ refers to cash positions (not including U.S. Treasury and agency securities) both unencumbered or posted as collateral, which also increased in March 2020, by around 23%.

Portfolio illiquidity (excluding cash) dropped by 11% during this period, with the fraction of assets that can be liquidated within a week increasing significantly. These findings speak to the literature on how a hedge fund manages its liquidity during a systematic stress period. When confronted with significant funding constraints, redemptions and other liquidity needs, asset managers face a trade-off: selling the more liquid assets first likely has smaller price impact and mitigates current realized losses, but increases overall portfolio illiquidity and thus the probability of future fire sales should the crisis persist or deepen. On the other hand, selling illiquid assets first, while potentially incurring greater current realized losses, improves the liquidity condition of the fund and its ability to withstand a protracted crisis. Our findings show that hedge funds took the latter, more prudent approach when managing liquidity during the March 2020 shock. On average, funds significantly increased both their cash holdings and the liquidity of their portfolios by reducing the size of their portfolios and disproportionately scaling down relatively illiquid positions.

These shifts may have been in part driven by the uncertainty associated with the initial COVID-19 shock. At the end of March, amid continued uncertainty regarding the pandemic's impact on financial markets and the economy, hedge funds were potentially confronted with the prospect of high future redemptions and continued losses, increasing their focus on preserving liquidity.

Our findings on portfolio illiquidity stand in contrast to the behavior of mutual funds as described by Ma, Xiao, and Zeng (2020), who show that in the March 2020 shock, corporate bond mutual funds sold *more* liquid bonds to meet investor redemptions. Further, Jorion (2000), in describing the LTCM meltdown in 1998, asserts that the hedge fund made a "mistake" when attempting to reduce risks by downsizing its asset portfolio because the fund got rid of its most liquid positions, which made the fund more vulnerable to further losses when the market continue to move against the fund's portfolio positions.

> The firm [LTCM] reportedly tried to reduce its risk profile, but made a major mistake: instead of selling off less-liquid positions, or raising fresh capital, it eliminated its most liquid investments because they were less profitable. ... This made LTCM more vulnerable to subsequent margin calls. [pg. 288, Jorion (2000)]

Given the contrast between LTCM's behavior and our findings for UST hedge funds during March 2020, it is possible that the hedge funds in our sample became aware of the risk management failures at LTCM and other subsequent hedge fund meltdowns, which influenced their decisions how to manage liquidity during this stress episode. Further evidence for this "learning" hypothesis is given in the Online Appendix. Hedge funds from advisers that experienced the LTCM period, that is, were incepted in or before 1998, reduced their portfolio illiquidity by more than younger hedge funds.[33]

[33]Form PF does not have information on adviser or fund age. We hand collected adviser founding years through

Finally, we analyze fund size and leverage in Panel C. Columns 1 and 2 show that $PortfolioGNE$—the notional exposure of securities and derivatives, excluding *Cash*—held by a hedge fund fell by around 22%, while the number of open positions fell by close to 5%. Columns 3 and 4 show that hedge fund NAV (equity) and GAV (total gross assets) generally dropped proportionally, by 13-14%. As such, the ratio of hedge fund GAV to NAV—*Leverage*—was unchanged at the end of the market stress episode. Thus, although there is no evidence of significant deleveraging, the results suggest that hedge funds actively managed the risk of their portfolios in March 2020. Despite significant negative returns depleting NAV, hedge funds held leverage ratios unchanged by scaling down their gross exposures proportionately to their capital base.

6 Conclusion

We examine hedge fund activity in U.S. Treasury markets during the March 2020 COVID-19 shock to understand constraints on hedge funds UST arbitrage and liquidity provision. During this period, the average hedge fund with UST holdings reduced its notional UST exposures on both the long and short sides by around 20%. Measures of hedge fund arbitrage and directional exposures declined by similar magnitudes. Taken together, the results indicate that hedge funds did not provide liquidity during this market dislocation.

We consider the constraints that likely limited hedge funds ability to engage in UST arbitrage trading. While UST funds experienced a *monthly* return of around -7%, investor redemptions during the turmoil were relatively modest. Hedge funds' stringent share restrictions were effective in dampening outflows during the crisis period. Moreover, repo borrowing levels, maturities, and collateral rates on repurchase agreements—the primary source of financing for hedge fund UST holdings and sovereign bond basis trades—remained stable, suggesting that borrowing constraints were not the primary reason for the decline in hedge funds' Treasury exposures.

We go deeper and analyze specific channels proposed in the prior literature through which hedge funds might face repo borrowing constraints. Specifically, we analyze the importance of creditor regulatory constraints using hedge fund-creditor level data and a within hedge fund-time methodology. Large creditors subject to enhanced regulations provided disproportionately higher

online searches.

repo financing to hedge funds during the crisis—over 11-13% higher funding compared to other dealers. A creditor's proximity to its minimum required Basel III leverage ratio was not a significant factor in the credit supplied. Our findings are inconsistent with the hypothesis that regulatory constraints at large broker dealers limited hedge fund access to funding and their UST arbitrage. Unlike during the GFC, in this period, the larger, bank-affiliated broker-dealers were subject to greater disclosures, periodic stress tests, and enhanced regulations constraining their liquidity and risk-taking and hence, were not exposed to significant concerns about opaqueness, solvency, and run risk. These dealers were able to provide relatively stable funding to hedge fund clients during this extreme episode.

We find evidence that the reduction in hedge fund UST exposures was driven by internal risk and liquidity management considerations. We find that hedge funds with higher ex-ante risk limits were able to hold onto more of their arbitrage positions during the crisis. By the end of March 2020, hedge funds with significant Treasury exposures increased their cash holdings by over 20% and scaled down the size and illiquidity of their portfolios. Longer share restrictions allowed hedge funds to avoid fire sales and hold onto more of their arbitrage positions, thereby bolstering both fund and Treasury market stability.

The average UST fund saw returns jump back in April and remain positive over the six month period following the March turmoil. However, hedge fund exposures and liquidity provision in UST markets did not revert to pre-shock levels even after the market turmoil subsided. Notably, in this post-shock period, UST funds faced greater investor outflows but met these redemptions in a market stabilized via government interventions. Our findings indicate that the quick intervention of the Federal Reserve to stabilize Treasury markets likely prevented a deleveraging spiral where hedge funds further sold off exposures in a declining market, realizing more losses and further depleting their equity.

Compared to previous crisis episodes, the March 2020 shock was unique, particularly in the speed and scale at which extreme moves occurred and in its impact on otherwise safe and liquid markets such as the UST market. By analyzing the activity of hedge funds during this episode in U.S. Treasury markets and bilateral repo funding markets, this paper sheds light on how the characteristics and funding structures of hedge funds affect the role they play in vital financial markets.

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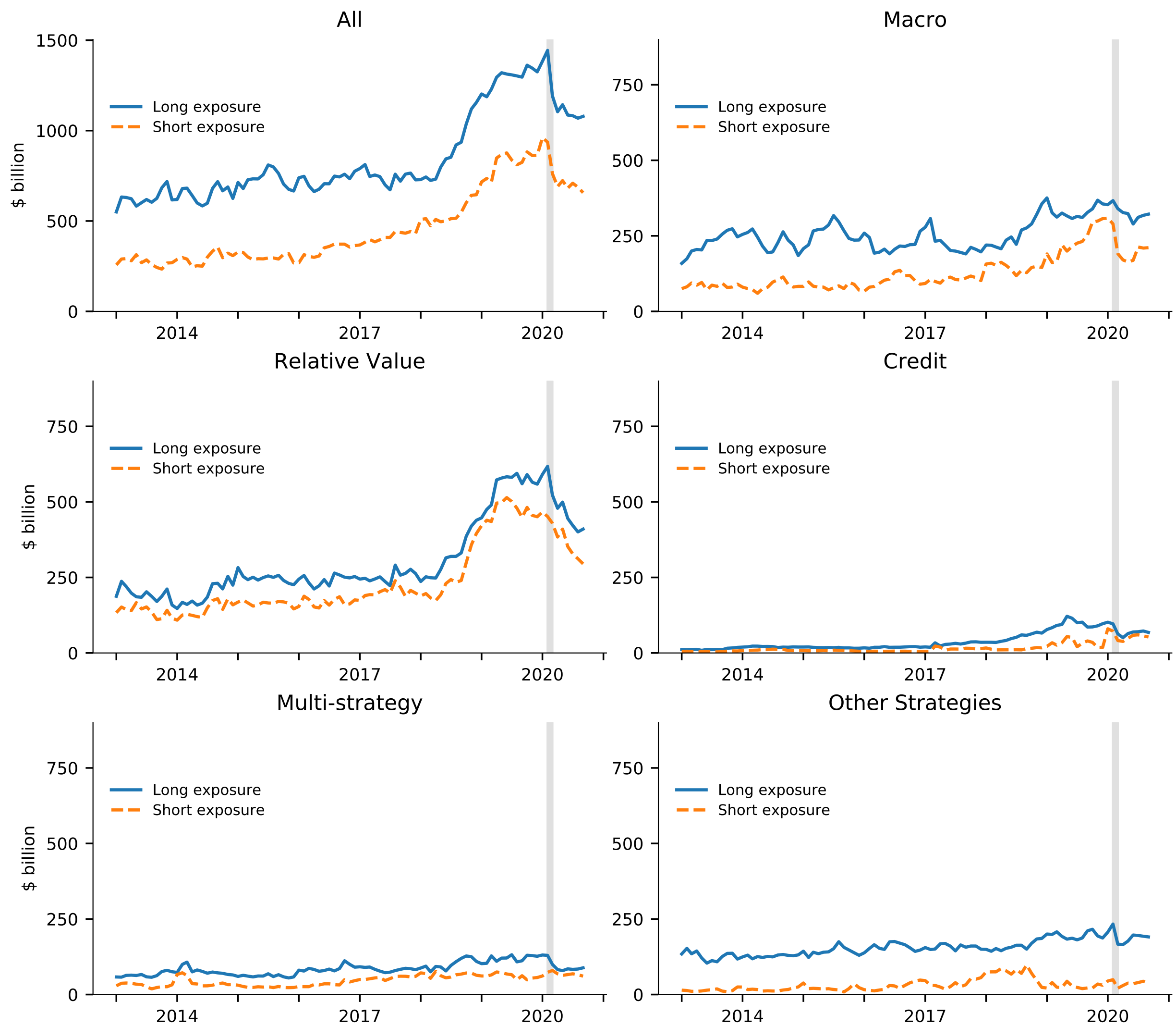


Figure 1: Hedge Fund U.S. Treasury Exposures

This figure presents the times series of aggregate long and short UST exposures from January 2013 to September 2020 for all hedge funds and hedge funds separated into broad strategies: macro, relative value, credit, multi-strategy, and all other strategies. March 2020 is shaded gray. Source: SEC Form PF.

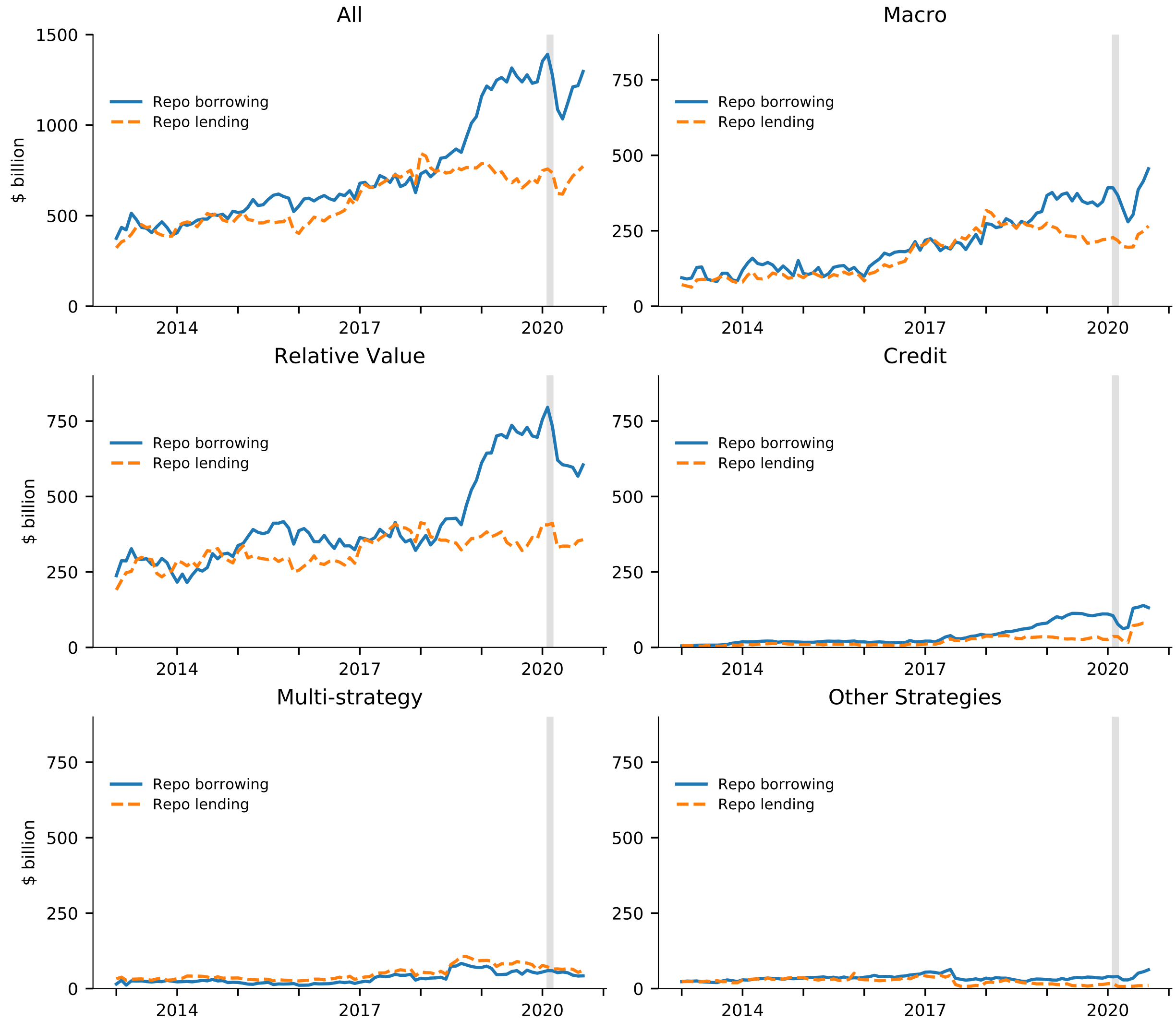


Figure 2: Hedge Fund Repo Exposures

This figure presents the times series of aggregate repo borrowing and lending exposures from January 2013 to September 2020 for all hedge funds and hedge funds separated into broad strategies: macro, relative value, credit, multi-strategy, and all other strategies. March 2020 is shaded gray. Source: SEC Form PF.

