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Abstract

Of first-order importance to the study of potential systemic risks in hedge funds is the aggregate size of the industry. The worldwide hedge fund industry has been estimated by regulators and industry experts as having total net assets under management of $2.3 – 3.7 trillion as of the end of 2016. Using a newly combined database of several hedge fund information vendors, augmented by the first detailed, systematic regulatory collection of data on large hedge funds in the United States, we estimate that the worldwide net assets under management were at least $5.2 trillion in 2016, over 40% larger than the most generous estimate. Gross assets, which represent the balance sheet value of hedge fund assets, exceed $8.5 trillion. We further decompose hedge fund assets by their self-reported strategy and by fund domicile. We also show that the total returns earned by funds that report to the public databases are significantly lower than the returns of funds that report only on regulatory filings, both in aggregate and within nearly every fund strategy. This difference appears to be driven entirely by alpha, rather than by differences in exposures to systematic risk factors. In fact, we find that market beta is substantially higher for publicly reporting funds. However, net investor flows are considerably higher for funds reporting publicly. Regression results show that previous estimates of the flow-performance relationship are likely biased. Our new, and much larger, estimates of the size of the hedge fund industry should help regulators and prudential authorities to better gauge the systemic risks posed by the industry, and to better evaluate potential data gaps in private funds. Our results also suggest that systematic risk is roughly similar in publicly and non-publicly reporting funds.

Key words: Hedge funds, net assets, gross assets, strategy, domicile, returns, flows
JEL: G23, G28

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1 Introduction

At least since the wind-down of Long-Term Capital Management in September 1998, hedge funds have been widely recognized as having the potential to pose systemic risks to financial markets.[1] The use of leverage, illiquidity of holdings, and the interconnectedness of hedge funds with other major financial market participants, such as prime brokers and repurchase agreement (repo) counterparties, further demonstrates the importance of hedge funds in the financial system. Additionally, the rapidly increasing scale of the industry, reflected in the growth of aggregate assets under management and its widening clientele base, magnify concerns about the potential systemic importance of hedge funds.[2]

Despite the interest in the hedge fund industry from both regulators and market participants, basic facts remain in question. Just how large is the worldwide hedge fund industry in terms of total assets under management (AUM)? And, how is the scale of the industry distributed among different hedge fund strategies and geographic regions? To which systematic risks are funds most exposed, and what does industry performance look like once those risks have been accounted for? Does risk-adjusted performance persist through time, or is performance largely unpredictable?

Reliable estimates of these quantities have proven elusive because, until recently, regulatory data collections on hedge fund activities were limited. This left public hedge fund vendor databases, such as Hedge Fund Research (HFR) and Lipper TASS, as the data most readily available to industry observers. However, such vendors collect data from funds on a purely voluntary basis, and many of the very largest hedge funds choose not to list in any of the vendor databases (Edelman, Fung, and Hsieh (2013) (EFH)).[3] Yet, it is exactly these mega hedge funds that may pose the largest systemic threats to financial markets (e.g., Long-Term Capital Management in 1998). While recent regulatory collections in the United States and Europe attempt to fill this gap, estimates based on these collections remain incomplete due to a lack of jurisdictional overlap.

The impediments to accurate estimates of key industry features are evident from the dispersion in the estimates of industry size: Eurekahedge ($2.33 trillion); HFR ($3.21 trillion); eVestment ($3.25 trillion); Barclay Hedge ($3.54 trillion); and Preqin ($3.55 trillion) constitute merely a subset of such estimates.[4] The vast majority of publicly

[1] More recently, the Dodd-Frank Act, Section IV, requires large U.S. hedge funds to register with the Securities and Exchange Commission, and to file periodic reports (either annual or quarterly) of their activities, a reflection of the growing concerns of Congress about the activities and scale of hedge funds.

[2] Size and interconnectedness are two of the basic factors stipulated in the Dodd-Frank Act to determine whether a financial institution is "systemically important."

[3] EFH collect historical printed volumes, over a 10-year period, from Institutional Investor's annual "Hedge Fund 100," which is a list of the 100 largest hedge fund firms, and Absolute Return+Alpha magazine's semiannual "Billion Dollar Club," which is a list of all firms managing $1 billion or more in assets.

[4] All estimates are as of 2017. Eurekahedge corresponds to the third quarter, whereas all others correspond to the fourth quarter.

available estimates fall between \$3.0-3.5 trillion.[5] The largest publicly available estimate to date is \$3.89 trillion, which comes from the Securities and Exchange Commission's (SEC) estimate based on regulatory data as of the fourth quarter of 2017.[6]

In this paper, we obtain the most credible estimates to date of the total size of the hedge fund industry, its overall performance, and the behavior of investor capital flows. To do so, we combine data from seven public hedge fund data vendors with the first-ever systematic regulatory collection of data on large hedge funds for the period 2013 – 2016. Many of the funds in the regulatory data do not report to any public database, whereas all hedge funds of sufficient size that register with the Securities and Exchange Commission must report on the regulatory filing. This allows us to conduct two sets of analyses: one that examines industry aggregates, such as the total size of the industry, and another that explores the differences between publicly and non-publicly reporting funds and the implications for bias in publicly available data.

Our analysis begins by addressing the most fundamental question first: how big is the hedge fund industry? Based on this newly aggregated data, our conclusion is that the industry is considerably larger than any existing estimate. We estimate the hedge fund industry is at least \$5.2 trillion in net assets under management as of the end of 2016, more than 40% larger than the next largest estimate. We estimate that the total gross assets under management, which represent assets purchased with equity capital and borrowing, exceed \$8.5 trillion. This implies an average leverage factor of 1.6 across all funds. When we augment gross assets with regulatory assets reported on Form ADV, total gross assets exceed \$8.7 trillion. For comparison, this makes the hedge fund industry's economic footprint almost 90% as large as total home loan mortgage debt in the United States, which stands at roughly \$10 trillion. The hedge fund industry in aggregate grew by around 33.6% between 2013 – 2016, but growth was largely in non-publicly reporting funds; publicly-reported assets grew by only 20.6%, whereas non-publicly reported assets grew by 48.7%. Our estimates are larger and more comprehensive because each previous estimate has missed a significant portion of the industry, and our approach in part closes this gap. For various reasons discussed in detail below, our much larger estimates of industry size are likely to still constitute an underestimate.

We also examine the distribution of assets, separately for publicly versus non-publicly reporting funds, by fund strategy and fund domicile. We find that some strategies are better represented in the public data than others. Publicly reporting Macro and Credit funds constitute 61% and 76% of total gross assets, respectively, while Multi-strategy and

[5] As a recent example, eVestment estimates the worldwide assets under management of hedge funds, as of June 30, 2018, at \$3.31 trillion (http://www.evestment.com/wp-content/uploads/2018/08/201807-Hedge-Fund-Asset-Flow-Report.pdf)

[6] See SEC's Private Fund Statistics: https://www.sec.gov/divisions/investment/private-funds-statistics/private-funds-statistics-2017-q4.pdf.

Relative Value funds constitute only 43%. Unsurprisingly, the publicly reported data under-represents the net assets in U.S. domiciled funds relative to the (U.S.) regulatory data, but significantly over-represents European domiciled fund assets. If the patterns of non-reporting U.S. funds are a reasonable proxy for non-reporting European funds, our data suggest the "missing" European funds' assets may indeed be substantial. This is one reason that our estimates of global hedge fund AUM may understate the industry's true size.

Next, we undertake a thorough assessment of industry performance, both in aggregate and separately for public and non-public reporters. Accurately measuring performance is crucial for understanding which risk factors hedge funds are exposed to as well as the sensitivity of investor capital to historical returns. Each is critical for evaluating the potential financial stability consequences of hedge fund activities. First, we document that the total returns earned by funds that do not report to any public database are dramatically higher than for publicly reporting funds. This performance difference is evident both in aggregate and within nearly every fund strategy. The total return to the AUM-weighted average portfolio of non-publicly reporting funds is 26.6% over the sample period; comparatively, the total return to the value-weighted portfolio of funds reporting to at least one public database is 9.4% over the same period. Similar differences are found within almost all strategy types.

The outperformance of non-publicly reporting funds could be due either to greater risk-adjusted returns (alphas), or greater exposure to systematic risks such as the return to the overall stock market or aggregate liquidity. Understanding the source of these observed higher returns therefore has important implications for systemic risk. If non-publicly reporting funds are both larger and earn higher returns through greater risk exposures, fund performance could be particularly poor during times of economic stress. This could serve to magnify declining prices across a variety of markets, or lead to forced liquidations during times when prices are already depressed. Instead, if return differences are due largely to differences in mean returns, then systematic risks may be no bigger in the larger, non-publicly reporting funds than in the smaller, publicly reporting funds.

We find that exposure to market risk, as measured by the market beta in a standard factor regression, is significantly higher and more varied for publicly reporting funds. The mean market beta for publicly reporting funds is 0.51, with a standard deviation of 0.52. For non-publicly reporting funds, average market beta is -0.03, with a standard deviation is 0.21. Differences in the tails of the distributions are even more pronounced; the 75^{th} and 90^{th} percentiles of market beta for publicly reporting funds are 0.82 and 1.13 respectively, but for non-publicly reporting funds is 0.04 and 0.14. Differences in exposures to the remaining risk factors, including value, momentum, and liquidity risk among others, are much smaller, although publicly reporting funds show greater exposures to four of the six non-market factors.

The greater exposure to systematic risks for publicly reporting funds, which on average earn a risk premium and associate with higher returns, points toward risk-adjusted returns as the primary source for the better performance of non-publicly reporting funds. We estimate alphas through three separate approaches. First, we compare the intercepts in our time-series factor regressions (Jensen's alpha). Monthly gross-of-fee alphas for publicly reporting funds have a mean of -0.146% and a median of -0.086%, compared with a mean and median of 0.913% and 0.707% for non-publicly reporting funds. This translates to an implied annual difference in alpha of nearly 10 percentage points.

Our next approach to measuring alpha uses the bootstrap methodology of Fama and French (2010) to create a synthetic sample of hedge fund returns that are zero-alpha by construction. This sample maintains all of the empirical characteristics of actual realized returns, but imposes that alpha in each fund is zero. We can then compare the t-statistics of the actual, realized alphas to the alpha t-statistics sampled from the zero-alpha distribution. We form a one-sided hypothesis test by calculating the fraction of bootstrapped values that are above the actual realized value at each quantile of the distribution. We find that for publicly reporting funds, we are unable to reject that null that alpha is zero at the 5%-level until the 80$^{\text{th}}$ percentile of the distribution. Alternatively, for non-publicly reporting funds we are able to reject the null of zero-alpha beginning at the 5$^{\text{th}}$ percentile. That is, we find little statistical evidence for alpha in publicly-reported data, but find substantial evidence of alpha in the non-public data.

To assess whether observable fund characteristics can explain differences in risk-adjusted performance between public and non-public reporters, we estimate cross-sectional Fama-MacBeth regressions of pricing errors (alphas plus residuals) estimated from the first-stage regression on controls for fund size, strategy, investor share illiquidity, fees, and lagged performance. These controls, while able to explain some of the variation in performance, do little to explain the differences in risk-adjusted returns between publicly and non-publicly reporting funds. Coefficient estimates indicate that, conditional on characteristics, monthly alphas in non-publicly reporting funds range between 0.28% – 0.45%, depending on the model. We conclude that performance differences are unlikely to result from observables.

Our final analysis of hedge fund performance examines persistence in returns. Previous studies have found mixed evidence of persistence in hedge fund returns, although most generally find some support for persistence.[7] Instead, we find strong empirical support for performance persistence — but again only for non-publicly reporting funds. Funds that report publicly show limited persistence over short horizons and no persistence over medium or long horizons. Non-publicly reporting funds display strong persistence, with economically large and highly significant coefficients, throughout nearly all estimation and prediction horizons. These results maintain when we account

[7] See Jagannathan, Malakhov, and Novikov (2010), Boyson (2008), and Fung, Hsieh, Naik, and Ramadorai (2008) as few examples.

for return smoothing, selection bias induced by survivorship, and numerous other controls.

Lastly, we examine investor flows. There is an extensive literature that examines the flow-performance relationship in hedge funds, and our data allow us to examine both aggregate industry flows and whether publicly reporting funds differ in the association between returns and net inflows of investor capital. The sensitivity of flows to performance has important consequences for financial stability. If funds face large redemptions during periods of poor performance, they may be forced to sell assets quickly and at steep discounts. In the extreme case, this could lead to fire sales in particular markets or assets. While the performance of publicly reporting funds is substantially lower than funds that do not report publicly, we find that investor flows into publicly reporting funds are substantially *higher*. This pattern once again holds both in aggregate and within fund strategies. This is consistent with funds using public data vendors as a tool to raise investor capital, and with large funds (which are less likely to report publicly) nearing their investment capacity.

The combination of lower performance and greater net flows for publicly reporting funds suggests the flow-performance relationship — a topic of significant interest in the study of asset management — may be biased upwards.[8] Indeed, Fama-MacBeth regressions suggest that the flow-performance relationship for non-publicly reporting funds is nearly 80% weaker. A 10 point improvement in percentile performance rank in the previous quarter is associated with a 1.03 percentage point greater expected flow for publicly reporting funds; non-publicly reporting funds would instead expect only a 0.18 percentage point increase in flows for a similar improvement in performance.

