MEASURING HEDGE FUND LIQUIDITY MISMATCH

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ABSTRACT

We construct a comprehensive measure of mismatch between the market liquidity of assets and the funding liquidity of liabilities of hedge funds. The measure captures the complete liquidity landscape of hedge funds by encompassing liquidity from both sides of the balance sheet. Using quarterly Form PF filings we use portfolio, investor, and financing illiquidity to construct the liquidity mismatch measure and study its dynamics over 2013-2015. We find that the market illiquidity of a hedge fund's assets is typically lower than the funding illiquidity of its borrowings and investor capital (negative liquidity mismatch). However, liquidity mismatch tends to be greater when VIX is high and among funds with higher leverage, lower managerial stake, and smaller size.

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1. Introduction

The 2007-2009 financial crisis has highlighted the importance of sound liquidity risk management to guarantee the viability of financial institutions, especially during severe market downturns. The large liquidity mismatch between the assets and liabilities of financial intermediaries fueled investor runs and triggered distressed asset sales that threatened insolvencies across the entire financial system. The potential inability of financial institutions to effectively manage their liquidity in times of need created concerns among policymakers that ultimately resulted in significant regulatory reforms around the globe. These concerns, however, reemerged in March 2020 when the large economic shock brought by the Covid-19 pandemic lead to a deterioration in market conditions, including in traditionally liquid market segments such as Treasury cash bonds and futures where levered hedge funds operate. This prompted a renew interest for understanding hedge funds operations and studying their liquidity profile.

A complete liquidity assessment for hedge funds includes illiquidity coming from asset, liability, and equity parts of the balance sheet. Specifically, on the asset side, a hedge fund's asset illiquidity is a function of liquidity profile of a hedge fund investment strategy. This depends on the illiquidity of its underlying non-cash assets (such as bond, equity, structured products, derivatives, etc.) that might vary with market conditions, and the amount of cash and cash-equivalent instruments held as a liquidity buffer. On the liability side, a hedge fund's financing illiquidity captures the terms of a fund's borrowing and measures the period during which a creditor has contractually committed to provide financing to the fund. As a result, a fund with large financing illiquidity is potentially more susceptible to sudden margin calls. On the equity side, hedge fund's investors are the

"equity" holders of a hedge fund. As a result, investor illiquidity captures the period within which fund investors can redeem their shares.

There is a large literature measuring individual sources of hedge fund illiquidity (see Getmansky, Lee, and Lo, 2015 for the survey); however, there is no one comprehensive and usable liquidity measure for hedge funds. In this paper we propose a novel hedge fund liquidity mismatch measure that encompasses liquidity on both sides of the balance sheet. It is also measured in days (compared to say autocorrelation coefficient), so this measure is operationally easy to measure, use, and compare across different funds.

To construct this measure, we use information extracted from Form PF filings that are submitted confidentially with the SEC.[2] Since mid-2012, Form PF filings are required by all Securities and Exchange Commission (SEC)-registered investment advisers with at least $150 million in private fund (PF) assets. The information reported in Form PF is nonpublic and contains information about each individual private fund under management, including the fund's identity, investment strategy and performance, assets under management, and borrowing. These disclosures provide detailed and complete information about hedge funds' operations and allow us to directly measure portfolio, investor, and financing illiquidity.[3] As a result, this is the first paper to capture the complete liquidity landscape of a hedge fund encompassing both sides of the balance sheet. An important advantage of our Form PF setting is that most liquidity variables are reported directly by

[2] A comprehensive picture of hedge funds and advisers that file form PF is provided in the quarterly statistics produced by the SEC Division of Investment Management and available here: https://www.sec.gov/divisions/investment/private-funds-statistics.shtml

[3] Illiquidity of a fund's assets, liabilities, and equity are taken from Questions 32, 50, and 46(b), respectively, in Form PF.

the fund adviser and measured in the same units (days), thus allowing for direct comparison and aggregation. Prior studies rely on liquidity proxies that allow only a partial view of a hedge fund's overall liquidity profile and/or cover only a limited sample of the funds' population. These proxies often lack important components and/or were polluted with other factors unrelated to funds' liquidity. Getmansky, Lo, and Makarov (2004), for instance, construct a joint measure of asset liquidity and return smoothing, thus only indirectly providing an assessment of hedge funds' asset liquidity. The commercially available databases such as Lipper TASS, Hedge Fund Research (HFR), Morningstar Hedge/CISDM, and Barclay Hedge, among others, do not provide the full picture of hedge fund liquidity. None of the available databases provide information on gates and many have missing or static information on lock-ups, redemption notice periods, and redemption frequency.

We construct a global measure of liquidity mismatch for each fund and quarter equal to the illiquidity of the fund's assets including cash (asset illiquidity) minus the illiquidity of the fund's liabilities (financing illiquidity) and equity (investor illiquidity). A fund's asset illiquidity is a weighted-average of the time it takes to liquidate the fund's portfolio. [4] Similarly, financing and investor illiquidity are weighted-averages of the time that creditors and investors have committed their loan facilities and equity capital to the

[4] Our measure of a fund's asset liquidity is a weighted average between the liquidity of the investment portfolio (Q32 on form PF) and cash. In principle, the sum of percentage values entered across all periods in Q32 (portfolio illiquidity) should be 100%. However, we observe some observations where these sums are very different from 100%. Therefore, we drop observations where either sum is either less than or equal to 90% or greater than or equals to 110%.

fund, respectively. Both sides of balance sheet liquidity are measured in the same units (days), and are reported by the fund manager on Form PF.

Using quarterly Form PF filings over 2013-2015, we find that liquidity mismatches in hedge funds are typically negative (-85 days, on average), meaning that hedge funds hold relatively liquid assets compared to the combined liquidity of their liabilities plus equity, though some funds in our sample have positive liquidity mismatches. Our results display significant variation across funds and market conditions. In particular, highly levered funds are associated with significantly greater (positive) mismatches. As we show, the terms of committed financing that a hedge fund arranges with its creditors are much shorter, on average, as compared to those of its equity investors. Therefore, a higher leverage ratio places relatively more weight on a fund's short-term liabilities, and this creates a greater mismatch ceteris paribus. This finding is interesting because higher leverage amplifies returns on assets and makes hedge funds more exposed to margin calls and redemptions by their prime brokers and investors, respectively. At the same time, liquidity mismatches can create so-called strategic complementarities whereby fund investors pre-emptively withdraw their capital in anticipation of outflows by other investors, to avoid significant costs from asset fire sales.[5] Taken together, our evidence suggests that an increase in leverage could make hedge funds more prone to asset fire sales that propagate funding shocks throughout the financial system.