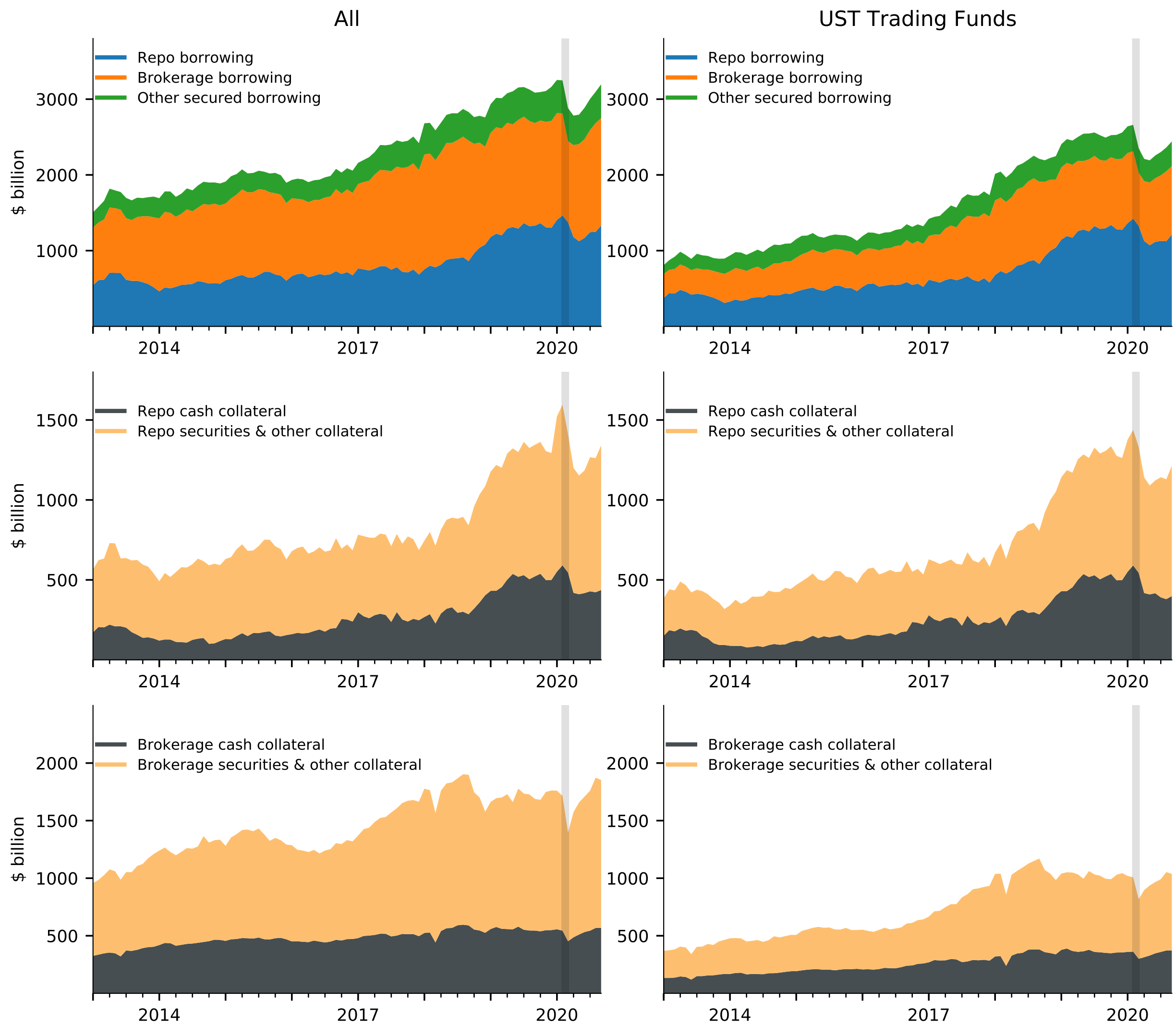


Figure 3: Hedge Fund Borrowing and Collateral

This figure presents the times series of aggregate borrowing and collateral amounts from January 2013 to September 2020 for all hedge funds (left) and all hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4 (right). The subfigures on the first row break down hedge fund borrowing by type (prime broker, repo, or other secured borrowing). The second and third rows show aggregate collateral for, respectively, repo and prime broker borrowing. Collateral amounts are shown separated by type: cash and cash equivalents, securities, and other. March 2020 is shaded gray. Source: SEC Form PF.

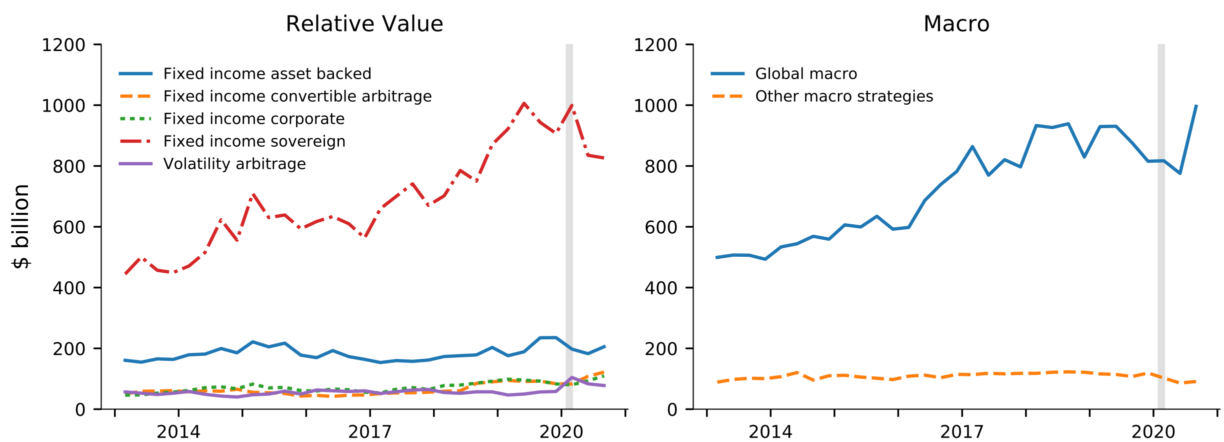


Figure 4: Gross Assets of Relative Value and Macro Strategies

This figure presents the times series of gross assets under management for subcategories within the relative value and macro broad strategy categories from Q1 2013 to Q3 2020. March 2020 is shaded gray. Source: SEC Form PF.

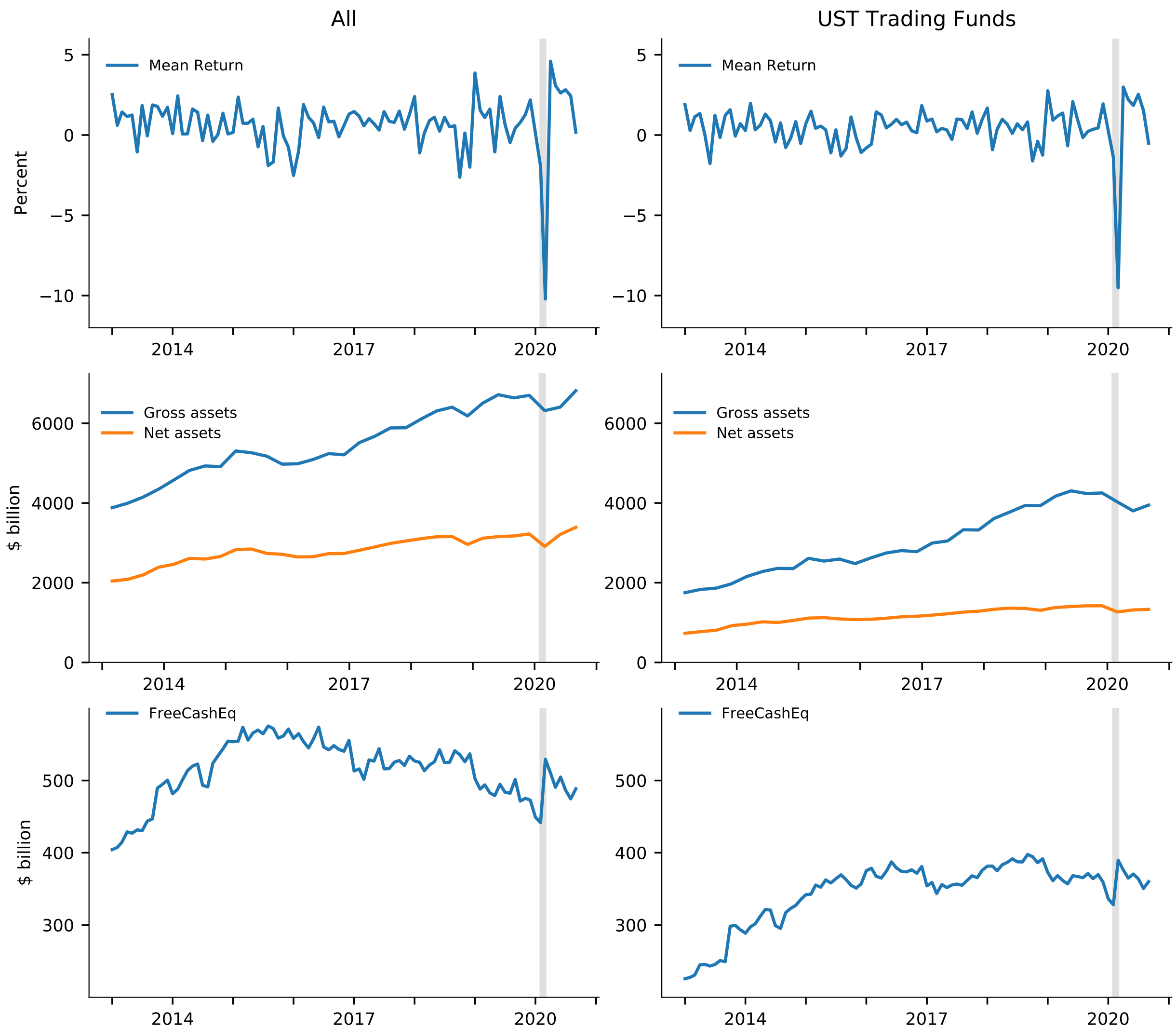


Figure 5: Hedge Fund Returns, Assets, and Unencumbered Cash and Cash Equivalents

This figure presents the times series of returns, assets under management, and unencumbered cash and cash equivalents from January 2013 to September 2020 for all hedge funds (left) and all hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4 (right). The subfigures on the first row show the monthly mean returns, net-of-fees. The second row shows the aggregate value of gross and net assets under management. The third row shows aggregate holdings of unencumbered cash and cash equivalents ($FreeCashEq$). March 2020 is shaded gray. Source: SEC Form PF.

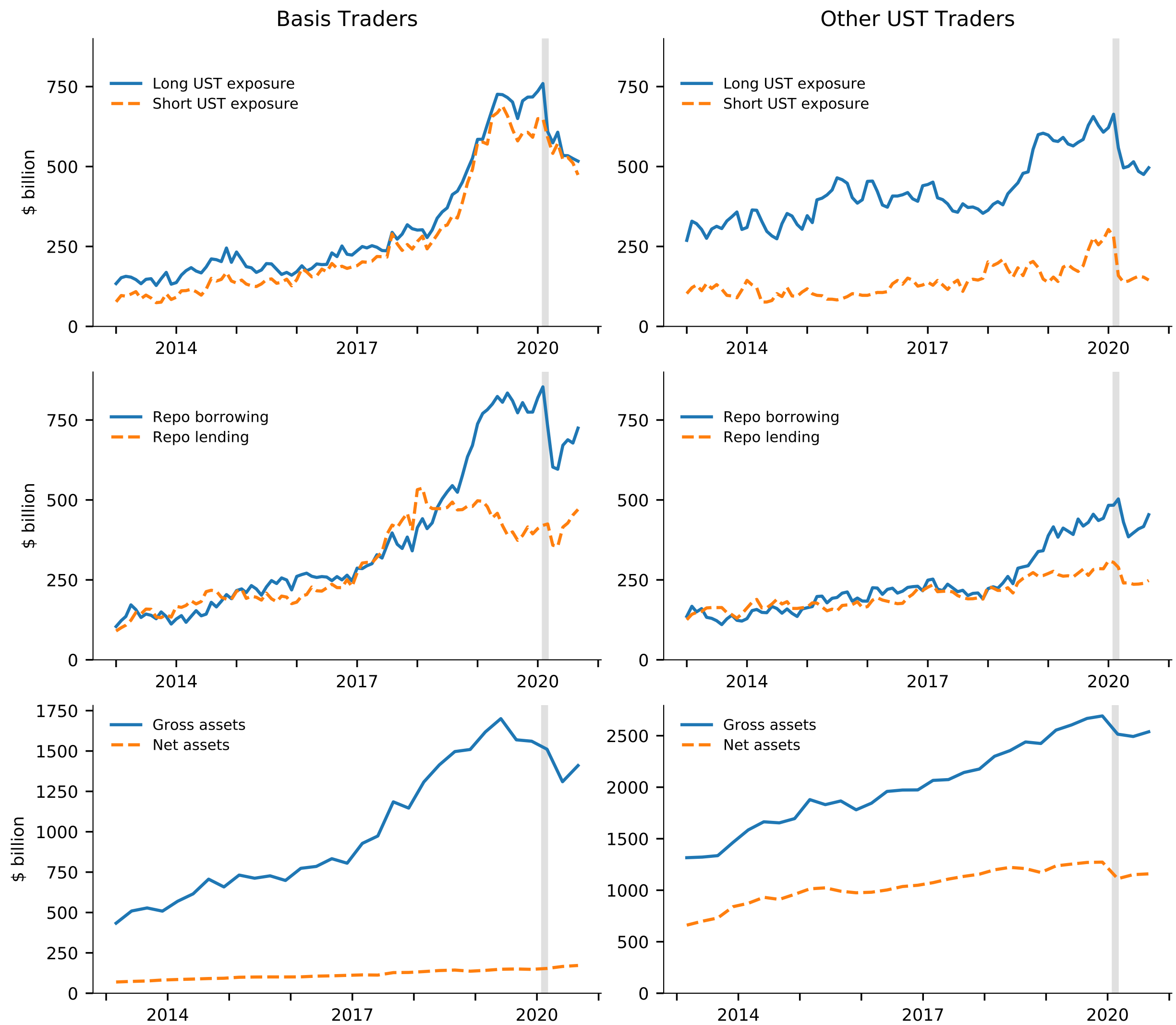


Figure 6: Predominantly UST Cash-Futures Basis Trading versus Other UST Trading Hedge Funds

This figure presents the times series of UST exposure, repo exposures, and leverage from January 2013 to September 2020 for hedge funds predominantly engaged in the UST cash-futures basis trade (left) and other UST trading hedge funds (right). Both sets of funds are hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4. The subfigures on the first row show aggregate long and short UST exposures. The second row shows the aggregate repo and reverse repo exposures. The third row shows aggregate gross and net assets under management. March 2020 is shaded gray. Source: SEC Form PF.