Our findings on the significant differences in performance and flows of publicly versus non-publicly reporting funds shed new light on selection bias in publicly available data. Aiken, Clifford, and Ellis (2013) and Agarwal, Fos, and Jiang (2013) find evidence that selection into public reporting biases performance upwards. Other biases in public data, including backfill and delisting biases, yield similar conclusions. In contrast, we find that selection bias is strongly negative in public data; the best performing funds are less likely to report publicly. Further, we document selection bias not only in risk-adjusted returns, but in risk exposures as well. In total, our results indicate that industry performance, risk, and the relationship between investor capital flows and performance are all substantially affected by funds' endogenous decision to report to a public database.

Our empirical methodology is straightforward, yet made possible by complicated matching tasks between funds in public databases and publicly available regulatory information. We first construct a sample of publicly reporting funds as the (mathematical) union of a matched sample of seven public hedge fund databases: HFR, Lipper TASS,

[8]See Fung, Hsieh, Naik, and Ramadorai (2008), Agarwal, Green, and Ren (2018), Getmansky (2012), and Liang, Schwarz, Sherman, and Wermers (2019) as some recent examples of the existing work on the flow-performance relationship in hedge funds.

Preqin, Barclay Hedge, Eurekahedge, Morningstar, and eVestment. Next, we take the full set of unique hedge funds from the Securities and Exchange Commission's (SEC) Form ADV (a publicly available filing), and name-match these funds to the merged public data. This determines which Form ADV funds provide information to one of the public hedge fund data services, and associates an SEC identifier with each publicly reporting fund that also reports on ADV. Finally, we collect data from Form PF — the first U.S. regulatory collection of data on hedge funds that have an economically significant size. We then exclude from Form PF any fund that already reports to one of the public databases, which we are able to determine from the matching exercise between the public data and (public) Form ADV. This gives us data for funds that don't report to any public database. The combination of data reported to the public data services, and those reported on Form PF but not to any public data services, generates our combined sample of publicly and non-publicly reporting funds.

To our knowledge, the only other paper that attempts to document the level of hedge fund AUM that is not reported to vendor databases is EFH. Specifically, EFH estimate that the hedge fund industry is 65% larger than a consolidation of three vendor databases (BarclayHedge, HFR, and TASS) would suggest, based on data from 2010. We find that a replication of the mega funds methodology from EFH produces an estimate of industry size that is $1.2 trillion larger than that obtained only from the public data. Alternatively, the Form PF data contribute an additional $2.7 trillion, or roughly $1.5 trillion more than would be added using the EFH methodology. This further highlights the contribution of this paper beyond what has previously been provided in the literature.

Our paper proceeds as follows. In Section 2, we describe the databases used in our study, as well as the matching procedures we use to link them together. Section 3 provides empirical results on the size of the worldwide hedge fund industry, including the distribution of assets under management by strategy and fund domicile. Section 4 examines fund performance. Section 5 studies investor flows. Section 6 concludes.

2 Data

2.1 Public Hedge Fund Data

To form the data set from the publicly available hedge fund databases (what we call the *public data*), we consolidate seven major commercial hedge fund databases: Lipper TASS, HFR, BarclayHedge, EurekaHedge, Morningstar, Preqin, and eVestment. Each database contains fund characteristics (e.g., investment style, compensation structure, and liquidity provisions), which we harmonize across databases, and monthly time series of returns and net asset values (NAVs), which we restrict to monthly net-of-fees returns and convert to U.S. dollars using rates we obtain from Bloomberg. We assign each database-level fund with a harmonized public fund and firm identifier. Our identifiers are common across and within databases. Harmonization within databases is important because, except for Preqin, individual databases assign distinct fund identifiers to share classes of the same fund (e.g., onshore and offshore classes). For additional details about the construction of the merged public data, we refer the reader to Joenvaara, Kauppila, Kosowski, and Tolonen (2019).

To calculate the total value of public NAV, we sum the individual fund-level NAV in each month and year across all seven databases. To avoid double-counting, we take great care to ensure we include only one NAV observation per fund in each period, and exclude all funds-of-funds. In cases where a fund reports different NAV values to different public databases, we use the average. Because funds may manage multiple share classes (e.g., onshore and offshore classes), each of which represent a separate pool of managed assets that should be included in the total, this summation may include multiple share classes within the same fund. In cases where one share class constitutes a master share class whose NAV represents the total NAV of the fund across all share classes, we use only the master share class in the summation. To calculate quarterly public NAV at fund level, we use the latest non-missing monthly NAV within the quarter.

2.2 Form PF

For non-public hedge fund data, we use fund-level regulatory data from the Security and Exchange Commission's (SEC) *Form PF* ("Private Fund").[9] Form PF was established in a joint rule-making by the SEC and the Commodity Futures Trading Commission in 2011 to fulfill a mandate in the Dodd-Frank Wall Street Reform and Consumer Protection Act of 2010 to collect data that allows monitoring of large private funds. Except for a short period in 2006, when hedge funds were required to register with the SEC (Brown, Goetzmann, Liang, and Schwarz (2008)), Form PF constitutes the first detailed regulatory data collection of various hedge fund activities in the United States.[10]

Form PF has different reporting requirements for hedge fund advisers of different sizes, and no reporting requirement for advisers who manage less than $150 million in aggregate hedge fund assets. All investment advisers registered with the SEC who manage at least $150 million in private fund assets (which include hedge funds, private equity funds, and liquidity funds), must file Form PF at least annually, and report information on gross and net asset values, gross and net returns, total borrowings, strategy classifications, investor composition, and their largest counterparties.[11] *Large Hedge Fund Advisers* — those with at least $1.5 billion in assets managed in hedge funds —

[9]Form PF data are confidential. The Office of Financial Research has access to the data through an agreement with the SEC. The form itself is publicly available and can be downloaded here: https://www.sec.gov/rules/final/2011/ia-3308-formpf.pdf.

[10]Form ADV, also filed with the SEC, is a public source of some limited hedge fund data. See https://www.sec.gov/fast-answers/answersformadvhtm.html. Form PF, however, requires much more granularity in reporting than that required by Form ADV.

[11]Non-U.S.-domiciled advisers are not required to report private fund assets that are not organized in the U.S. and are not offered to

are required to report this information quarterly for each of their *Qualifying Hedge Funds* — funds with a net asset value of at least $500 million — as well as more detailed information regarding portfolio, investor, and financing liquidity; asset class exposures; collateral posted; risk metrics; and more.[12]

Because many large funds do not report to any of the public hedge fund data services (EFH), and such data services predominantly comprise smaller funds, Form PF offers an unprecedented view of the activities of some of the largest hedge funds offered to U.S. investors. The lack of public reporting by many large funds is the primary reason estimates of the size of the hedge fund industry based on public databases are too small.

2.3 Matching Procedure

To calculate the total size of the hedge fund industry, we aggregate the total net assets of funds that report to one or more of the public databases and the net assets of funds reporting to Form PF, without double-counting funds that report to both. To do so, we first match the public data to regulatory data contained in SEC's Form ADV.

Form ADV is a publicly available filing that requires investment advisers to report, on an aggregated basis, information on the private funds that they advise. Form ADV also requires advisers to list the SEC identifier (an "805-" number) of each private fund advised by the adviser.

To match SEC identifiers to funds in the public data, we first collect the names and SEC identifiers of all private funds identified by their adviser as "hedge funds" on Form ADV. Next, we match each ADV-reporting hedge fund name with public fund name clusters, which group similarly named funds across the seven public databases.[13] We then tentatively assign each ADV fund name to the cluster that contains its closest public fund name. Next, we manually verify and correct these tentative matches, using the public adviser name and Form ADV adviser name as context clues. If a private fund cannot be matched to a reasonably similar public fund cluster, we mark it as a non-matched private fund during the manual verification. For these non-matched private funds, our only fund-level data come from Form PF. Finally, to resolve the mapping of SEC fund identifiers to individual public funds (not clusters),

U.S. investors. Detailed investment adviser registration requirements can be found at: https://www.sec.gov/about/offices/oia/oia_investman/rplaze-042012.pdf.

[12] The thresholds for filing Form PF and for the "Large Hedge Fund Adviser" classification are on a gross basis, but the threshold for "Qualifying Hedge Fund" status is on a net basis, and is as of the last day in any month in the fiscal quarter immediately preceding the adviser's most recently completed fiscal quarter. Moreover, when determining whether a reporting threshold is met, advisers must aggregate the asset values of the funds themselves, associated parallel funds, dependent parallel managed accounts, and master-feeder funds. Advisers must also include these items for related persons that are not separately operated. Finally, while reporting thresholds are determined on an aggregate basis, advisers are permitted to report fund-level data on either an aggregate or disaggregate basis. Thus, some qualifying hedge funds in our sample have a NAV less than the associated threshold of $500 million. See Flood, Monin, and Bandyopadhyay (2015) and Flood and Monin (2016) for more information on the structure and history of Form PF. The additional information filed by Qualified Hedge Funds is reported in Section 2b of Form PF.

[13] In the merged public hedge fund data, fund names are manually clustered across databases in the initial stage of matching, then additional mapping steps are employed based on return correlations and other characteristics. For details see Joenvaara, Kauppila, Kosowski, and Tolonen (2019).

for each fund name (and its associated SEC identifier) in ADV, we pick the closest public fund name appearing in the matching original (uncorrected) name cluster.

The value of matching the funds in the public data to funds in ADV is that the SEC identifiers are common between Form ADV and Form PF. This allows us to determine whether a given fund reporting to Form PF has also reported net assets to one of the public databases. To estimate the total net assets of hedge funds that do not report to any of the public databases, we add up the net assets reported on Form PF for funds that were not matched to any fund in any of the public databases, or for funds that were matched but do not report net asset values to any public database. Many funds that report returns and other information to public databases often do not provide information on net assets. Thus, the net assets we calculate from Form PF are associated with funds that either (i) do not report to any public database, or (ii) report to a public database but do not provide data on their net assets. We note that, due to data restrictions associated with confidential Form PF data, for funds that appear in both Form PF and at least one of the public databases, we use the value of the assets reported to the public database rather than to Form PF. While the regulatory data are likely more accurate in cases where the net assets are reported to both Form PF and a public database, confidentiality requirements make using the regulatory data unfeasible in such cases.

Finally, we note that there is no formal definition of a "hedge fund." In order to avoid including private funds that are not properly considered hedge funds, we only include funds that report to public hedge fund databases, or funds that categorize themselves as a hedge fund on Form PF. We note that some funds file as a hedge fund on Form ADV, but file as an ”Other” private fund on Form PF. Out of an abundance of caution, such funds are not included in our analysis.

3 The Size of the Hedge Fund Industry

3.1 Net Assets Under Management

Our estimate of the size of the hedge fund industry is the aggregation of net assets reported to the public databases (*public net assets*), plus net assets reported on Form PF excluding funds that report net assets to any of the public databases (*non-public net assets*). As noted previously, we are not able to capture data for funds that are listed neither in Form PF nor the union of public databases. This will include small hedge funds that do not meet the minimum size threshold for regulatory reporting, or large funds that are not required to register with the SEC (for example, funds with no U.S. resident investors). These "omitted assets" can be substantial, as suggested by

EFH, who show that very large hedge funds often do not report to public vendors.[14] Thus, while our estimates of the size of the hedge fund industry are substantially larger than any prior estimates, we are nonetheless still likely to underestimate the industry's true size.

The top panel of Figure 1 plots the time series of net assets for funds that report net assets to at least one of the public databases, as well as for funds that do not report net assets to any of the public databases, but do report on Form PF. The total net assets of funds reporting to at least one public database is just over $2.5 trillion as of December 2016. The total net assets of funds that do not report net assets to any of the public databases, but do report to Form PF, is $2.7 trillion, larger than the net assets reported across the *entirety* of the publicly available data. Note that this disparity excludes funds that report to both the public databases and Form PF, as the net assets for such funds are included in the calculation of public net assets (and not in the calculation of non-public net assets).

The times-series of total net assets (both public and private) is shown in the bottom panel of Figure 1. In total, the combination of publicly reporting and non-publicly reporting funds' net assets is $5.2 trillion as of the end of 2016. This is about 42% larger than the next highest estimate of $3.66 trillion as of December 2016, which is provided by the SEC using (only) data derived from Form PF. We note that our estimate is not larger due to a new estimation technique or imputation procedure; rather, our estimates are larger simply because we have a larger cross-section of funds than has been previously available in any other analyses. The bottom row of Panel A in Table 1 reports the precise values of public and non-public net assets, as well as their total, as of year-end for the period 2013–2016.

Further, while the net assets reported to public databases have slightly declined since mid-2015, the net assets reported to Form PF, but not to the public data, have grown steadily over the 2013-2016 period. From first quarter 2013 to fourth quarter 2016, public net assets have grown from $2.1 to $2.5 trillion (a 19% increase), while non-public net assets have grown from $1.8 to $2.7 trillion (a 49% increase). This further highlights the importance of regulatory data to build a more precise estimate of the size and growth of the industry.

We also note that while the regulatory data are an important source of information not available in the public data, it is also incomplete. Figure 2 shows the time-series of total net assets managed by funds with no corresponding SEC identifier; that is, for funds with no requirement to report to Form PF or Form ADV. As of 2016, such funds managed nearly $1.4 trillion in net assets, which demonstrates a significant data gap in U.S. regulatory collections of global hedge fund data. While U.S. regulatory agencies have no direct oversight over such funds, they nonetheless are likely to participate in U.S. financial markets and may engage with U.S. counterparties.

[14] We also cannot capture the perhaps thousands of very small hedge funds, even in the United States, that choose not to market themselves through vendor databases—and are too small to be required to be included in a Form PF filing.