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[5] See, e.g.,Chen, Goldstein, and Jiang (2010), Liu and Mello (2011, 2017), Goldstein, Jiang, and Ng (2017), and Agarwal, Aragon, and Shi (2019). On the investor side, many hedge funds impose lockups on investor capital (Aragon, 2007; Aragon, Liang, and Park, 2013) and can enact gates and suspend redemptions outright to prevent investor runs (Aiken, Clifford, and Ellis, 2015). We account for such discretionary liquidity restrictions in our analysis of liquidity mismatch.

We also find that larger mismatches are more pronounced among smaller funds and funds in which managers have a smaller personal stake. Such funds face strong incentives to raise capital and, in line with an agency explanation, are more prone to take excessive liquidity risk (Teo, 2011). In addition, hedge fund mismatches are positively correlated with market volatility (78% with VIX). We show that the positive relation between mismatch and VIX is driven by the asset side of the balance sheet, i.e., as VIX increases, portfolio illiquidity tends to increase. In sum, while hedge funds generally aim to hold assets that are more liquid than their liabilities (negative mismatch), the degree of mismatch is strongly related to fund characteristics and market conditions. Liquidity mismatches are predicted to be significantly greater (i.e., more positive) among more levered hedge funds, funds with weak incentives, and during a market crisis.

Our analysis is related to empirical work on liquidity mismatches in commercial banks, especially by Berger and Bouwman (2009). [6] In contrast to our findings of negative mismatches in most hedge funds, they find that banks tend to have positive mismatches and, hence, "create" liquidity. Their findings support prior theories of capital structure that help rationalize why banks mainly finance illiquid assets with liquid demand deposits. By allowing depositors to force liquidation, demand deposits provide a disciplining force against a bank's incentive to take actions against the interest of depositors. [7] Our findings

[6] The main difference of our measure from Berger and Bouwman (2009) is that our measure is based on hedge fund managers' own assessments of the liquidity of its balance sheet (as reported on Form PF) and is not dependent on our judgment of the liquidity of specific balance sheet items. Berger and Bouwman (2009) construct several alternate measures using different ways of classifying a bank's balance sheet items as liquid, semi-liquid, or illiquid. Other empirical studies of liquidity mismatches in banks include Deep and Schaefer (2004) and Bai, Krishnamurty, and Weymuller (2017).

[7] See, e.g., Diamond and Dybvig (1983), Gorton and Pennacchi (1990), Calomiris and Kahn (1991), Flannery (1994), and Diamond and Rajan (2000, 2001).

of negative mismatches among hedge funds suggest that funds can adopt alternative devices, besides a "fragile" capital structure, to mitigate conflicts between fund managers and investors. However, given that that our sample period (2013 to 2015) covers a period of relative calm in financial markets, we expect (as mentioned above) significantly greater mismatches in hedge funds during periods of market crisis.

Our work also contributes to recent efforts to measure liquidity mismatches among asset managers. Agarwal, Aragon, and Shi (2019) study funds of hedge funds (FoFs) and compute mismatch as the difference between the average redemption frequency of their investments in underlying hedge funds (assets) and the redemption frequency they offer to its own investors (equity). Compared to their study, we focus on mismatches in hedge funds (versus FoFs) and extend their measure to incorporate leverage. This is important because leverage is used extensively by hedge funds and, as we show, the committed period of a fund's borrowings (financing illiquidity) is typically much lower than its investor illiquidity.

The rest of the paper is organized as follows: Section 2 discusses hedge funds' individual liquidity components and introduces our mismatch measure. Section 3 presents the data and summary statistics. Section 4 discusses our findings for liquidity mismatches both in the univariate setting and regression framework. Section 5 concludes.

2. Hedge funds liquidity components and mismatch measure

The main objective of our study is to measure liquidity mismatches in hedge funds – that is, differences between a hedge fund's asset illiquidity and the illiquidity of its liabilities and equities. The Form PF data makes this possible because it provides detailed

data on a hedge fund's asset holdings and capital structure, two critical components of liquidity mismatch. Moreover, the Form PF filings include information about the illiquidity of a fund's assets, liabilities, and equity, all measured in the same units. The following subsection provides a detailed discussion of our methodology.

2.1. Asset illiquidity

Asset illiquidity is a function of a hedge fund's strategy, including its underlying non-cash assets as well as its holdings of cash and cash-equivalent assets. We obtain information about the illiquidity of a hedge fund's non-cash assets from Question 32 of Form PF. This question asks each fund to report the percentage of non-cash assets that could be liquidated assuming no fire-sale discounting within each of the following intervals of days: 1 or fewer, 2-7, 8-30, 31-90, 91-180, 181-365, and 365 or more. We calculate the illiquidity of a hedge fund's non-cash assets (*PortIlliq*) by summing up the products of the reported percentage and the midpoint of the corresponding interval. Intuitively, *PortIlliq* is greater for funds that hold more illiquid assets, because such a fund would require more time to liquidate its assets in absence of fire sales. For example, the value of *PortIlliq* for a hedge fund holding the most liquid (illiquid) non-cash assets would be one (365) days.