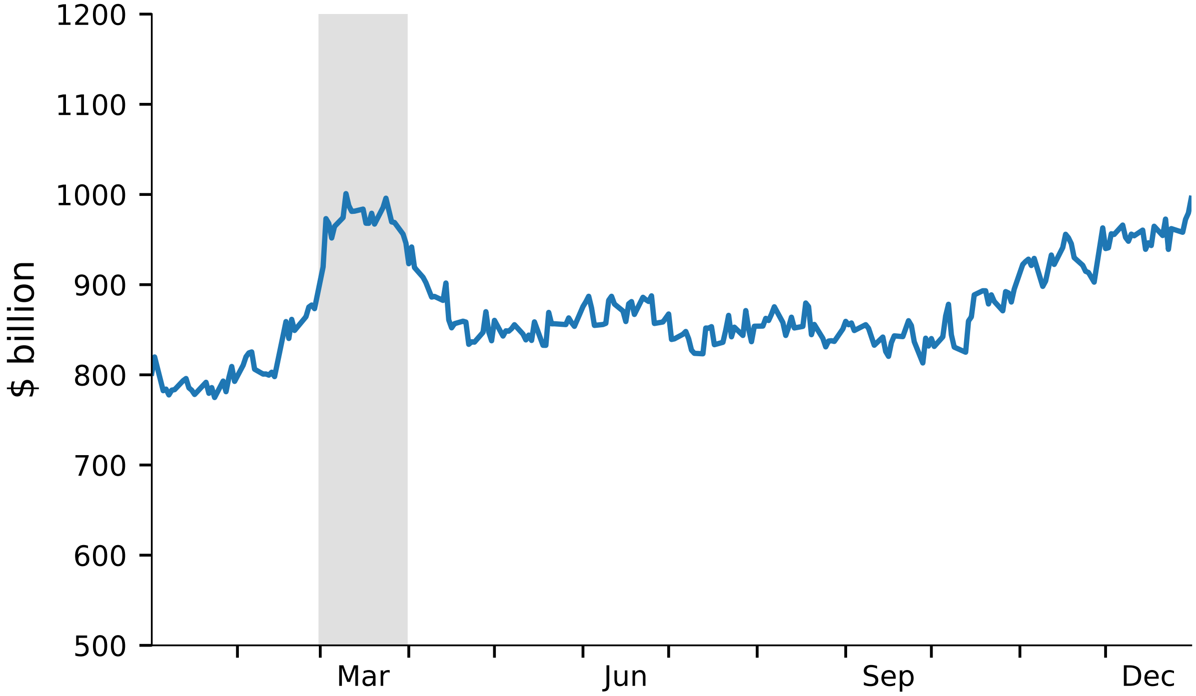


Figure 7: Daily UST Bilateral Repo Lending by the Top 10 G-SIB dealers in 2020

The figure presents the aggregate bilateral UST reverse repo (repo lending) to asset managers during 2020 by 10 G-SIB dealers, including Bank of America, Barclays, Citi, Credit Suisse, Deutsche Bank, Goldman Sachs, JP Morgan, Morgan Stanley, UBS, and Wells Fargo. March 2020 is shaded gray. Source: FR 2052a.

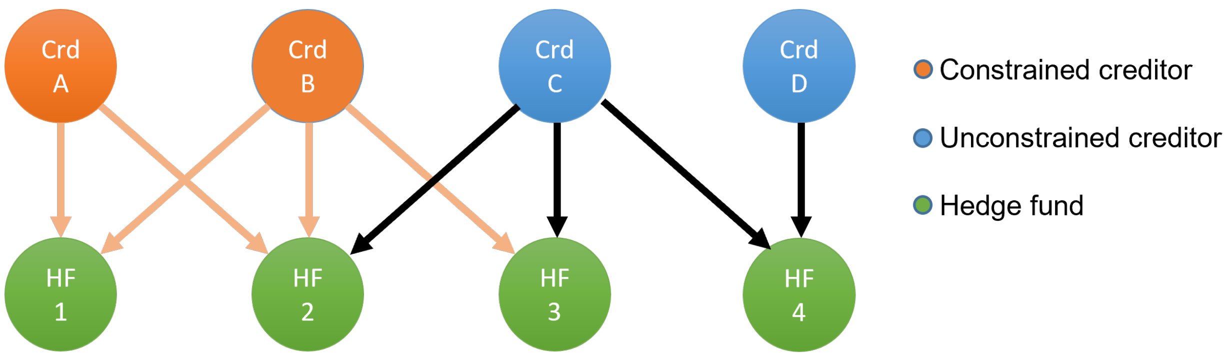
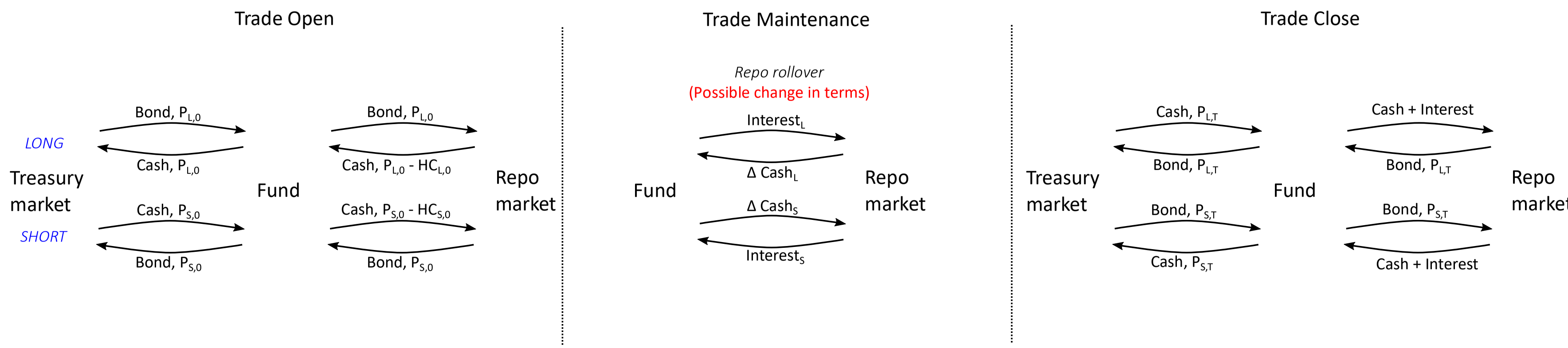
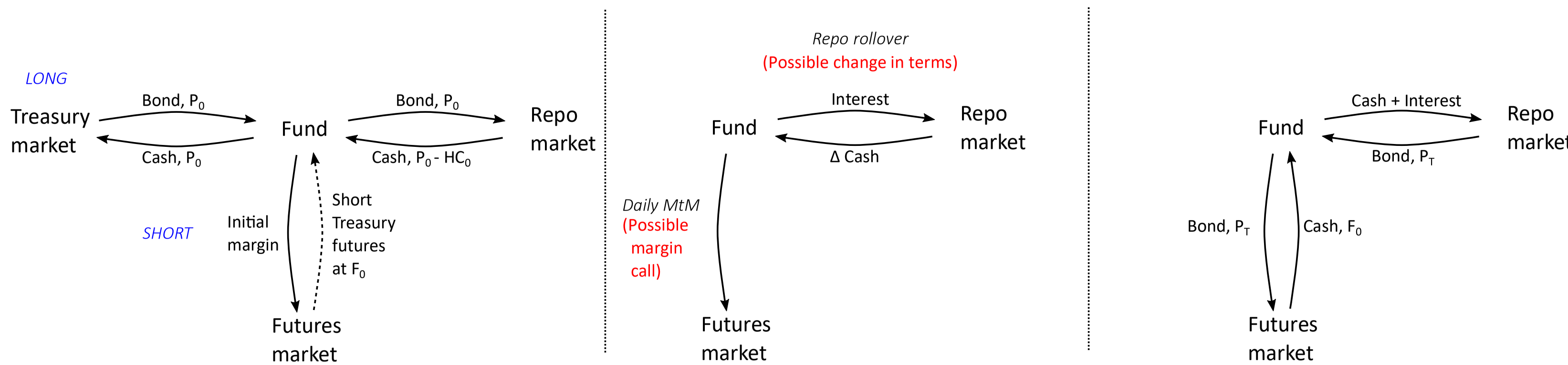


Figure 8: Empirical strategy for analyzing hedge fund-creditor bilateral data

This figure illustrates the identification strategy used when analyzing hedge fund-creditor bilateral repo data to test whether dealers constrained by enhanced regulation cut repo lending to their hedge fund clients. The figure depicts an example bilateral repo lending network with eight nodes: four dealers (A, B, C, and D) and four hedge funds (1, 2, 3, and 4). The amount of repo lending from dealer p to hedge fund h at time t, $HF\_Crdtr\_Credit_{h,p,t}$, determines the strength of the link (edge) between that hedge fund-dealer pair. All hedge funds in this analysis borrow simultaneously from at least two dealers allowing for the use of hedge fund-time fixed effects. In this sample network, two dealers A and B (nodes in orange) are subject to enhanced regulation, while two dealers C and D (nodes in blue) are not. Hedge funds 2 and 3 both borrow from at least one dealer subject to enhanced regulation and at least one that is not.



(a) Bond spread trade



(b) Cash-futures basis trade

Figure 9: Exposures and cash flows at trade open, trade maintenance, and trade close

This figure illustrates the securities flows, cash flows, and the exposures created at trade open, trade maintenance and trade close when trading a typical (a) long-short bond spread trade and (b) Treasury cash-futures basis trade. HC represents the amount of the haircut, i.e., the difference between the repo loan amount provided to the hedge fund by the dealer and the value (P) of the collateral posted with the dealer by the fund.

Table 1: Summary statistics

This table shows the summary statistics for the main variables used in the paper. The data are from January 2013 to September 2020 and include all hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4. All variables are described in Table 13. The N column shows the number of observations used to calculate the statistics in a particular row. The last four columns show percentiles.

Panel A: Hedge fund characteristics

	N	Mean	Median	Stdev	25th	75th	10th	90th
$NAV_{h,t}$ (m US$)	12,503	2,828.349	1,397.077	4,127.828	714.734	3,068.911	379.007	6,894.295
$LeverageRatio_{h,t}$	12,503	2.476	1.335	3.713	1.042	2.120	1.002	3.923
$PortIlliq_{h,t}$ (days)	12,284	33.096	7.181	61.221	1.725	35.325	0.500	90.399
$ShareRes_{h,t}$ (days)	12,492	125.835	60.500	123.596	19.000	227.625	0.500	316.278
$FinDur_{h,t}$ (days)	9,836	37.107	10.710	54.451	0.500	59.256	0.500	118.853
$MgrStake_{h,t}$ (%)	11,472	13.761	3.000	25.690	0.000	13.000	0.000	44.000
$RiskLimit_{h,t}$ (%)	17,898	4.676	3.783	4.496	2.100	5.411	1.146	7.925
$NetRetQ_{h,t}$ (%)	12,713	2.316	1.690	8.129	-0.470	4.080	-4.160	8.286
$NetRetM_{h,t}$ (%)	36,351	0.437	0.510	2.668	-0.490	1.560	-2.220	3.100
$NetFlows_{h,t}$ (%)	12,023	-0.605	-0.179	13.905	-4.462	2.770	-12.404	10.974
$FreeCashEq_{h,t}$ (m US$)	37,133	824.945	219.609	1,650.080	39.652	784.817	0.056	2,180.929
$Cash_{h,t}$ (m US$)	32,140	759.771	253.933	1,372.204	65.022	805.677	11.794	1,933.981
$\frac{FreeCashEq_{h,t}}{NAV_{h,t}}$ (%)	36,596	26.779	16.276	27.846	3.888	43.313	0.013	72.622
$\frac{Cash_{h,t}}{NAV_{h,t}}$ (%)	31,716	30.623	16.572	41.535	5.216	39.079	1.128	74.434
$OpenPositions_{h,t}$	37,548	2,561.640	599.000	6,366.386	219.000	1,804.000	86.000	5,768.300
$GNE_{h,t}$ (m US$)	37,292	25,642.859	5,957.733	61,005.277	1,932.317	18,433.384	784.600	59,207.269
$PortfolioGNE_{h,t}$ (m US$)	37,292	24,592.608	5,445.073	59,761.393	1,752.156	17,174.351	710.106	56,505.466
$Turnover_{h,t}$	33,292	138,743.171	20,619.797	219,547.595	2,300.267	216,286.521	401.213	428,360.170
$EqTurnover_{h,t}$	33,292	9,792.620	1,302.997	22,957.386	141.588	7,999.925	0.191	19,414.891
$FITurnover_{h,t}$	33,292	21,610.450	2,824.357	42,959.217	411.433	15,878.278	56.848	85,010.462
$USTTurnover_{h,t}$	33,292	14,266.717	1,161.214	33,230.990	101.455	7,261.607	0.001	45,533.569