Finally, we can compare the incremental increase in net assets due to the inclusion of Form PF data to that which would be achieved through the inclusion of “mega funds.” Edelman, Fung, and Hsieh (2013) show that estimates of net assets for some of the largest hedge funds are available through various public sources, including the HFM Absolute Return Billion Dollar Club list, the Top 100 Hedge Fund list, and the Top 50 European Hedge Fund list. Does Form PF, which captures data on larger funds, contribute any additional information about industry size beyond what could be obtained through these publications alone? The answer is yes. The inclusion of data from these sources would add an additional $1.197 to our existing public-data estimate of $2.5 trillion, bringing the total to roughly $3.7 trillion. Instead, the Form PF data contribute an additional $2.7 trillion, more than $1.5 trillion more in net assets than would be captured from these additional sources. Thus, our tabulation of hedge fund assets greatly exceeds even the most earnest previous attempts to classify the true size of the hedge fund industry.

3.2 Gross Assets Under Management

A well-known feature of hedge funds is the use of balance sheet leverage. Balance sheet leverage arises from the investment of borrowed funds — generally through collateralized borrowing (e.g., securities lending or repurchase agreement borrowing) or through direct borrowing from the fund’s prime brokers — and simultaneously increases the assets and liabilities of the fund. All else equal, leverage increases the magnitudes of gains and losses of an investment strategy relative to the payoff of the strategy funded only by investor capital. Because hedge fund investments are funded by both investor capital and borrowing, the *gross assets* of the fund are a better measure of funds’ economic exposures and potential systemic risk to various sectors of financial markets than net assets, which only represent the equity capital of the fund.[15]

Form PF explicitly collects the gross assets of reporting hedge funds in addition to their net assets, giving us a direct and reliable measure of funds’ balance sheet leverage.[16] Unfortunately, the public databases only collect this information for a subset of funds, as fund leverage is a potentially sensitive part of a fund’s strategy. For public funds, we calculate funds’ gross asset values (GAV) by scaling the NAV reported to the public database by the funds reported leverage ratio. If the leverage ratio is not reported, we impute it as the NAV-weighted mean leverage ratio within the same quarter and investment style of publicly reporting funds. If the fund reports multiple leverage ratios that differ across databases, we use the median.

While our approach for determining leverage in public funds is likely to suffer from estimation error, the average

[15]The so-called “Quant Crisis” of August 2007 illustrated that deleveraging by some very large hedge funds very likely was responsible, in part, for the dislocation in financial markets (Khandani and Lo (2011)). Another example is the panic created by the specter of a large “wind-down” by Long-Term Capital Management in September 1998.

[16]Balance sheet leverage is simply gross assets divided by net assets.

leverage we estimate for public funds is highly sensible. We estimate average leverage of 1.54, which is nearly identical to the average level of 1.63 estimated from Form PF. An alternative approach to estimating gross assets in public funds that simply multiplies public net assets by average leverage (in total or by strategy) estimated from Form PF would therefore produce highly similar results.

The top panel of Figure 3 shows the value of gross assets separately for publicly and non-publicly reporting funds, and the bottom panel shows their total. Our estimates indicate that gross assets in the hedge fund industry exceed $8.5 trillion at the end of 2016. By comparison, total U.S. home loan mortgage debt is roughly $10 trillion; that is, hedge fund gross assets are about 85% as large as the entire U.S. home loan mortgage industry. Note, again, the higher growth rate of gross assets of the non-publicly reporting funds over the sample period.

We make one additional modification to our estimates of hedge fund gross assets using Form ADV. Because investment advisers must report to Form ADV if their total regulatory assets under management (gross assets) exceed $150 million, while advisers only report to Form PF if their *private* regulatory assets under management exceed $150 million, there are some hedge funds that report on Form ADV but not on Form PF. For these hedge funds, we add their gross assets to our measure of total gross assets from Form PF.

We again exercise an abundance of caution by excluding funds that report either as a master or a feeder fund on Form ADV, that categorize themselves as a fund-of-funds, or that are a parallel fund in a parallel fund structure. The addition of these funds increases our estimates of gross assets by roughly $200 billion, pushing our estimates of total gross hedge fund assets above $8.7 trillion. The time-series of gross assets that include data Form ADV is shown in Figure 4.

3.3 Net and Gross Assets by Fund Strategy

Panel A of Table 1 decomposes the size of the industry by strategy category. Our strategy classifications are derived from Form PF, which asks funds to report the fraction of their assets that fall into each of 22 pre-selected strategy categories. These 22 categories fall under eight broader categories: Equity, Relative Value, Macro, Event Driven, Managed Futures, Credit, Invests in Other Funds, and Other. We classify funds that have less than 75% of AUM in any particular category as Multi-strategy funds. Because net assets that are invested in other private funds are excluded from NAV values in Form PF (to avoid double-counting), rather than exclude funds-of-funds from the strategy classification, we simply include them in the Other category. Note that the net assets of funds-of-funds included in any of our aggregates necessarily reflect direct investments of investor equity capital.

For the public data, we manually allocate funds to a strategy based on the Form PF categorization. The details of the specific mapping from self-reported strategy in the public data to Form PF strategy categories are shown in the Appendix.

The first observation from Table 1 is that researchers using public data, even if it is aggregated across all major vendors, miss a large fraction of funds within each strategy category. This calls into question the robustness of the conclusions found in the numerous previous hedge fund studies that rely exclusively on data from public sources.[17] This issue is particularly salient given the non-random nature of reporting to public databases.

Table 1 shows that in 2013 the most under-represented strategies are the Multi-strategy and Other categories, for which public databases include only 40% and 8% of reported net assets, respectively. By the end of 2016, several more categories join the "majority missing from public data" set — specifically, Equity, Event Driven, and Relative Value. This means that by 2016, more than half of all strategies had less than half of worldwide net assets accounted for by funds in any of the seven public databases — a substantial data gap by any measure. A similar result is found from gross assets, which is shown in Panel B.

One confounding factor in this analysis is the size of the Other category in the Form PF data. Publicly reporting funds, which presumably intend to raise additional capital, are incentivized to provide prospective investors with a clear strategy mandate. No such incentive exists in Form PF data, and funds are allowed to indicate that no broad strategy category fits their specific investment objective. In this case, funds are allowed to select the strategy "Other" and write in a self-reported strategy description. While our Form PF strategy classifications include manually assigning funds to a pre-selected strategy in cases where their write-in responses suggest such an assignment is appropriate, for many funds such a mapping is not possible. This may suggest that assets in the Other category in Form PF data are artificially inflated, and the over-representation of publicly reporting funds in certain strategy categories simply results from too many Form PF funds being categorized as Other when a standard category is suitable.

However, the size of the Other assets in Form PF funds may not solely result from noisy data. If funds with particularly unique or bespoke strategies are also the most harmed by or susceptible to reverse-engineering or front-running, then such funds would face the highest costs of reporting to public databases. We should then expect that the Other category in Form PF would be significantly larger than the Other category in public databases, because managers of rightly categorized Other strategies endogenously choose not to report to the public data to maintain a greater degree of secrecy. In this case, the results in Table 1 would suggest an important data gap arising from analysis based only on public data: many hedge funds with non-standard or difficult-to-classify strategies my be substantially under-represented.

[17] A salient example is the numerous very large hedge funds that do not report to public databases, as per EFH.

3.4 Net and Gross Assets by Fund Domicile

Table 2 decomposes net and gross assets by fund domicile. Fund domicile is a standard characteristic funds report to the public databases, because these often associate with considerations relevant to prospective investors (such as tax implications). Form PF does not contain information on fund domicile, but Form ADV does. Based on a mapping of Form PF funds to Form ADV (made possible by the common SEC identifier), we are able to determine fund domiciles for funds reporting to Form PF as well.

The results in Panel A show that Caribbean-domiciled hedge funds have the largest amount of total net assets missing from the public databases. This fraction of assets in Caribbean-domiciled funds missing from the public data has also grown over time. Roughly 52% of total net assets were missing from the public data in 2013, while more than 57% were missing by the end of 2016. Nearly 60% of U.S.-domiciled assets are missing from the public data; this is unsurprising given that the Form PF collection is based on private funds advised by investment advisers that are registered with SEC, and therefore may be skewed toward U.S.-domiciled funds.

Meanwhile, European-domiciled hedge funds are dramatically over-represented in the public data. Again, this is unsurprising given that the Form PF data covers only advisers registered with the SEC, a U.S. regulator. However, the difference in European-domiciled assets is suggestive of the potential size of missing assets in large European funds. For funds domiciled in the United States in 2016, non-publicly reporting funds have total net assets that are 142% larger than the total net assets in publicly reporting funds. If we apply the same percentage of "under-reporting" to European-domiciled funds, this would suggest an additional *$970 billion* in missing net assets. Of course, this number is purely speculative, and it may be that large hedge funds are more likely to domicile in the United States or the Caribbean, making this estimate of missing European hedge fund assets an overestimate. Nonetheless, if the pattern of reporting between public and non-public data in the United States is informative for European-domiciled funds, our estimates of the total size of the industry are likely to be too small by a significant margin.

The remaining domiciles appear to contain relatively little of the total net and gross assets of the global hedge fund industry (less than 10%). Similar patterns by domicile arise for total gross assets, which are shown in Panel B.

4 Performance

4.1 Gross Returns

> *The immediate question might be how so many hedge fund managers failed to do better...A bigger question, however, is why the investment performance of hedge funds has been so poor for so long.*

– Dan Mccrum, Financial Times, January 5th, 2017

The dramatic underperformance of hedge funds is pretty amazing considering the survivorship and backfill biases in the index data that skew hedge fund returns upwards by 3% to 5% per year.

– Peter Lazaroff, Enterprising Investor blog at CFAInstitute.org, February 24, 2016

Since the 2007 – 2009 financial crisis, the financial press and industry observers have lamented the relatively poor performance of hedge funds. While the nature of hedge funds (at least in their original conception) presupposes that funds should underperform a broad stock index during bull markets and outperform during bear markets, the *degree* of recent under-performance has received scrutiny.

Most hedge fund studies focus on the returns provided to investors, or the alphas that result from the application of asset-pricing models (most notably, the Fung and Hsieh (2004) model of hedge fund returns).[18] The vast majority of these studies rely solely on return data contained in public hedge fund databases, and industry observers are likewise limited to data available from industry service providers or private (and likely incomplete) collections.[19]

However, without a comprehensive accounting of fund returns, it is difficult to know the extent to which the performance of funds with publicly available data is representative of the experience of the industry as a whole. Yet, fund performance is an integral part of the potential for systemic risk in hedge funds. Because investor flows (studied in the following section) and the availability of capital have been shown to be sensitive to fund performance, understanding the aggregate performance of hedge funds is crucial for understanding the potential for large-scale asset sales and anticipating the future growth of the industry. Further, if well-capitalized funds provide liquidity during periods of stress, then historical returns may proxy for funds' ability to absorb underpriced assets.

The top panel of Figure 5 shows the size-weighted (by net asset value) average net-of-fee rate of return earned by funds reporting to at least one of the public databases, and by funds reporting only to Form PF, for the period January 2013 through December 2016. The top panel of Figure 5 shows that the returns to the public and private datasets appear to be highly correlated. Indeed, the time-series correlation of the value-weighted return series is 85% over the sample period. However, while the returns to public and non-public funds move together, the magnitudes appear to differ; the returns to funds in the public databases appear to have larger downsides and smaller upsides than the not-publicly reporting funds. Small differences in magnitudes in monthly rates of return could produce relatively large differences in total returns.

The bottom panel of Figure 5 plots the growth of one dollar invested at the end of 2012 in the value-weighted

[18] Getmansky, Lee, and Lo (2015) (GLL), provide an excellent survey of studies of hedge fund returns and alphas.

[19] Exceptions include EFH and Brown, Goetzmann, Liang, and Schwarz (2008).

portfolios of funds in the public and non-public databases. That is, the bottom panel of Figure 5 reports the cumulative, total return earned by the value-weighted portfolio of public and non-public funds, separately. The results are dramatic. A dollar invested in the public funds would be worth just under $1.09 at the end of 2016; the same investment in non-reporting funds would be worth $1.27. Privately reporting funds earned 18 percentage points higher total returns than publicly reporting funds over the four-year sample.

Figure 6 shows that the outperformance of non-publicly reporting funds is consistent across nearly every hedge fund strategy. One dollar invested in the NAV-weighted portfolio of public Equity-style funds would be worth $1.14; one dollar invested in the portfolio of private Equity-style funds would be worth $1.36, a cumulative performance difference of 22 percentage points. Similar outperformance of the non-publicly reporting funds is found in Relative Value strategies (9% total return vs. 32%), Credit strategies (5% vs. 20%), Event Driven strategies (19% vs. 42%), Multi-strategy (9% vs. 25%), and Other strategies (10% vs. 21%). The only strategies for which the non-publicly reporting funds did not outperform the publicly reporting funds are Macro strategies (3% total return for publicly reporting funds vs. 0% for non-publicly reporting funds), and Managed Futures (9% vs -5%). Although we note that Managed Futures funds in the Form PF data may not be representative due to commodity trading advisers ability to report to the CFTC and not to Form PF. These results are consistent with Barth and Monin (2018), who find substantial alpha using the Form PF data over a similar sample period.