Next we create an overall asset illiquidity measure by combining *PortIlliq* with unencumbered cash and cash equivalents (*Cash*).

$$AssetIlliq = PortIlliq \times \left(1 - \frac{Cash}{GAV}\right) + 1 \times \left(\frac{Cash}{GAV}\right)$$

The above expression is a weighted average of the illiquidity of a fund's non-cash assets (*PortIlliq*) and the illiquidity of its cash (one day). The weight applied to *PortIlliq* is

essentially the value of a fund's non-cash assets as a percentage of gross asset value (*GAV*). We assign *Cash* the lowest possible time-to-liquidate of just one day (i.e., most liquid).[8]

2.2. *Financing and Investor Illiquidity*

Advisers for each hedge fund report in Q46(b) the percentage of a fund's total available (i.e., used and unused) borrowing that has been contractually committed to the fund for the same set of intervals listed in Question 32.[9] This provides a measure of financing illiquidity (*FinIlliq*), which is calculated as the weighted average of the interval midpoints. Likewise, for the same set of intervals, respondents to Question 50 report the percentage of investor capital that is contractually committed to the fund. The latter intends to account for all relevant investor liquidity, such as lock-up periods, imposed gates, redemption frequency, and notice periods. We calculate investor illiquidity (*InvIlliq*) as the weighted average of interval midpoints. Finally, we combine financing and investor illiquidity to create an overall measure of the illiquidity of a fund's equity and liabilities:

$$FinInvIlliq = \left(\frac{NAV}{GAV}\right) \times InvIlliq + \left(1 - \frac{NAV}{GAV}\right) \times FinIlliq$$

[8] We focus on unencumbered cash since it is freely available to the manager to meet margin calls or investor redemptions and provides a liquidity buffer. In contrast, a fund's total cash position may include cash posted as margin. Even so, for robustness, we repeated our analysis of liquidity mismatch (Table 3) after replacing *Cash* with total cash (from Form PF Q26 or Q30) in our calculation of *Mismatch*. The results from this robustness check are qualitatively unchanged from those using unencumbered cash.

[9] We understand that hedge funds that may not report obligations under derivatives contracts as "borrowings" in Q12, Q43 or Q46(b) of Form PF. To the extent that funds do not include these obligations in their PF filings, the liquidity terms reported in Q46(b) may overstate their financing illiquidity and underestimate its overall liquidity mismatch.

FinInvIlliq is simply a weighted-average of *InvIlliq* and *FinIlliq*, where the weight on *InvIlliq* is the inverse of the fund's leverage ratio. [10]

2.3. *Liquidity Mismatch*

We then construct a global measure of liquidity mismatch for each fund and quarter equal to the illiquidity of the fund's assets including cash (asset illiquidity) minus the illiquidity of the fund's liabilities (financing illiquidity) and equity (investor illiquidity). Both sides of balance sheet liquidity are measured in days. Thus, *Mismatch* is measured as the difference between *AssetIlliq* and *FinInvIlliq*:

$$Mismatch = AssetIlliq - FinInvIlliq$$

Intuitively, positive values of *Mismatch* will occur when a fund pursues a long-term investment strategy while maintaining shorter-term commitments from its investors and creditors. A fund that "borrows short" therefore has *Mismatch* > 0. In contrast, a fund that is financing very liquid assets with relatively long-term capital will show negative values of *Mismatch*. A fund that "borrows long" therefore has *Mismatch* < 0.

3. Data and summary statistics

3.1. Form PF and other data sources

[10] For robustness, we compute the inverse of the fund's leverage ratio by replacing *GAV* with *NAV* + *UsedBrw* (where *UsedBrw* is actual used borrowing from Form PF, Q43 or, if missing, Q12). We then repeat our analysis of liquidity mismatch (Table 3). The results from this robustness check are qualitatively unchanged from those using *GAV*.

The main data in our analysis come from Form PF regulatory filings. Since mid-2012, Form PF filings are required by all Securities and Exchange Commission (SEC)-registered investment advisers with at least $150 million in private fund (PF) assets.[11] The information reported in Form PF is nonpublic and contains information about each individual private fund under management, including the fund's identity, investment strategy and performance, assets under management, borrowing, and balance sheet liquidity.

Our analysis focuses on the subsample of private funds that report their fund type as "Hedge Fund" and answer Section 2b of Form PF.[12] Section 2b provides fund-level information that is central to our analysis, such as the fund's asset illiquidity, unencumbered cash, available borrowing, and the committed periods of investor and lender financing. Furthermore, this information is available on a quarterly basis; therefore, we can study how hedge funds manage their liquidity in a dynamic setting at a relatively high frequency. We exclude quarterly filings with missing or extreme values for our variables of interest (see Section 2.3 for details). Our final sample contains 12,384 quarterly filings

[11] As noted in the adopting release (17 CFR Parts 275 and 279 – Release No. IA–3308), "The information contained in Form PF is designed, among other things, to assist the Financial Stability Oversight Council in its assessment of systemic risk in the U.S. financial system."

[12] Only the so-called *Qualifying Hedge Funds*, which have at least $500 million in net assets, answer Section 2b. Note that the Form requires aggregating all master-feeder funds, parallel funds, and dependent parallel managed accounts associated with a fund to determine whether it is a Qualifying Hedge Fund or not. However, advisers are allowed to report fund level data separately as well as on an aggregated basis; thus, some Qualifying Hedge Funds may have net assets less than $500 million (see Form PF General Instructions for reporting and aggregation requirements). Some results in this paper, and the conclusions we draw from them, could conceivably change if our sample included information from all funds, not just the Section 2b filers.

over 2013-2015 made by 1,809 funds of 559 advisers. It contains a cross-section of both small and large funds (see Table 1 for details).

We also use data from the public Form ADV regulatory filings of hedge fund advisers in our sample, including the adviser's percentage ownership stake in the fund, whether the fund uses an independent administrator to value the fund's assets, and the number of prime brokers used by the fund. Finally, we use VIX data supplied by DataStream. All variables used in our analysis are defined in the Appendix.

Figure 1 plots the number of advisers and hedge funds in our estimation sample. The number of advisers grows from 331 to 436 over 2013Q1-2015Q3, while the number of corresponding funds grows from 891 to 1,292.

Our final sample excludes fund/quarter observations with missing values for net asset value (*NAV*), gross asset value (*GAV*), non-cash asset illiquidity (*PortIlliq*), fund investor illiquidity (*InvIlliq*), unencumbered cash (*Cash*), unused borrowing capacity (*UnuBrwRatio*), and investment strategy. We also drop observations where *Cash* or *UnuBrwRatio* have negative values, *GAV* is either strictly less than either *NAV* or *Cash*, or *NAV* is less than or equal to zero. In principle, the sum of percentage values entered across all periods in Q32 (portfolio illiquidity), Q46(b) (Financing Illiquidity), and Q50 (Investor Illiquidity) should be 100%. However, we observe some observations where these sums are very different from 100%. Therefore, we drop observations where either sum is either

less than or equal to 90% or greater than or equals to 110%.[13] All variables (except *VIX* and dummies) are winsorized each quarter at the 1% and 99% levels.

