Hedge Fund Treasury Trading and Funding Fragility: Evidence from the COVID-19 Crisis*

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Abstract

Hedge fund gross U.S. Treasury (UST) exposures doubled from 2018 to February 2020 to $2.4 trillion, primarily driven by relative value arbitrage trading and supported by corresponding increases in repo borrowing. In March 2020, amid unprecedented UST market turmoil, the average UST trading hedge fund had a return of -7% and reduced its UST exposure by close to 20%, despite relatively unchanged bilateral repo volumes and haircuts. Analyzing hedge fund-creditor borrowing data, we find the large, more regulated dealers provided disproportionately more funding during the crisis than other creditors. Hedge funds exited the turmoil with 20% higher cash holdings and smaller, more liquid portfolios, despite low contemporaneous outflows. This precautionary flight to cash was more pronounced among funds exposed to greater redemption risk through shorter share restrictions. Hedge funds predominantly trading the cash-futures basis faced greater margin pressure and reduced UST exposures and repo borrowing the most. After the market turmoil subsided following Fed intervention, hedge fund returns recovered quickly, but UST exposures did not revert to pre-shock levels over the subsequent months. Overall, the step back in hedge fund UST activity was primarily driven by fund-specific liquidity management constrained by margin pressure and expected redemptions, rather than creditor regulatory constraints.

JEL classification: G11, G23, G24, G01.

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

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1 Introduction

The role of hedge funds in U.S. Treasury (UST) markets is thought to have increased in importance 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. 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, compared to other asset managers, hedge funds employ substantial leverage coupled with investment strategies that are less liquid. They also have distinct funding structures, the resilience of which is key to understanding how they operate during periods of financial market turmoil. Following the unprecedented volatility in Treasury markets in March 2020 in the wake of the sudden brakes on economic activity imposed by the COVID-19 pandemic, there has been much debate in industry, policy, and academic circles about the role hedge funds played during this crisis and, more broadly, the financial stability implications of hedge fund UST market activities.[1,2]

In this paper, comprehensive regulatory data and our empirical approach give, for the first time, a granular view of how hedge funds face a systematic crisis in terms of their liquidity and leverage management.[3] Of particular importance for understanding the March 2020 shock, we analyze changes to hedge fund UST long/short notional and duration exposures, bilateral repo borrowing, collateral and funding terms, cash buffers, portfolio liquidity, and leverage. Further, we harness hedge fund-creditor level counterparty credit exposure data to investigate the role of creditor constraints and funding supply shocks. The COVID-19 crisis provides a unique opportunity to examine the strengths and vulnerabilities of the current model of UST market intermediation in which hedge funds play an important role. We ask two main questions to probe deeper into the factors that may have constrained hedge fund arbitrage activity and liquidity provision. (i) What was the impact of external debt and equity financing constraints? Specifically, we analyze whether the regulatory constraints of creditors—particularly those of dealers that are subject to enhanced regulations as part of

[1] See, for example, *How a Little Known Trade Upended the U.S. Treasury Market* (https://www.bloomberg.com/news/articles/2020-03-17/treasury-futures-domino-that-helped-drive-fed-s-5-trillion-repo); *Revisiting the Ides of March, Parts I-III* (https://www.cfr.org/blog/revisiting-ides-march-part-i-thousand-year-flood); Di Maggio (2020); Duffie (2020); He, Nagel, and Song (2020); and Schrimpf, Shin, and Sushko (2020).

[2] "The Fed did unbelievable things this time." —Janet Yellen, July 2020, https://www.nytimes.com/2020/07/23/business/economy/hedge-fund-bailout-dodd-frank.html.

[3] 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.

global systemically important banks (G-SIBs)—hindered the ability of hedge funds to obtain funding, thus exacerbating the liquidity shock in UST. On hedge fund equity, we examine investor outflows during the market turmoil and the differential impact of hedge fund share restrictions that place limits on redemptions. (ii) What was the impact of hedge fund-specific liquidity management considerations? These involve both meeting unexpected, immediate liquidity drains such as margin calls and reacting to *anticipated* future liquidity needs in a time of aggregate uncertainty. These questions are of great importance for financial stability and UST market functioning.

In the period leading up to the March 2020 COVID-19 shock, we find 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, which held close to \$600 billion in long UST exposure in February 2020. 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). Since 2018Q2 there has been a significant increase in repo 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.[4] 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.[5] 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. We describe the cash flows and exposures involved with both types of fixed income arbitrage strategies in Appendix section B.1.

In March 2020—as investors around the world engaged in a flight to cash and liquidity

[4]A common case study on liquidity risk and the risks inherent in "arbitrage" trading is 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 (Edward (1999); Jorion (2000); Lowenstein (2000); Duarte, Longstaff, and Yu (2007)). Industry insiders and observers drew parallels between the 1998 LTCM episode and the impact of the March 2020 shock on fixed income hedge funds (e.g., *A Hedge Fund Bailout Highlights How Regulators Ignored Big Risks*, https://www.nytimes.com/2020/07/23/business/economy/hedge-fund-bailout-dodd-frank.html). There are indeed some parallels, but also important distinctions between the two episodes.

[5]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").

amid an unprecedented, sudden economic shutdown—there was a sharp divergence in the UST spreads that hedge funds generally bet will converge. We find the average hedge fund with UST holdings in our sample experienced a *monthly* return of around -7%. By the end of March 2020, 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%. Despite the fall in UST exposures, borrowing levels and collateral rates on bilateral repurchase agreements—the primary source of financing for hedge fund UST holdings and cash-futures basis trades—remained relatively unchanged in March 2020 for the average hedge fund. Although significant negative returns depleting their equity, hedge funds held leverage ratios largely unchanged, indicating that they scaled back their exposures proportionately to the declines in asset valuations. 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. We specifically analyze the impact of creditor constraints, redemption risk, and margin pressure on hedge fund liquidity provision and consumption during this crisis.

There has been much debate about the impact of post-GFC regulations on UST and other fixed income market liquidity and the impact of dealer constraints on hedge fund arbitrage activity.[6] 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. We do not find evidence that the sell-off in UST was driven by a credit supply shock stemming from the regulatory constraints of dealer banks. Using data on borrowing amounts available at the hedge fund-creditor level, we examine the differences between funding provided by creditors constrained and unconstrained by enhanced regulations using a within hedge fund-time methodology.[7] We find that G-SIBs—which face enhanced regulations and are often taken as the dealer set more constrained by regulations—provided over 11-13% higher repo funding compared to other dealers during the crisis to hedge funds. This finding is 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. Contrary to the regulatory constraints hypothesis, the largest dealers that are subject to enhanced prudential regulations provided disproportionately better access to funding to their hedge fund counterparties during this

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

[7]Kruttli, Monin, and Watugala (2020) use Form PF data and a similar empirical strategy, adapted from Khwaja and Mian (2008), to examine the impact of idiosyncratic prime broker / creditor distress on hedge funds.

period of market stress.

The boost to precautionary liquidity holdings and the step back from UST market activity were less pronounced for funds with lower redemption risk due to longer (stricter) share restrictions including lock-ups, gates, and redemption notice periods, which can dampen the pace and volatility of redemptions in times of stress. Funds with less stringent share restrictions likely expect higher contemporaneous and anticipated future outflows and hence, anticipate greater need for ready liquidity to meet redemptions. Indeed, we find that hedge funds with higher redemption risk (shorter share restrictions) increased their precautionary liquidity holdings to a greater extent during the March 2020 market stress episode. Such funds traded out of and closed out more portfolio positions, and in particular, cut their UST exposures by more. In our sample, the share restrictions of the median hedge fund are such that it would have at least 30 days' notice before the first 1% of investor capital (net asset value) is redeemed. In a short duration market dislocation like in March 2020, long share restrictions employed by hedge funds were likely stabilizing, allowing funds to hold onto more of their convergence trades without engaging in fire sales to meet large investor outflows.[8]

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. We find that basis trading funds decreased their UST exposures and repo borrowing to a greater extent amid worsening 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 more than other hedge funds. These findings are consistent with basis traders facing greater immediate liquidity needs and funding pressures.

Overall, we find that the reduction in hedge funds' UST exposures is consistent with a flight to cash and precautionary hoarding of liquidity amid significant losses, increased uncertainty, and anticipated redemptions.

Researchers have discussed how asset managers such as mutual funds face a crisis that impacts liquidity conditions, but little is known about the liquidity management behavior

[8] There are contrasting predictions for hedge funds in the literature. 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. Our results on share restrictions are consistent with the model in Hombert and Thesmar (2014), which shows that contractual impediments to investor withdrawals can be stabilizing for a fund.

of the hedge fund sector in stressed conditions.[9,10] 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, with adverse implications for fund performance and financial market functioning. On the other hand, selling illiquid assets earlier, while potentially incurring greater current realized losses, improves the liquidity condition of the fund in the future, when the crisis might deepen.[11] The pecking order of liquidity risk management by hedge fund managers therefore has important implications for financial stability. We find evidence of the latter approach being used by the hedge funds in our sample—funds with UST exposure 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 assets. These shifts are likely primarily driven by the consideration of *future* redemptions. Although the period of extreme market stress lasted less than three weeks before the Fed's unprecedented intervention[12]—too short a period for hedge fund investors to redeem their shares en masse given the long lockups of the typical fund—we find that it resulted in a precautionary flight to liquidity, likely motivated in part by concerns about future investor redemptions.

Certain characteristics of hedge funds may increase their financial fragility. For instance, compared to other asset managers such as mutual funds or money market funds, which are subject to regulatory constraints regarding portfolio liquidity and leverage, hedge funds tend to hold more illiquid portfolios, use greater leverage, and have a more concentrated investor

[9]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.

[10]Jorion (2000) draws together press reports for a case study of the LTCM meltdown, describing the likely risk management choices at that hedge fund and how its liquidity and leverage likely evolved as the fund 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.

[11]There are contrasting findings on this trade-off in the asset management literature. Jiang, Li, and Wang (2019) 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.

[12]See the timeline of the market stress episode described in, among many others, Haddad, Moreira, and Muir (2020); He, Nagel, and Song (2020).

base.[13] Hedge funds can attempt to manage these structural risks by imposing stricter share restrictions, holding greater precautionary cash, or increasing the maturity of their financing. We show that hedge funds are quick to significantly increase their unencumbered cash holdings and portfolio liquidity when faced with severe market stress, but this precautionary flight to cash was less for funds with longer share restrictions. Longer share restrictions were particularly useful for UST trading hedge funds during the sell-off in March 2020, allowing them to avoid fire sales and hold onto more of their convergence trades, thereby bolstering both fund and market stability. Our findings illustrate a crisis episode during which the liquidity management and funding structure of hedge funds likely were more stabilizing than that of mutual funds and money market funds.[14] Our analyses yield insights into the efficacy of various methods hedge funds deploy to overcome frictions that impose limits to arbitrage activity.