Of course, there may be different reasons why hedge funds choose not to list in public databases, many of which have been previously addressed in the literature, and which would naturally lead to average return differences between the public and non-public datasets. First, as documented by EFH, very large and successful hedge funds — those most likely to possess skill — may be reticent to list in public databases due to the potential for reverse-engineering or otherwise intensified attention to their strategies. Large and successful funds may also be nearing diseconomies-of-scale in the capacity of their investment style. If diseconomies-of-scale bind, we might expect larger, more successful funds to have worse performance than smaller funds who have yet to reach their full investment capacity.[20] Second, unsuccessful hedge funds may strategically choose to not publicize their returns in order to minimize the publicity that their poor performance generates (e.g., through word-of-mouth or through the media) in order to stem outflows from existing investors or to promote inflows from new investors.

These issues, in conjunction with our results, highlight the complex nature of biases in hedge fund returns data. As illustrated by the quote to begin this section, conventional wisdom is that returns to hedge funds in general are

[20] The fact that some of the largest hedge funds choose not to list in public databases (EFH) is consistent with their recognition of a diseconomy-of-scale in accepting too much inflows from investors. Berk and Green (2004) show that diseconomies-of-scale may explain the lack of alpha in the mutual fund industry.

likely *worse* than those reporting publicly due to backfill and survivorship biases. However, while survivorship and backfill bias likely inflate returns relative to an unbiased estimate for the full sample of *publicly reporting funds*, this upward-biased sample of returns appears to dramatically under-estimate the returns to the industry as a whole. This is because sample selection bias in public data appears to be strongly *negative* for returns, and much larger than the positive biases associated with publicly reporting funds. In aggregate, the result is that the hedge fund industry has performed significantly better than would be indicated by the publicly available data, despite the upward-bias associated with publicly reporting funds *in sample*.

We note one final, albeit speculative, observation. The public funds that perform the best relative to the non-public funds are in Macro and Managed Futures strategies. Perhaps coincidentally, Table 1 shows that these are also the strategies with the highest percentage of total net assets being reported to the public data (73% and 88%, respectively, as of the end of 2016). That is, the strategies with the best performance of public compared to non-public funds are the strategies with largest proportion of publicly reporting funds. This may suggest biases in public hedge fund data originate from the historical experience of funds' broad investment objectives, rather than from individual fund performance only.

4.2 Systematic Risk

There are two possible sources of difference in performance for publicly and non-publicly reporting funds: exposures to systematic risk factors and alpha. Understanding the underlying source of performance heterogeneity between publicly and non-publicly reporting funds is important because it has implications for the total amount hedge fund capital exposed to various sources of risk, which may in turn have important consequences for financial stability. If non-publicly reporting funds have better overall performance because of greater exposures to particular risk factors, then the industry exposure as a whole may be misrepresented by information derived only from publicly reporting funds. Alternatively, if these differences arise primarily from alpha (skill or other sources of returns not captured by systematic risks) then aggregate industry risk exposures may be well represented by publicly available data.

To decompose the sources of difference in gross performance, we estimate a standard factor model of the form:

$$R_{i,t} = \alpha_i + \beta_i' F_t + \varepsilon_{i,t}, \tag{1}$$

where $R_{i,t}$ is fund i's return in period t, α_i is the average return not captured by systematic risk, β_i is a vector of sensitivities to systematic risk factors, F_t is the time t vector of systematic risk factors, and $\varepsilon_{i,t}$ is the residual. We use risk factors from the "Global 7" factor model developed in Joenvaara, Kauppila, Kosowski, and Tolonen (2019). The Global 7 model has been shown to have greater explanatory power for hedge fund returns than the traditional Fung and Hsieh (2004) model, and has the added benefit of comprising true asset pricing factors (returns to long-short portfolios sorted on characteristics). Instead, the Fung-Hsieh model often used in hedge fund research includes style portfolios that cannot be interpreted as risk factors. The Global 7 model includes: the Fama and French (1993) and Carhart (1997) factors — the excess market return (Mkt), value (HML), size (SMB), and cross-sectional momentum (CS MOM), the time-series momentum factor (TS MOM) from Moskowitz, Ooi, and Pedersen (2012), the betting against beta factor (BAB) from Frazzini and Pedersen (2014), and the traded liquidity factor (PS LIQ) from Pastor and Stambaugh (2003). Each of the Global 7 factors have been shown to be important sources of systematic risk in hedge fund portfolios.

Figure 9 plots the densities of each $\widehat{\beta}_i$, estimated from gross-of-fee returns, separately for publicly and non-publicly reporting funds. We focus on gross-of-fee returns to evaluate the risk exposures of hedge funds' invested capital, rather than the exposures ultimately faced by investors. The most dramatic difference is exposure to market risk. For publicly reporting funds, market betas are larger on average and are much more varied than for non-publicly reporting funds. The mean market beta for publicly reporting funds is 0.51 with a standard deviation of 0.52. For non-publicly reporting funds, the mean market beta is -0.03, with a standard deviation is 0.21. Differences in the tails of the distributions are even more pronounced; the 75$^{\text{th}}$ and 90$^{\text{th}}$ percentiles of market beta for publicly reporting funds are 0.82 and 1.13 respectively, but for non-publicly reporting funds are 0.04 and 0.14. That is, on average publicly reporting funds have a fairly sizeable exposure to market risk, whereas for non-publicly reporting funds exposure to market risk is virtually non-existent.

The differences in market beta exposure between publicly and non-publicly reporting funds suggests that the aggregate market risk of the industry is overstated in public data. Non-publicly reporting funds have considerably lower market exposure than funds that report publicly. The exact cause of the substantial differences in market exposure is unclear, but we speculate on a few possibilities. First, it may be that funds with less traditional strategies, and therefore lower exposure to market risk, are less likely to report publicly for fear of revealing too much information about their investment approach. It might also be that consumers of public hedge fund data are more interested in "enhanced mutual fund" strategies, which seek a greater market exposure, than investors who rely less on publicly available data. Finally, it may be that among funds that would consider reporting publicly, funds with larger market exposures have had better performance during the sample period when stocks performed well generally, and have therefore endogenously chosen to report publicly. We highlight the relevant counterfactual in this case is among the set of funds that would consider reporting publicly, as the previous section demonstrated that non-publicly reporting funds have superior performance in aggregate and lower market betas on average.

Differences in exposures to non-market risk factors are much smaller. Figure 9 shows that publicly reporting funds appear to have somewhat larger exposures to size, value, time-series momentum, and betting-against-beta factors. Non-publicly reporting funds appear to be more exposed to momentum, and slightly more exposed to Pastor-Stambaugh liquidity risk. However, compared to market beta, these differences are much more subtle.

The results from this section indicate that exposure to market risk is dramatically different for publicly and non-publicly reporting funds. While less severe, publicly reporting funds appear to be more highly exposed to four of the six other factors as well. Because each of these risk factors have been shown to associate with positive risk premia, this would suggest that compensation for systematic risk should be *higher* for publicly reporting funds. Yet, gross performance for publicly reporting funds is *lower*, as shown in section 4.1. This points toward alpha as a key component of the performance difference between publicly and non-publicly reporting funds.

4.3 Alphas

In this section, we examine the extent to which alphas differ between publicly and non-publicly reporting funds. We evaluate alphas through three separate approaches: the intercept from the first stage regression in equation (1) (Jensen's alpha), a bootstrap approach that incorporates the sampling distribution of fund returns, and a Fama-MacBeth approach that allows us to control for fund characteristics. The analysis examines both the level and persistence of alphas in publicly and non-publicly reporting funds.

4.3.1 Jensen's Alpha

The top-left panel of Figure 9 plots the densities of $\widehat{\alpha}_i$ estimated from equation (1) for publicly and non-publicly reporting funds and gross-of-fee returns. As expected from the evidence in sections 4.1 and 4.2, estimated alphas in non-publicly reporting funds are substantially larger and less varied. Monthly alphas for publicly reporting funds have a mean of -0.146%, a median of -0.086%, and a standard deviation of 5.02%, while for non-publicly reporting funds the mean alpha is 0.913%, the median is 0.707%, and the standard deviation is 2.483%. This corresponds to an implied annual difference in median alpha of nearly 10 percentage points. These differences show up throughout the distribution; the 25$^{\text{th}}$, 75$^{\text{th}}$, and 90$^{\text{th}}$ percentile values of monthly $\widehat{\alpha}_i$ for publicly reporting funds are -0.984%, 0.611%, and 1.205%, and for non-publicly reporting funds are 0.322%, 1.210%, and 1.849%.

4.3.2 Bootstrap Distributions

The differences in the distributions of $\widehat{\alpha}_i$ in Figure 9 are significant, but they don't lend themselves easily to hypothesis testing without parametric assumptions. In this section we offer evidence that follows from the bootstrap methodology developed in Fama and French (2010). For each fund i, we generate a vector of empirical returns under the counterfactual that $\alpha_i = 0$. That is, we construct $\widetilde{R}_{i,t} = R_{i,t} - \widehat{\alpha}_i$. The set of returns $\widetilde{R}_{i,t}$ maintain all of the empirical characteristics of the actual realized returns, except for alphas for each fund are zero by construction. Using this zero-alpha empirical distribution of returns, we then bootstrap 10,000 simulated samples of the same size as our empirical data (48 months). In the Fama and French (2010) approach, a simulated sample is generated by randomly sampling dates with replacement. However, hedge fund returns are known to have a strong autocorrelation structures (Getmansky, Lo, and Makarov (2004)), and sampling dates at random would destroy this structure. Instead, we employ the stationary bootstrap of Politis and Romano (1994), which samples an initial date $t = 1$ at random from the empirical data (a date between January 2013 and December 2016). Then, for each remaining date $t = 2, \ldots, T$, we set $s_t^b = 1 + s_{t-1}^b$ with probability $1 - \frac{1}{L}$, and sample s_t^b uniformly otherwise. If t equals December 2016, we set $t+1$ to January 2013 if $t+1$ is not randomly drawn. This ensures that bootstrapped dates are sampled in continuous "blocks" to preserve the autocorrelation structure. Following Ledoit and Wolf (2008), we set $L = 6$ in our analyses.

Finally, for each of the 10,000 bootstrapped (zero-alpha) samples, we re-estimate the factor model specified in equation (1), and calculate the t-statistic of the estimated alpha for each fund, $t(\widehat{\alpha}_i^b)$, where b indexes the bootstrap samples. As in Fama and French (2010), we use the t-statistics of alphas instead of alphas to account for differences in estimation precision that arise from differences in the number of months the fund is observed in the data. The interpretation of $t(\widehat{\alpha}_i^b)$ is similar to a Sharpe ratio — it is the estimated level of alpha divided by its standard error. This gives us 10,000 cross-sectional samples of alpha t-statistics from a sample with alphas equal to zero by construction. This comprises the empirical zero-alpha counterfactual distribution to which we can compare the actual observed distribution of hedge fund alpha t-statistics.

The benefit of this bootstrap approach is that it allows for the empirical distributions of publicly and non-publicly reporting funds to differ; that is, we do not have to impose that the only difference in the distributions are due to differences in means. Further, the empirical distributions of fund returns may not be well-approximated by ex-ante specified parametric distributions, and the non-parametric bootstrap approach avoids incorrect inferences that may result from assumptions about functional forms.

Figure 7 plots the empirical cumulative distribution functions (CDFs) of alpha t-statistics from the actual hedge fund data against the CDFs obtained by taking the average t-values across all 10,000 bootstrapped samples at each quantile. The top-left panel plots the simulated and actual CDFs of gross-of-fee alpha t-statistics for publicly reporting funds, while the right-panel plots CDFs for non-publicly reporting funds. Estimated alpha t-statistics in publicly reporting funds are near zero on average, and the CDFs intersect just above the 50th percentile. publicly reporting funds have slightly larger alphas in the upper end of the distribution than the zero-alpha sample, but slightly smaller alphas in the lower end. That is, actual alphas appear to be more fat-tailed compared with the simulated data for publicly reporting funds.

Conversely, the top-right panel of Figure 7 shows that for non-publicly reporting funds, actual gross-of-fee alphas are uniformly higher than in the simulated distribution. The CDF of the actual return data is always below — and quite substantially in the heart of the distribution — the CDF of the simulated data. This indicates that alphas in non-publicly reporting funds are statistically much larger than those implied by the zero-alpha simulated data throughout the entirety of the distribution.

The bottom row of Figure 7 plots CDFs based on net-of-fee returns. The results are largely unchanged. For publicly reporting funds, a majority of the actual distribution lies above the simulated distribution, suggesting that funds do slightly worse net-of-fee than would be implied by a zero-alpha (net-of-fee) distribution. For non-publicly reporting funds, the CDF of actual alphas continues to be below the simulated CDF for the entire distribution. This suggests the positive alphas in non-publicly reporting funds are not entirely captured by managers in the form of higher fees (as may be predicted in a Berk and Green (2004) style model, for instance), but instead are partially passed through to fund investors. Aragon (2007), Agarwal, Daniel, and Naik (2009) and Barth and Monin (2019) suggest this may be due to investors demanding additional compensation for tighter share restrictions, which managers use to pursue more illiquid strategies with less certain payoff horizons.

Figure 8 shows the same result is evident in the probability density functions (PDFs). publicly reporting funds have alpha t-statistics centered around zero (or below zero) with fatter tails than the simulated distribution. Non-publicly reporting funds also exhibit a fatter-tailed distribution than the simulated data, but it is centered well to the right of zero. That is, while publicly reporting funds exhibit no statistically detectable alpha, non-publicly reporting funds show significantly positive estimated alpha.