Panel B: U.S. Treasury exposures

	N	Mean	Median	Stdev	25th	75th	10th	90th
$UST\_Gross_{h,t}$ (m US$)	33,027	2,790.343	348.228	8,451.260	76.688	1,553.683	18.180	5,736.337
$UST\_Long_{h,t}$ (m US$)	33,027	1,858.255	240.291	5,192.603	34.999	1,131.989	0.484	4,337.850
$UST\_Short_{h,t}$ (m US$)	33,027	896.717	17.140	3,351.960	0.000	214.722	0.000	1,554.543
$UST\_Net_{h,t}$ (m US$)	33,027	846.016	124.704	2,262.571	-2.692	737.179	-134.569	2,616.289
$USTDirectional_{h,t}$ (m US$)	33,027	1,096.909	220.822	2,386.734	48.658	906.084	12.505	2,939.572
$USTArbitrage_{h,t}$ (m US$)	33,027	1,559.734	3.967	6,330.412	0.000	253.073	0.000	2,201.270
$\frac{UST\_Gross_{h,t}}{NAV_{h,t}}$	32,612	99.720	26.663	248.848	7.294	78.759	1.802	189.425
$\frac{USTDirectional_{h,t}}{UST\_Gross_{h,t}}$	33,027	75.219	97.864	32.881	50.827	100.000	17.330	100.000
$\frac{USTArbitrage_{h,t}}{UST\_Gross_{h,t}}$	33,027	24.781	2.136	32.881	0.000	49.173	0.000	82.670
$UST\_Long\_Drtn_{h,t}$ (years)	32,038	4.178	2.478	4.770	0.200	6.874	0.020	10.370
$UST\_Short\_Drtn_{h,t}$ (years)	32,038	4.288	2.754	4.965	0.000	7.315	0.000	11.290
$UST\_Net\_Drtn_{h,t}$ (years)	32,036	4.458	3.134	9.350	0.209	7.668	-0.063	12.671

Panel C: Repo, other borrowing, and collateral

	N	Mean	Median	Stdev	25th	75th	10th	90th
$RepoBorrowing_{h,t}$ (m US$)	14,261	3,616.378	280.089	11,129.562	37.898	1,440.943	0.000	7,039.536
$RepoLending_{h,t}$ (m US$)	15,340	2,710.582	126.539	8,668.318	12.569	850.733	0.000	5,916.215
$RepoBrrwTerm_{h,t}$ (days)	12,439	25.683	8.661	43.691	1.463	29.220	0.000	69.398
$RepoLendTerm_{h,t}$ (days)	13,037	12.198	3.653	22.079	0.000	10.958	0.000	40.178
$\frac{RepoTotalCollateral_{h,t}}{RepoBorrowing_{h,t}}$ (%)	13,250	118.174	103.290	27.569	100.388	128.431	100.000	152.999
$\frac{RepoCashCollateral_{h,t}}{RepoBorrowing_{h,t}}$ (%)	12,910	31.619	2.428	41.006	0.039	69.532	0.000	100.146
$\frac{RepoSecCollateral_{h,t}}{RepoBorrowing_{h,t}}$ (%)	13,249	85.348	100.914	52.852	35.772	124.193	0.000	139.759
$\frac{RepoCashCollateral_{h,t}}{RepoTotalCollateral_{h,t}}$ (%)	12,910	29.758	1.863	40.311	0.034	65.271	0.000	100.000
$RepoClearedCCP_{h,t}$ (%)	5,059	13.721	0.000	33.782	0.000	0.000	0.000	100.000
$RepoBilateral_{h,t}$ (%)	6,172	79.484	100.000	39.031	95.000	100.000	0.000	100.000

Panel D: Creditor exposures

	N	Mean	Median	Stdev	25th	75th	10th	90th
$TotalMCBorrowing_{h,t}$ (m US$)	6,129	6,008.282	975.979	17,719.835	329.311	3,729.416	112.594	11,833.454
$NumCrdtrsPerHF_{h,t}$	6,129	4.512	3.000	4.404	2.000	5.000	1.000	9.000
$HFCrdtrHHI_{h,t}$	6,129	49.325	39.459	30.680	25.098	67.518	16.485	100.000
$HF\_Ctpty\_Credit_{h,p,t}$ (m US$)	27,930	1,327.842	434.083	2,701.381	154.146	1,230.545	69.509	3,012.068
$\Delta logHF\_Ctpty\_Credit_{h,p,t}$ (%)	23,294	1.304	0.798	48.744	-20.583	22.976	-54.101	56.342
$HFRankInCrdtr_{h,p,t}$	27,930	0.602	0.640	0.287	0.366	0.858	0.177	0.965
$CrdtrRankInHF_{h,p,t}$	27,930	0.610	0.600	0.295	0.333	0.889	0.200	1.000
$IsCrdtrPB_{h,p,t}$	27,930	0.466	0.000	0.499	0.000	1.000	0.000	1.000
$IsCrdtrCustodian_{h,p,t}$	27,930	0.504	1.000	0.500	0.000	1.000	0.000	1.000

Table 2: Hedge fund U.S. Treasury exposures

This table presents results of the panel regression model given in equation (3). The dependent variables are shown in the first row. The data are monthly from January 2013 to March 2020, Panels A and B include all hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4. Panel B also show changes to arbitrage exposures for the set of UST hedge funds that had "medium" or "large" arbitrage exposures in 2019:Q4. The medium (large) set is defined as the UST arbitrage hedge funds with above 25^{th} (50^{th}) percentile $USTArbitrage$ on average in 2019:Q4. The specifications include fund fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variable $March2020_t$, are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

Panel A: U.S. Treasury exposure

	$\Delta LogUST\_Gross$	$\Delta LogUST\_Long$	$\Delta LogUST\_Short$	$\Delta \frac{UST\_Gross}{NAV}$	$\Delta \frac{UST\_Long}{NAV}$	$\Delta \frac{UST\_Short}{NAV}$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	-19.374***	-18.888***	-23.642***	-15.013***	-8.386***	-7.522***
	-15.499	-11.425	-7.661	-11.459	-8.851	-10.242
$ShareRes_{h,t-1}$	3.037*	3.653*	-1.899	1.799	1.239*	0.564
	1.744	1.962	-0.524	1.299	1.810	0.775
$PortIlliq_{h,t-1}$	1.181	-0.886	1.533	0.125	0.084	0.137
	0.795	-0.418	0.656	0.095	0.126	0.168
$FinDur_{h,t-1}$	-0.543	-0.669	0.729	-0.360	-0.130	-0.175
	-0.808	-0.788	0.360	-1.034	-0.424	-0.602
$LogNAV_{h,t-1}$	-2.117*	-0.460	-2.897	0.579	0.533	-0.050
	-1.886	-0.345	-1.308	0.329	0.429	-0.063
$NetRet_{h,t-1}$	0.888	1.859**	-0.212	-0.417	0.070	-0.488
	1.142	2.425	-0.107	-0.773	0.189	-1.243
$NetFlows_{h,t-1}$	0.901**	0.821**	1.714*	0.046	-0.256	0.246
	2.409	2.286	1.927	0.142	-1.115	1.489
$MgrStake_{h,t-1}$	0.432	0.218	0.280	1.251	0.412	0.948*
	0.803	0.200	0.342	0.919	0.397	1.684
$Leverage_{h,t-1}$	-2.151*	-1.318	-2.735*	-3.533	-1.312	-2.294**
	-1.818	-1.037	-1.777	-1.572	-0.860	-2.189
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,849	16,874	12,978	18,801	18,801	18,801
R^2	0.016	0.015	0.017	0.017	0.016	0.014

Panel B: U.S. Treasury directional and arbitrage exposure

	All UST funds			Mid UST arbitrage positions		Large UST arbitrage positions	
	$\Delta LogUSTDir$	$\Delta LogUSTArb$	$\Delta \frac{USTArb}{Gross}$	$\Delta LogUSTArb$	$\Delta \frac{USTArb}{Gross}$	$\Delta LogUSTArb$	$\Delta \frac{USTArb}{Gross}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$March2020_t$	-15.502***	-24.949***	-2.065***	-46.938***	-5.965***	-44.433***	-7.863***
	-8.370	-8.300	-6.139	-14.233	-8.284	-10.893	-8.428
$ShareRes_{h,t-1}$	2.966	-2.109	-0.252	-0.162	0.231	-0.056	0.003
	1.374	-0.533	-0.542	-0.040	0.327	-0.011	0.005
$PortIlliq_{h,t-1}$	0.638	1.356	0.685	0.121	0.287	0.197	0.456
	0.344	0.675	1.558	0.080	0.677	0.080	0.840
$FinDur_{h,t-1}$	-0.677*	1.969	-0.063	1.598	-0.022	-0.296	-0.572
	-1.743	0.940	-0.184	0.630	-0.046	-0.121	-0.945
$LogNAV_{h,t-1}$	-1.447	-2.393	-0.157	-2.367	-0.218	-4.471	-0.679
	-1.053	-1.171	-0.490	-0.847	-0.586	-1.076	-1.325
$NetRet_{h,t-1}$	0.566	0.595	-0.001	0.720	0.155	1.119	0.134
	0.582	0.331	-0.003	0.294	0.335	0.419	0.243
$NetFlows_{h,t-1}$	0.585	1.640	0.056	1.726	-0.010	1.760	-0.350
	0.843	1.590	0.309	1.622	-0.029	1.123	-0.823
$MgrStake_{h,t-1}$	-0.999	1.008	0.312	1.849	0.416	1.287	0.493
	-1.095	0.666	1.204	1.364	1.266	0.874	0.965
$Leverage_{h,t-1}$	-0.427	-3.191*	-0.386	-3.299**	-0.388	-2.915	-0.377
	-0.205	-1.901	-0.910	-2.036	-0.862	-1.490	-0.763
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,834	11,053	18,849	7,642	9,155	5,322	6,186
R^2	0.007	0.013	0.005	0.016	0.005	0.017	0.008

Table 3: Hedge fund bilateral repo activity

This table presents results of the panel regression model given in equation (3). The dependent variables are shown in the first row. The data are monthly from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4. The specifications include fund fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variable $March2020_t$, are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

	Repo Borrowing				Repo Lending	
	Amount	*Maturity*	*Collateral*	*Haircut*	*Amount*	*Maturity*
	$\Delta LogRepoBrrw$	$\Delta RepoBrrwTerm$	$\Delta LogRepoCollateral$	$\Delta \frac{RepoCollateral}{RepoBorrowing}$	$\Delta LogRepoLend$	$\Delta RepoLendTerm$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	-1.467	3.002***	0.711	-0.671**	-24.760***	-0.994**
	-0.722	6.182	0.352	-2.332	-9.233	-2.289
$ShareRes_{h,t-1}$	-0.418	0.471	0.986	0.698	1.418	0.807**
	-0.250	1.298	0.559	1.487	0.435	2.560
$PortIlliq_{h,t-1}$	0.778	-0.182	0.707	0.104	-2.221	0.218
	0.366	-0.219	0.464	0.404	-0.665	0.422
$FinDur_{h,t-1}$	-0.164	-0.094	-0.171	0.132	2.695*	-0.033
	-0.126	-0.191	-0.121	0.741	1.726	-0.210
$LogNAV_{h,t-1}$	-0.527	0.415	-0.573	-0.230	0.800	0.170
	-0.214	1.483	-0.287	-0.873	0.353	0.660
$NetRet_{h,t-1}$	1.564	-0.155	1.135	0.016	0.718	-0.292
	1.146	-1.103	0.958	0.151	0.546	-0.959
$NetFlows_{h,t-1}$	2.297***	0.120	1.773***	0.038	0.092	0.080
	3.260	0.654	2.814	0.440	0.107	0.510
$MgrStake_{h,t-1}$	0.001	-0.323	-0.158	0.219***	0.627	-0.095
	0.001	-1.109	-0.202	3.439	0.407	-0.622
$Leverage_{h,t-1}$	-2.556***	-0.040	-2.142**	0.036	-1.976**	0.004
	-2.831	-0.362	-2.394	0.585	-2.098	0.034
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,387	9,387	9,810	9,810	9,083	9,083
R^2	0.014	0.022	0.015	0.012	0.014	0.021

Table 4: The regulatory constraints of creditors and hedge fund borrowing

This table presents results of the panel regression model given in equations (4), (5), and (6). The dependent variable is $\Delta \log HF\_Crdtr\_Credit_{h,p,t}$ (in %). The data are quarterly from Q1 2013 to Q1 2020 and include hedge funds with gross UST exposure of at least $1 million that borrow predominantly through repo on average during 2019:Q4. The specifications include combinations of fund, quarter, and creditor fixed effects where indicated. The standard errors are clustered at the creditor and time level. The independent variables, with the exception of the indicator variables $March2020_t$ and $IsGSIB_{p,t}$, are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t \times IsGSIB_{p,t}$	12.032***	11.285***	13.374***	12.637**	13.335***	13.375***
	9.589	4.141	3.701	2.496	3.318	3.316
$IsGSIB_{p,t}$	-0.602	-5.143***	-6.230**	-2.516	14.215***	13.540***
	-0.464	-2.972	-2.315	-0.840	4.630	4.742
$LogHF\_Crdtr\_Credit_{h,p,t-1}$					-80.762***	-74.351***
					-27.208	-16.801
$CrdtrRankInHF_{h,p,t-1}$						-0.325
						-0.222
$HFRankInCrdtr_{h,p,t-1}$						-6.428**
						-2.451
Other Controls	No	No	No	No	No	Yes
Fund FE	Yes	Yes	No	No	No	No
Time FE	Yes	Yes	No	No	No	No
Creditor FE	No	Yes	Yes	No	No	No
Fund × Time FE	No	No	Yes	Yes	Yes	Yes
Fund × Creditor FE	No	No	No	Yes	Yes	Yes
Observations	9,816	9,816	9,816	9,816	9,816	9,816
R^2	0.031	0.038	0.236	0.318	0.516	0.517

Table 5: The leverage ratio constraint of creditors and hedge fund borrowing

This table presents results of the panel regression model given in equations (4), (5), and (6). The dependent variable is $\Delta \log HF\_Crdtr\_Credit_{h,p,t}$ (in %). The independent variable $DistancetoLRT_{p,t-1}$ measures the distance between a bank's leverage ratio and its minimum required leverage ratio threshold (LRT). The data are quarterly from Q1 2015 (when banks were required to start disclosing leverage ratios) to Q1 2020 and include hedge funds with gross UST exposure of at least \$1 million that borrow predominantly through repo on average during 2019:Q4. The specifications include combinations of fund, quarter, and creditor fixed effects where indicated. The standard errors are clustered at the creditor and time level. In Panel A, the sample consists of US G-SIBs only and the indicator variable $PostJanuary2018_t$ controls for the effective date of the leverage ratio requirement in the US. In Panel B, the sample consists of all US and foreign banks. The indicator variable $PostEffectiveDate_{p,t}$ is included to control for the effective date of the leverage ratio requirement for each bank, which can differ across countries and institutions. The independent variables, with the exception of the indicator variables, are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