We find that hedge fund UST trading exposures did not revert to their previous levels after the market turmoil subsided, even as the average UST fund saw returns jump back in April and remain positive over the subsequent months. Notably, in the post-shock period, UST funds faced greater investor outflows, but met those redemptions in a market stabilized via Federal Reserve interventions. Our findings indicate that the quick intervention of the Federal Reserve to stabilize Treasury markets likely prevented a deleveraging spiral in which hedge funds would have further sold off positions in a declining market, realizing more losses and further depleting their equity.

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

[13]See, for example, Aragon (2007); Agarwal, Daniel, and Naik (2009); Kruttli, Monin, and Watugala (2019). Aragon, Ergun, Getmansky, and Girardi (2017) find that, in general, hedge funds likely attempt to match the liquidity of their portfolios against the liquidity of their financing and investor capital. Barth and Monin (2020) find that hedge funds employ more leverage when holding assets with lower fundamental risk.

[14]See, for example, Ma, Xiao, and Zeng (2020) on mutual fund fire sales in bond markets and Li, Li, Macchiavelli, and Zhou (2020) on the potentially destabilizing effects of the contingent liquidity restrictions of prime money market funds.

2020 shock is unprecedented, 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, which was unprecedented in its impact on the Treasury market. We show that hedge funds were quick to significantly increase their unencumbered cash holdings and portfolio liquidity when faced with severe market stress, actions which would have likely reduced the liquidity and financial stability risks associated with hedge fund fire sales had market functioning not quickly returned to normal in the wake of Federal Reserve interventions and asset purchases later in March.

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 value at risk (VaR) (Shleifer and Vishny (1997); Gromb and Vayanos (2010); Hombert and Thesmar (2014)). 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.[15] 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. 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, 2020). Hedge fund arbitrage implicitly depends on broker-dealer balance sheets since it requires funding, which is typically provided by dealers and prime brokers.[16] Dealer balance sheet and risk management constraints can therefore limit the provision of

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

[16] 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 (2020) 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.

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 have 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 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 are 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. These include papers examining the investor outflows and fire sales of corporate bond mutual funds (see, for example, Falato, Goldstein, and Hortaçsu (2020); Ma, Xiao, and Zeng (2020) and money market funds (Li, Li, Macchiavelli, and Zhou, 2020). Duffie (2020); Schrimpf, Shin, and Sushko (2020) describe the stress to UST markets and present suggestions for market reform. He, Nagel, and Song (2020) 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 (2020); Kargar, Lester, Lindsay, Liu, Weill, and Zúñiga (2020); 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,[17] and follow the data cleaning and validation procedure outlined in Kruttli, Monin, and Watugala (2020). 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.[18] A summary reference of variable definitions is included as the last table in this paper in Table B.2.

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 ≤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.

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

[17] 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.

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

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.[19] 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, $UST\_GNE_{h,t}$, is on average \$2.8 billion. Importantly, this measure includes exposure to UST through derivatives and futures, as well as physical exposures. The $UST\_GNE_{h,t}$ is the sum of the long and short UST exposure, which we observe separately and are named $UST\_LNE_{h,m}$ and $UST\_SNE_{h,m}$, respectively. The net UST exposure is given by the difference of the two and named $UST\_NNE_{h,m}$. On average, the $UST\_NNE_{h,m}$ is positive with \$846.0 million, indicating that the average long exposure is larger than the short exposure.

The term $min(UST\_LNE_{h,t}, UST\_SNE_{h,t})$ captures part of the gross UST exposure that is long-short balanced, which we use as a proxy for the UST arbitrage activity of a fund. The term $abs(UST\_NNE_{h,t})$ captures the unbalanced, directional UST exposure. The two are related to the $UST\_GNE_{h,t}$ as

$$UST\_GNE_{h,t} = abs(UST\_NNE_{h,t}) + 2 \times min(UST\_LNE_{h,t}, UST\_SNE_{h,t}). \tag{1}$$

The duration of a hedge fund's long and short UST exposure are provided separately, $UST\_LNE\_Drtn_{h,t}$ and $UST\_SNE\_Drtn_{h,t}$, with an average value of 4.6 and 6.8 years, respectively. The duration of the net exposure, $UST\_NNE\_Drtn_{h,t}$, is on average 0.8 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

[19] 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 Appendix section B.3.

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, (repo) financing, liquidity and leverage management 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,

$$\Delta y_{h,t} = \beta_1 D_t + \gamma Z_{h,t-1} + \mu_h + \epsilon_{h,t}, \tag{2}$$

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 ($LogNAV$, $NetRet$, $NetFlows$, $PortIlliq$, $ShareRes$, $FinDur$, and $MgrStake$). 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 as in Q4 2019.

4.1 Changes to U.S. Treasury and repo activity

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 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.

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.

Besides changing their notional exposures, funds may have responded to the March 2020 shock by adjusting their exposure to duration risk. Table 2 Panel B analyzes changes in the duration of hedge fund portfolios. It shows that hedge funds on average increased their duration exposure following the March 2020 shock, with the net duration exposure going up by 0.4 years. This finding is intriguing, in particular since the wider Treasury market sell off is considered to have occurred predominantly at the 10-year and longer maturities (He and Krishnamurthy (2020); He, Nagel, and Song (2020)). The increase in durations is both statistically and economically significant, and largely driven by a decrease in the duration on the short side of the UST portfolio. As shown in Table 1, funds are generally duration-matched on the long and short sides, with average and median net duration exposures of 0.8 and 0.3 years, respectively. As such, an increase of over 0.4 years in duration exposure represents a significant adjustment.

Table 2 Panel C examines the directional exposure and arbitrage activity in UST portfolios. As discussed in section 3, $min(UST\_LNE_{h,t}, UST\_SNE_{h,t})$ captures the part of a hedge fund's UST portfolio that is long-short balanced. The regression in column 1 indicates that following the March 2020 shock, hedge funds reduced their UST arbitrage portfolios by around 25%. Column 2 shows that purely directional exposures also dropped, by close to 15%. The last two columns in the panel indicate that, as a fraction of a fund's total UST exposure, the long-short balanced exposure decreased, and correspondingly, the directional exposures increased.

Having found notable declines in hedge funds' UST exposures following the March 2020 shock, we analyze whether the declines were accompanied by a corresponding decrease in hedge funds' repo activity. Previously, very little was known about hedge funds' repo activity because it is largely conducted on a bilateral, uncleared basis, in what is considered the most opaque segment of the repo market. 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 makes clear the extent to which hedge fund repo borrowing is predominantly 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. In Panel A, 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. Since long UST trades are typically financed through repo, this finding indicates that the sizeable declines in hedge funds' UST exposures were not driven by trading positions that were financed in repo. In other words, the declines in UST exposures were likely driven by non-financed exposures, including derivatives exposures and those held outright without financing.

In contrast to repo borrowing, column 2 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.

Columns 3 and 4 in Panel A further show that changes to repo borrowing terms (maturities) in March 2020 are also consistent with hedge funds conserving liquidity during this period of high uncertainty: the repo borrowing maturity increased, while the lending maturity decreased, though to a lesser extent. Borrowing for longer periods and lending for shorter periods mitigates rollover risk, a risk associated with not being able to roll over financing for existing positions at favorable terms and potentially being forced to close out of arbitrage positions before they converge or being forced into fire sales. These findings suggest that hedge funds sought to avoid these risks through increasingly conservative repo financing terms during the March sell-off.

Table 3 Panel B examines the collateral terms on repo financing. Surprisingly, we do not find evidence that repo haircuts or collateral rates 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%. However, the fraction of $CashCollateral$ to $TotalCollateral$ increased by 1.5%, possibly indicating lenders' preference for cash and cash equivalents as collateral.[20]

Overall, these baseline results 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 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.

[20]Cash equivalents include bank deposits, certificates of deposits, and money market fund investments.

4.2 Performance and investor flows

Next, we examine the performance and flows of hedge funds with UST exposures. Table 4 presents results for regression specification (2) with monthly returns, quarterly returns and flows as the dependent variable. Unsurprisingly, the coefficient on $March2020$ is significantly negative for all three outcome variables. Monthly and quarterly returns show coefficients of -6.6% and -9.9%, respectively. Given that the mean quarterly return over our sample is 2.3% with a standard deviation of 8.1%, a sector-wide return of -9.9% reflects unprecedented losses for these hedge funds, which is also depicted in Figure 5. This indicates that during the COVID-19 crisis in March, these hedge funds were under a significant amount of stress, to a greater extent than at any point since Form PF reporting started in 2012. Clearly, the current crisis unfolded more precipitously than the global financial crisis in 2007-2009, which was characterized by relatively longer periods of a buildup of uncertainty from 2007 onward.

It is notable that the flows estimate of -1.8% for the quarter ending in March 2020, though negative, reflects relatively mild outflows. For reference, the mean quarterly investor flow during the 2012-2020 sample period is -0.6% with a standard deviation of 13.9%. In contrast, other asset management firms like corporate bond mutual funds and prime money market funds experienced much greater outflows during this period (Ma, Xiao, and Zeng, 2020; Li, Li, Macchiavelli, and Zhou, 2020). This difference in investor redemptions likely stems from structural features unique to hedge funds, specifically, share restrictions, which include lock-ups, restrictions on redemption frequency and redemption notice periods. The redemption restrictions and notice periods are likely to be particularly helpful for hedge funds when managing liquidity during short-lived systematic stress episodes. The March 2020 extreme market stress period lasted less than three weeks until the Fed's intervention, too brief a period for hedge fund investors to redeem their shares at a significant scale during the stress period itself, given the share restrictions of the typical fund (see share restrictions in Table 1, Panel A). By the end of March 2020, hedge funds may have received notices of significant *future* redemptions. We consider this scenario in our examination of changes to cash and liquidity in the next section and further analyze the implications of restrictions to investor redemptions in section 6.

4.3 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 5 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. The first four columns of Panel A show 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 B.2). $FreeCashEq$ 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%. Column 5 and 6 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%. Panel B shows that portfolio illiquidity dropped by over 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 stand in contrast to the behavior of mutual funds as described by Ma, Xiao, and Zeng (2020), who posit that in the March 2020 shock, corporate bond mutual funds sold *more* liquid bonds to meet investor redemptions. Interestingly, 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 studied LTCM and other subsequent hedge fund meltdowns when planning how to manage liquidity during a stress episode.

Finally, we analyze the changes in gross hedge fund leverage, measured as the ratio of gross balance sheet assets (GAV) to fund capital or net assets (NAV). Table 5 Panel C shows 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.

4.4 Post COVID-19 shock period

The March 2020 shock to the UST market was unprecedented in scale, but due to the speed and extent of Federal Reserve interventions, relatively short-lived. While UST prices and arbitrage spreads largely recovered by April, it is unclear how quickly hedge fund activity in this market rebounded. To examine the post-shock period, we extend our sample to September 2020 and run regressions similar to equation (2), with additional time indicators capturing the months (or, alternatively, quarters) following March 2020. Table A.1 in the Appendix presents the results of these regressions.