Table 3 offers an alternative way to view the distributions of alpha t-statistics. The first two columns of each set of comparisons repeats the information in Figure 7, which shows the average value of alpha t-statistics across the 10,000 bootstrapped samples at various quantiles and the value of the actual alpha t-statistics at those same quantiles. The third column shows the fraction of bootstrapped samples for which the simulated quantile value is below the actual quantile value, which is equivalent to a p-value in a one-sided hypothesis test under the null that alpha is zero. This is shown for both gross and net-of-fee returns.

Table 3 shows just how much larger the alphas are for non-publicly reporting funds than publicly reporting funds. For publicly reporting funds and gross-of-fee returns, at the 50$^{\text{th}}$ percentile less than 29% of the bootstrapped, zero-alpha samples had average alpha t-statistics below the actual median value. The fraction of bootstrapped samples that are below the actual value for publicly reporting funds doesn't surpass 90% until around the 70$^{\text{th}}$ percentile. Alternatively, for non-publicly reporting funds, by the 5$^{\text{th}}$ percentile more than 95% of bootstrapped samples generate alpha t-statistics below the actual observed alpha t-statistic, and this percentage remains at or above 97% for each quantile after. That is, one can reject the null hypothesis at the 5% level that actual alphas in non-publicly reporting funds are equivalent to those in the zero-alpha sample at each quantile above the 10$^{\text{th}}$ percentile.

These key takeaways are similar for net-of-fee returns as well. For publicly reporting funds, net-of-fee alpha is not greater than at least 90% of bootstrapped samples until the 95$^{\text{th}}$ percentile. For non-publicly reporting funds, this threshold is exceeded by the 10$^{\text{th}}$ percentile, and in most cases the null of zero-alpha can be rejected at the 5%-level or greater. Table 3 offers further evidence that alphas in publicly reporting funds between 2013 and 2016 are statistically no different from zero, while they are economically large and significantly different from zero for non-publicly reporting funds.

4.3.3 Fama-MacBeth Regressions

The previous sections showed significant differences in the distributions of estimated alphas between publicly and non-publicly reporting funds. In this section, we examine whether this can be explained by differences in observables, specifically size, lagged returns intended to proxy for return smoothness, share restrictions, broad fund strategy, and fees.

Such analyses are difficult due to the sharing restrictions and confidentiality associated with the respective public vendor and Form PF data sets. Performing regressions while respecting the confidentiality of our data sets is nonetheless possible with some simple linear algebra. Let X_1 denote the design matrix and y_1 the observations for the publicly reporting funds, and X_2 and y_2 the same for the non-publicly reporting funds. The combined design matrix and observation vector are defined as:

$$X = \begin{bmatrix} X_1 \\ X_2 \end{bmatrix}, \quad y = \begin{bmatrix} y_1 \\ y_2 \end{bmatrix} \tag{2}$$

The combined OLS regression coefficient estimates are then obtained as

$$\widehat{\beta} = \left(X'X\right)^{-1}X'y = \left(X_1'X_1 + X_2'X_2\right)^{-1}\left(X_1'y_1 + X_2'y_2\right) \tag{3}$$

That is, we can estimate regressions on the full sample of data by estimating $X_1'X_1$, $X_2'X_2$, $X_1'y_1$, and $X_2'y_2$ separately and then combining them after.[21]

We estimate two-stage Fama and MacBeth (1973) regressions where the first-stage is given by equation (1). In the second stage, we estimate cross-sectional regressions of $\widehat{\alpha}_{i,t} = R_{i,t} - \beta_i' F_t$ on an indicator for whether the fund reports publicly. We include results from various factor models, including the G7 model described above, the standard Fung and Hsieh (2004) seven factor model, and the Fung-Hsieh model augmented by an emerging market factor from Edelman, Fung, Hsieh, and Naik (2012) and the out of the money option factor from Agarwal and Naik (2004). We also include a specification with gross-of-fee alphas from the G7 model, and net-of-fee alphas from the G7 model based on unsmoothed returns as in Getmansky, Lo, and Makarov (2004). Final coefficient estimates are then obtained as the respective time-series averages of the second stage regressions, with heteroskedastic and autocorrelated Newey and West (1987) standard errors.

The Fama-MacBeth approach is useful because a number of potentially important characteristics can be included as controls. Because non-publicly reporting funds are substantially larger, and previous research suggests better managers will endogenously acquire more capital and reach larger efficient sizes (Berk and Green (2004)), size may be an important source of the performance gap between publicly and non-publicly funds.[22] Performance differences could also result from differences in the liquidity of fund portfolios. Aragon (2007) and Barth and Monin (2019) show that portfolio illiquidity and investor share restrictions can explain a significant portion of hedge fund alpha; if non-publicly reporting funds have more illiquid portfolios or tighter share restrictions, this could explain their higher returns. We proxy for portfolio illiquidity using the one-period lagged excess return, as previous work demonstrates that return autocorrelations are related to the illiquidity of the assets. We also construct indicator variables for funds with highly liquid and highly illiquid shares. We define highly liquid funds as those for which all investors are contractually permitted to redeem their capital within at least seven days, including lockups, notice periods, and redemption frequencies. Highly illiquid funds are defined as those for which the most restricted investors are unable to redeem capital within one year or longer. We also include the levels of management and incentive fees. Form

[21] The matrices $X_1'X_1$ and $X_1'Y_1$ are transformations of the public data that would be impossible to reverse engineer into their constituent raw data series.

[22] Due to the difficulty in scaling various hedge fund strategies, fund size and performance may also be related. See Teo (2009) and Ramadorai (2013) as two of many examples.

PF does not explicitly report management and incentive fees separately, so we estimate them following the method of Barth and Monin (2019). Finally, to account for differences in performance associated with various investment objectives, we include controls for the same broad strategy classifications described in section 3.3.[23]

Table 4 reports coefficient estimates. Column (1) shows results for net-of-fee excess returns, whereas columns (2) – (7) show results for alphas estimated from various factor models. In each case, the coefficient on the publicly reporting indicator is negative and statistically significant, consistent with the results in Table 3. Column (1) shows that non-publicly reporting funds earn an additional 38 basis points per month in net-of-fee excess returns. Estimated alpha differences are similar. In column (2), we find that gross-of-fee alphas from the G7 model are 41 basis points higher per month on average for non-publicly reporting funds.

The remaining columns focus on net-of-fee performance, although gross performance yields similar findings. Column (3) shows that net-of-fee alpha from the G7 model is 45 basis points per month greater on average for non-publicly reporting funds. To evaluate whether differences in alphas result from return smoothing, column (4) uses alphas derived from returns that have been filtered by an MA(2) process as in Getmansky, Lo, and Makarov (2004). The coefficient on the publicly reporting indicator is -0.45, highly similar to the coefficient in column (3). This is unsurprising given that the lagged excess return is already included as a control to partially account for smooth returns. In columns (5)–(7), we use alphas from the Fung and Hsieh (2004) style benchmarks, augmented by an emerging market factor from Edelman, Fung, Hsieh, and Naik (2012) and the out of the money option factor from Agarwal and Naik (2004). Coefficient estimates are similar to those estimated for the G7 model. In each specification, t-statistics are no smaller than three, and in the first five specifications are greater than four, indicating the results are strongly statistically significant.

The significantly larger alphas for non-publicly reporting funds persist despite the inclusion of various controls potentially related to outperformance. Indeed, Table 4 shows that highly liquid funds earn significantly lower alphas on average, whereas highly illiquid funds earn significantly larger alphas. The lagged net excess return, intended to capture the effect on alpha from smoothed returns, is also strongly related to performance, foreshadowing the persistence results we document in the following section. But while certain characteristics are associated with performance, none of the observables in Table 4, including fund size, liquidity, or smoothed returns, can explain the large differences in alpha between publicly and non-publicly reporting funds. Instead, the endogenous decision to report continues to be a leading candidate for the primary underlying source of these differences.

[23] In the Form PF data, returns are provided at a monthly frequency but the other control variables are reported quarterly. We fill forward missing values in non-quarter-end months based on the values at the end of the previous quarter.

4.3.4 Performance Persistence

Tables 3 and 4 document a substantial difference between the alphas earned by publicly and non-publicly reporting funds. This could arise either because non-publicly reporting funds display higher "skill" or because they take additional risks that are poorly captured by standard factor models. An alternative possibility is that predicted returns for non-publicly reporting funds are estimated with greater noise.

One approach to assessing whether the alphas documented in Tables 3 and 4 arise from estimation error is to examine performance persistence. If alphas are precisely estimated – that is, if they capture real information about the return generating process – then we would expect on average that high-alpha funds in one period would also earn high alphas in future periods. In this sense, performance persistence serves as a type of out-of-sample analysis. Persistence in hedge fund returns has also been of interest to researchers and practitioners generally.[24] However, if publicly and non-publicly reporting funds display different levels of persistence, previous findings may be incomplete.

To examine whether performance persistence differs between publicly and non-publicly reporting funds, we perform Fama-MacBeth regressions as in Busse, Goyal, and Wahal (2010). For each monthly cross-section, we regress the performance over a future horizon on the performance over a past horizon, plus controls for fund size, lagged returns, fees, share illiquidity, and strategy. Performance is measured as the average monthly return minus the return to the fund's style index, which we refer to as α for convenience. Using style indices instead of risk factors avoids potential benchmark misspecification, to the extent that funds within a style are subject to similar risk factors (see Jagannathan, Malakhov, and Novikov (2010) for further discussion). We use three past horizons (three months, six months, and one year) and four future horizons (three months, six months, one year, and two years) in the analysis. Specifically, we estimate:

$$\widetilde{r}_{i,t+k_1:t+k_2} = \beta_{0,t} + \beta_{1,t}\widetilde{r}_{i,t-k:t} + \beta_{2,t}Z_{i,t} + \varepsilon_{i,t}, \tag{4}$$

where $t+k_1$ to $t+k_2$ defines the horizon over which we estimate future returns, $t-k$ to k defines the horizon of past returns, and $Z_{i,t}$ is a vector of controls. Standard errors are adjusted for autocorrelation, which may arise from overlapping estimation windows.

We estimate equation (4) separately for the sample of publicly and non-publicly reporting funds. To assess

[24] See Jagannathan, Malakhov, and Novikov (2010), Glode and Green (2011), Boyson (2008), and Fung, Hsieh, Naik, and Ramadorai (2008) as few examples.

whether $\beta_{1,t}$ differs systematically between publicly and non-publicly reporting funds, we also estimate the model for the full sample of funds and interact an indicator for whether the fund reports publicly:

$$\widetilde{r}_{i,t+k_1:t+k_2} = \beta_{0,t} + \beta_{p,t} Public_{i,t} + \beta_{1,t} \widetilde{r}_{i,t-k:t} + \gamma_{i,t} \times Public_{i,t} \times \widetilde{r}_{i,t-k:t} + \beta_{2,t} Z_{i,t} + \varepsilon_{i,t}, \tag{5}$$

where $\gamma_{i,t}$ captures the performance persistence difference between publicly and non-publicly reporting funds.

We estimate three specifications. The first contains no corrections for smooth returns or sample selection. In the second, to avoid persistence estimates being driven by short-term autocorrelation due to illiquid strategies or return smoothing, we apply an MA(2) filter as in Getmansky, Lo, and Makarov (2004) to both fund returns and style indices. Finally, in the third specification we address potential selection bias arising from funds disappearing during future horizons by employing a Heckman (1979) correction; for each monthly cross-section, and separately for non-public and public data, we estimate a probit regression for whether the fund continues reporting through the future horizon. The inverse Mills ratio is then added as a control variable in the cross-sectional persistence regression. The control variables in the probit regression are the same as in the persistence regression, but we add squared past performance as an additional control, as attrition (at least in public funds) is known to be associated with both good and bad performance (Jagannathan, Malakhov, and Novikov (2010)).[25]

Table 5 reports results. For each past and future horizon, we report the coefficient on past performance estimated separately for publicly and non-publicly reporting funds, as well as the coefficient on the interaction term $\widehat{\gamma}_t$ in the full sample. Coefficients are time-series averages across all monthly cross-sections. Panel A includes controls for fund size and strategy but no corrections for smoothing or sample selection. For publicly reporting funds, coefficients range between 0.025 to 0.176, and are statistically insignificant for future horizons greater than six months. Conversely, for non-publicly reporting funds coefficients are much larger, ranging from 0.405 to 0.677, and are highly statistically significant across all past and future performance horizons with t-statistics that exceed five in every specification. The coefficient on the interaction term shows the magnitude of differences in average persistence. It ranges from -0.56 to -0.338, with t-statistics always exceeding five.

In panels B and C, we include corrections for return smoothing and sample selection, respectively. These adjustments have little effect on our findings. For non-publicly reporting funds in panel B, the coefficient on prior performance remains large and highly statistically significant. In panel C, magnitudes decrease slightly for the longest

[25] To increase the power of our tests we do not correct returns for backfill bias in the public data. Jorion and Schwarz (2019) show that persistence results are not sensitive to the choice of backfill bias correction method. Further, backfill bias would likely attenuate any differences in persistence between publicly and non-publicly reporting funds.

horizons, and become statistically insignificant in the three-month/two-year and six-month/one-year specifications. Nonetheless, in every specification in both panels B and C, the coefficient on the interaction term remains large, ranging from -0.582 to -0.335, again with t-statistics always above five.