3.2. Summary statistics

Table 1 Panel A shows that the mean illiquidity of a fund's assets (65.9 days) is lower than the illiquidity of its liabilities plus equity (145.9 days). The average *Mismatch* in our sample is -85.5 days, indicating that the typical fund in our sample has a "liquidity cushion."[14] In other words, it takes a shorter time for the typical fund to liquidate its assets than it takes for its stakeholders to reclaim their financing and redeem equity shares. This is consistent with Agarwal, Aragon, and Shi's (2019) finding of a negative illiquidity gap, on average, in their sample of funds of funds over 2004-2011. The top panel of Figure 2 plots the average value of *Mismatch* over our sample period. We see that liquidity mismatches in hedge funds co-vary positively with market volatility, as measured by a pairwise correlation between *Mismatch* and *VIX* of 0.78. The bottom panel of Figure 2 shows that greatest (i.e., least negative) mismatches are found among the smaller hedge funds. We investigate these relations further in a multivariate setting.

A further partitioning of *AssetIlliq* yields additional insights. Table 1 Panel A shows that the ratio of unencumbered cash to net asset value (*CashRatio*) has a sample median of

[13] For robustness, we repeated our analysis after applying more (less) restrictive filters by dropping observations where either sum in Q32, Q46(b), or Q50 is either less than or equal to 95% (85%) or greater than or equals to 105% (115%). The results from this robustness check are qualitatively unchanged from those using the 90% – 110% thresholds.

[14] The average *Mismatch* does not equal the difference between the average *AssetIlliq* and *FinInvIlliq* because *FinIlliq* is missing for 3,159 observations in our final sample. For these observations, we can compute *AssetIlliq* but neither *FinInvIlliq* nor *Mismatch*.

6.9%. This is higher than Chernenko and Sunderam's (2016) estimates of the median cash ratios for equity (4.36%) and bond (5.28%) mutual funds. In addition, while a fund's investors typically commit their capital for a mean period of 173 days, its creditors commit their financing for only 52.9 days. Strikingly, *FinIlliq* has a median value of just one day implying that hedge funds largely rely on very short-term loans.[15] The disparity between investor and financing illiquidity highlights the dependence of a hedge fund's liquidity mismatch on its leverage ratio, with a greater leverage ratio placing more weight on *FinIlliq* and, hence increasing *Mismatch*.

Table 1 also summarizes the ratio of unused borrowing to total (used plus unused) borrowing (*UnuBrwRatio*).[16] The dollar amount of unused borrowing reflects the credit available through a committed line of credit and/or the fund's free credit balance in its margin account – that is, the excess of the value of margin securities over the margin requirement.[17] In our sample, *UnuBrwRatio* has a sample mean of 28.7%. To put this

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[15] Some filers may report their financing terms as "1 day or less" despite having longer-term agreements in place. According to form PF instructions: "(If a creditor […] is permitted to vary unilaterally the economic terms of the financing or to revalue posted collateral in its own discretion and demand additional collateral, then the financing should be deemed uncommitted for purposes of this question. Uncommitted financing should be included under "1 day or less.")". The data do not allow us to distinguish between filers that agree on one-day-term loans vs. filers that agree on longer terms but are subject to daily revaluation of collateral.

[16] Unused borrowing is taken as the difference between available borrowing and actual borrowing. Available borrowing is reported in Question 46(a), which asks each fund to report the "aggregate dollar amount of borrowing by and cash financing available to the reporting fund (including all drawn and undrawn, committed and uncommitted lines of credit as well as any term financing)." Actual borrowing is reported in Questions 43. Specifically, we compute actual borrowing as the sum of the responses to the subcategories of Question 43. In some cases, where responses to Question 43 are missing, we use the response to Question 12. Lastly, we drop observations with negative values of unused borrowing. We do not have an economic interpretation for negative values of unused borrowing and, therefore, attribute these observations to reporting error.

[17] Suppose a hedge fund has $100 worth of margin securities, a debit balance (i.e., margin borrowing) of $25, and the remaining $75 is equity. If the maintenance margin requirement is 50%, then the fund could withdraw cash up to $25, reduce its equity down to $50, and increase its debit balance to $50. Alternatively, if the

number into perspective, we compute a measure of publicly-reported margin loan capacity from the aggregate margin balances reported by member organizations of the New York Stock Exchange.[18] Specifically, for each quarter in our sample, we divide the total credit balances in margin accounts (i.e., unused margin borrowing) by the total available margin borrowing (i.e., credit balances in margin accounts plus margin debt balances). We find (not tabulated) that this NYSE-based variable has a sample mean of 26% and a correlation with *UnuBrwRatio* of 73%. This suggests that *UnuBrwRatio* – which includes undrawn lines of credit and credit balances in margin accounts – is comparable to and correlated with aggregate margin loan capacity among customers of broker-dealers.

Table 1 Panel B shows basic summary statistics for other variables in our analysis. The median fund has gross assets value (*GAV*) of $1.249 billion and net asset value (*NAV*) of $907.9 million. In comparison, Agarwal, Daniel, and Naik (2011) and Aragon and Nanda (2017) report a median size of $29 million and $25 million, respectively. The difference shows that our sample contains more funds with larger assets under management compared to these prior studies. [19]

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margin requirement is only 25% the fund could withdraw cash up to $50, reduce its equity to $25, and increase its debit balance to $75. In other words, the fund has an excess margin, or free credit balance, of $25 and $50, respectively. See Fortune (2000) for additional discussion of margin accounting.

[18] The data are from the Margin Debt and Stock Loan, Securities Market Credit segment of the NYSE Facts and Figures website (http://www.nyxdata.com/nysedata/asp/factbook/main.asp). The NYSE notes, "NYSE member organizations are required to report monthly their aggregate debits (amount borrowed by customers to purchase securities) in margin accounts, as well as aggregate free credits (cash balances) in cash and margin accounts."

[19] This is, of course, partially due to the fact that only QHFs (as defined in Form PF) are reported in Section 2b. This essentially places a soft floor of $500 million on the NAV of the funds in our sample.

The equal-weighted mean leverage of hedge funds in our sample is 1.6, which is lower than the few existing estimates of hedge fund leverage.[20] Jiang (2017) combines the gross asset values from Form ADV filings with the net asset values from client brochures to infer the leverage levels of hedge fund advisers over 2011-2013. He reports mean leverage of 1.92 (i.e., aggregated across an adviser's underlying hedge funds). Ang, Gorovyy, and van Inwegen (2011) report an average leverage of 2.13 using a proprietary sample of hedge funds obtained from a fund of fund investor. They also report a downward trend in leverage use since the financial crisis, which could partly explain why our estimate (from a more recent sample) is lower.