Importantly, Table A.1 Panel A shows that investor *outflows* from UST hedge funds were significantly larger in 2020Q2 and 2020Q3 than during the shock period itself. This is in spite of the fact that returns broadly recovered from the substantial decline in March 2020 (also illustrated in the returns time series in Figure 5). The delayed outflows are likely due to the long share restrictions that hedge funds impose on their investors, which we analyze in greater detail in Section 6. Hedge funds met these larger investor redemptions in the post-shock period while UST markets were stabilized via government intervention.

Broadly, the results in Table A.1 Panels B and C show that neither hedge fund UST exposures nor repo exposures reverted back to pre-crisis (pre-March 2020) levels over the two quarters following March 2020. Both long and short UST exposures generally continued to decrease until September 2020. While being relatively unchanged in March, repo borrowing fell significantly in April and May before stabilizing in June 2020. Hedge funds lengthened their repo borrowing maturities in the post-crisis period, and faced significantly higher collateral ratios.

Taken together, these results indicate that Federal Reserve interventions helped to stabilize UST markets even as hedge funds continued to scale down their UST market activities.

5 Dealer regulatory constraints and bilateral repo lending

We proceed next to analyze in greater detail the factors that contributed to the Treasury sell-off in March. First, 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.[21] The panel regressions take the form,

$$\begin{aligned}
\Delta \log HF_Crdtr_Credit_{h,p,t} =& \gamma_1 DealerConstraint_{p,t} + \gamma_2 DealerConstraint_{p,t} \times D_t \\
& + \phi Z_{h,p,t-1} + \mu_h + \theta_t + \psi_p + \epsilon_{h,p,t}, \qquad (3) \\
\Delta \log HF_Crdtr_Credit_{h,p,t} =& \gamma_1 DealerConstraint_{p,t} + \gamma_2 DealerConstraint_{p,t} \times D_t \\
& + \nu_{h,t} + \psi_p + \epsilon_{h,p,t}, \qquad (4) \\
\Delta \log HF_Crdtr_Credit_{h,p,t} =& \gamma_1 DealerConstraint_{p,t} + \gamma_2 DealerConstraint_{p,t} \times D_t \\
& + \nu_{h,t} + \xi_{h,p} + \epsilon_{h,p,t}, \qquad (5)
\end{aligned}$$

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. Eqn. 3 includes hedge fund (μ_h), creditor (ψ_p), and time (θ_t) fixed effects. Eqn. 4 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. Eqn. 5 includes both fund-time and fund-creditor ($\xi_{h,p}$) fixed effects, with the

[21] This identification strategy is similar to Khwaja and Mian (2008), Kruttli, Monin, and Watugala (2020), and many others that use borrower-creditor data to isolate credit supply effects.

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 in repo, we limit the sample for this anlysis to hedge funds with gross UST exposure of at least $1 million that primarily borrow via repo (50% or more of their borrowing is in 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 7. We use a dealer's status as a global systemically important financial institution (G-SIB) as the $DealerConstraint_{p,t}$ measure.[22] 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 Table 6 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 appendix, we present additional results. Table A.4 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.

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,[23] 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., He, Nagel, and Song (2020); Schrimpf, Shin, and Sushko (2020)).

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

[22]See Table B.1 for the list of primary dealer and G-SIB institutions, including the timeline of G-SIB classifications.

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

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).[24] 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 Fed post-GFC—were not exposed to significant concerns about solvency and run risk, unlike during the GFC.[25] This may have mitigated precautionary liquidity hoarding behavior by bank-dealers.

6 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,

$$\begin{aligned}\Delta y_{h,t} &= \beta_0 + \beta_1 D_t + \beta_2 ShareRes_{h,t-1} + \beta_3 D_t \times ShareRes_{h,t-1} \\ &\quad + \gamma Z_{h,t-1} + \mu_h + \epsilon_{h,t},\end{aligned} \tag{6}$$

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 (2). The regression is run with fund fixed effects (μ_h) or both fund and time fixed effects (not shown). β_3 is the coefficient of interest and captures the differential effect between funds with long and short share restrictions. Table 7 presents results for the regressions with fund fixed effects; results with both fund and time fixed effects included are qualitatively similar.

Table 7 Panel A examines cash holdings, portfolio size and liquidity. The estimates of β_3, the coefficients on $March2020 \times ShareRes$, show that hedge funds with longer share restrictions boosted their cash holdings and portfolio liquidity by less, and decreased their portfolio size and number of open positions by less, compared to funds with shorter share restrictions. This finding is consistent with hedge funds with *higher* redemption risk (shorter share restrictions) increasing their precautionary liquidity holdings to a greater extent during the March 2020 market stress episode. Such funds appear to have traded out of and closed out more portfolio positions. Funds with less stringent share restrictions likely have higher

[24] As shown in Table B.1, the set of primary dealers' parent companies overlaps significantly with the set of G-SIB institutions.

[25] 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.

contemporaneous and anticipated future outflows and hence, greater need for ready liquidity to meet redemptions.

Consistent with the finding that hedge funds with looser share restrictions reduced their portfolio positions to a greater extent, Table 7 Panel B shows that redemption risk also impacted UST portfolios. Hedge funds with shorter share restrictions cut their UST exposures by more (Column 1), reducing both their directional exposures (Column 2) and arbitrage activity (Column 3) to a greater degree than funds with longer share restrictions.

Taken together, the results so far illustrate that hedge funds were quick to significantly increase their unencumbered cash holdings and portfolio liquidity when faced with severe market stress. Hedge funds disproportionately sold off relatively more illiquid positions first, which likely preserved future solvency. The tendency to retain more liquid positions in their portfolios may have moderated the selling of relatively liquid Treasury securities by hedge funds during the COVID-19 shock. Importantly, longer share restrictions were particularly useful for hedge funds to avoid fire sales and hold onto more of their convergence trades. As such, hedge fund share restrictions likely prevented more significant asset fire sales in March 2020 and prevented further Treasury market and hedge fund sector destabilization.

Our analysis yields insights into the efficacy of one of the methods hedge funds deploy to overcome frictions that impose limits to arbitrage activity (Shleifer and Vishny, 1997; Gromb and Vayanos, 2010). Our results are consistent with Hombert and Thesmar (2014), who present a model where contractual impediments to investor withdrawals can be stabilizing for a fund. In contrast, Ben-David, Franzoni, and Moussawi (2012)—in an examination of 13-F filings of long equity holdings during the GFC—find that equity hedge funds were forced to delever to meet redemptions because hedge fund investors subject to share restrictions react quickly to adverse performance. 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 GFC spanned multiple year. We analyze UST 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. Our use of regulatory covering detailed data on the holdings and characteristics of a substantial portion of the hedge fund sector allows for a comprehensive analysis.

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. A concept early considered in classical theories of bank runs (Diamond and Dybvig, 1983), in the context of investment funds, strategic complementarities refers to the idea that when an investor internalizes the likelihood that other investors will also run on a fund, the probability that the investor will redeem her investment in the fund is amplified beyond the level attributable purely to fundamentals, leading to a run on the fund. This mechanism is especially relevant for funds with illiquid investments and during crisis periods because investors who are late to redeem are more likely to be left with fund investments severely depressed in value due to fire sales. 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, 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.

During the GFC, in the days following the collapse of Lehman, money market funds were subject to severe runs surprising many who considered such funds relatively "safe" venues to park liquidity (Schmidt, Timmermann, and Wermers, 2016). Part of the post-GFC reforms aimed at bolstering the stability of money markets specifically allowed MMFs to impose contingent restrictions on investor redemptions. Li, Li, Macchiavelli, and Zhou (2020) explicitly consider the role of these liquidity restrictions in how MMFs fared during the March 2020 turmoil and find evidence consistent with the restrictions exacerbating run-like behavior among MMF investors, adding to fund and market instability. In effect, following post-GFC reforms, when a prime MMF's share of liquid assets that can be converted to cash within a week—weekly liquidity assets (WLA)—falls below a pre-specified threshold of 30%, the MMF can impose redemption gates and liquidity fees. However, in tranquil times outside of such liquidity crunches or even during a crisis period before an MMF reaches the pre-specified WLA threshold, MMFs offer cash-like shares that are redeemable on demand. As discussed previously, this is in stark contrast to the typical redemption periods faced by hedge fund investors. The share restrictions of the hedge funds in our sample are such that the number of days it takes for investors to withdraw *even 1%* of a hedge fund's net asset value has a median of 30 days, with the 25^{th} and 75^{th} percentile at 30 and 180 days, respectively. In other words, the median hedge fund would have at least 30 days notice before the first 1% of investor capital (net asset value) is redeemed.

Intuitively, during the March turmoil, while contingent (ex post) redemption restrictions were likely destabilizing for MMFs, our results show that existing (ex ante) redemption restrictions were stabilizing for hedge funds. For investors valuing the cash-like liquidity typically provided by an MMF, knowledge of the WLA threshold for contingent redemption restrictions and strategic complementarities likely augmented incentives to run on MMFs. For the typical hedge fund investor, in the intense, but short-lived March 2020 turmoil, reacting immediately and withdrawing her investment was not an option. As such, the redemption restrictions weakened strategic complementarities and shutdown the channel of self-fulfilling run-like behavior during the peak of market instability. Such ex ante share restrictions also dampen the liquidity mismatch between hedge fund assets and liabilities and reduce the liquidity transformation performed by hedge funds.[26]

7 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.[27,28] 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, $min(UST\_LNE_{h,t}, UST\_SNE_{h,t})$, and *net* repo exposure, $RepoBorrowing - RepoLending$, as funds that predominantly engage in the basis

[26] 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, consistent with our findings, conclude that the extent of liquidity transformation a fund of hedge funds provides is positively associated with greater exposure to investor runs.

[27] See Figure 8 and Appendix section B.1 for an overview of both types of fixed income arbitrage strategies.

[28] 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.

trade.[29]

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 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 (have a larger $LeverageRatio = GAV/NAV$).

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

$$\begin{aligned}\Delta y_{h,t} = \beta_0 + \beta_1 D_t + \beta_2 BasisTrader_h + \beta_3 D_t \times BasisTrader_h \\ + \gamma Z_{h,t-1} + \mu_h + \epsilon_{h,t}, \end{aligned} \tag{7}$$

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 (2). The regression is run with fund fixed effects (μ_h) or both fund and time fixed effects (not shown). β_3 is the coefficient of interest that captures the differential effect between basis traders and other UST traders. Table 8 presents results for the regressions with fund fixed effects; results with both fund and time fixed effects included are qualitatively similar.

Table 8 Panels A and B examine changes to UST exposures. The estimates of β_3, the coefficients on $March2020 \times BasisTrader$, show that basis trading hedge funds reduced their UST long notional exposure significantly more than other hedge funds, and predominantly reduced their directional exposure. As a result, they held more balanced portfolios in terms of long-short UST notional exposure at the end of March 2020.