Panel A: US G-SIBs

	(1)	(2)	(3)	(4)	(5)
$March2020_t \times DistanceToLRT_{p,t-1}$	22.452*	10.179	5.625	4.472	4.665
	2.122	0.750	0.364	0.325	0.334
$PostJanuary2018_t \times DistanceToLRT_{p,t-1}$	-2.227*	-0.488	-0.998	1.376	1.704
	-1.963	-0.319	-0.329	0.248	0.318
$DistanceToLRT_{p,t-1}$	-0.441	1.025	4.168	-1.359	-1.242
	-0.112	0.224	0.938	-0.212	-0.202
$LogHF\_Crdtr\_Credit_{h,p,t-1}$				-81.877***	-73.071***
				-19.573	-12.035
$CrdtrRankInHF_{h,p,t-1}$					-2.837
					-1.355
$HFRankInCrdtr_{h,p,t-1}$					-3.619
					-0.512
Other Controls	No	No	No	No	Yes
Fund FE	Yes	No	No	No	No
Time FE	Yes	No	No	No	No
Creditor FE	Yes	Yes	No	No	No
Fund × Time FE	No	Yes	Yes	Yes	Yes
Fund × Creditor FE	No	No	Yes	Yes	Yes
Observations	3,281	3,281	3,281	3,281	3,281
R^2	0.074	0.435	0.507	0.641	0.642

Panel B: All banks

	(1)	(2)	(3)	(4)	(5)
$March2020_t \times DistanceToLRT_{p,t-1}$	-2.246	-1.580	0.922	-2.383	-2.173
	-1.283	-0.795	0.397	-0.942	-0.786
$PostEffectiveDate_{p,t} \times DistanceToLRT_{p,t-1}$	0.569	0.709	-0.731	2.604	2.643
	0.234	0.267	-0.284	0.819	0.841
$DistanceToLRT_{p,t-1}$	1.801	1.907	3.086	-0.463	-0.229
	0.692	0.747	1.060	-0.124	-0.061
$PostEffectiveDate_{p,t}$	-0.481	-0.638	1.754	-6.614	-6.495
	-0.118	-0.141	0.410	-1.191	-1.147
$LogHF\_Crdr\_Credit_{h,p,t-1}$				-85.796^{***}	-80.519^{***}
				-21.366	-14.995
$CrdtrRankInHF_{h,p,t-1}$					-0.076
					-0.044
$HFRankInCrdtr_{h,p,t-1}$					-5.495
					-1.697
Other Controls	No	No	No	No	Yes
Fund FE	Yes	No	No	No	No
Time FE	Yes	No	No	No	No
Creditor FE	Yes	Yes	No	No	No
Fund × Time FE	No	Yes	Yes	Yes	Yes
Fund × Creditor FE	No	No	Yes	Yes	Yes
Observations	7,385	7,385	7,385	7,385	7,385
R^2	0.042	0.232	0.329	0.531	0.532

Table 6: Hedge fund-creditor relationships and bilateral repo

This table presents results of a panel regression model similar to equation ((5). The dependent variable is $\Delta \log HF\_Crdtr\_Credit_{h,p,t}$ (in %). The data are quarterly from Q1 2013 to Q1 2020 and include hedge funds with gross UST exposure of at least $1 million that borrow predominantly through repo on average during 2019:Q4. The specifications include combinations of fund, quarter, and creditor fixed effects where indicated. The standard errors are clustered at the creditor and time level. The independent variables, with the exception of the indicator variable are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

Panel A: Relative size of credit relationship

	(1)	(2)	(3)	(4)	(5)	(6)
$HFRankInCrdtr_{h,p,t-1}$	-31.227***	-14.877***			-23.195***	-14.408***
	-20.341	-7.762			-11.823	-6.531
$March2020$	8.423***	7.324***			8.138**	6.674**
$\times HFRankInCrdtr_{h,p,t-1}$	5.956	5.058			2.757	2.365
$CrdtrRankInHF_{h,p,t-1}$			-15.432***	-2.730*	-5.698***	-1.456
			-16.956	-1.897	-4.945	-0.966
$March2020 \times CrdtrRankInHF_{h,p,t-1}$			2.841***	2.226***	-0.032	2.022*
$\times CrdtrRankInHF_{h,p,t-1}$			17.908	7.129	-0.032	1.830
$LogHF\_Ctpty\_Credit_{h,p,t-1}$		-20.478***		-29.627***		-18.497***
		-7.544		-9.521		-6.091
$March2020$		2.264***		5.896***		-0.416
$\times LogHF\_Ctpty\_Credit_{h,p,t-1}$		5.230		16.279		-0.433
Fund × Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Creditor × Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	9,816	9,816	9,816	9,816	9,816	9,816
R^2	0.447	0.454	0.435	0.451	0.450	0.454

Panel B: Hedge fund activity levels

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$LogEqTurnover_{h,t-1}$	2.022	0.060					-0.276	0.070
	1.184	0.028					-0.119	0.031
$March2020_t$	-0.798	0.659					0.467	0.172
$\times LogEqTurnover_{h,t-1}$	-0.407	0.379					0.258	0.095
$LogFITurnover_{h,t-1}$			2.314	12.735**			12.779**	
			1.024	2.267			2.282	
$March2020_t$			4.178*	7.470***			7.275***	
$\times LogFITurnover_{h,t-1}$			1.940	3.359			2.858	
$LogUSTTurnover_{h,t-1}$					-0.360	-0.342		-0.347
					-0.333	-0.172		-0.167
$March2020_t$					4.409	10.527***		10.413***
$\times LogUSTTurnover_{h,t-1}$					1.148	3.438		3.138
$LogHF\_Ctpty\_Credit_{h,p,t-1}$		-75.798***		-76.699***		-75.732***	-76.719***	-75.729***
		-16.933		-18.597		-16.829	-18.671	-16.861
$March2020_t$		1.826		0.372		0.062	0.392	0.076
$\times LogHF\_Ctpty\_Credit_{h,p,t-1}$		0.407		0.082		0.013	0.085	0.016
Other controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund × Creditor FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Creditor × Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8,534	8,534	8,534	8,534	8,534	8,534	8,534	8,534
R^2	0.051	0.480	0.051	0.483	0.051	0.480	0.483	0.480

Table 7: Portfolio risk limits and hedge fund UST activity

This table presents results of the panel regression model given in equation (7). The dependent variables are shown in the first row. The data are monthly from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4. Columns 5 to 7 show changes to arbitrage exposures for the set of UST hedge funds that had "medium" or "large" arbitrage exposures in 2019:Q4. The medium (large) set is defined as the UST arbitrage hedge funds with above 25^{th} (50^{th}) percentile $USTArbitrage$ on average in 2019:Q4. The specifications include fund and time fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variable $March2020_t$, are standardized. Controls are included separately and interacted with the $March2020_t$ variable. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

					$\Delta LogUSTArb$		
	$\Delta LogUST\_Gross$	$\Delta LogUST\_Long$	$\Delta LogUST\_Short$	$\Delta LogUSTDir$	All	Mid	Large
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$RiskLimit_{h,t-1}$	-1.046	-0.418	-4.014	-1.259	-1.513	-0.617	-2.671
	-0.846	-0.176	-1.059	-0.454	-0.336	-0.108	-0.417
$March2020_t$	14.600^{***}	13.459^{***}	19.785^{***}	6.217^{**}	47.165^{***}	27.654^{***}	12.212^{**}
$\times RiskLimit_{h,t-1}$	7.303	5.213	4.791	2.130	9.931	5.758	2.503
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls $\times March2020_t$	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,509	9,835	7,768	10,509	7,126	5,113	3,530
R^2	0.047	0.044	0.064	0.022	0.054	0.073	0.086

Table 8: Redemption risk and hedge fund UST activity

This table presents results of the panel regression model given in equation (8). The dependent variables are shown in the first row. The data are monthly from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least \$1 million on average during 2019:Q4. Columns 5 to 7 show changes to arbitrage exposures for the set of UST hedge funds that had "medium" or "large" arbitrage exposures in 2019:Q4. The medium (large) set is defined as the UST arbitrage hedge funds with above 25^{th} (50^{th}) percentile $USTArbitrage$ on average in 2019:Q4. The specifications include fund and time fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variable $March2020_t$, are standardized. Controls are included separately and interacted with the $March2020_t$ variable. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

					$\Delta LogUSTArb$		
	$\Delta LogUST\_Gross$	$\Delta LogUST\_Long$	$\Delta LogUST\_Short$	$\Delta LogUSTDir$	All	Mid	Large
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$ShareRes_{h,t-1}$	2.768	3.595*	-3.009	3.069	-3.308	-2.314	-2.937
	1.594	1.987	-0.819	1.421	-0.847	-0.564	-0.661
$March2020_t$	-0.863	-8.172***	15.523***	-9.155***	-1.558	13.446***	21.407***
$\times ShareRes_{h,t-1}$	-0.659	-4.250	5.966	-4.666	-0.421	2.978	4.385
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls $\times March2020_t$	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,849	16,874	12,978	18,834	11,053	7,642	5,322
R^2	0.031	0.032	0.040	0.017	0.035	0.050	0.060

Table 9: Funding, redemption risk, and internal risk limits

This table presents results of a panel regression model similar to equation (8). The dependent variables are shown in the first row. The data are monthly from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4. Columns 5 to 7 show changes to arbitrage exposures for the set of UST hedge funds that had "medium" or "large" arbitrage exposures in 2019:Q4. The medium (large) set is defined as the UST arbitrage hedge funds with above 25^{th} (50^{th}) percentile $USTArbitrage$ on average in 2019:Q4. The specifications include fund and time fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variable $March2020_t$, are standardized. Controls are included separately and interacted with the $March2020_t$ variable. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

	$\Delta LogUST\_Gross$	$\Delta LogUST\_Long$	$\Delta LogUST\_Short$	$\Delta LogUSTDir$	$\Delta LogUSTArb$		
					All	Mid	Large
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$RiskLimit_{h,t-1}$	-1.046	-0.394	-4.136	-1.243	-1.671	-1.061	-3.098
	-0.848	-0.165	-1.081	-0.436	-0.365	-0.179	-0.469
$GSIB\_BrrwShare_{h,t-1}$	-0.261	1.101	-6.014	1.452	-6.192	-8.041	-9.146
	-0.127	0.365	-1.326	0.365	-1.150	-1.219	-1.074
$ShareRes_{h,t-1}$	2.498	2.836	-5.230	2.834	-6.125	-5.278	-4.032
	1.426	1.300	-1.463	1.003	-1.534	-1.220	-0.775
$March2020_t$	14.341^{***}	13.545^{***}	20.381^{***}	6.849^{**}	47.988^{***}	30.271^{***}	16.371^{***}
$\times RiskLimit_{h,t-1}$	7.150	5.231	5.039	2.352	9.960	6.494	3.681
$March2020_t$	-7.073^{*}	2.049	40.211^{***}	17.410^{**}	32.254^{***}	48.297^{***}	64.068^{***}
$\times GSIB\_BrrwShare_{h,t-1}$	-1.705	0.371	4.667	2.595	3.571	4.855	6.265
$March2020_t$	16.184^{***}	8.432^{***}	23.885^{***}	-1.032	3.992	27.130^{***}	33.265^{***}
$\times ShareRes_{h,t-1}$	6.923	2.825	4.584	-0.282	0.671	4.017	4.113
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls $\times March2020_t$	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,509	9,835	7,768	10,509	7,126	5,113	3,530
R^2	0.047	0.044	0.064	0.022	0.054	0.074	0.088

Table 10: Basis traders versus other UST traders

This table presents results of the panel regression model given in equation (9). The data are from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least \$1 million on average during 2019:Q4. Panel A columns 5 to 7 show changes to arbitrage exposures for the set of UST hedge funds that had "medium" or "large" arbitrage exposures in 2019:Q4. The medium (large) set is defined as the UST arbitrage hedge funds with above 25^{th} (50^{th}) percentile $USTArbitrage$ on average in 2019:Q4. The dependent variables are shown in the first row. All regressions are with monthly data with the exception of the last two columns in Panel C. The specifications include fund and time fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variables $March2020_t$ and $BasisTrader_h$, are standardized. Controls are included separately and interacted with the $March2020_t$ variable. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

Panel A: U.S. Treasury exposure

					$\Delta LogUSTArb$		
	$\Delta LogUST\_Gross$	$\Delta LogUST\_Long$	$\Delta LogUST\_Short$	$\Delta LogUSTDir$	All	Mid	Large
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$March2020_t$	4.938	0.120	4.325	-9.176	9.161	22.586***	22.612***
$\times BasisTrader_h$	1.243	0.028	0.630	-1.328	1.233	3.308	3.193
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls $\times March2020_t$	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,849	16,874	12,978	18,834	11,053	7,642	5,322
R^2	0.031	0.032	0.040	0.017	0.035	0.050	0.060

Panel B: Repo exposure, maturity, and collateral haircuts

	Exposure		Maturity		Haircut
	$\Delta LogRepoBorrowing$	$\Delta LogRepoLending$	$\Delta RepoBrrwTerm$	$\Delta RepoLendTerm$	$\Delta \frac{RepoTotalCollateral}{RepoBorrowing}$
	(1)	(2)	(3)	(4)	(5)
$March2020_t$	23.206***	-6.666	-3.355***	-0.414	1.361**
$\times BasisTrader_h$	4.174	-1.054	-5.801	-0.355	2.307
Controls	Yes	Yes	Yes	Yes	Yes
Controls $\times$ $March2020_t$	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Observations	9,387	9,083	9,387	9,083	9,810
R^2	0.039	0.041	0.045	0.072	0.029

Panel C: Cash and liquidity position

	$\Delta LogFreeCashEq$	$\Delta \frac{FreeCashEq}{NAV}$	$\Delta LogCash$	$\Delta \frac{Cash}{NAV}$	$\Delta LogPortfolioGNE$	$\Delta LogOpenPositions$	$\Delta LogPortIlliq$	$\Delta LeverageRatio$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$March2020_t$	-15.382***	-2.178***	18.269***	8.902***	7.805***	-3.403***	15.363***	-0.687***
$\times BasisTrader_h$	-4.976	-2.856	2.869	4.338	7.087	-3.864	3.464	-2.977
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls $\times$ $March2020_t$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,236	21,377	18,765	18,973	21,694	21,676	7,625	7,625
R^2	0.022	0.044	0.022	0.032	0.120	0.098	0.099	0.135