Quarterly returns (1.6%) and net flows (1.0%) are positive, on average, over our sample period, but there is a considerable variation in outcomes. For example, the standard deviation of returns and flows is 5.3% and 16.7%, respectively, across both time and filers.

Table 1 Panels C and D summarize other Form PF variables used in our sample. Hedge funds allocate 36.2% of their assets to equity strategies, on average, as compared to just 2.0% for managed futures strategies. *HHI* is a Herfindahl-Hirschman Index calculated as the sum of squared percentage allocations to seven portfolio strategies. This captures the fund's strategy concentration and can take a maximum value of unity (most concentrated). Our sample has a median *HHI* of unity, suggesting that hedge fund portfolios are typically focused on a single investment strategy. On average, the top five investors and the hedge fund adviser have ownership stakes in the fund of 61.3% and 12.5%, respectively, suggesting that many hedge funds are majority owned by a few investors. Lastly, the

[20] The asset-weighted mean leverage of hedge funds in our sample is 1.77.

quarter-end level of *VIX* has a sample mean of 16.5% and ranges from 11.6% to 24.5% over our sample period.

4. Liquidity mismatches

The above discussion shows that liquidity mismatches are negative, on average, indicating that a fund's assets are more liquid than its liabilities and equity. In this section we examine how liquidity mismatches vary across hedge funds and time. We also examine the separate components of liquidity mismatches to shed light on how hedge funds manage liquidity.

4.1. *Liquidity mismatches: Univariate comparisons*

Table 2 shows the average characteristics of funds with low (bottom quartile), medium (middle quartiles), and high (top quartile) values of *Mismatch*. A few interesting patterns emerge. First, high (positive) liquidity mismatches are associated with smaller funds (*Ln(NAV)*) and funds in which the adviser has a small ownership stake (*AdvOwner*). Teo (2011) argues that such funds face strong incentives to raise capital and, in line with an agency explanation, are more prone to take excessive liquidity risk. Second, large (positive) mismatches are associated with greater leverage. This makes sense in light of our earlier findings that the illiquidity of a fund's creditors (*FinIlliq*) is typically much lower than that of its investors.[21] Ceteris paribus, a higher leverage ratio places more weight on the former and increases *Mismatch*. Finally, low (negative) mismatches are associated with certain investment strategies, such as Credit and Event Driven. On one hand, these strategies typically involve greater asset illiquidity (e.g., fixed income

[21] This result is largely dependent on the fact that most filers report their financing terms as "1 day or less".

securities and merger arbitrage), which would increase mismatch. However, in our sample, these strategies are associated with a greater liability plus equity illiquidity, and the net effect is a lower mismatch. Relative value strategies tend to have larger (positive) mismatches which makes them vulnerable to illiquidity shocks similar to that of March 2020, leading to unwinding of levered futures and cash bonds positions that may result in large losses.

4.2. *Liquidity mismatches: Regression framework*

Next, we assess these relations more closely in a multivariate regression framework. The first two columns of Table 3 present results in which the dependent variable is $Mismatch_{iq}$ – that is, the liquidity mismatch of fund i at the end of quarter q. All explanatory variables are measured at the end of quarter q. The results largely confirm our univariate findings: liquidity mismatches are greater among smaller funds, and funds with greater leverage.[22] The latter result contrasts with Berger and Bouwman's (2009) finding of a positive relation between a bank's equity capital ratio and liquidity mismatch in large banks.[23] Rather, our evidence shows that hedge funds tend to have a higher mismatch (worse liquidity condition) when they have a higher leverage ratio. Higher mismatch is also present among funds where advisers have a lower ownership stake. A possible

[22] The investment strategy variables *Credit* and *EventDriven* (not tabulated to save space) are associated with significantly lower mismatches, as we find in Table 2.

[23] We again find a positive relation between mismatches and leverage when we repeat the regression on subsamples of funds in the bottom, middle, and top quartiles of *NAV*. Our results are also qualitatively similar when we replace *NAV* with *GAV* in Table 3 regressions.

interpretation is that funds that are more prone to agency problems take on "excessive" liquidity risk, as argued by Teo (2011).

Bai, Krishnamurthy, and Weymuller (2017) show that aggregate liquidity mismatch in banks – i.e., the difference between asset illiquidity and liability illiquidity – increased significantly during the crisis. The reason is that drops in market-wide measures of liquidity can significantly impact the liquidity weights assigned to the assets and liabilities on the bank's balance sheet, thereby increasing the vulnerability of banks to liquidity stress. While our sample period lies outside the crisis period, we exploit time variation in market conditions by including a measure of market illiquidity (*VIX*) as an additional explanatory variable in our *Mismatch* regression.

Consistent with hedge funds being more susceptible to liquidity runs during periods of market stress, we find a positive and significant relation between mismatches and *VIX*.[24] Specifically, a one standard deviation increase in *VIX* is associated with an increase in *Mismatch* of 3.11 days. Furthermore, Columns (3) and (4) run separate regressions for each component – *AssetIlliq* and *FinInvIlliq* – of mismatch. The results show that the significant positive relation between *VIX* and *Mismatch* is driven by a positive relation between *VIX* and asset illiquidity. This makes sense given that *AssetIlliq* depends directly on *PortIlliq* and, according to Question 32 of Form PF, *PortIlliq* is based on the manager's "good faith

[24] We find qualitatively similar results when we replace *VIX* with either the TED spread or Pastor and Stambaugh's (2003) market liquidity measure.

estimates for liquidity [of non-cash assets] based on market conditions over the reporting period."[25]

Several variables load significantly and in the same direction in explaining both components of mismatch, indicating that fund characteristics associated with greater *AssetIlliq* also tend to be associated with greater *FinInvIlliq*. This provides preliminary evidence of hedge funds matching the maturity structure of their assets with that of their equity and liabilities.

5. Conclusions

Using a comprehensive hedge fund dataset (Form PF), we construct a global measure of liquidity mismatches in hedge funds. This measure captures the complete liquidity landscape of hedge funds by encompassing liquidity from both sides of the balance sheet and providing a novel measure of liquidity mismatch. The measure is operationally easy to use (as it is calculated in days), easy to calculate, and comparable across different funds.