Table 8 Panel C 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. Importantly, we find that basis traders decreased their repo borrowing by about 17% in March, while other UST traders saw no significant change in repo borrowing levels. The terms of borrowing also appear to have worsened for basis traders. The maturity of repo borrowing declined by 9.12 days for basis traders compared to other UST traders, a substantial decline considering the median repo borrowing term is 8.66 days and the mean is 25.63 days. Other UST traders lengthened their repo borrowing terms in March 2020 by 4.46 days. Finally, we find that basis traders

[29] Appendix section B.2 provides a detailed explanation of the methodology.

posted more collateral to their repo counterparties with their ratio of total repo collateral to borrowing increasing by around 3.82%, compared to a *decline* in the same ratio for the average UST hedge fund by 1.46%.

In Table 8 Panel D, 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, Panel E shows that basis trader hedge funds delevered more in March 2020. The β_3 estimate of -0.79 is substantial given that the average $LeverageRatio$ is 2.48 and the median is 1.34.

Overall, these findings show that hedge funds engaged in the UST cash-futures basis trade and faced greater margin pressure 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 kept the terms for other hedge fund counterparties relatively unchanged. 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.

8 Conclusion

In this paper, we examine hedge fund activity in U.S. Treasury markets during the March 2020 COVID-19 shock. During this period, the average hedge fund with UST holdings experienced a *monthly* return of around -7%, and 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 in this paper do not indicate that hedge funds provided liquidity during this market dislocation. However, our findings are inconsistent with massive hedge fund deleveraging driving the Treasury sell-off. Hedge fund leverage ratios remained largely unchanged. Borrowing levels and collateral rates on repurchase agreements—the primary source of financing for hedge fund UST holdings and sovereign bond basis trades—remained largely unchanged, indicating that funding constraints were not the primary reason for the decline in hedge funds' Treasury exposures.

We specifically 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 repo financing to hedge funds during the crisis—over 11-13% higher funding compared to other dealers. Our findings are inconsistent with the hypothesis that regulatory constraints at large broker dealers limited hedge fund access to funding and their UST arbitrage.

We find evidence that the cutback in hedge fund UST exposures was driven by liquidity management considerations and investor redemption risks. 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. This boost to the precautionary liquidity holdings and the step back from UST market activity were less pronounced for funds with stricter share restrictions and lower redemption risk. Longer share restrictions allowed hedge funds to avoid fire sales and hold onto more of their convergence trades, 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, we find that 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 unprecedented, 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/reverse repo funding markets, this paper sheds light on how the characteristics and funding structures of hedge funds impact the role it plays in vital financial markets. Our findings yield insights into the efficacy of various methods hedge funds deploy to overcome frictions that impose limits to arbitrage activity.

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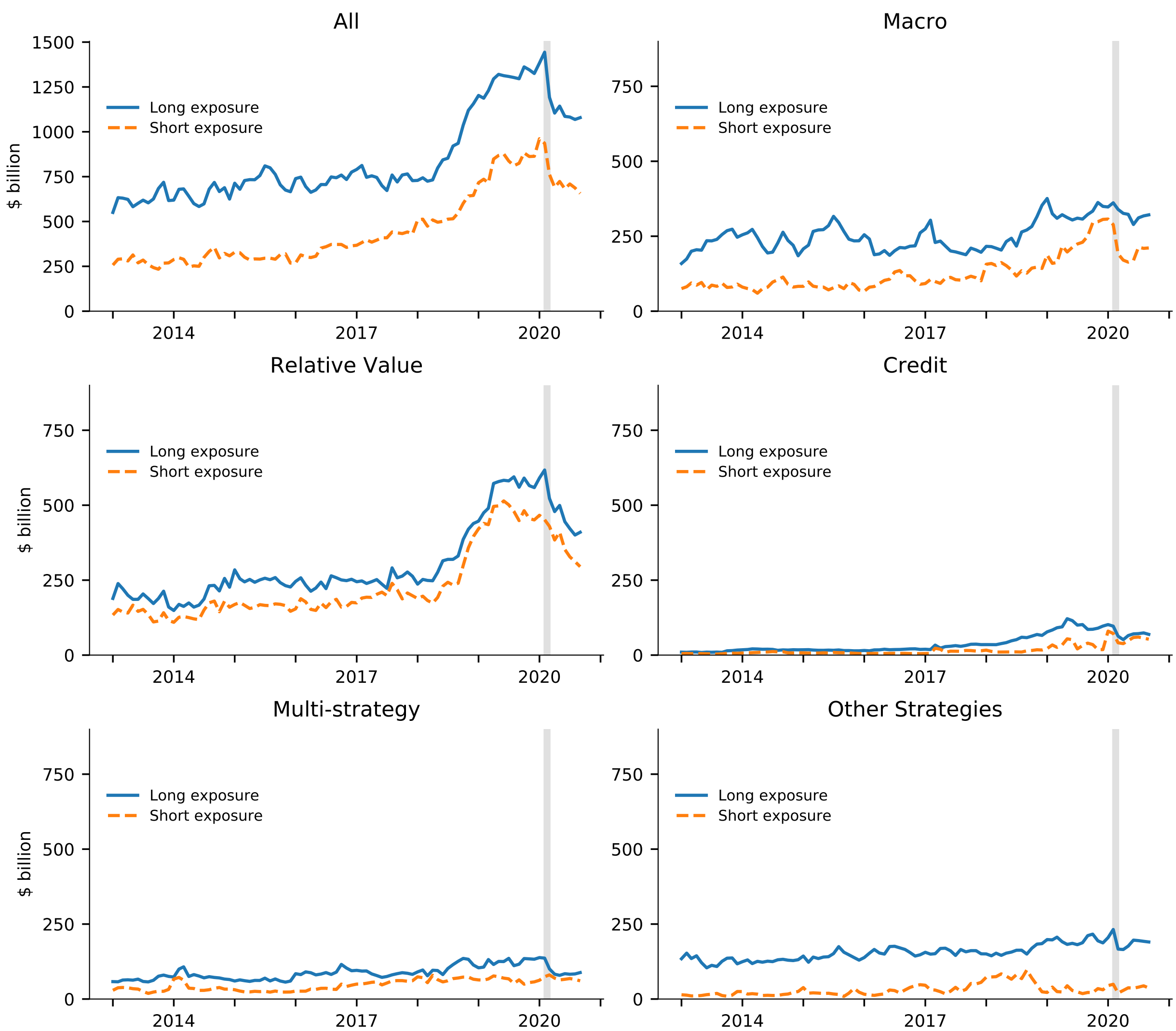


Figure 1: Hedge Fund U.S. Treasury Exposures

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.

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.

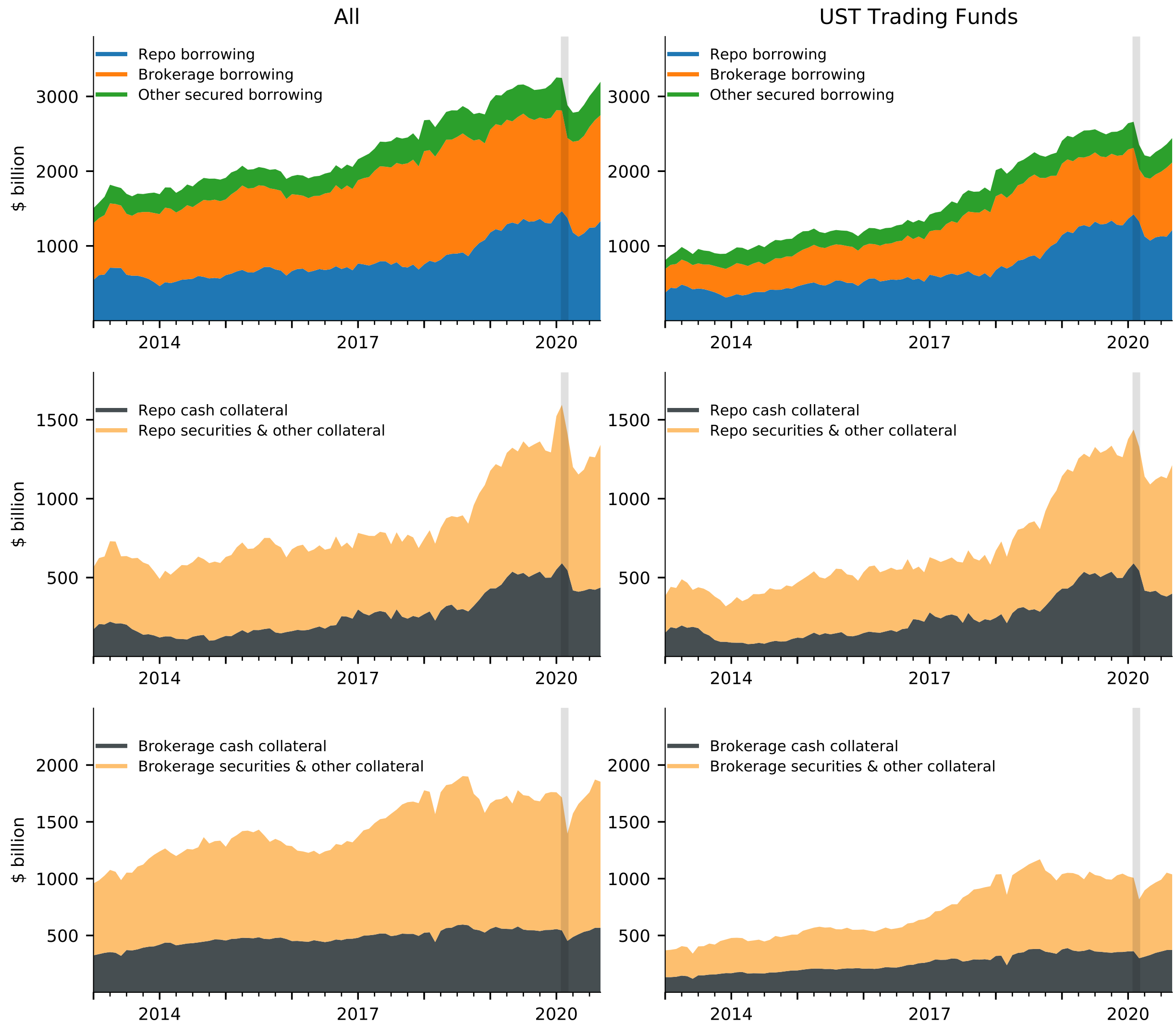


Figure 3: Hedge Fund Borrowing and Collateral

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 Q4 2019 (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.