The results in Table 5 offer strong evidence in support of performance persistence in hedge fund returns, but only for the funds that do not report to any public data vendor. For funds that report publicly, we find only limited evidence of persistence and only for shorter future horizons. While our sample period is relatively short, spanning only 2013 – 2016, the performance persistence results found for non-publicly reporting funds offer some assurance that estimated differences in alphas are not the result of estimation error. Because these specifications also include controls for fund size and broad strategy, and adjust for return smoothing and sample selection, these differences do not appear to result from differences in observable characteristics.

In total, the results in sections 4.1 – 4.3 point toward funds' endogenous decision to report publicly as an important potential source of bias in public data. Selection bias in hedge fund data has been examined previously, but those studies have reached different conclusions. Edelman, Fung, and Hsieh (2013) analyze a set of large non-reporting funds and find that public performance data fairly well represent the broader industry. In contrast, Aiken, Clifford, and Ellis (2013) and Agarwal, Fos, and Jiang (2013) conclude that selection bias in public data is positive, and that public data exaggerate the average skill in the industry. Our findings, based on the most comprehensive data available to date, show the opposite. Our results indicate that selection bias is both large and negative, and that performance estimated from public data substantially *understates* the true performance of the industry. There are various reasons that non-reporters may be expected to outperform publicly reporting funds: to protect potentially unique investment strategies (supported but the much lower representation of "other" strategy funds in the public data), because the fund has already reached an efficient size, or because the fund's success is sufficiently well known that additional publicity is unnecessary. Each would produce negative selection in publicly available performance measures.

Other well-known biases in publicly available hedge fund data, such as backfill bias, which results from funds reporting return histories after a stretch a good performance, and delisting bias, where funds with poor performance stop reporting to a public database, would imply a positive performance bias in public data.[26] Our results suggest that these biases are small compared with the negative selection bias induced by non-reporters. Further, our results demonstrate that selection bias affects not only risk-adjusted returns, but also risk exposures. Publicly reporting

[26]On the importance of backfill bias and related discussion, see Jorion and Schwarz (2019) and Bhardwaj, Gorton, and Rouwenhorst (2014); for a nice discussion of delisting bias see Edelman, Fung, and Hsieh (2013).

funds have significantly larger exposure to market risk than non-reporters. Our results suggest that much of the conventional wisdom in the hedge fund literature may need to be revisited.

5 Flows

5.1 Aggregate Flows

The larger growth of assets under management in non-publicly reporting funds, demonstrated in Figures 1 and 3, could result from higher returns or higher net inflows of investor capital. The previous section showed that non-publicly reporting funds have outperformed funds in the public databases. In this section, we examine whether flows to non-publicly reporting funds have also been higher.

Several hedge fund studies examine the relationship between investor flows and past performance.[27] These studies seek to determine whether hedge fund investors infer the quality of a hedge fund from its past performance record. However, the selection bias demonstrated in the public data brings into question whether these past studies are similarly biased in their inference of the flow-performance relation. The findings in this section therefore also provide some preliminary evidence on potential biases in studies that use only public data.

A prediction of how the selection bias of listing in the public data effects the flow-performance relation is complicated by two competing affects. First, listing in a public database may draw attention to the past performance of a hedge fund, and may result in an exaggerated response of investor flows to observed past performance. Second, performance in a non-publicly reporting fund may be more indicative of manager skill, especially if funds strategically list in the public database when their past returns have been good. Which of these two effects will dominate is an empirical question.

Due to the delisting issues associated with hedge fund data — listing and delisting that arises from strategic and voluntary reporting in public databases, and with size-based reporting thresholds in regulatory data — calculating net investor flows is not a trivial task. Further, neither the public databases nor Form PF collect data on subscriptions and redemptions explicitly, which means flows must be approximated from net assets and fund returns. One approach would be to calculate the total net assets in the public and non-public funds in quarter t and $t-1$, and use the NAV-weighted average returns to each to infer the net flows in quarter t. However, this method will conflate the net flows to funds that report to a database (or Form PF) in both t and $t-1$, the increase in net assets due to newly reporting funds that did not report in $t-1$, and the decrease in net assets due to funds that report in $t-1$ but exit the data prior to reporting assets in period t. For this reason, it is also not possible to calculate credible flow estimates based on

[27] See Christoffersen, Musto, and Wermers (2014), for a survey of studies of the flow-performance relation.

aggregated asset and performance data, either by public versus non-public reporting or by fund strategy.

Instead, our approach is to calculate flows for each fund that reports in both quarters $t-1$ and t, and then to calculate average flows by value-weighting individual fund flows by net assets in $t-1$:

$$Flow_{i,t} = \frac{NAV_{i,t} - NAV_{i,t-1}(1+r_{i,t})}{NAV_{i,t-1}} \tag{6}$$

$$Flow_t = \sum_i \frac{NAV_{i,t-1}}{NAV_{t-1}} \times Flow_{i,t}, \;\; NAV_{t-1} = \sum_i NAV_{i,t-1} \tag{7}$$

For each fund i we calculate quarterly flows, $Flow_{i,t}$, using the standard approach in the literature, which subtracts net assets in period $t-1$, multiplied by the fund's quarterly return, from net assets in period t and scaled by net assets in $t-1$. Aggregate flows, $Flow_t$, are then simply the NAV-weighted average of individual fund flows (weighted by NAV in quarter $t-1$). Similarly to returns, we calculate total flows, $Flow_t$, separately for public versus non-public funds as well as for strategy.

It is important to interpret $Flow_t$ appropriately; it is the weighted-average flows of funds that appear in the data in both $t-1$ and t. To the extent that such funds are representative of the hedge fund industry in aggregate, then the flow results documented here will be a good approximation of total industry flows. However, if this is not the case, then aggregate industry flows may differ from the flows documented below.

The top panel of Figure 10 shows the value-weighted, quarterly flows for funds that report to one of the public databases and for funds that report to Form PF but not to any public database. The empirical patterns differ substantially from the return results show in Figure 5; in all but one quarter, the average flows to publicly reporting funds exceed those to non-publicly reporting funds. Further, for non-publicly reporting funds, flows are negative in most quarters, whereas they are positive in most quarters for publicly reporting funds. The bottom panel of Figure 10 shows the effect such quarterly differences has on cumulative flows over the entire sample period. Public funds have experienced an almost 10% total net inflow over the period 2013-2016, while non-publicly reporting funds have experienced a nearly -15% cumulative net outflow.

Figure 11 shows that, similar to the return results reported earlier, the flow results are largely consistent across fund strategy. Within every strategy, the publicly reporting funds experienced greater cumulative net flows than non-publicly reporting funds. For many strategies, the size of these cumulative flow differences is substantial. publicly reporting Equity funds had a total cumulative flow of 17% versus -3% for non-publicly reporting funds. Similar disparities exist for Relative Value funds (-11% versus -21%), Credit funds (15% versus -19%), Event Driven funds (-7% versus -23%), Multi-strategy funds (35% versus -15%), and Other strategy funds (55% versus -28%). publicly reporting Macro and Managed Futures funds also had higher total cumulative flows, but the differences are much smaller.

The results in Figures 10 and 11 are not necessarily surprising. Funds that report to public databases likely do so to increase investor awareness and raise additional capital, and one would expect such funds to have greater net flows than funds that are not actively marketing to new prospective investors. Further, if the larger, non-publicly reporting funds are more likely to have reached economies-of-scale, and are therefore no longer open to new investment, the patterns in Figure 10 would also be expected. However, the flows results offer an interesting contrast with the return results; while the publicly reporting funds perform considerably worse than than the non-publicly reporting funds, they nonetheless have raised substantially more capital as a fraction of net assets than their better-performing non-public counterparts.

5.2 The Flow-Performance Relationship

A large body of literature investigates the relationship between performance and capital flows in delegated asset management.[28] The combination of results in Sections 4 and 5.1 has important implications for this relationship. Funds reporting to the public data simultaneously exhibit (i) poorer performance, and (ii) greater net flows. This suggests that the true flow-performance relationship in hedge funds may differ significantly from that estimated in the existing literature, which almost exclusively relies on publicly available data.

In Table 6, we report results from Fama-MacBeth regressions similar to the approach described in Section 4.3.3, but with quarterly flows as the dependent variable. In column (1), we include only an indicator variable for whether the fund reports publicly, and confirm the results in Figure 10. Without additional controls, publicly reporting funds experience 3.55 percentage point larger flows *per quarter* than non-publicly reporting funds. Column (2) shows this coefficient is virtually unchanged with the addition of strategy controls.

In columns (3)–(6) we investigate the flow-performance relationship. Columns (3) and (4) include the fund's percentile rank in the net excess return distribution for each period (lagged by one quarter). Previous research has found that the performance rank may be a better predictor of flows than performance levels (Sirri and Tufano (1998), Liang, Schwarz, Sherman, and Wermers (2019)). Due to data sharing restrictions and the confidentiality of Form PF data, performance distributions are calculated separately for publicly and non-publicly reporting funds. That is, a publicly reporting fund with median (50^{th} percentile rank) performance in a given quarter may have a different return than the median non-publicly reporting fund in the same quarter. Column (3) shows that, consistent with previous

[28]The literature is far to large to cite exhaustively. See Fung, Hsieh, Naik, and Ramadorai (2008), Agarwal, Green, and Ren (2018), Getmansky (2012), and Liang, Schwarz, Sherman, and Wermers (2019) as a few of many examples.

studies, the performance rank of the fund is strongly related to flows. An increase in rank of 10 percentiles (going from the 50th to the 60th percentile, for instance) is associated with a 97 basis point higher expected quarterly flow. The coefficient has a t-statistic greater than nine. Flows are also strongly positively related to the flow in the previous quarter, and negatively related to fund size. Each is consistent with funds raising capital until they reach an efficient scale.

Once performance-rank and other controls are included, publicly reporting funds no longer demonstrate greater flows on average than non-publicly reporting funds. This suggests it may be differences in fund characteristics, or the slope of the flow-performance relationship, that explains the difference in flows between publicly and non-publicly reporting funds. In column (4), we interact performance rank with an indicator for whether the fund reports publicly. The coefficient on the interaction term is economically large and highly significant. Publicly reporting funds expect an 85 basis points greater flow for a 10 percentile-rank increase in performance than non-publicly reporting funds. The t-statistic is 6.47. That is, flows appear to be substantially more sensitive to performance for publicly reporting funds. The specification in column (4) includes controls for fund size, lagged flow, liquidity, and fees, suggesting again that the endogenous decision to report publicly is linked to observed differences in flows and performance, rather than only observable fund characteristics.

Because ranking performance within publicly and non-publicly reporting funds separately may be problematic, in columns (5) and (6) we instead include the level of the net excess return as the measure of performance. The conclusions are the same as those found in columns (3) and (4). Column (5) shows that performance is strongly positively related to flows; a one percentage point higher quarterly return in the previous quarter is associated with 27 basis point greater flow. Again, the result is highly statistically significant. In column (6), the coefficient on the interaction term shows that publicly reporting funds expect to receive 22 basis points higher flows per quarter for a one percentage point higher lagged quarterly return than do non-publicly reporting funds. The t-statistic is somewhat smaller at 2.69. While neither the separate rankings of performance in columns (3) and (4) or the level of performance in columns (5) and (6) are the ideal specification, the similarity and strength of the results across specifications suggests the flow-performance relationship is dramatically different between publicly and non-publicly reporting funds.

The findings in Table 6 have important implications for the flow-performance relationship estimated using only public data. Our results suggest public data dramatically overstate the the sensitivity of flows to performance in hedge funds. This may be best seen by the size of the performance coefficients in columns (4) and (6), which captures the relationship between performance and flows for non-publicly reporting funds. The coefficients are roughly 80%

smaller than the implied coefficients on performance for publicly reporting funds. Because our sample includes substantially more publicly reporting funds than non-publicly reporting funds, the coefficient on performance in the full sample is highly similar to the coefficient for publicly reporting funds in the specifications with interactions. However, Figure 1 shows that total amount of assets managed by publicly and non-publicly reporting funds are roughly equal, which would suggest that full-sample regressions weighted by size rather than fund count would produce a coefficient on performance that is around 40% smaller than the coefficient estimated only from public data.

As in the previous section, these findings suggest that the selection bias induced by non-publicly reporting hedge funds may substantially affect estimates of the flow-performance relationship in publicly available data. Large, well-performing funds appear less likely to report publicly and less willing take on new capital. Our results suggest that true flow-performance relationship in hedge funds is likely much weaker than previous understood.

6 Conclusions

We use data from a merged set of seven public hedge fund data vendors, in combination with filings from the first systematic U.S. regulatory collection on large hedge funds, to form the most comprehensive hedge fund data set to date. We estimate worldwide net assets under management of $5.2 trillion, and gross assets under management of $8.5-8.7 trillion, both of which are roughly 40% greater than the largest prevailing estimates. These findings indicate a much bigger "footprint" of hedge funds in financial markets than previously believed, and highlight the importance of regulatory data collections for filling data gaps and assessing the potential systemic risks associated with hedge fund activities.

Our larger estimates arise because neither the public data vendors nor regulators have a comprehensive view of total industry assets. Public data services collect information only on a voluntary basis, and regulatory data is collected only for funds within the appropriate jurisdictions. Further, due to yet unresolved data gaps, our results likely still represent an underestimate of the total industry size; our combined data may miss many large funds that neither report to public databases nor have any U.S. investors. While U.S. regulators have no direct oversight over private funds with no U.S. investors, such funds may nonetheless be significant participants in U.S. financial markets or have relationships with U.S. counterparties. Our estimates of the size of missing non-U.S. fund assets should therefore be of interest to U.S. regulators with little visibility into such funds.