We further analyze the measure, its dynamics, and characteristics over the period 2013-2015. First, hedge funds typically hold assets that are more liquid than the combined liquidity of their liabilities and equity (i.e., negative liquidity mismatches). Second, liquidity mismatches are more pronounced during periods of high market volatility, and among smaller funds, funds with high leverage, and funds in which the manager owns a smaller proportion of the fund. Overall, our findings suggest that attention to liquidity

[25] The coefficients in Column (2) of Table 3 do not exactly equal the difference in coefficients between Columns (3) and (4) due to the winsorization of *Mismatch*, *AssetIlliq*, and *FinInvIlliq*.

mismatches in hedge funds is especially important for funds with greater leverage, weaker incentives, and during periods of market crisis.

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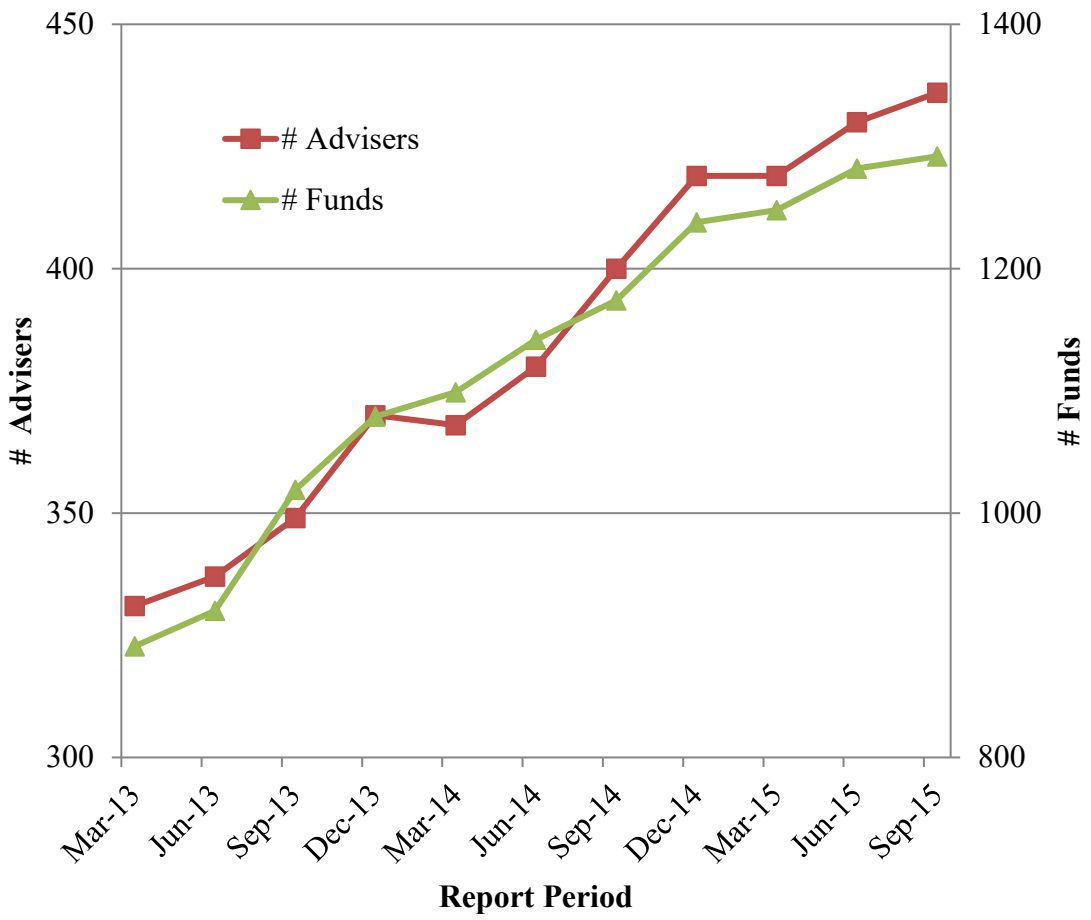

Figure 1. The figure plots the number of hedge funds and advisers in our estimation sample for each quarter of our sample period 2013Q1-2015Q3.