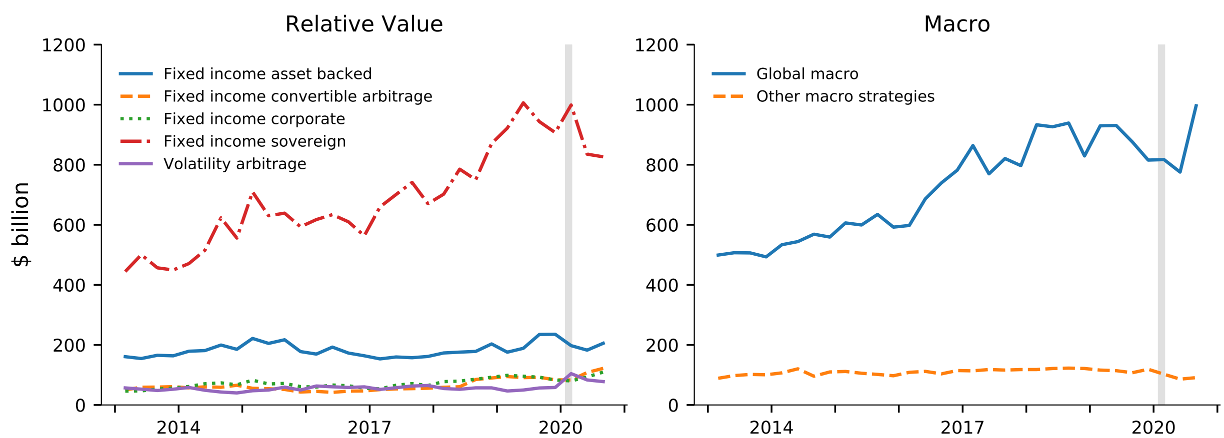


Figure 4: Gross Assets of Relative Value and Macro Strategies

This figure shows 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.

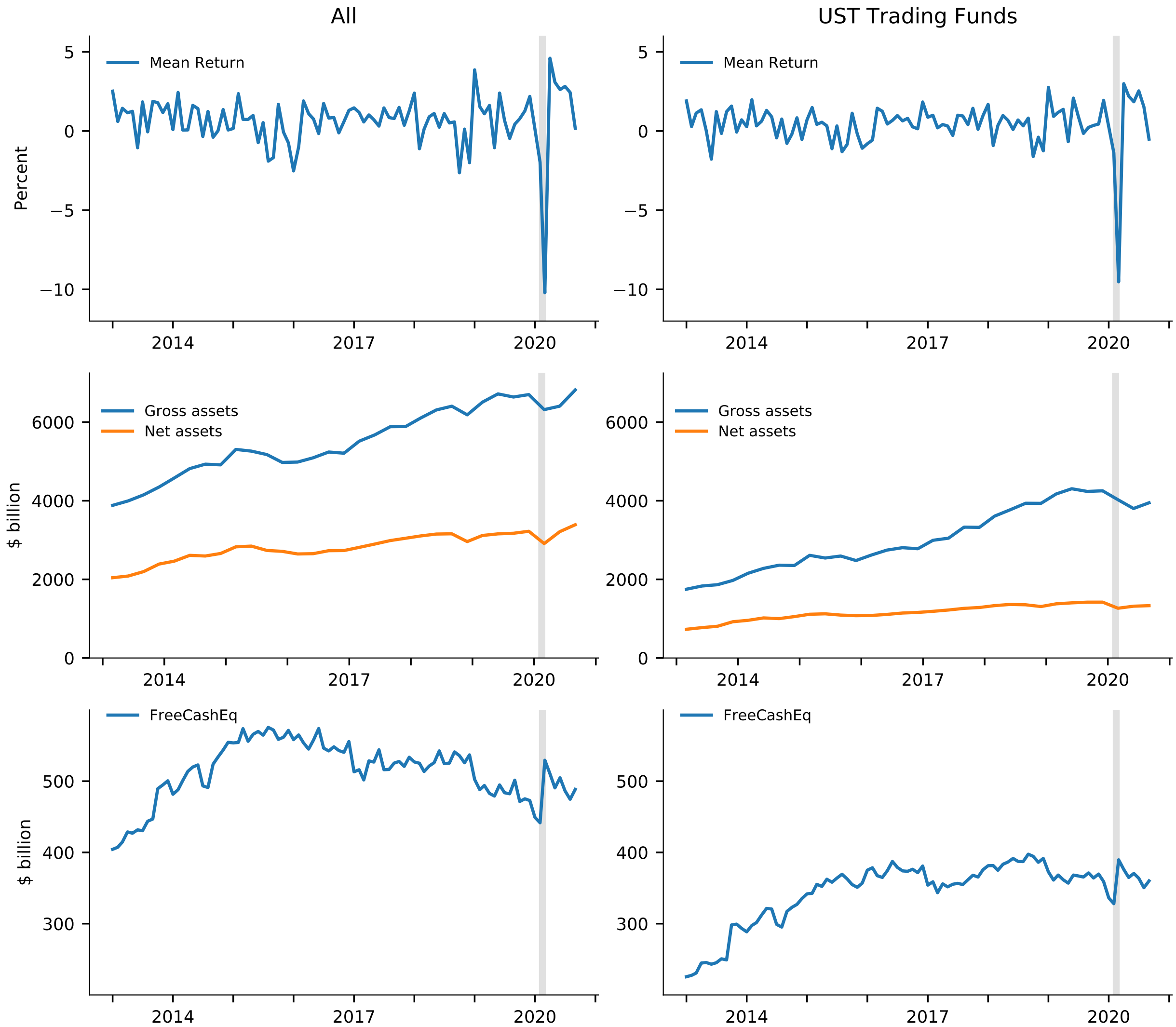


Figure 5: Hedge Fund Returns, Assets, and Unencumbered Cash and Cash Equivalents

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 $1 million on average during Q4 2019 (right). The subfigures on the first row show the monthly mean returns, net-of-fees. The second row shows the aggregate value of gross and net assets under management. The third row shows aggregate holdings of unencumbered cash and cash equivalents ($FreeCashEq$).

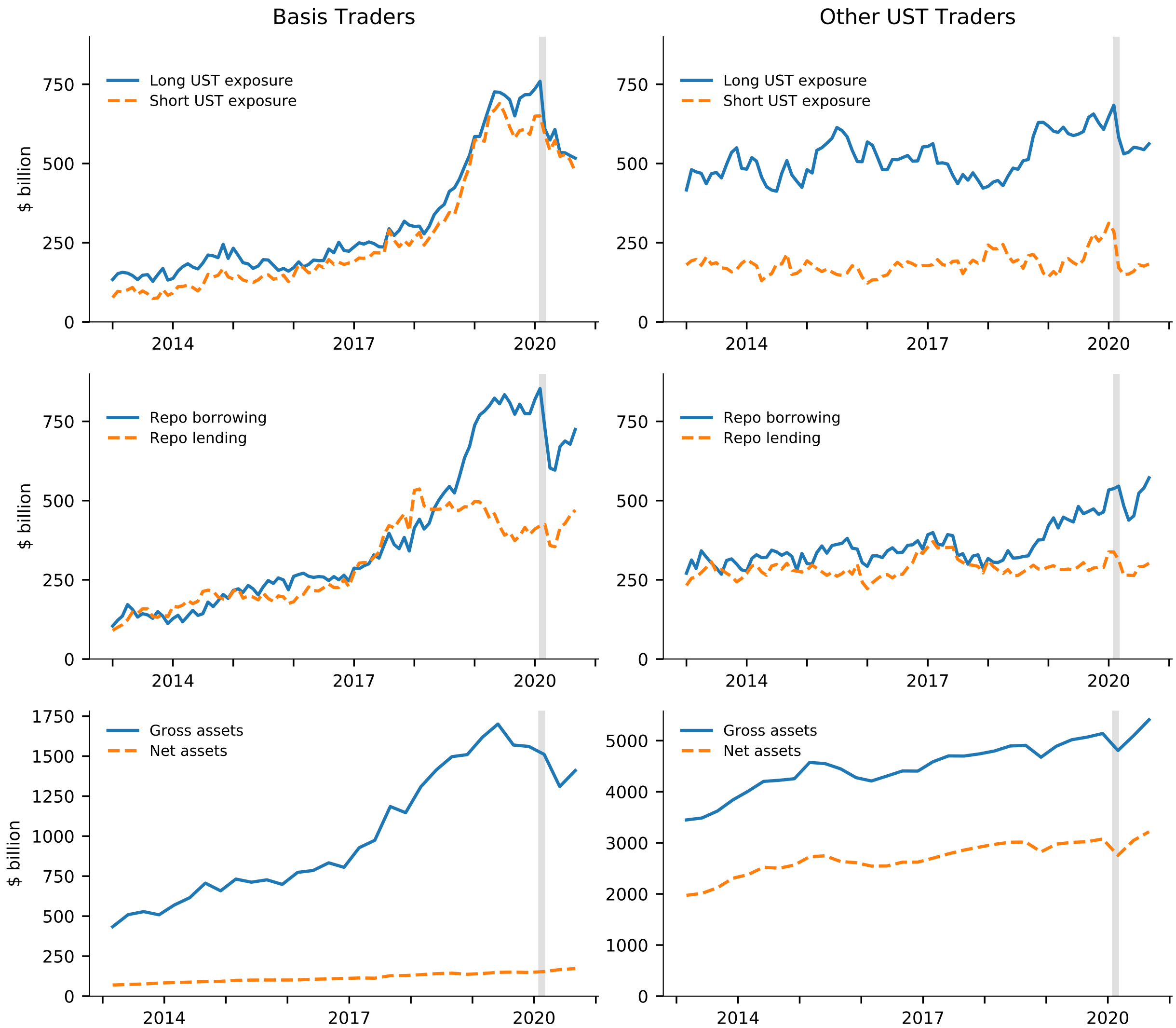


Figure 6: Predominantly UST Cash-Futures Basis Trading versus Other UST Trading Hedge Funds
This figure presents the times series of UST exposure, repo exposures, and leverage from January 2013 to September 2020 for hedge funds predominantly engaged in the UST cash-futures basis trade (left) and other UST trading hedge funds (right). Both sets of funds are hedge funds with gross UST exposure of at least $1 million on average during Q4 2019. 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.