We then decompose hedge fund assets by broad strategy and fund domicile, and find that the AUM of all strategies are significantly understated by publicly available data. Many, including Equity, Event Driven, Relative

Value, Multi-strategy, and Other, have less than 50% of assets accounted for by the public data. The Other strategy is particularly poorly represented; this may reflect the noisiness of strategy classifications in the regulatory data, or may reflect that funds with unique and idiosyncratic strategies may be particularly unlikely to report to any public data source. Additionally, a breakdown of assets by fund domicile suggests the "missing" assets in large European funds is likely substantial, highlighting that our much larger estimates of the size of the industry are almost surely still an underestimate.

Next, we explore the difference in performance between funds that report to at least one public data vendor and those that report only on regulatory filings. This analysis is motivated in part by the well-documented under-performance of hedge funds in the aftermath of the financial crisis. Our findings suggest that non-publicly reporting funds dramatically outperform those that report to the public databases, both in aggregate and within nearly every fund strategy category. This relatively poor performance of publicly reporting funds could, in part, motivate the recent criticism of hedge fund returns by industry observers and the financial press.

Further, we find that this outperformance is driven almost exclusively by larger alphas, rather than greater exposures to systematic risk factors. In fact, publicly reporting funds show much higher exposure to market risk; market betas are virtually zero for non-publicly reporting on average. We find that the much larger alphas in non-publicly reporting funds survive various statistical tests, and are not explained by observable characteristics. Finally, we document that risk-adjusted returns are persistent — but only for non-publicly reporting funds. publicly reporting funds show only weak persistence and only for short horizons.

Finally, given the vast literature on the hedge fund and mutual fund flow-performance relation, we estimate the average flows (as a percentage of AUM) from investors to hedge funds in the public and non-public data. *A priori*, it is not clear whether hedge funds that choose to list in public datasets should have a greater ability to gather assets (due to the increased publicity) or a lesser ability (due to the worse performance documented in this paper). We find that the average net flow is significantly *higher* for publicly reporting funds compared with non-publicly reporting funds, despite these funds having significantly worse performance. We then show that the flow-performance relationship for non-publicly reporting funds is substantially weaker than for publicly reporting funds, suggesting estimates from only public data likely overstate the sensitivity of investor flows to performance.

Our results demonstrate a multitude of potential biases associated with public hedge fund data. First, the net assets of funds that report publicly has grown by 20.6% over the period 2013-2016; the growth of assets for non-publicly reporting funds is 48.7% for this same period. Second, conventional wisdom suggests that the performance of publicly reporting funds is likely to *overestimate* the true performance of the industry, due to backfill, delisting, and survivorship biases. We find that (negative) selection bias dominates these effects, so that performance estimates based on publicly reporting funds are instead biased significantly *downward*. Selection appears to be largely related to skill; differences in performance between publicly and non-publicly reporting funds is exclusively due to alpha. Third, the combination of better performance and lower net flows associated with non-public funds results in a flow-performance relationship that is much flatter than is estimated from public data alone.

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7 Tables and Figures

7.1 Tables

Table 1: Industry Size by Strategy

PANEL A: NET ASSETS ($ Billions)

	2013			**2014**			**2015**			**2016**		
Strategy	Non-Public	Public	Total	Non-Public	Public	Total	Non-Public	Public	Total	Non-Public	Public	Total
Equity	680	737	1,417	739	778	1,517	803	775	1,578	769	710	1,479
Multi-strategy	421	275	696	411	314	724	430	345	775	463	328	791
Other	570	47	617	654	57	711	705	56	760	779	64	842
Macro	126	477	603	131	466	596	165	454	619	172	457	630
Event Driven	171	210	381	208	228	436	179	209	389	205	169	374
Credit	106	254	360	123	287	410	126	405	531	147	411	558
Relative Value	92	129	221	123	133	256	122	122	244	129	121	250
Managed Futures	18	214	232	22	206	228	25	251	276	35	254	289
Total	2,184	2,343	4,527	2,409	2,469	4,878	2,555	2,617	5,172	2,699	2,514	5,213

PANEL B: GROSS ASSETS ($ Billions)

	2013			**2014**			**2015**			**2016**		
Strategy	Non-Public	Public	Total	Non-Public	Public	Total	Non-Public	Public	Total	Non-Public	Public	Total
Equity	1,050	1,126	2,176	1,103	1,212	2,315	1,203	1,238	2,440	1,094	1,146	2,240
Multi-strategy	812	510	1,322	787	588	1,376	824	659	1,483	930	693	1,623
Other	734	80	814	854	70	924	884	67	951	1,020	83	1,104
Macro	292	874	1,166	337	841	1,178	354	783	1,137	477	739	1,216
Event Driven	215	300	515	268	331	599	229	303	532	262	252	514
Credit	149	464	613	167	492	659	188	676	864	220	696	917
Relative Value	173	228	401	261	238	500	287	250	537	341	253	594
Managed Futures	20	258	278	26	252	278	30	311	341	42	298	340
Total	3,445	3,841	7,286	3,804	4,025	7,829	3,999	4,287	8,285	4,388	4,160	8,548

Table 1 reports total net and gross assets for publicly reporting and non-publicly reporting funds in aggregate and by strategy. Strategy categories are determined by Form PF.

Table 2: Industry Size by Geographic Region

PANEL A: NET ASSETS ($ Billions)

	2013			2014			2015			2016		
Region	Non-Public	Public	Total	Non-Public	Public	Total	Non-Public	Public	Total	Non-Public	Public	Total
Caribbean	1,086	1,020	2,106	1,200	1,087	2,287	1,260	1,067	2,327	1,300	976	2,276
North America	859	585	1,444	930	618	1,547	969	755	1,724	1,081	757	1,838
Europe	89	620	708	92	650	742	95	695	790	95	680	776
Other	150	119	269	188	114	302	231	100	331	223	102	324
Total	2,184	2,343	4,527	2,409	2,469	4,878	2,555	2,617	5,172	2,699	2,514	5,213

Panel B: GROSS ASSETS ($ Billions)

	2013			2014			2015			2016		
Region	Non-Public	Public	Total	Non-Public	Public	Total	Non-Public	Public	Total	Non-Public	Public	Total
Caribbean	1,869	1,898	3,767	2,085	2,033	4,118	2,155	2,027	4,182	2,367	1,865	4,231
North America	1,206	888	2,095	1,292	942	2,234	1,346	1,069	2,415	1,512	1,061	2,572
Europe	115	906	1,021	111	935	1,047	113	1,125	1,238	114	1,160	1,274
Other	255	193	448	315	183	498	384	129	514	396	132	527
Total	3,445	3,886	7,331	3,804	4,093	7,897	3,999	4,351	8,350	4,388	4,217	8,605

Table 2 reports total net and gross assets for publicly reporting and non-publicly reporting funds in aggregate and by fund domicile. For non-publicly reporting funds, domicile is determined from Form ADV.

Table 3: Distribution of Alphas

	Gross of Fee Returns						Net of Fee Returns					
	Publicly Reporting			Non-Publicly Reporting			Publicly Reporting			Non-Publicly Reporting		
Pct	Sim	Act	% < Act	Sim	Act	% < Act	Sim	Act	% < Act	Sim	Act	% < Act
1	-2.63	-3.38	12.90	-2.36	-2.09	59.30	-2.61	-3.70	7.08	-2.38	-2.24	51.75
2	-2.24	-3.12	7.78	-1.96	-1.43	79.62	-2.23	-3.38	4.14	-1.97	-1.69	63.21
3	-2.02	-2.90	6.23	-1.74	-1.10	88.52	-2.01	-3.13	3.42	-1.75	-1.33	74.73
4	-1.86	-2.76	4.99	-1.59	-0.90	92.67	-1.85	-2.98	2.64	-1.60	-1.08	83.39
5	-1.73	-2.60	4.51	-1.47	-0.74	95.41	-1.72	-2.86	2.02	-1.48	-0.91	87.63
10	-1.32	-2.09	3.73	-1.09	-0.26	99.56	-1.31	-2.36	1.33	-1.09	-0.39	97.56
20	-0.85	-1.47	2.86	-0.67	0.30	99.93	-0.85	-1.75	0.62	-0.67	0.17	99.64
30	-0.52	-1.01	2.72	-0.39	0.69	99.55	-0.52	-1.30	0.22	-0.39	0.56	98.59
40	-0.25	-0.58	4.83	-0.15	1.00	98.46	-0.25	-0.86	0.19	-0.15	0.85	96.62
50	0.00	-0.11	28.57	0.07	1.31	97.67	0.00	-0.42	0.63	0.07	1.15	95.47
60	0.25	0.34	70.68	0.29	1.62	97.10	0.25	-0.01	6.50	0.30	1.44	94.60
70	0.52	0.83	89.98	0.53	1.97	96.97	0.52	0.46	44.29	0.53	1.77	94.42
80	0.84	1.41	95.80	0.82	2.39	97.06	0.84	1.03	74.93	0.82	2.19	94.90
90	1.30	2.30	98.15	1.23	3.19	98.02	1.31	1.81	87.64	1.23	2.92	96.87
95	1.71	3.12	98.87	1.59	4.08	98.97	1.73	2.52	92.06	1.60	3.77	98.06
96	1.84	3.41	99.00	1.71	4.41	99.15	1.86	2.78	93.16	1.72	4.07	98.49
97	2.00	3.88	99.34	1.86	4.78	99.28	2.03	3.17	95.09	1.87	4.45	98.72
98	2.22	4.46	99.54	2.07	5.41	99.38	2.26	3.74	96.81	2.08	5.09	98.98
99	2.62	6.13	99.86	2.46	7.09	99.54	2.68	4.82	98.30	2.47	6.66	99.34

Table 3 shows various percentile values for alpha t-statistics from the actual data, and the values calculated by averaging (at each percentile) across the 10,000 bootstrapped samples. Pct is the percentile, Sim is average alpha t-statistic at that percentile across the 10,000 bootstrapped samples, Act is the alpha t-statistic value in the actual data at that percentile, and % < Act is the percentage of the 10,000 bootstrapped samples that have alpha t-statistics that are lower than the actual alpha t-statistic at that percentile. Values are shown for gross-of-fee and net-of-fee returns, and for publicly and non-publicly reporting funds.

Table 4: Fama MacBeth Performance Regressions

Dep. Var.	Net Excess Return	Gross G7 Alpha	Net G7 Alpha	Net G7 (GLM Adj.) Alpha	Net FH Alpha	Net FH + Em Mkt Alpha	Net FH + Option Alpha
Public	-0.38	-0.41	-0.45	-0.45	-0.37	-0.28	-0.34
	-4.24	-7.20	-7.97	-6.63	-4.31	-3.17	-3.98
log(Size)	-0.03	-0.01	-0.01	-0.01	-0.02	-0.04	-0.02
	-2.17	-0.62	-0.74	-1.06	-2.41	-4.26	-2.02
Net excess return (% pq)	0.03	0.04	0.04	0.02	0.03	0.03	0.03
	3.06	6.70	7.94	4.23	3.32	3.81	2.64
Management fee (%)	-0.02	0.01	-0.06	-0.06	-0.02	0.03	0.00
	-0.75	0.44	-2.12	-2.11	-0.63	1.64	0.02
Incentive fee (%)	0.00	0.02	0.01	0.01	0.01	0.01	0.01
	0.80	6.71	5.05	4.43	5.38	8.87	6.46
Highly liquid	-0.11	-0.36	-0.34	-0.29	-0.22	-0.15	-0.18
	-1.66	-7.69	-8.61	-6.83	-4.05	-2.36	-3.22
Highly illiquid	0.16	0.37	0.34	0.33	0.19	0.11	0.18
	2.37	6.68	6.63	5.99	4.00	2.26	3.83
Strategy Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Number of observations	287,556	214,511	262,392	262,392	262,392	262,392	262,392

Table 4 shows regressions of risk-adjusted returns, defined as $\widehat{\alpha}_{i,t} = R_{i,t} - \beta_i' F_t$, on various controls. log(Size) is the log value of net assets; Net excess return is the gross-of-fee return minus the risk-free rate, Management fee is the fee rate charged on assets under management, Incentive fee is the variable fee charged as a proportion of returns, Highly liquid is an indicator variable for funds where all investors can redeem within seven days, and Highly illiquid is an indicator for funds where the longest amount of time needed to redeem capital exceeds 365 days. Strategy controls indicate whether broad strategy indicator variables are included in the regression. t-statistics are reported below coefficients with Newey-West standard errors.