Table 11: Pre-crisis UST exposure and hedge fund UST activity

This table presents results of the panel regression model given in equation (3). The dependent variables are shown in the first row. The data are monthly from January 2013 to March 2020. Results are shown for three sets of hedge funds that, on average during 2019:Q4, had: (i) \$1 million $\leq UST\_Gross \geq$ \$100 million; (ii)\$100 million $\leq UST\_Gross \geq$ \$1 billion; and (iii) $UST\_Gross \geq$ \$1 billion. Columns 5 to 7 show changes to arbitrage exposures for the set of UST hedge funds that had "medium" or "large" arbitrage exposures in 2019:Q4. The medium (large) set is defined as the UST arbitrage hedge funds with above 25^{th} (50^{th}) percentile $USTArbitrage$ on average in 2019:Q4. The specifications include fund fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variable $March2020_t$, are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

						$\Delta LogUSTArb$		
Pre-crisis		$\Delta LogUST\_Gross$	$\Delta LogUST\_Long$	$\Delta LogUST\_Short$	$\Delta LogUSTDir$	All	Mid	Large
UST_Gross		(1)	(2)	(3)	(4)	(5)	(6)	(7)
1m to 100m	$Mar2020_t$	8.634***	8.778***	-4.514	23.918***	-34.651***	-40.714***	12.019
		4.066	2.684	-1.094	8.110	-3.292	-2.947	0.859
	Obs	5,326	3,821	3,360	5,326	1,887	1,069	571
	R^2	0.015	0.021	0.022	0.012	0.018	0.017	0.020
100m to 1b	$Mar2020_t$	-16.659***	-19.717***	0.005	-20.109***	-3.978	-33.261***	-35.930***
		-7.112	-6.979	0.001	-6.143	-0.616	-4.742	-3.825
	Obs	6,904	6,511	4,344	6,889	3,966	2,402	1,672
	R^2	0.016	0.011	0.021	0.009	0.014	0.017	0.019
≥1b	$Mar2020_t$	-47.600***	-33.687***	-53.132***	-46.861***	-35.607***	-55.458***	-55.666***
		-25.913	-12.703	-10.846	-13.785	-9.209	-13.818	-9.854
	Obs	6,619	6,542	5,274	6,619	5,200	4,171	3,079
	R^2	0.036	0.024	0.016	0.010	0.014	0.019	0.020

Table 12: Hedge fund liquidity and leverage

This table presents results of the panel regression model given in equation (3). The data are from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4. The dependent variables are shown in the first row. The specifications include fund fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variable $March2020_t$, are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

Panel A: Cash and liquidity

	$\Delta LogFreeCashEq$	$\Delta \frac{FreeCashEq}{NAV}$	$\Delta LogCash$	$\Delta \frac{Cash}{NAV}$	$\Delta PortIlliq$
	(1)	(2)	(3)	(4)	(5)
$March2020_t$	25.708***	6.284***	23.001***	8.817***	-10.682***
	18.866	36.677	20.196	27.559	-8.389
Controls	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes
Observations	20,236	21,377	18,765	18,973	7,625
R^2	0.012	0.025	0.015	0.021	0.084

Panel B: Fund size and leverage

	$\Delta LogPortfolioGNE$	$\Delta LogPortGNEnoUST$	$\Delta LogOpenPositions$	$\Delta LogNAV$	$\Delta LogGAV$	$\Delta LeverageRatio$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	-21.735***	-23.942***	-4.634***	-14.102***	-13.046***	-0.005
	-44.125	-43.468	-8.262	-25.187	-18.178	-0.194
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	21,694	21,611	21,676	7,625	7,625	7,625
R^2	0.071	0.073	0.026	0.246	0.188	0.121

Table 13: Variable definitions

This table presents definitions of the main variables used in this paper. The first column gives the variable name. The second column includes a short description. The last column gives the reference to the raw data source in Form PF (https://www.sec.gov/about/forms/formpf.pdf) or Form ADV (https://www.sec.gov/about/forms/formadv.pdf). Variables are monthly where the description indicates "(m)" and quarterly otherwise . Detailed descriptions and summary statistics of these variables are in section 3.

Variable Name	Description	Source
$NAV_{h,t}$	Net asset value, or the amount of investor equity, of the hedge fund.	PF Q9
$GAV_{h,t}$	Gross asset value, akin to balance sheet assets, of the hedge fund.	PF Q9
$LeverageRatio_{h,t}$	Balance sheet leverage, i.e. the ratio of gross asset value to net asset value, of the hedge fund.	PF Q8, Q9
$PortIlliq_{h,t}$	The weighted average time (in days) it would take to liquidate the hedge fund's portfolio, assuming no fire sale discounting.	PF Q32
$ShareRes_{h,t}$	The weighted average time (in days) it would take for the investors of the hedge fund to withdraw all the fund's NAV.	PF Q50
$FinDur_{h,t}$	The weighted average maturity (in days) of the hedge fund's borrowing.	PF Q46(b)
$MgrStake_{h,t}$	The percent of the net asset value of the hedge fund owned by the managers or their related persons.	ADV Schedule D, Section 7.B.(1), Q14
$NetRetQ_{h,t}$ ($NetRetM_{h,t}$)	Net-of-fee quarterly (monthly) returns of the hedge fund.	PF Q17
$NetFlows_{h,t}$	Net investor flows to the hedge fund, estimated as $NetFlows_{h,t} = \frac{NAV_{h,t} - NAV_{h,t-1} \times (1+r_{h,t})}{NAV_{h,t-1}}$ (m)	PF Q9, Q17
$RiskLimit_{h,t}$	The 12 month rolling average VaR with a time horizon of one month and a probability of 5% (m)	PF Q40
$FreeCashEq_{h,t}$	Unencumbered cash and cash equivalents. Includes Treasury and agency securites not posted as collateral.[†] (m)	PF Q33
$Cash_{h,t}$	Cash and cash equivalents, excluding government securites. (m)	PF Q30
$OpenPositions_{h,t}$	Number of open positions in the hedge fund's portfolio. (m)	PF Q34
$GNE_{h,t}$	Gross notional exposure estimated by summing long and short asset class exposures. (m)	PF Q30
$PortfolioGNE_{h,t}$	Gross notional exposure estimated by summing long and short exposures to non-cash asset classes. (m)	PF Q30
$Strategy_h$	Investment strategy of the hedge fund (Credit, Equity, Event Driven, Macro, Relative Value, Multi-strategy, or Other). See Online Appendix for classification methodology.	PF Q20

Continued on the next page.

Table 13: Variable definitions (continued)

Variable Name	Description	Source
$UST\_Gross_{h,t}$	Sum of long and short notional exposures to U.S. Treasury securities, including derivatives. (m)	PF Q30
$UST\_Long_{h,t}$	Long notional exposure to U.S. Treasury securities, including derivatives. (m)	PF Q30
$UST\_Short_{h,t}$	Short notional exposure to U.S. Treasury securities, including derivatives. (m)	PF Q30
$USTArbitrage_{h,t}$	The long-short balanced share of a fund's U.S. Treasury securities notional exposure, including derivatives. (m)	PF Q30
$USTDirectional_{h,t}$	The unbalanced share of a fund's U.S. Treasury securities notional exposure, including derivatives. (m)	PF Q30
$UST\_Long\_Drtn_{h,t}$	Duration in years of long notional exposure to U.S. Treasury securities. (m)	PF Q30
$UST\_Short\_Drtn_{h,t}$	Duration in years of short notional exposure to U.S. Treasury securities. (m)	PF Q30
$UST\_Net\_Drtn_{h,t}$	Duration in years of net (long minus short) notional exposure to U.S. Treasury securities. (m)	PF Q30
$RepoBorrowing_{h,t}$	Value of repurchase agreements through which the hedge fund has borrowed cash and lent securities. (m)	PF Q30
$RepoLending_{h,t}$	Value of repurchase agreements through which the hedge fund has borrowed securities and lent cash. (m)	PF Q30
$RepoBrrwTerm_{h,t}$	Average term (in days) of the hedge fund's $RepoBorrowing_{h,t}$. (m)	PF Q30
$RepoLendTerm_{h,t}$	Average term (in days) of the hedge fund's $RepoLending_{h,t}$. (m)	PF Q30
$RepoTotalCollateral_{h,t}$	Total collateral posted by the hedge fund in support of its $RepoBorrowing_{h,t}$. (m)	PF Q43(b)(ii)(A-C)
$RepoCashCollateral_{h,t}$	Total collateral posted in the form of cash and cash equivalents[†] by the hedge fund in support of its $RepoBorrowing_{h,t}$. (m)	PF Q43(b)(ii)(A)
$RepoSecCollateral_{h,t}$	Total collateral posted in the form of securities by the hedge fund in support of its $RepoBorrowing_{h,t}$. (m)	PF Q43(b)(ii)(B)
$RepoClearedCCP_{h,t}$	Estimated percentage (by value) of repo trades entered into by the hedge fund that were cleared by a CCP.	PF Q24(d)
$RepoBilateral_{h,t}$	Estimated percentage (by value) of repo trades entered into by the hedge fund that were bilaterally transacted.	PF Q24(d)
$BasisTrader_{h}$	Indicator for whether the hedge fund predominantly engages in the cash-futures basis trade in its UST portfolio. See Online Appendix for classification methodology.	PF Q20, Q30
$TotalMCBorrowing_{h,t}$	Total borrowings of the hedge fund across its major creditors, i.e. those from whom it borrows amounts totalling 5% or more of its net asset value.	PF Q47
$NumCrdtrsPerHF_{h,t}$	The number of creditors lending to the hedge fund.	PF Q47
$HFCreditorHHI_{h,t}$	Creditor concentration of the hedge fund.	PF Q47

Continued on the next page.

Table 13: Variable definitions (continued)

Variable Name	Description	Source
$HF\_Crdtr\_Credit_{h,p,t}$	Amount borrowed by hedge fund h from creditor p at the end of quarter t.	PF Q47
$IsCrdtrPB_{h,p,t}$	Indicator for whether creditor p is one of hedge fund h's prime brokers as of the end of quarter t.	ADV Schedule D, Section 7.B.(1), Q24
$IsCrdtrCustodian_{h,p,t}$	Indicator for whether creditor p is one of hedge fund h's custodians as of the end of quarter t.	ADV Schedule D, Section 7.B.(1), Q24/25
$CrdtrRankInHF_{h,p,t}$	Rank of creditor p based on hedge fund h's borrowing at the end of quarter t, normalized to the range $[0, 1]$.	PF Q47
$HFRankInCrdtr_{h,p,t}$	Rank of hedge fund h based on creditor p's lending at the end of quarter t, normalized to the range $[0, 1]$.	PF Q47

†In the data, "cash and cash equivalents" refer to cash, cash equivalents (e.g., bank deposits, certificates of deposits, money market fund investments).

Online Appendix for "LTCM Redux? Hedge Fund Treasury Trading and Funding Fragility"

Mathias S. Kruttli, Phillip J. Monin, Lubomir Petrasek, Sumudu W. Watugala*

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1 Background and Data

1.1 Overview of Fixed Income Arbitrage Strategies

In this section, we give a high-level overview of the economics of fixed income arbitrage strategies hedge funds engage in. Figure 9 illustrates the securities flows, cash flows, and exposures associated with trade open, trade maintenance, and trade close for a typical (a) long-short bond spread trade and (b) Treasury cash-futures basis trade.

Duarte, Longstaff, and Yu (2007) gives an overview of several arbitrage trading strategies of fixed income hedge funds and simulates their risk-return trade offs. Edward (1999); Jorion (2000) discuss the liquidity risk, volatility risk, default risk, and other risks inherent in fixed income "arbitrage" trading in the context of the 1998 meltdown of Long-Term Capital Management (LTCM), which engaged in such bond spread trading until a systematic shock caused massive losses that threatened systemic stability and led to a Fed-arranged broker takeover of the fund's positions. Industry insiders and observers drew parallels between the 1998 LTCM episode and the impact of the March 2020 shock on fixed income hedge funds. There are indeed some parallels, but, as we describe when presenting the main results in the paper, also important differences between the two episodes.

*Kruttli: The Board of Governors of the Federal Reserve System. Email: mathias.s.kruttli@frb.gov. Monin: The Board of Governors of the Federal Reserve System. Email: phillip.monin@frb.gov. Petrasek: The Board of Governors of the Federal Reserve System. Email: lubomir.petrasek@frb.gov. Watugala: Indiana University. Email: sumudu@iu.edu.

1.1.1 Long-short bond spread trading

This type of trade bets on the convergence of a particular bond spread—such as the on-the-run/off-the-run (ONR-OFFR) spread—due to theoretical or statistical predictions on the relative value of the two securities forming the spread. Details on the life cycle of a typical long-short bond spread trade are depicted in Figure 9(a). For such trades to be sufficiently profitable, these arbitrage trades must be significantly leveraged. Long UST securities positions are primarily financed via repurchase agreements (repo borrowing), while short UST securities positions are primarily sourced through reverse repo (repo lending).

Hedge funds generally go long the more illiquid security and short the more liquid security to capture the liquidity premium. In the case of the ONR-OFFR spread, this means going long the OFFR bond and short the ONR bond. In a typical market stress episode, liquidity risk spikes and such spreads widen. During such an episode, if a fund is unable to obtain sufficient capital or funding to hold onto such spread convergence trades, the fund would have to liquidate the trades at unfavorable prices in illiquid markets and realize losses.

In addition to liquidity risk, trade maintenance exposes a fund to repo rollover risk. Under extreme conditions, the dealer may refuse to roll over the repo loan funding the long side of the trade. Newly rolled-over loans might have higher haircuts if Treasury collateral is suddenly more volatile, may involve a higher interest rate, or a lower borrowing amount if the value of the collateral (bond price) has gone down. Each of these possibilities increases the cost of carrying the trade.

1.1.2 Cash-futures basis trading

The UST cash-futures basis trade became popular in recent years. In essence, it is a cross-market arbitrage constructed by shorting a Treasury futures contract and going long a Treasury security deliverable into that contract, funding the long position with repo borrowing.[1] We find that since 2018Q2 there has been a significant increase in repo borrowing, indicating a marked increase in long UST securities holdings (see Figures 2 and 3). Until that point, aggregate hedge fund repo borrowing and lending exposures were generally matched, as one would observe with UST arbitrage strategies such as trading on-the-run/off-the-run spreads or yield spreads. The divergence between

[1] The long Treasury security in a cash-futures basis trade is typically a Treasury note. We will use the term "bond" when describing the economics of the trade.

hedge fund repo borrowing and lending is likely driven by a significant increase in recent years in UST cash-futures basis trading.