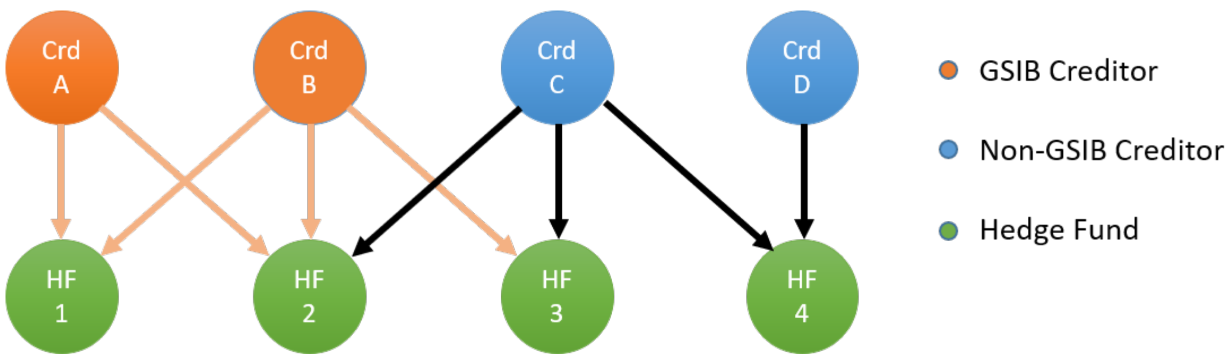
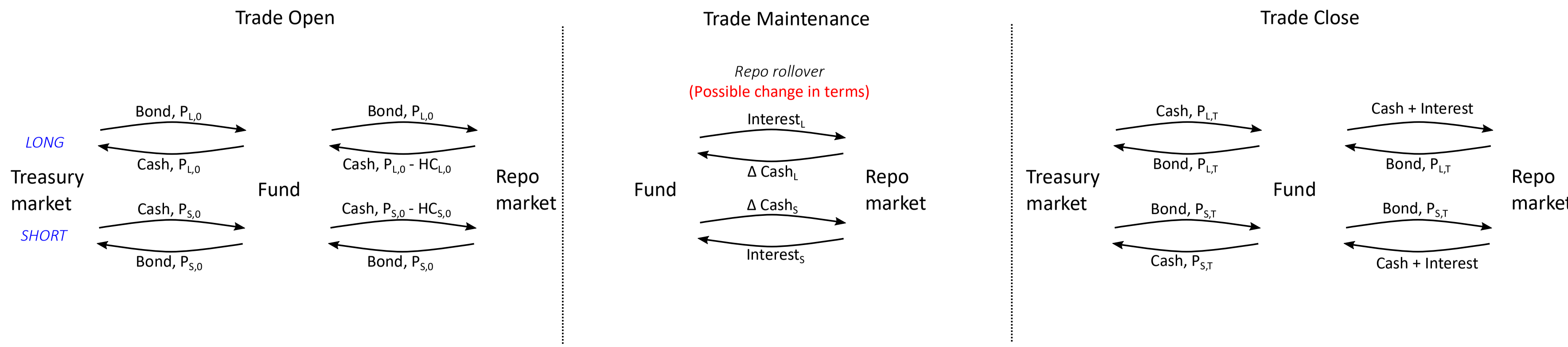
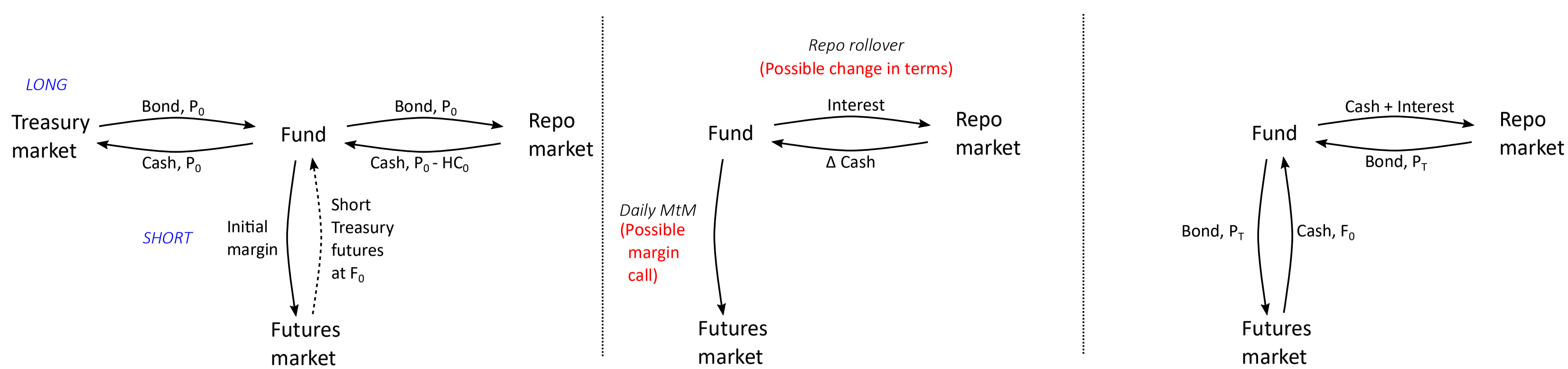


Figure 7: Empirical strategy for analyzing hedge fund-creditor bilateral data

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 8: 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 Q4 2019. All variables are described in Table B.2. 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
$NetRetQ_{h,t}$ (%)	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

Panel B: U.S. Treasury exposures

	N	Mean	Median	Stdev	25th	75th	10th	90th
$UST\_GNE_{h,t}$ (m US$)	33,027	2,790.343	348.228	8,451.260	76.688	1,553.683	18.180	5,736.337
$UST\_LNE_{h,t}$ (m US$)	33,027	1,858.255	240.291	5,192.603	34.999	1,131.989	0.484	4,337.850
$UST\_SNE_{h,t}$ (m US$)	33,027	896.717	17.140	3,351.960	0.000	214.722	0.000	1,554.543
$UST\_NNE_{h,t}$ (m US$)	33,027	846.016	124.704	2,262.571	-2.692	737.179	-134.569	2,616.289
$abs(UST\_NNE)$ (m US$)	33,027	1,096.909	220.822	2,386.734	48.658	906.084	12.505	2,939.572
$min(LNE_{h,t}, SNE_{h,t})$ (m US$)	33,027	779.867	1.983	3,165.206	0.000	126.536	0.000	1,100.635
$\frac{UST\_GNE_{h,t}}{NAV_{h,t}}$	32,612	99.720	26.663	248.848	7.294	78.759	1.802	189.425
$\frac{abs(UST\_NNE)}{UST\_GNE_{h,t}}$	33,027	75.219	97.864	32.881	50.827	100.000	17.330	100.000
$\frac{UST\_NNE_{h,t}}{UST\_GNE_{h,t}}$	33,027	40.873	77.628	71.193	-3.902	100.000	-96.158	100.000
$\frac{min(LNE_{h,t},SNE_{h,t})}{UST\_GNE_{h,t}}$	33,027	24.781	2.136	32.881	0.000	49.173	0.000	82.670
$UST\_LNE\_Drtn_{h,t}$ (years)	29,259	4.578	3.515	4.818	0.288	7.331	0.120	10.720
$UST\_SNE\_Drtn_{h,t}$ (years)	20,221	6.810	6.210	4.745	3.523	9.100	0.920	13.122
$UST\_NNE\_Drtn_{h,t}$ (years)	32,025	0.834	0.299	10.365	-1.616	5.436	-8.530	10.039

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
$IsCrdtrPB_{h,p,t}$	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 (2). 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 Q4 2019. 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 notional exposure

	$\Delta LogUST\_GNE$	$\Delta LogUST\_LNE$	$\Delta LogUST\_SNE$	$\Delta \frac{UST\_GNE}{NAV}$	$\Delta \frac{UST\_LNE}{NAV}$	$\Delta \frac{UST\_SNE}{NAV}$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	-19.530***	-19.010***	-23.882***	-15.270***	-8.481***	-7.689***
	-15.378	-11.342	-7.773	-11.585	-8.843	-10.579
$LogNAV_{h,t-1}$	-1.922*	-0.329	-2.404	0.899	0.652	0.158
	-1.828	-0.261	-1.142	0.534	0.540	0.203
$NetRet_{h,t-1}$	0.871	1.847**	-0.232	-0.445	0.059	-0.506
	1.124	2.410	-0.118	-0.831	0.167	-1.285
$NetFlows_{h,t-1}$	0.983***	0.875**	1.860**	0.181	-0.206	0.333*
	2.773	2.458	2.164	0.537	-0.876	1.975
$PortIlliq_{h,t-1}$	1.425	-0.707	1.930	0.526	0.233	0.398
	0.950	-0.337	0.799	0.383	0.316	0.487
$ShareRes_{h,t-1}$	3.035*	3.648*	-1.884	1.796	1.237*	0.562
	1.747	1.960	-0.527	1.306	1.852	0.774
$FinDur_{h,t-1}$	-0.542	-0.667	0.742	-0.356	-0.128	-0.173
	-0.806	-0.785	0.366	-0.987	-0.432	-0.585
$MgrStake_{h,t-1}$	0.398	0.196	0.197	1.197	0.392	0.913
	0.777	0.179	0.248	0.875	0.376	1.641
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	18,849	16,874	12,978	18,801	18,801	18,801
R^2	0.015	0.015	0.017	0.016	0.016	0.012

Panel B: U.S. Treasury duration

	ΔUST_LNE_Drtn	ΔUST_SNE_Drtn	ΔUST_NNE_Drtn
	(1)	(2)	(3)
$March2020_t$	0.113***	-0.418***	0.435*
	3.393	-5.482	1.864
Other Controls	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes
Observations	16,512	12,633	18,328
R^2	0.007	0.008	0.004

Panel C: U.S. Treasury fund-level long-short exposure

	$\Delta log(min(LNE, SNE))$	$\Delta log(abs(LNE - SNE))$	$\Delta \frac{2 \times min(LNE,SNE)}{GNE}$	$\Delta \frac{abs(LNE-SNE))}{GNE}$
	(1)	(2)	(3)	(4)
$March2020_t$	-25.331***	-15.533***	-2.093***	2.093***
	-8.462	-8.230	-6.160	6.160
Other Controls	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes
Observations	11,053	18,834	18,849	18,849
R^2	0.013	0.007	0.005	0.005

Table 3: Hedge fund bilateral repo activity

This table presents results of the panel regression model given in equation (2). 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 Q4 2019. 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: Repo exposure and maturity

	$\Delta LogRepoBorrowing$	$\Delta LogRepoLending$	$\Delta RepoBrrwTerm$	$\Delta RepoLendTerm$
	(1)	(2)	(3)	(4)
$March2020_t$	-1.767	-25.015***	2.997***	-0.993**
	-0.864	-9.544	6.190	-2.293
$LogNAV_{h,t-1}$	-0.164	1.086	0.421	0.169
	-0.069	0.481	1.555	0.654
$NetRet_{h,t-1}$	1.512	0.682	-0.156	-0.292
	1.106	0.522	-1.113	-0.958
$NetFlows_{h,t-1}$	2.483***	0.241	0.123	0.080
	3.555	0.284	0.664	0.512
$PortIlliq_{h,t-1}$	1.322	-1.622	-0.173	0.217
	0.612	-0.484	-0.210	0.411
$ShareRes_{h,t-1}$	-0.347	1.494	0.472	0.807**
	-0.208	0.461	1.307	2.563
$FinDur_{h,t-1}$	-0.175	2.678*	-0.094	-0.033
	-0.134	1.711	-0.191	-0.209
$MgrStake_{h,t-1}$	-0.014	0.564	-0.323	-0.095
	-0.019	0.369	-1.111	-0.627
Fund FE	Yes	Yes	Yes	Yes
Observations	9,387	9,083	9,387	9,083
R^2	0.014	0.014	0.022	0.021