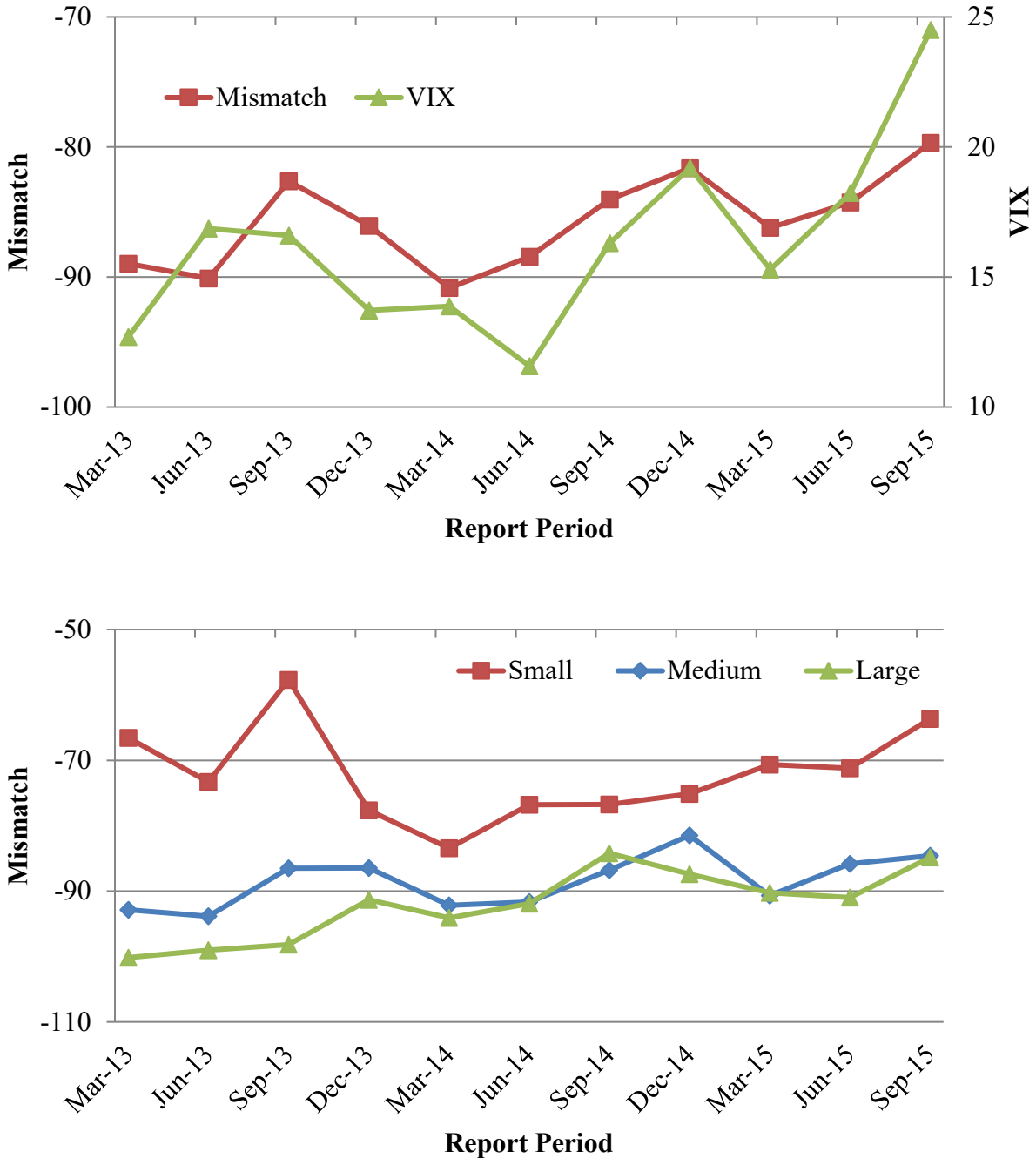

Figure 2. Top panel shows the average liquidity mismatch of hedge funds (squares) and the level of VIX (triangles) at the end of each quarter of our sample period 2013Q1-2015Q3. Bottom panel shows the average liquidity mismatch for small (squares), medium (diamonds), and large (triangles) hedge funds. Small, medium, and large funds are those in the bottom, middle, and top quartiles based on quarter-end net asset values.

Table 1: Characteristics of the hedge fund sample over 2013Q1-2015Q3
This table reports summary statistics. All variables are winsorized at 1% and 99% levels and defined in the Appendix.

Variable	N	mn	sd	p25	p50	p75
Panel A: Liquidity variables						
Mismatch	9298	-85.5	85.9	-135.6	-62.7	-17.4
AssetIlliq	12384	65.9	105.4	3.5	13.7	64.1
FinInvIlliq	9298	145.9	119.5	45.0	110.9	238.5
PortIlliq	12384	71.2	112.2	4.3	14.9	72.3
InvIlliq	12384	172.8	135.1	60.5	143.7	306.1
FinIlliq	9298	52.9	96.7	1.0	1.0	60.5
CashRatio	12384	16.7%	22.9%	0.7%	6.9%	22.7%
UnuBrwRatio	12384	28.7%	35.6%	0.0%	7.8%	52.8%
Panel B: Size, leverage, and flow variables						
GAV	12384	2955.6	5328.9	577.5	1249.3	2847.7
NAV	12384	1723.6	2397.6	472.1	907.9	1900.2
Leverage	12384	1.6	1.3	1.0	1.2	1.7
NetReturn	10779	1.6%	5.3%	-0.7%	1.6%	4.0%
NetFlow	9612	1.0%	16.7%	-3.7%	0.0%	3.3%
Panel C: Investment strategy variables						
Credit	12384	9.1	25.4	0.0	0.0	0.0
Equity	12384	36.2	45.4	0.0	0.0	100.0
EventDriven	12384	11.0	27.7	0.0	0.0	0.0
InvestOtherFunds	12384	2.1	12.2	0.0	0.0	0.0
Macro	12384	7.6	24.2	0.0	0.0	0.0
ManagedFutures	12384	2.0	13.0	0.0	0.0	0.0
RelativeValue	12384	10.6	27.7	0.0	0.0	0.0
Other	12384	21.4	38.5	0.0	0.0	18.0
HHI	12384	0.8	0.3	0.6	1.0	1.0
Panel D: Other variables						
Ln(AdvNAV)	12384	22.8	1.3	21.6	22.7	23.9
DiscRestrict	12384	0.7	0.4	0.0	1.0	1.0
IndepAdmin	12384	0.6	0.5	0.0	1.0	1.0
#Brokers	9200	2.2	2.6	0.0	2.0	3.0
Top5Owner	12384	61.3	28.1	37.0	58.0	92.0
AdvOwner	9200	12.5	23.5	0.0	3.0	11.0
VIX	12384	16.5	3.5	13.7	16.3	18.2

Table 2: Characteristics of hedge funds with high and low liquidity mismatches
The table reports sample averages of hedge fund characteristics for different subsamples based on a fund's end-of-quarter liquidity mismatch. Low, Medium, and High mismatch categories are those with *Mismatch* values in the bottom, middle two, and top quartiles, respectively. All variables are defined in the Appendix.

	Low *Mismatch* (bottom 25th pct)	Medium *Mismatch* (25th-75th pct)	High *Mismatch* (top 25th pct)
Panel A: Liquidity variables			
Mismatch	-209.22	-68.22	3.76
AssetIlliq	46.65	48.24	100.53
FinInvIlliq	256.67	116.45	94.09
PortIlliq	52.39	53.86	104.90
InvIlliq	297.71	151.19	112.04
FinIlliq	77.13	42.67	49.22
CashRatio	13.67%	16.46%	19.72%
UnuBrwRatio	43.03%	33.60%	41.36%
Panel B: Size, leverage, and flow variables			
Ln(NAV)	20.80	20.63	20.55
Ln(GAV)	21.08	21.13	21.02
Ln(Leverage)	0.28	0.50	0.44
NetReturn	1.94%	1.68%	1.61%
NetFlow	1.15%	1.38%	1.64%
Panel C: Investment strategy variables			
Credit	13.32	10.47	5.63
Equity	33.61	45.22	32.56
EventDriven	18.42	12.52	4.21
InvestOtherFunds	1.24	1.12	0.95
Macro	1.97	6.76	8.55
ManagedFutures	0.13	1.00	1.22
RelativeValue	10.90	9.51	14.41
Other	20.40	13.39	32.44
HHI	0.69	0.76	0.84
Panel D: Other variables			
Ln(AdvNAV)	22.72	22.61	23.06
DiscRestrict	0.68	0.83	0.68
IndepAdmin	0.68	0.72	0.57
#Brokers	2.80	3.22	1.83
Top5Owner	56.39	58.10	65.24
AdvOwner	13.31	13.95	12.49