In this trading strategy, a hedge fund goes long the (cheapest-to-deliver) Treasury security and goes short the corresponding Treasury futures contract. The futures leg does not require reverse repo, so the divergence between hedge fund repo borrowing and lending is consistent with reports of a significant increase in recent years in UST cash-futures basis trading. Typically, this is a low volatility, low yield convergence strategy that is operationally intensive and requires leverage to be worthwhile. The trade is profitable as long as the actual cost of carrying the cash position (the "repo rate" or the cost of repo borrowing for the hedge fund) is below the implied cost of carry on the futures (the "implied repo rate").

As with many other spread trades hedge funds engage in, these trades are also primarily "short liquidity," and perform worst in states of the world in which liquidity is scarce. In addition to liquidity risk, this trade is exposed to basis risk, i.e., the risk that the underlying asset price dynamics diverge from the futures price dynamics. Maintaining the trade exposes a fund to repo rollover risk and margin risk, described further below.

Details on the basis trade are depicted in Figure 9(b), which follows a typical trade's lifecycle. The transactions and cash flows at initiation are shown on the left. The cash flows include initial margin on the short futures contract and net cash needed above repo borrowings to complete the purchase of the bond. Given low haircuts on Treasury repo and low margin levels on futures, these initial cash outlays are low relative to the exposure of the trade. Thus, the cash-futures basis trade is very highly leveraged. As the figure suggests, it is also an operationally intensive trade.

Maintaining the trade to realize the its gains exposes the fund to two risks: rollover risk and margin risk. Although the fund would prefer to use term repo with maturity matched to the expiry of the futures, shorter-term or overnight repo is common and exposes the fund to the risk of not being able to continue financing the bond. Under extreme conditions, the dealer may refuse to roll over the repo loan. Newly rolled-over loans might have higher haircuts if Treasury collateral is suddenly more volatile, may involve a higher interest rate, or a lower borrowing amount if the value of the collateral (bond price) has gone down. Each of these possibilities increases the cost of carrying the bond. The second risk is margin risk. If futures prices increase rapidly or volatility leads to higher margin requirements, the fund might have to make variation margin payments to satisfy margin calls. It is worth noting that if cash and futures prices move in lockstep, margin payments may be made using increased repo borrowings from the appreciating collateral. However, if futures prices increase more than bond prices, i.e., if the futures basis widens, as they did in March of last year, there may be net cash demands on the fund related to margin payments. In such a case, the hedge fund would have to immediately meet the margin call to hold on to the basis trade position or liquidate the position at unfavorable prices and realize a loss.

Finally, at trade close on the right, the fund closes its repo and delivers the Treasury into the futures contract. The fund may alternatively choose to roll the trade to the following futures expiry.

1.2 Value-at-Risk Measure

Form PF Question 40 requires qualifying hedge funds to report detailed information about their fund-level value-at-risk (VaR) calculations if the fund "regularly calculates" VaR. Information reported includes confidence level, time horizon in days, and the VaR level as a percentage of the fund's NAV for each month in the reporting period. Details about calculation method (historical simulation, parametric, Monte Carlo simulation), length of historical lookback period, and weighting method are also reported. If a fund calculates VaR for multiple combinations of confidence interval, horizon, and historical observation period, then information about each of these combinations is reported.

To make reported VaRs comparable across funds, we use the following method to convert reported VaRs to the same confidence level and time horizon. Let $VaR(\alpha_1, T_1)$ and $VaR(\alpha_2, T_2)$ be a fund's VaR (expressed as a percentage of NAV) for two potentially different confidence levels, α_1 and α_2, and two potentially different time horizons, T_1 and T_2. Under the assumption that the fund's continuously compounded daily returns are independent and identically normally distributed with zero mean and constant variance, we can show that

$$VaR(\alpha_2, T_2) = \frac{z_{\alpha_2}}{z_{\alpha_1}} \sqrt{\frac{T_2}{T_1}} VaR(\alpha_1, T_1), \tag{1}$$

where z_{α_i} is the quantile of the standard normal distribution, i.e. $z_{\alpha_i} = \Phi^{-1}(\alpha_i)$. By writing the fund's reported VaR as $VaR(\alpha_1, T_1)$ and setting $\alpha_2 = 0.05$ and $T_2 = 21$ trading days, we convert all reported VaRs to a confidence level of 5% and a monthly time horizon. If a fund reports VaRs for multiple combinations of confidence level, horizon, and historical observation period, then all VaRs are first converted and are then averaged to obtain a single, fund-month level VaR.

1.3 Basis Trader Classification

We use the following methodology to classify a hedge fund as predominantly engaging in the UST cash-futures basis trade as opposed to other UST trading strategies. The classification recognizes that a basis trade has broadly balanced long and short UST notional exposures, but the long "cash" side is a physical bond while the short "futures" side is a derivative. As such, only the long side is funded via repo, while the short side is not. This generally contrasts with other UST arbitrage strategies such as on-the-run/off-the-run spread trading where the long and short side of the trade is funded via more balanced repo borrowing and repo lending, respectively.

The algorithm begins by subsetting funds to those whose strategy allocation according to Form PF Question 20 includes some allocation to either "Relative Value, Fixed Income Sovereign" or "Macro, Global Macro." We then classify a fund in this set as a Basis Trader if, during the height of the basis trade between January 2018 and February 2020 (inclusive), its balanced UST position, $USTArbitrageNE$, is positively and significantly correlated at the 5% level with its *net* repo exposure ($RepoBorrowing - RepoLending$). Finally, we manually inspect the results of the algorithm for consistency.

1.4 Duration of U.S. Treasury Exposure

Funds supplement their reporting of notional exposures to U.S. Treasury securities on Form PF Question 30 by reporting either the duration, weighted average tenor (WAT), or 10-year bond equivalent values for both their long and short exposures. To facilitate comparison across funds, we convert entries of WAT and 10-year bond equivalents to duration.

Our method begins with the observation (see section 1.4.1) that one can approximate the modified duration of a semi-annual coupon bond at par value given its yield and remaining maturity according to the formula:

$$ModDur(y, \tau) \approx \frac{1}{y}\left(1 - \frac{1}{(1 + \frac{1}{2}y)^{2\tau}}\right), \qquad (2)$$

where y is the yield-to-maturity (expressed as a decimal) and τ is the remaining time-to-maturity of the bond in years. For zero-coupon bonds such as T-bills, the modified duration is computed as

$$ModDur(y, \tau) = \frac{\tau}{1 + \frac{y}{k}}, \tag{3}$$

where k is the compounding frequency per year. Thus we use $k = 12$ for the 4-week T-bill, $k = 6$ for the 8-week T-bill, $k = 4$ for the 13-week T-bill, and so on.

Our analysis also requires the monthly time series of the Treasury yield curve. We obtain month-end historical constant maturity Treasury rates from the Federal Reserve's H.15 data and linearly interpolate between maturities to form a yield curve estimate. In particular, we use (2) to produce a time-varying estimate of the modified duration of the 10-year Treasury note.

Given the above, to convert from a 10-year bond equivalent value to duration we use

$$Duration = \frac{(Reported10yrBE) * (DurationOf10yrUST)}{ReportedUSTExposure} \tag{4}$$

Finally, to convert from WAT to duration, we first use the interpolated U.S. Treasury yield curve to find the approximate yield-to-maturity for a Treasury with WAT remaining years to maturity. The duration is then approximated using (2) if WAT is greater than one, or computed using (3) if WAT is less than or equal to one.

1.4.1 Derivation of (2)

Consider a semi-annual coupon bond with yield-to-maturity y and coupon C with $2n$ remaining semi-annual coupon payments. Write the price P of the bond in terms of two components: the present value of an annuity represented by the coupon payments, and the present value of the par value payment at maturity. The price P per $100 of par can be written as:

$$P = C\left[\frac{1 - \frac{1}{(1+y/2)^{2n}}}{y/2}\right] + \frac{100}{(1 + y/2)^{2n}}. \tag{5}$$

Computing the modified duration by taking the derivative with respect to y, we obtain

$$ModDur = -\frac{1}{P}\frac{\partial P}{\partial y} = \frac{\frac{2C}{y^2}\left[1 - \frac{1}{(1+y/2)^{2n}}\right] + \frac{n(100-2C/y)}{(1+y/2)^{2n+1}}}{P} \tag{6}$$

For a semi-annual coupon bond at par value, we have that $P = 100$ and $C = 100y/2$ (y is a decimal). Inserting this into the above, we obtain

$$ModDur = \frac{\frac{2\times 100y/2}{y^2}\left[1 - \frac{1}{(1+y/2)^{2n}}\right] + \frac{n(100-2\times 100y/2y)}{(1+y/2)^{2n+1}}}{100} \tag{7}$$

$$= \frac{1}{y}\left(1 - \frac{1}{(1+y/2)^{2n}}\right). \tag{8}$$

1.5 Average Term of Repo and Reverse Repo

As in the case of U.S. Treasury exposures, funds report on Form PF Question 30 the duration, weighted average tenor (WAT), or 10-year bond equivalent values for both their repo borrowing and repo lending. We use these values to estimate the average term of their repo borrowing and repo lending.

A repo can be viewed as a collateralized loan with a single payment of principal and interest at maturity. The duration and WAT of a repo is thus equal to its term, much like the duration and WAT of a zero-coupon bond is its maturity. Finally, we use this observation and (4) to convert a 10-year bond equivalent value to the repo term.

1.6 Investment Strategy Classification

Question 20 on Form PF contains 22 strategy categories to which hedge funds assign shares of their invested NAV. Among these is an "Other" category to which funds can manually enter strategies that are not covered by the other 21 sub-strategies. The 22 strategy categories roll up to 8 broad strategies: equity, macro, relative value, event driven, credit, managed futures, investment in other funds, and other. We use these data to classify a hedge fund's broad strategy.

First, we inspect the strategies entered in the "Other" category and reclassify entries that are similar to other listed broad strategies. For example, a description of "Relative Value Fixed Income" is reclassified from "Other" to "Relative Value."

Next, the data are normalized so that the sum of each hedge fund's allocation across the 22 strategy categories equals 100% of their NAV. These normalized values are aggregated to the broad strategy categories, and then further aggregated across all the fund's filings over time. A hedge fund is considered to use a given broad strategy if more than 50% of its aggregated, normalized assets are allocated to that broad strategy. If there is not a broad strategy to which more than 50% of the normalized assets are allocated, then the fund is classified as a multi-strategy fund.

Table A1: G-SIB and primary dealer classifications

This table presents G-SIB and primary dealer classifications as of December 2019. The source for the G-SIB classifications is the Financial Stability Board (https://www.fsb.org/work-of-the-fsb/policy-development/addressing-sifis/global-systemically-important-financial-institutions-g-sifis/) and for primary dealers is the New York Fed (https://www.newyorkfed.org/medialibrary/media/markets/Dealer_Lists_1960_to_2014.xls and https://www.newyorkfed.org/markets/primarydealers#additions-and-removals).

Institution	Jurisdiction	G-SIB designated years	Primary dealer subsidiary
Amherst Pierpont	US		1
Agricultural Bank of China	CN	2014 -	0
Bank of America	US	2011 -	1
Bank of China	CN	2011 -	0
Bank of Montreal	CA		1
Bank of New York Mellon	US	2011 -	0
Bank of Nova Scotia	CA		1
Barclays	UK	2011 -	1
BBVA	ES	2012 - 2014	0
BNP Paribas	FR	2011 -	1
Cantor Fitzgerald	US		1
China Construction Bank	CN	2015 -	0
Citigroup	US	2011 -	1
Commerzbank	DE	2011	0
Credit Suisse	CH	2011 -	1
Daiwa Securities Group	JP		1
Deutsche Bank	DE	2011 -	1
Dexia	BE	2011	0
Goldman Sachs	US	2011 -	1
Groupe BPCE	FR	2011 -	0
Groupe Crédit Agricole	FR	2011 -	0
HSBC	UK	2011 -	1
Industrial and Commercial Bank of China	CN	2013 -	0
ING Bank	NL	2011 -	0
Jefferies Group	US		1
JP Morgan Chase	US	2011 -	1
Lloyds Banking Group	UK	2011	0
Mitsubishi UFJ FG	JP	2011 -	0
Mizuho FG	JP	2011 -	1
Morgan Stanley	US	2011 -	1
Nomura Holdings	JP		1
Nordea	SE	2011 - 2017	0
Royal Bank of Canada	CA	2017 -	1
Royal Bank of Scotland	UK	2011 - 2017	1
Santander	ES	2011 -	0
Société Générale	FR	2011 -	1
Standard Chartered	UK	2012 -	0
State Street	US	2011 -	0
Sumitomo Mitsui FG	JP	2011 -	0
Toronto Dominion	CA	2019 -	1
UBS	CH	2011 -	1
Unicredit	IT	2011 -	0
Wells Fargo	US	2011 -	1

2 Additional tables

Table A2: Hedge fund U.S. Treasury exposures with time series controls

This table presents results of the panel regression model given in equation (3) with additional time series controls included. The dependent variables are shown in the first row. The data are monthly from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4. Panel B also show changes to arbitrage exposures for the set of UST hedge funds that had "medium" or "large" arbitrage exposures in 2019:Q4. The medium (large) set is defined as the UST arbitrage hedge funds with above 25^{th} (50^{th}) percentile $USTArbitrage$ on average in 2019:Q4. The specifications include fund fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variable $March2020_t$, are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

Panel A: U.S. Treasury exposure

	$\Delta LogUST\_Gross$	$\Delta LogUST\_Long$	$\Delta LogUST\_Short$	$\Delta \frac{UST\_Gross}{NAV}$	$\Delta \frac{UST\_Long}{NAV}$	$\Delta \frac{UST\_Short}{NAV}$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	-20.525***	-21.330***	-22.190***	-15.330***	-9.102***	-7.200***
	-13.089	-12.102	-7.287	-10.281	-8.637	-9.611
$MOVE1_t$	1.100**	1.937**	0.477	0.209	0.592*	-0.324
	2.144	2.624	0.339	0.446	1.790	-1.614
$YieldSlope_t$	-0.256	-0.632	1.009	-1.358***	-0.901**	-0.515***
	-0.522	-1.057	0.723	-2.862	-2.286	-2.710
HPW_t	-0.534	-0.363	-2.767***	-0.321	-0.357	0.018
	-0.823	-0.471	-2.906	-0.509	-0.749	0.079
Other controls	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,849	16,874	12,978	18,801	18,801	18,801
R^2	0.016	0.016	0.018	0.018	0.017	0.015