Panel B: Repo collateral

	$\Delta LogRepoTotalCollateral$	$\Delta \frac{RepoTotalCollateral}{RepoBorrowing}$	$\Delta \frac{RepoCashCollateral}{RepoBorrowing}$	$\Delta \frac{RepoCashCollateral}{RepoTotalCollateral}$
	(1)	(2)	(3)	(4)
$March2020_t$	0.565	-0.668**	1.524***	1.326***
	0.280	-2.329	4.189	4.544
Other Controls	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes
Observations	9,810	9,810	9,478	9,478
R^2	0.014	0.012	0.019	0.020

Table 4: Hedge fund returns and investor flows

This table presents results of the panel regression model given in equation (2). The data are from January 2013 to March 2020 and include all hedge funds with gross UST exposure of at least $1 million on average during Q4 2019. The dependent variables are shown in the first row. Regression (1) is on monthly net returns ($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)
$March2020_t$	-6.624***	-9.895***	-1.830***
	-37.499	-23.683	-6.040
$LogNAV_{h,t-1}$	-0.408***	-1.172**	-7.648***
	-2.760	-2.292	-7.232
$NetRet_{h,t-1}$	0.026	1.332*	-0.994**
	0.197	1.792	-2.355
$NetFlows_{h,t-1}$	-0.024	-0.588***	3.077***
	-0.650	-3.279	6.579
$PortIlliq_{h,t-1}$	-0.149	-0.120	-1.966***
	-1.377	-0.227	-3.296
$ShareRes_{h,t-1}$	0.055	0.021	1.199
	0.763	0.147	1.389
$FinDur_{h,t-1}$	0.043	0.398	0.516*
	0.875	1.316	1.806
$MgrStake_{h,t-1}$	-0.076*	-0.170	0.705
	-1.714	-1.309	1.448
Fund FE	Yes	Yes	Yes
Observations	21,659	7,630	7,618
R^2	0.193	0.549	0.344

Table 5: Hedge fund liquidity and leverage

This table presents results of the panel regression model given in equation (2). 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 Q4 2019. The dependent variables are shown in the first row. Regressions in Panel A are on monthly data, while those in Panels B and C are on quarterly data. 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 portfolio size

	$\Delta LogFreeCashEq$	$\Delta \frac{FreeCashEq}{NAV}$	$\Delta LogCash$	$\Delta \frac{Cash}{NAV}$	$\Delta LogPortfolioGNE$	$\Delta LogOpenPositions$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	25.723***	6.289***	23.003***	8.824***	-21.769***	-4.643***
	18.937	37.199	20.388	28.202	-43.878	-8.428
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,236	21,377	18,765	18,973	21,694	21,676
R^2	0.012	0.025	0.015	0.021	0.070	0.026

Panel B: Portfolio liquidity

		Δ share of assets that can be liquidated in:		
	$\Delta LogPortIlliq$	≤ 7 days	≤ 30 days	≥ 31 days
	(1)	(2)	(3)	(4)
$March2020_t$	-10.734***	1.005***	0.070	-0.070
	-8.741	5.672	0.570	-0.570
Other Controls	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes
Observations	7,625	7,625	7,625	7,625
R^2	0.084	0.067	0.091	0.091

Panel C: Fund assets, equity, and leverage

	$\Delta LogNAV$	$\Delta LogGAV$	$\Delta LeverageRatio$
	(1)	(2)	(3)
$March2020_t$	-14.139***	-13.545***	-0.037
	-24.985	-18.623	-1.472
Other Controls	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes
Observations	7,625	7,625	7,625
R^2	0.246	0.149	0.038

Table 6: The regulatory constraints of creditors and hedge fund borrowing

This table presents results of the panel regression model given in equations (3), (4), and (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 Q4 2019. 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 $March2020_t$, 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 $p < 0.01$.

	(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 7: Redemption risk and UST hedge fund activity

This table presents results of the panel regression model given in equation (6). 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 Q4 2019. 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 position

	$\Delta LogFreeCashEq$	$\Delta \frac{FreeCashEq}{NAV}$	$\Delta LogPortfolioGNE$	$\Delta LogOpenPositions$	$\Delta LogPortIlliq$
	(1)	(2)	(3)	(4)	(5)
$March2020_t$	27.019***	7.069***	-23.098***	-5.166***	-12.907***
	20.211	40.083	-43.441	-8.539	-10.008
$ShareRes_{h,t-1}$	1.500	0.248	0.520	0.239	1.285
	0.767	1.200	1.278	0.996	0.531
$March2020_t \times ShareRes_{h,t-1}$	-6.571***	-3.728***	6.197***	2.416***	8.830***
	-5.875	-23.922	16.183	6.612	7.711
Other Controls	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes
Observations	20,236	21,377	21,694	21,676	7,625
R^2	0.012	0.030	0.073	0.027	0.087

Panel B: U.S. Treasury exposure

	$\Delta LogUST\_GNE$	$\Delta log(min(LNE, SNE))$	$\Delta \frac{min(LNE,SNE)}{GNE}$
	(1)	(4)	(5)
$March2020_t$	-20.977***	-27.312***	-2.331***
	-15.687	-8.757	-6.682
$ShareRes_{h,t-1}$	2.907*	-2.402	-0.274
	1.672	-0.614	-0.586
$March2020_t \times ShareRes_{h,t-1}$	8.140***	15.624***	1.340***
	6.655	4.915	3.224
Other Controls	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes
Observations	18,849	11,053	18,849
R^2	0.016	0.014	0.005

Table 8: Basis traders versus other UST traders

This table presents results of the panel regression model given in equation (7). 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 Q4 2019. The dependent variables are shown in the first row. Regressions in Panels A, B, C, and columns 1-6 of Panel D are on monthly data, while those in column 7 of Panel D and Panel E are on quarterly data. 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

	$\Delta LogUST\_GNE$	$\Delta LogUST\_LNE$	$\Delta LogUST\_SNE$	$\Delta \frac{UST\_GNE}{NAV}$	$\Delta \frac{UST\_LNE}{NAV}$	$\Delta \frac{UST\_SNE}{NAV}$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	-18.910***	-17.330***	-24.701***	-10.432***	-3.798***	-6.843***
	-13.575	-9.400	-6.987	-10.619	-5.150	-10.493
$March2020_t \times BasisTrader_h$	-6.278***	-14.376***	5.752	-49.015***	-47.451***	-8.575*
	-2.695	-5.690	1.456	-6.006	-10.223	-1.924
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	0.015	0.015	0.017	0.018	0.020	0.013

Panel B: U.S. Treasury fund-level long-short exposure

	$\Delta log(min(LNE, SNE))$	$\Delta log(abs(LNE - SNE))$	$\Delta \frac{2\times min(LNE,SNE)}{GNE}$	$\Delta \frac{abs(LNE-SNE))}{GNE}$
	(1)	(2)	(3)	(4)
$March2020_t$	-25.868***	-12.564***	-2.778***	2.778***
	-7.152	-6.469	-7.465	7.465
$March2020_t \times BasisTrader_h$	2.956	-30.078***	6.948***	-6.948***
	0.701	-5.496	9.609	-9.609
Other Controls	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes
Observations	11,053	18,834	18,849	18,849
R^2	0.013	0.007	0.005	0.005

Panel C: Repo exposure, maturity, and collateral

	$\Delta LogRepoBorrowing$	$\Delta LogRepoLending$	$\Delta RepoBrrwTerm$	$\Delta RepoLendTerm$	$\Delta \frac{RepoTotalCollateral}{RepoBorrowing}$
	(1)	(2)	(3)	(4)	(5)
$March2020_t$	1.098	-23.899***	4.459***	-0.823*	-1.456***
	0.463	-8.017	8.259	-1.900	-4.031
$March2020_t$	-17.882***	-5.962	-9.124***	-0.910	3.822***
$\times BasisTrader_h$	-6.071	-1.494	-14.804	-1.010	8.298
Other Controls	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes
Observations	9,387	9,083	9,387	9,083	9,810
R^2	0.014	0.014	0.023	0.021	0.012

Panel D: Cash and liquidity position

	$\Delta LogFreeCashEq$	$\Delta\frac{FreeCashEq}{NAV}$	$\Delta LogCash$	$\Delta\frac{Cash}{NAV}$	$\Delta LogPortfolioGNE$	$\Delta LogOpenPositions$	$\Delta LogPortIlliq$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$March2020_t$	26.467***	6.560***	21.333***	8.239***	-21.807***	-3.755***	-11.687***
	17.809	36.868	17.744	25.506	-44.288	-6.992	-9.132
$March2020_t$ $\times BasisTrader_h$	-7.664***	-2.863***	18.440***	6.580***	0.412	-9.623***	10.782***
	-3.186	-4.165	5.705	5.130	0.498	-12.469	2.985
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,236	21,377	18,765	18,973	21,694	21,676	7,625
R^2	0.012	0.025	0.015	0.022	0.070	0.027	0.084

Panel E: Fund assets, equity, and leverage

	$\Delta LogNAV$	$\Delta LogGAV$	$\Delta LeverageRatio$
	(1)	(2)	(3)
$March2020_t$	-15.328***	-13.667***	0.033
	-26.861	-18.403	1.491
$March2020_t \times BasisTrader_h$	13.447***	1.379	-0.790***
	13.418	0.636	-4.163
Other Controls	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes
Observations	7,625	7,625	7,625
R^2	0.251	0.149	0.042

Appendix A Additional tables

Table A.1: Hedge fund UST trading and funding after the March 2020 shock

This table presents results of the panel regression model given in equation (2). 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 Q4 2019. 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)
$March2020_t$	-9.625***	-1.933***	-14.064***	-13.291***	-0.028
	-22.092	-5.921	-24.445	-18.541	-1.162
$2020Q2_t$	6.617***	-3.347***	2.797***	-1.137	-0.210***
	5.931	-5.040	3.193	-1.225	-7.559
$2020Q3_t$	1.254**	-3.330***	-2.244***	-1.764**	0.080***
	2.159	-6.565	-3.462	-2.474	3.353
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	0.133	0.036