Table 3: Determinants of liquidity mismatches and its components
The table reports the results from pooled regressions of hedge fund liquidity mismatches. The dependent variable in Columns (1) and (2) is the fund's liquidity mismatch (*Mismatch*) measured at the end of the quarter. In Columns (3) and (4) the dependent variable is the quarter-end illiquidity of the fund's assets (*AssetIlliq*) and liabilities and equity (*FinInvIlliq*). Independent variables are measured contemporaneously with the dependent variable and (except for dummies) standardized to have a zero mean and unit variance. All regressions include (not tabulated) an intercept, *Credit*, *Equity*, *EventDriven*, *InvestOtherFunds*, *Macro*, *ManagedFutures*, *RelativeValue*, and *Other*. Quarter dummies are included in (1). *t*-statistics are reported in parentheses. Standard errors account for heteroskedasticity and fund-level clustering. *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Mismatch		*AssetIlliq*	*FinInvIlliq*
	(1)	(2)	(3)	(4)
Ln(NAV)	-9.84***	-9.80***	-16.39***	-6.51*
	(-2.81)	(-2.81)	(-5.10)	(-1.75)
Ln(Leverage)	16.24***	16.23***	-6.46***	-23.00***
	(7.31)	(7.31)	(-3.38)	(-9.76)
HHI	1.61	1.64	0.89	-1.34
	(0.38)	(0.39)	(0.25)	(-0.27)
Ln(AdvNAV)	6.09**	6.08**	11.79***	5.46*
	(2.36)	(2.36)	(4.75)	(1.94)
DiscRestrict	28.06***	28.05***	-88.46***	-117.15***
	(3.48)	(3.47)	(-10.97)	(-12.06)
IndepAdmin	-26.31**	-26.08**	-70.09***	-42.72***
	(-2.55)	(-2.53)	(-6.44)	(-4.51)
#Brokers	-8.54***	-8.55***	-2.36	6.42***
	(-3.78)	(-3.79)	(-1.26)	(2.60)
Top5Owner	0.70	0.66	-18.03***	-18.67***
	(0.22)	(0.20)	(-6.46)	(-5.38)
AdvOwner	-4.65**	-4.59**	-4.19**	0.56
	(-2.05)	(-2.03)	(-2.05)	(0.21)
VIX		3.11***	2.16***	-0.90
		(4.51)	(3.71)	(-1.27)
Quarter dummies?	Yes	No	No	No
Strategy controls?	Yes	Yes	Yes	Yes
Observations	6,944	6,944	6,944	6,944
R-squared	0.110	0.109	0.513	0.486

Appendix: Variable definitions

Variable	Description and data source
#Brokers	Number of prime brokers used by the fund
AdvNAV	Adviser HFs AUM.
AdvOwner	Ownership % of Adviser and Related Persons. Form ADV.
AssetIlliq	Asset illiquidity is defined as *PortIlliq**(1-(*Cash*/*GAV*))+1*(*Cash*/*GAV*).
Cash	Unencumbered cash available to the fund at the end of the quarter. Form PF, Q33
CashRatio	*Cash*/*NAV*
Credit	Percentage of fund's NAV following Credit strategy. Form PF, Q20.
DiscRestrict	Dummy equal to 1 if fund can enact discretionary liquidity restrictions. Form PF, Q49(b,c).
Equity	Percentage of fund's NAV following Equity strategy. Form PF, Q20.
EventDriven	Percentage of fund's NAV following Event Driven strategy. Form PF, Q20.
FinIlliq	Average commitment period of available borrowing. Form PF, Q46(b).
GAV	Gross asset value (millions). Form PF, Q8.
HHI	Herfindahl-Hirschman Index using NAV percentage weights of seven portfolio strategies. It is defined as *Credit*^2 + *Equity*^2 + *EventDriven*^2 + *InvestsOtherFunds*^2 + *Macro*^2 + *ManagedFutures*^2 + *OtherStrategy*^2.
IndepAdmin	Dummy variable equal 1 if fund uses an independent administrator. Form ADV.
InvestsOtherFunds	Percentage of fund's NAV following Investment in Other Funds strategy. Form PF, Q20.
InvIlliq	Average commitment period of equity investors. Form PF, Q50.
Leverage	Fund leverage: *GAV*/*NAV*
FinInvIlliq	Liability and equity illiquidity is defined as *InvIlliq***NAV*/*GAV*+*FinIlliq**(1-*NAV*/*GAV*).
Macro	Percentage of fund's NAV following Macro strategy. Form PF, Q20.
ManagedFutures	Percentage of fund's NAV following managed Futures strategy. Form PF, Q20.
Mismatch	The difference between the illiquidity of a hedge fund's assets (*AssetIlliq*) and the illiquidity of its liabilities and equity (*FinInvIlliq*).
NAV	Net asset value (millions). Form PF, Q9.
NetFlow	Quarterly net flows computes as [*NAV*(q)-*NAV*(q-1)*(1+*NetReturn*(q))]/*NAV*(q-1)
NetReturn	Quarterly net-of-fees returns computed as the product of (one plus) the monthly returns within the quarter, minus one.
OtherStrategy	Percentage of fund's NAV following Other strategy. Form PF, Q20.
PortIlliq	Average number of day needed to liquidate fund's non-cash assets. Form PF, Q32.
RelativeValue	Percentage of fund's NAV following Relative Value strategy. Form PF, Q20.
Top5Owner	Percentage of fund's equity own by top 5% owners. Form PF, Q15.
TotBrwAvail	Total borrowing available. Form PF, Q46 (a).
UnusedBrw	Unused borrowing. Equals *TotBrwAvail* - *UsedBrw*.
UnuBrwRatio	*UnusedBrw* / *TotBrwAvail*
UsedBrw	Actual used borrowing. Form PF, Q43 or, if missing, then Q12.
VIX	Level of VIX