Panel B: U.S. Treasury directional and arbitrage exposure

	All UST funds			Mid UST arbitrage positions		Large UST arbitrage positions	
	$\Delta LogUSTDir$	$\Delta LogUSTArb$	$\Delta \frac{USTArb}{Gross}$	$\Delta LogUSTArb$	$\Delta \frac{USTArb}{Gross}$	$\Delta LogUSTArb$	$\Delta \frac{USTArb}{Gross}$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$March2020_t$	-16.876***	-25.040***	-1.960***	-45.373***	-5.750***	-42.824***	-7.596***
	-6.351	-6.989	-3.536	-10.427	-5.648	-9.414	-6.314
$MOVE1_t$	1.551*	1.814	0.006	0.052	-0.189	-0.443	-0.149
	1.984	1.182	0.029	0.028	-0.530	-0.218	-0.344
$YieldSlope_t$	-0.131	0.832	0.066	0.015	-0.141	-0.273	-0.022
	-0.154	0.494	0.301	0.007	-0.392	-0.127	-0.063
HPW_t	-1.047	-3.150**	-0.145	-2.350	0.023	-1.479	-0.094
	-1.085	-2.384	-0.868	-1.442	0.090	-0.946	-0.287
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,834	11,053	18,849	7,642	9,155	5,322	6,186
R^2	0.007	0.014	0.005	0.017	0.006	0.017	0.008

Table A3: Hedge funds that experienced LTCM

This table presents results of the panel regression model given in equation (8) including an additional interaction term for the variable $LTCMExp_h$, which captures if the fund's adviser experienced the LTCM crisis in 1998. The dependent variable is $\Delta LogPortIlliq_{h,t}$ (in %). The data are monthly from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4. The specifications include fund and time fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variables $March2020_t$ and $LTCMExp_h$, are standardized. Controls are included separately and interacted with the $March2020_t$ variable. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

	$\Delta LogPortIlliq$			
	(1)	(2)	(3)	(4)
$March2020_t$	-7.298***	-7.004***		
	-14.268	-5.456		
$LTCMExp_h$	0.518		0.493	
	0.687		0.657	
$March2020_t \times LTCMExp_h$	-10.069***	-9.955***	-10.044***	-9.926***
	-9.235	-4.910	-9.334	-4.921
$ShareRes_{h,t-1}$	1.920***	1.596	1.922***	1.812
	3.330	0.639	3.326	0.723
$March2020_t \times ShareRes_{h,t-1}$	4.613***	6.090***	4.610***	6.146***
	5.658	4.933	5.637	4.958
Controls	Yes	Yes	Yes	Yes
Controls $\times$ $March2020_t$	Yes	Yes	Yes	Yes
Fund FE	No	Yes	No	Yes
Time FE	No	No	Yes	Yes
OObservations	7,625	7,625	7,625	7,625
R^2	0.022	0.093	0.028	0.099

Table A4: Valuation-adjusted changes in U.S. Treasury exposures

This table presents results of the panel regression model given in equation (3). The dependent variables are shown in the first row and are the changes in UST Gross, Long, and Short, but adjusted for changes in UST prices. The data are monthly from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least $1 billion on average during 2019:Q4. The specifications include fund fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variable $March2020_t$, are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

	$\Delta LogUST\_Gross$	$\Delta LogUST\_Long$	$\Delta LogUST\_Short$	$\Delta \frac{UST\_Gross}{NAV}$	$\Delta \frac{UST\_Long}{NAV}$	$\Delta \frac{UST\_Short}{NAV}$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	-7.281***	-23.343***	12.496***	4.390***	-10.922***	26.297***
	-6.127	-12.965	7.296	3.203	-9.495	12.438
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,082	16,667	11,815	18,079	16,306	12,532
R^2	0.020	0.025	0.050	0.014	0.016	0.011

Table A5: UST duration

This table presents results of the panel regression model given in equation (3). The dependent variables are shown in the first row. The data are monthly from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least $1 billion on average during 2019:Q4. The specifications include fund fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variable $March2020_t$, are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

	ΔUST_Long_Drtn	ΔUST_Short_Drtn	ΔUST_Net_Drtn	$\Delta LogUST\_Gross\_10yrEQ$	$\Delta LogUST\_Long\_10yrEQ$	$\Delta LogUST\_Short\_10yrEQ$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	0.149***	-0.100*	0.939***	-17.090***	-15.039***	-33.105***
	4.046	-1.757	4.791	-9.914	-6.845	-8.452
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,341	18,341	18,340	18,341	16,512	12,633
R^2	0.007	0.005	0.005	0.015	0.013	0.017

Table A6: Summary statistics for hedge funds primarily borrowing via repo

This table shows select summary statistics over the period from January 2013 to September 2020 for the hedge funds that primarily borrow via repo and have at least \$1 million in UST exposure on average during 2019:Q4. This is the main sample of hedge funds used in the hedge fund-creditor level analysis on changes to repo borrowing. The N column shows the number of observations used to calculate the statistics in a particular row. The last four columns show percentiles.

	N	Mean	Median	Stdev	25th	75th	10th	90th
$\frac{RepoBorrowing}{TotalBorrowing}$ (%)	8,995	88.786	99.241	15.740	79.379	100.000	59.829	100.000
$TotalMCBorrowing_{h,t}$ (m US\$)	2,189	8,738.516	1,027.546	26,954.468	314.389	4,320.877	107.501	21,159.939
$NumCrdtrsPerHF_{h,t}$	2,189	6.265	5.000	5.464	2.000	8.000	1.000	13.200
$HFCrdtrHHI_{h,t}$	2,189	39.306	29.235	28.747	18.143	50.356	12.891	100.000
$HF\_Crdtr\_Credit_{h,p,t}$ (m US\$)	13,819	1,267.736	351.938	2,818.642	132.387	1,087.282	61.780	2,946.323
$\Delta logHF\_Crdtr\_Credit_{h,p,t}$	11,121	1.370	0.381	52.724	-22.847	25.015	-60.263	62.666
$IsCrdtrPB_{h,p,t}$	13,819	0.228	0.000	0.420	0.000	0.000	0.000	1.000
$IsCrdtrCustodian_{h,p,t}$	13,819	0.296	0.000	0.457	0.000	1.000	0.000	1.000

Table A7: The regulatory constraints of creditors and hedge fund borrowing

This table presents results of the panel regression model given in equations (4), (5), and (6). The dependent variable is $\Delta \log HF\_Crdtr\_Credit_{h,p,t}$ (in %). The data are quarterly from Q1 2013 to Q1 2020 and include all hedge funds that borrow predominantly via repo (without filtering out hedge funds with less than $1 billion on average during 2019:Q4). The specifications include combinations of fund, quarter, and creditor fixed effects where indicated. The standard errors are clustered at the creditor and time level. The independent variables, with the exception of the indicator variables $March2020_t$ and $IsGSIB_{p,t}$, are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t \times IsGSIB_{p,t}$	10.503***	9.434***	13.641***	13.797***	14.545***	14.548***
	9.067	3.812	4.025	2.941	3.935	3.882
$IsGSIB_{p,t}$	-0.260	-3.226**	-5.160**	-1.183	14.599***	13.493***
	-0.267	-2.619	-2.066	-0.361	4.700	4.490
$LogHF\_Crdtr\_Credit_{h,p,t-1}$					-82.417***	-73.815***
					-26.900	-17.131
$CrdtrRankInHF_{h,p,t-1}$						-0.985
						-0.850
$HFRankInCrdtr_{h,p,t-1}$						-7.512**
						-2.554
Other Controls	No	No	No	No	No	Yes
Fund FE	Yes	Yes	No	No	No	No
Time FE	Yes	Yes	No	No	No	No
Creditor FE	No	Yes	Yes	No	No	No
Fund × Time FE	No	No	Yes	Yes	Yes	Yes
Fund × Creditor FE	No	No	No	Yes	Yes	Yes
Observations	13,995	13,995	13,995	13,995	13,995	13,995
R^2	0.043	0.048	0.293	0.382	0.562	0.562

Table A8: Hedge fund returns and investor flows

This table presents results of the panel regression model given in equation (3). The data are from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least \$1 million on average during 2019:Q4. The dependent variables are shown in the first row. Regression (1) is on monthly net returns ($NetRetM$), while regressions (2) and (3) are on quarterly returns ($NetRetQ$) and flows ($NetFlows$), respectively. The specifications include fund fixed effects. The standard errors are clustered at the fund and time level. The independent variables, with the exception of the indicator variable $March2020_t$, are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

	$NetRetM$	$NetRetQ$	$NetFlows$
	(1)	(2)	(3)
$March2020_t$	-6.629***	-9.903***	-1.792***
	-37.528	-23.493	-5.967
$ShareRes_{h,t-1}$	0.055	0.022	1.196
	0.761	0.148	1.387
$PortIlliq_{h,t-1}$	-0.142	-0.111	-2.011***
	-1.319	-0.208	-3.364
$FinDur_{h,t-1}$	0.042	0.398	0.517*
	0.874	1.315	1.812
$LogNAV_{h,t-1}$	-0.402***	-1.162**	-7.696***
	-2.714	-2.275	-7.402
$NetRet_{h,t-1}$	0.025	1.331*	-0.989**
	0.193	1.790	-2.346
$NetFlows_{h,t-1}$	-0.021	-0.583***	3.054***
	-0.570	-3.301	6.573
$MgrStake_{h,t-1}$	-0.076*	-0.171	0.709
	-1.731	-1.319	1.450
$Leverage_{h,t-1}$	0.081	0.128	-0.634
	1.347	0.624	-1.405
Fund FE	Yes	Yes	Yes
Observations	21,659	7,630	7,618
R^2	0.194	0.549	0.344

Table A9: Hedge fund UST trading and funding after the March 2020 shock

This table presents results of the panel regression model given in equation (3). The data are from January 2013 to September 2020 and include all hedge funds with gross UST exposure of at least $1 million on average during 2019:Q4. Panel B columns 5 to 7 show changes to arbitrage exposures for the set of UST hedge funds that had "medium" or "large" arbitrage exposures in 2019:Q4. The dependent variables are shown in the first row. Regressions in Panel A are on quarterly data, while those in Panels B and C are on monthly data. The specifications include fund fixed effects. The standard errors are clustered at the fund and time level. All independent variables except $March2020_t$ are standardized. t-statistics are shown below the corresponding coefficient estimates. The significance of the coefficient estimate is indicated by * for $p < 0.10$, ** for $p < 0.05$, and *** for $p < 0.01$.

Panel A: Returns, flows, and leverage

	$NetRetQ$	$NetFlows$	$\Delta LogNAV$	$\Delta LogGAV$	$\Delta LeverageRatio$
	(1)	(2)	(3)	(4)	(5)
$March2020_t$	-9.643***	-1.905***	-14.048***	-12.743***	0.008
	-22.043	-5.838	-24.562	-17.621	0.339
$2020Q2_t$	6.601***	-3.324***	2.810***	-0.677	-0.179***
	5.896	-5.012	3.206	-0.705	-7.278
$2020Q3_t$	1.260**	-3.339***	-2.249***	-1.942***	0.068***
	2.166	-6.630	-3.473	-2.803	2.919
Other Controls	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes
Observations	8,361	8,349	8,356	8,356	8,356
R^2	0.556	0.335	0.231	0.176	0.135

Panel B: U.S. Treasury exposure

					$\Delta LogUSTArb$		
	$\Delta LogUST\_Gross$	$\Delta LogUST\_Long$	$\Delta LogUST\_Short$	$\Delta LogUSTDir$	All	Mid	Large
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$March2020_t$	-19.486***	-19.172***	-22.019***	-15.602***	-24.883***	-45.354***	-41.942***
	-12.534	-9.979	-7.169	-7.739	-7.244	-10.842	-8.831
$April2020_t$	5.364**	2.889	-3.869	4.867*	-8.587	-10.005	9.815*
	2.555	1.340	-0.699	1.735	-1.479	-1.377	1.893
$May2020_t$	-4.204***	-3.082**	-12.824***	-7.746***	-12.203***	-12.306***	-3.292
	-4.162	-2.099	-5.400	-3.968	-4.874	-3.723	-0.809
$June2020_t$	-5.579***	-4.031***	-16.479***	-7.038***	-16.959***	-13.331***	-4.039
	-4.490	-3.010	-6.028	-3.332	-6.317	-3.926	-1.268
$July2020_t$	-6.547***	-9.836***	-6.005**	-19.833***	-0.546	3.277	-4.076
	-6.657	-5.384	-2.204	-8.978	-0.181	0.876	-1.310
$Aug2020_t$	-3.448***	-3.431***	-6.920***	1.174	-5.850***	-3.341	0.699
	-4.207	-3.960	-2.932	0.534	-2.786	-1.304	0.244
$Sept2020_t$	-4.080***	-3.145***	1.065	-1.154	4.132	-10.459***	-10.634***
	-5.004	-2.751	0.479	-0.670	1.519	-5.266	-4.607
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,776	18,495	14,293	20,761	12,075	8,401	5,872
R^2	0.015	0.016	0.015	0.007	0.013	0.016	0.017

Panel C: Repo exposure, maturity, and collateral haircut

	Repo Borrowing				Repo Lending	
	Amount	*Maturity*	*Collateral*	*Haircut*	*Amount*	*Maturity*
	$\Delta LogRepoBrrw$	$\Delta RepoBrrwTerm$	$\Delta LogRepoCollateral$	$\Delta \frac{RepoCollateral}{RepoBorrowing}$	$\Delta LogRepoLend$	$\Delta RepoLendTerm$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	-0.317	3.025***	1.359	-0.746	-21.446***	-0.838*
	-0.136	5.822	0.541	-1.595	-5.917	-1.697
$April2020_t$	-15.228***	1.101	-13.463***	4.651***	-24.196***	0.601
	-3.004	1.441	-2.927	7.973	-5.624	0.801
$May2020_t$	-9.504***	-0.167	0.940	2.813***	7.767**	-0.177
	-3.140	-0.222	0.423	5.977	2.343	-0.400
$June2020_t$	12.260***	0.391	-2.813	1.433***	-5.544*	-0.851**
	4.426	0.734	-1.406	3.318	-1.807	-2.014
$July2020_t$	2.242	1.843***	-10.417***	0.335	-6.561**	0.408
	0.860	3.919	-4.157	0.882	-2.396	1.019
$Aug2020_t$	2.455	1.872***	2.522	-0.503	-4.460	0.060
	1.262	3.467	1.499	-1.398	-1.636	0.129
$Sept2020_t$	1.423	2.098***	-6.940***	0.264	2.197	0.248
	0.977	4.183	-4.249	0.626	0.767	0.531
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,373	10,373	10,815	10,815	10,011	10,011
R^2	0.019	0.019	0.019	0.021	0.017	0.020