Panel B: U.S. Treasury exposure

	$\Delta LogUST\_GNE$	$\Delta LogUST\_LNE$	$\Delta LogUST\_SNE$	$\Delta \frac{UST\_GNE}{NAV}$	$\Delta \frac{UST\_LNE}{NAV}$	$\Delta \frac{UST\_SNE}{NAV}$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	-19.659***	-19.335***	-22.236***	-16.132***	-9.525***	-7.539***
	-12.624	-10.031	-7.273	-10.441	-8.838	-8.896
$April2020_t$	5.143**	2.700	-4.145	-12.031***	-6.737***	-4.820***
	2.471	1.253	-0.752	-5.173	-4.434	-3.905
$May2020_t$	-4.352***	-3.212**	-13.029***	2.281	1.147	0.534
	-4.309	-2.203	-5.471	1.317	1.078	0.543
$June2020_t$	-5.641***	-4.089***	-16.545***	-8.378***	-5.398***	-3.147***
	-4.522	-3.051	-6.055	-4.710	-4.747	-4.127
$July2020_t$	-6.626***	-9.899***	-6.090**	-1.058	-2.237***	0.795
	-6.724	-5.414	-2.222	-0.821	-2.769	1.146
$Aug2020_t$	-3.530***	-3.491***	-7.001***	-2.187*	-0.958	-0.792
	-4.351	-4.014	-2.961	-1.694	-1.447	-1.059
$Sept2020_t$	-4.015***	-3.086***	1.192	-5.526***	-2.839***	-2.524***
	-4.861	-2.690	0.536	-4.436	-3.201	-4.183
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	20,776	18,495	14,293	20,728	20,728	20,728
R^2	0.015	0.015	0.015	0.012	0.013	0.009

Panel C: Repo exposure, maturity, and collateral

	$\Delta LogRepoBorrowing$	$\Delta LogRepoLending$	$\Delta RepoBrrwTerm$	$\Delta RepoLendTerm$	$\Delta \frac{RepoTotalCollateral}{RepoBorrowing}$
	(1)	(2)	(3)	(4)	(5)
$March2020_t$	-0.698	-21.708***	3.027***	-0.834*	-0.743
	-0.300	-5.988	5.880	-1.691	-1.589
$April2020_t$	-15.784***	-24.529***	1.105	0.606	4.656***
	-3.107	-5.757	1.444	0.809	7.977
$May2020_t$	-9.801***	7.564**	-0.165	-0.174	2.816***
	-3.251	2.280	-0.220	-0.393	5.990
$June2020_t$	12.132***	-5.611*	0.392	-0.850**	1.434***
	4.359	-1.825	0.735	-2.015	3.321
$July2020_t$	2.092	-6.630**	1.844***	0.409	0.337
	0.797	-2.428	3.917	1.021	0.886
$Aug2020_t$	2.306	-4.533	1.873***	0.061	-0.501
	1.185	-1.660	3.467	0.131	-1.394
$Sept2020_t$	1.625	2.382	2.097***	0.245	0.260
	1.108	0.831	4.189	0.524	0.616
Other Controls	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes
Observations	10,373	10,011	10,373	10,011	10,815
R^2	0.018	0.017	0.019	0.020	0.021

Table A.2: Hedge funds with large U.S. Treasury exposures

This table presents results of the panel regression model given in equation (2). 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 Q4 2019. 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 notional exposure

	$\Delta LogUST\_GNE$	$\Delta LogUST\_LNE$	$\Delta LogUST\_SNE$	$\Delta \frac{UST\_GNE}{NAV}$	$\Delta \frac{UST\_LNE}{NAV}$	$\Delta \frac{UST\_SNE}{NAV}$
	(1)	(2)	(3)	(4)	(5)	(6)
$March2020_t$	-42.363***	-30.310***	-54.077***	-69.607***	-45.994***	-28.842***
	-26.767	-12.062	-11.339	-12.105	-11.459	-9.906
Other Controls	Yes	Yes	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes	Yes	Yes
Observations	6,619	6,542	5,274	6,604	6,604	6,604
R^2	0.034	0.022	0.016	0.019	0.020	0.017

Panel B: U.S. Treasury duration

	ΔUST_LNE_Drtn	ΔUST_SNE_Drtn	ΔUST_NNE_Drtn
	(1)	(2)	(3)
$March2020_t$	-0.132***	-0.960***	4.310***
	-2.902	-8.875	6.779
Other Controls	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes
Observations	6,498	5,248	6,575
R^2	0.007	0.008	0.006

Panel C: U.S. Treasury fund-level long-short exposure

	$\Delta log(min(LNE, SNE))$	$\Delta log(abs(LNE - SNE))$	$\Delta \frac{2 \times min(LNE,SNE)}{GNE}$	$\Delta \frac{abs(LNE-SNE))}{GNE}$
	(1)	(2)	(3)	(4)
$March2020_t$	-35.132***	-46.139***	-1.849**	1.849**
	-9.871	-13.235	-2.618	2.618
Other Controls	Yes	Yes	Yes	Yes
Fund FE	Yes	Yes	Yes	Yes
Observations	5,200	6,619	6,619	6,619
R^2	0.013	0.010	0.002	0.002

Table A.3: Summary statistics for hedge funds primarily borrowing via repo

This table shows select summary statistics over the period from January 2013 to March 2020 for the hedge funds that primarily borrow via repo and have at least $1 million in UST exposure on average during Q4 2019. 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 A.4: The regulatory constraints of creditors and hedge fund borrowing

This table presents results of the panel regression model given in equations (3), (4), and (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 all hedge funds that borrow predominantly via repo. 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 $March2020_t$, 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 $p < 0.01$.

	(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 A.5: The regulatory constraints of creditors and hedge fund borrowing

This table presents results of the panel regression model given in equations (3), (4), and (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 all hedge funds that borrow predominantly via repo. 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 $PostJanuary2018_t$, 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)
$March2020_t \times IsGSIB_{p,t}$	10.763***	9.157***	13.743***	14.179**	13.134***	13.307***
	3.972	2.878	3.099	2.614	3.129	3.126
$PostJanuary2018_t \times IsGSIB_{p,t}$	-0.423	0.570	-0.199	-1.426	5.280	4.637
	-0.134	0.148	-0.041	-0.250	0.926	0.838
$IsGSIB_{p,t}$	-0.112	-3.371	-5.112*	-0.829	13.302***	12.368***
	-0.158	-1.610	-1.805	-0.249	3.646	3.512
$LogHF\_Crdtr\_Credit_{h,p,t-1}$					-82.474***	-73.967***
					-27.027	-17.461
$CrdtrRankInHF_{h,p,t-1}$						-0.980
						-0.842
$HFRankInCrdtr_{h,p,t-1}$						-7.412**
						-2.530
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	0.563

Table A.6: The regulatory constraints of creditors and hedge fund borrowing

This table presents results of the panel regression model given in equations (3), (4), and (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 all hedge funds that borrow predominantly via repo. 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 $PostJuly2015_t$, 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)
$March2020_t \times IsGSIB_{p,t}$	9.883***	8.815***	13.219***	13.607***	15.356***	15.379***
	6.830	3.461	3.562	2.828	4.254	4.224
$PostJuly2015_t \times IsGSIB_{p,t}$	2.942	3.953	2.610	2.522	-10.697**	-10.953**
	0.777	1.096	0.648	0.657	-2.324	-2.444
$IsGSIB_{p,t}$	-2.548	-6.151**	-7.084**	-3.173	23.087***	22.181***
	-0.837	-2.264	-2.107	-0.879	4.477	4.448
$LogHF\_Crdtr\_Credit_{h,p,t-1}$					-82.667***	-74.107***
					-27.363	-17.206
$CrdtrRankInHF_{h,p,t-1}$						-0.929
						-0.812
$HFRankInCrdtr_{h,p,t-1}$						-7.584**
						-2.550
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	0.563

Appendix B Background and Data

B.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 8 illustrates the securities flows, cash flows, and exposures created at trade option, 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 and simulates the potential the risk-return trade offs to the arbitrage trading strategies of fixed income hedge funds. 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 distinctions between the two episodes.

B.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 8(a). For such trades to be sufficiently profitable, these arbitrage trades involve substantial leverage. 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 liquidity security and capture the liquidity premium. In the case of the ONR-OFFR spread, this would mean going long the OFFR bond and short the ONR bond. In a typical market stress episode, liquidity risk spikes and such spreads typically 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.

B.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.[30] 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 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 8(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

[30] 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.

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.

B.2 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 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, $min(UST\_LNE_{h,t}, UST\_SNE_{h,t})$, 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.

B.3 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 B.3.1) 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:

$$ModDur(y,\tau) \approx \frac{1}{y}\left(1 - \frac{1}{(1+\frac{1}{2}y)^{2\tau}}\right), \tag{8}$$

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

$$ModDur(y,\tau) = \frac{\tau}{1+\frac{y}{k}}, \tag{9}$$

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 (8) 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

$$Duration = \frac{(Reported10yrBE) * (DurationOf10yrUST)}{ReportedUSTExposure} \tag{10}$$

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 (8) if WAT is greater than one, or computed using (9) if WAT is less than or equal to one.

B.3.1 Derivation of (8)

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:

$$P = C\left[\frac{1-\frac{1}{(1+y/2)^{2n}}}{y/2}\right] + \frac{100}{(1+y/2)^{2n}}. \tag{11}$$

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

$$ModDur = -\frac{1}{P}\frac{\partial P}{\partial y} = \frac{\frac{2C}{y^2}\left[1-\frac{1}{(1+y/2)^{2n}}\right] + \frac{n(100-2C/y)}{(1+y/2)^{2n+1}}}{P} \tag{12}$$

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

$$\begin{aligned} ModDur &= \frac{\frac{2\times 100y/2}{y^2}\left[1-\frac{1}{(1+y/2)^{2n}}\right] + \frac{n(100-2\times 100y/2y)}{(1+y/2)^{2n+1}}}{100} && (13)\\ &= \frac{1}{y}\left(1-\frac{1}{(1+y/2)^{2n}}\right). && (14)\end{aligned}$$

B.4 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 (10) to convert a 10-year bond equivalent value to the repo term.

B.5 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 B.1: G-SIB and primary dealer classifications

This table presents G-SIB and primary dealer classifications. 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).

Institution	Jurisdiction	G-SIB designated years	Primary dealer subsidiary
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 -	0

Table B.2: 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
$Strategy_h$	Investment strategy of the hedge fund (Credit, Equity, Event Driven, Macro, Relative Value, Multi-strategy, or Other).	PF Q20
$NAV_{h,t}$	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 $NetFlows_{h,t} = \frac{NAV_{h,t} - NAV_{h,t-1} \times (1+r_{h,t})}{NAV_{h,t-1}}$	PF Q9, Q17
$FreeCashEq_{h,t}$	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

Continued on the next page.

Table B.2: Variable definitions (continued)

Variable Name	Description	Source
$UST\_GNE_{h,t}$	Sum of long and short exposures to U.S. Treasury securities, including derivatives. (m)	PF Q30
$UST\_LNE_{h,t}$	Long exposure to U.S. Treasury securities, including derivatives. (m)	PF Q30
$UST\_SNE_{h,t}$	Short exposure to U.S. Treasury securities, including derivatives. (m)	PF Q30
$UST\_LNE\_Drtn_{h,t}$	Duration in years of long exposure to U.S. Treasury securities. (m)	PF Q30
$UST\_SNE\_Drtn_{h,t}$	Duration in years of short exposure to U.S. Treasury securities. (m)	PF Q30
$UST\_NNE\_Drtn_{h,t}$	Duration in years of net (long minus short) 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)
$TotalMCBorrowing_{h,t}$	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 B.2: 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).