Table 5: Performance Persistence

Panel A: Standard Controls

α Estimation Horizon		3 Months			6 Months			1 Year		
α Prediction Horizon	**Reported Value**	**Non-Public**	**Public**	$\widehat{\gamma}_t$	**Non-Public**	**Public**	$\widehat{\gamma}_t$	**Non-Public**	**Public**	$\widehat{\gamma}_t$
3 Months	Estimate	0.516	0.090	-0.423	0.641	0.176	-0.463	0.677	0.131	-0.545
	t-statistic	10.339	1.971	-6.981	7.603	2.762	-7.707	11.063	0.963	-6.348
6 Months	Estimate	0.507	0.086	-0.420	0.618	0.130	-0.488	0.660	0.099	-0.561
	t-statistic	7.361	2.640	-6.870	6.513	2.026	-9.818	7.984	0.482	-6.188
1 Year	Estimate	0.513	0.063	-0.453	0.611	0.087	-0.528	0.658	0.119	-0.545
	t-statistic	11.688	1.842	-10.382	17.294	0.566	-12.661	21.544	0.457	-5.948
2 Year	Estimate	0.405	0.057	-0.358	0.488	0.107	-0.392	0.537	0.025	-0.520
	t-statistic	6.137	0.906	-12.389	7.666	0.796	-9.497	9.426	0.645	-19.084

Panel B: GLM (2004) Corrections

α Estimation Horizon		3 Months			6 Months			1 Year		
α Prediction Horizon	**Reported Value**	**Non-Public**	**Public**	$\widehat{\gamma}_t$	**Non-Public**	**Public**	$\widehat{\gamma}_t$	**Non-Public**	**Public**	$\widehat{\gamma}_t$
3 Months	Estimate	0.468	0.053	-0.412	0.615	0.152	-0.461	0.665	0.110	-0.553
	t-statistic	8.977	1.108	-6.323	7.206	2.290	-7.466	10.389	0.787	-6.431
6 Months	Estimate	0.475	0.069	-0.404	0.599	0.115	-0.484	0.650	0.088	-0.563
	t-statistic	7.294	2.367	-6.603	7.381	1.783	-9.536	10.165	0.521	-6.086
1 Year	Estimate	0.482	0.052	-0.434	0.595	0.077	-0.522	0.648	0.110	-0.544
	t-statistic	12.888	1.707	-10.158	15.200	0.449	-13.194	23.532	0.429	-5.636
2 Year	Estimate	0.377	0.052	-0.335	0.472	0.100	-0.383	0.529	0.019	-0.518
	t-statistic	6.797	0.891	-10.272	6.636	0.840	-10.555	9.860	0.537	-20.841

Panel C: GLM (2004) and Heckman Corrections

α Estimation Horizon		3 Months			6 Months			1 Year		
α Prediction Horizon	**Reported Value**	**Non-Public**	**Public**	$\widehat{\gamma}_t$	**Non-Public**	**Public**	$\widehat{\gamma}_t$	**Non-Public**	**Public**	$\widehat{\gamma}_t$
3 Months	Estimate	0.588	0.046	-0.433	0.727	0.147	-0.478	0.726	0.084	-0.580
	t-statistic	11.031	0.884	-7.162	17.941	1.725	-7.338	8.143	0.539	-6.152
6 Months	Estimate	0.580	0.073	-0.426	0.644	0.112	-0.515	0.593	0.106	-0.582
	t-statistic	7.012	2.367	-7.732	12.850	1.567	-8.223	12.656	0.440	-5.638
1 Year	Estimate	0.496	0.050	-0.453	0.237	0.078	-0.536	0.689	0.154	-0.546
	t-statistic	3.375	1.284	-7.545	0.844	0.656	-9.132	3.888	0.676	-5.109
2 Year	Estimate	0.244	0.047	-0.338	0.282	0.110	-0.385	0.504	-0.014	-0.536
	t-statistic	1.660	0.794	-9.118	6.834	0.831	-9.449	5.297	-0.332	-12.255

Table 5 shows regressions of future performance, measured as returns minus the return to the broad strategy index, on historical performance, each over horizons of three months, six months, one year, and two years. Controls include those described in Table 4. Getmansky, Lo, and Makarov (2004) corrections use returns filtered from an MA(2) process, and the Heckman correction includes the inverse Mills ratio from a probit regression of continued reporting through the future horizon as an additional control. t-statistics are reported below coefficients with Newey-West standard errors.

Table 6: Fama MacBeth Flow Regressions

Dep. Var.	Flow (% Qtr)	Flow (% Qtr)	Flow (% Qtr)	Flow (% Qtr)	Flow (% Qtr)	Flow (% Qtr)
Public	3.553	3.521	-0.900	-5.001	-0.397	-0.828
	9.313	12.813	-1.593	-3.943	-0.741	-1.063
Public x Performance rank				0.085		
				6.472		
Performance rank (percentile)			0.097	0.018		
			18.796	2.411		
Public x Net excess return						0.225
						2.688
Net excess return (% pq)					0.274	0.057
					16.062	0.728
Flow (% pq)			0.161	0.161	0.163	0.163
			29.665	29.673	29.014	28.818
log(Size)			-1.223	-1.226	-1.211	-1.213
			-13.859	-14.118	-15.000	-15.197
Management fee (%)			-0.911	-0.885	-0.910	-0.906
			-11.991	-11.300	-11.892	-11.913
Incentive fee (%)			-0.003	-0.004	-0.005	-0.007
			-0.326	-0.526	-0.637	-0.748
Highly liquid			1.229	1.228	1.058	1.056
			2.757	2.742	2.559	2.590
Highly illiquid			-0.282	-0.263	-0.069	-0.064
			-1.374	-1.269	-0.302	-0.285
Strategy Controls	No	Yes	Yes	Yes	Yes	Yes
Number of observations	109,848	107,276	84,134	84,134	84,134	84,134

Table 6 shows shows regressions of quarterly investor flows on various controls. Public is an indicator equal to one if the fund reports publicly; Performance rank is the percentile value of fund gross-of-fee returns in the previous quarter, Net excess return is the gross-of-fee quarterly return minus the risk-free rate; log(Size) is the log value of net assets, Net excess return is the gross-of-fee return minus the risk-free rate, Management fee is the fee rate charged on assets under management, Incentive fee is the variable fee charged as a proportion of returns, Highly liquid is an indicator variable for funds where all investors can redeem within seven days, and Highly illiquid is an indicator for funds where the longest amount of time needed to redeem capital exceeds 365 days. Strategy controls indicate whether broad strategy indicator variables are included in the regression. t-statistics are reported below coefficients with Newey-West standard errors.

7.2 Figures

Figure 1: Hedge Fund Industry Net Assets

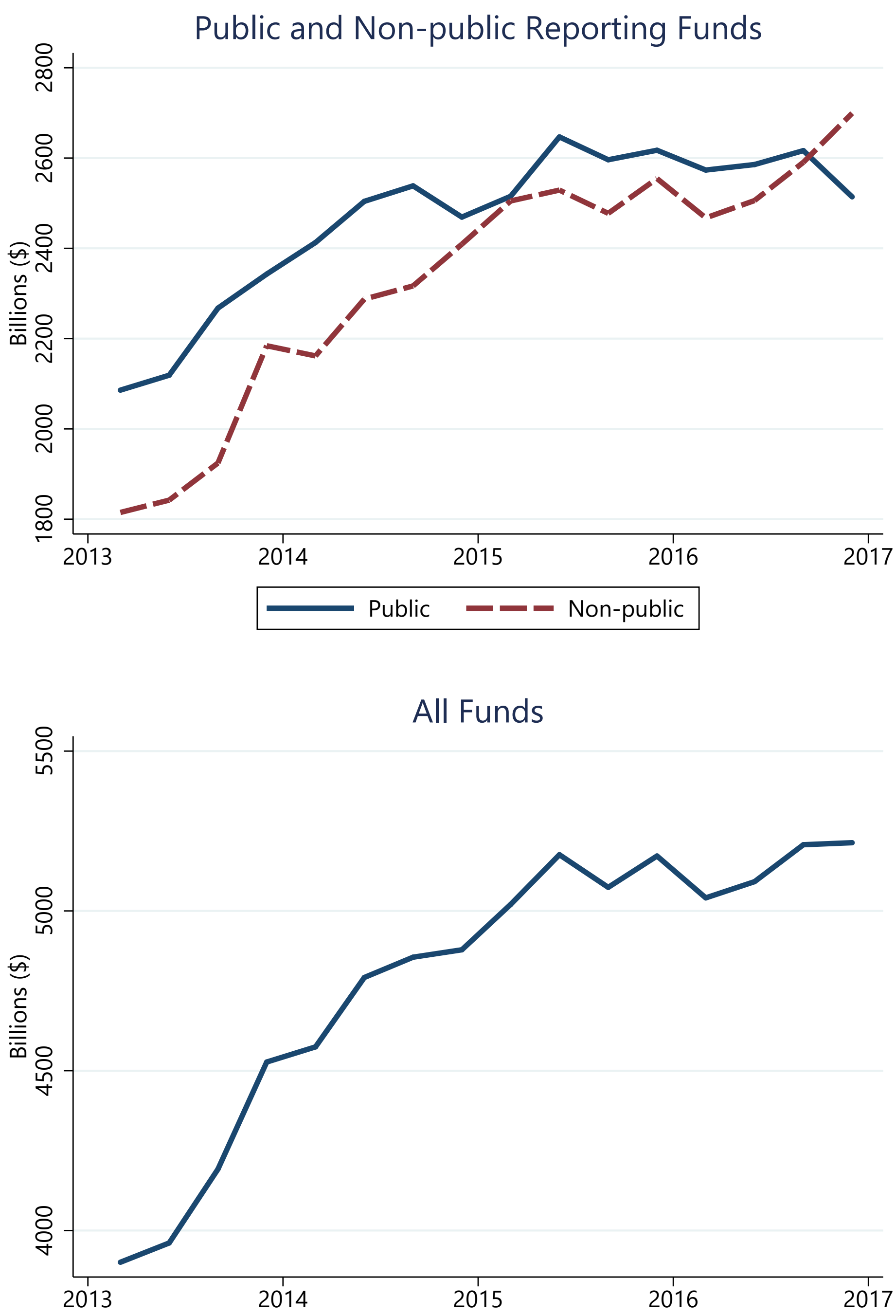


Figure 1 plots net assets for publicly reporting and non-publicly reporting funds, separately, as well as their total.

Figure 2: Net and Gross Assets for Funds That Do Not Report to SEC

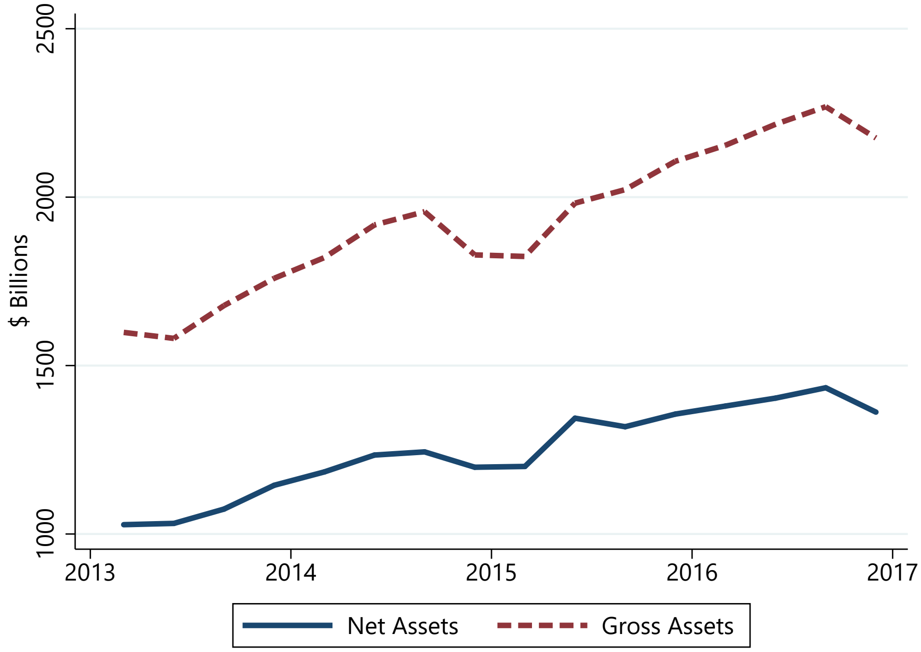
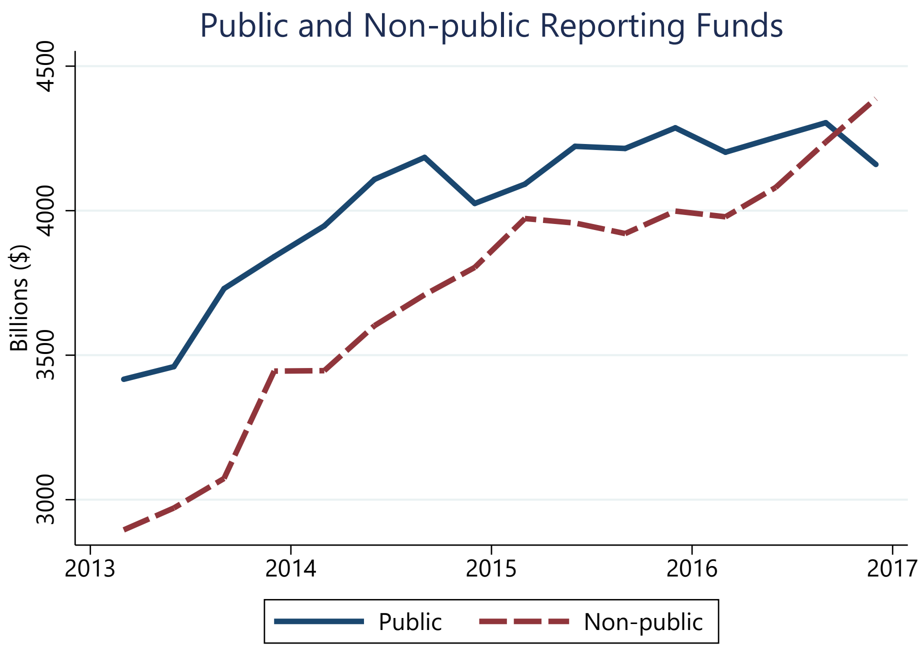


Figure 2 plots net and gross assets for funds that report to at least one public database but do not register with SEC as an investment adviser. Such funds do not report on Form PF or Form ADV.

Figure 3: Hedge Fund Industry Gross Assets



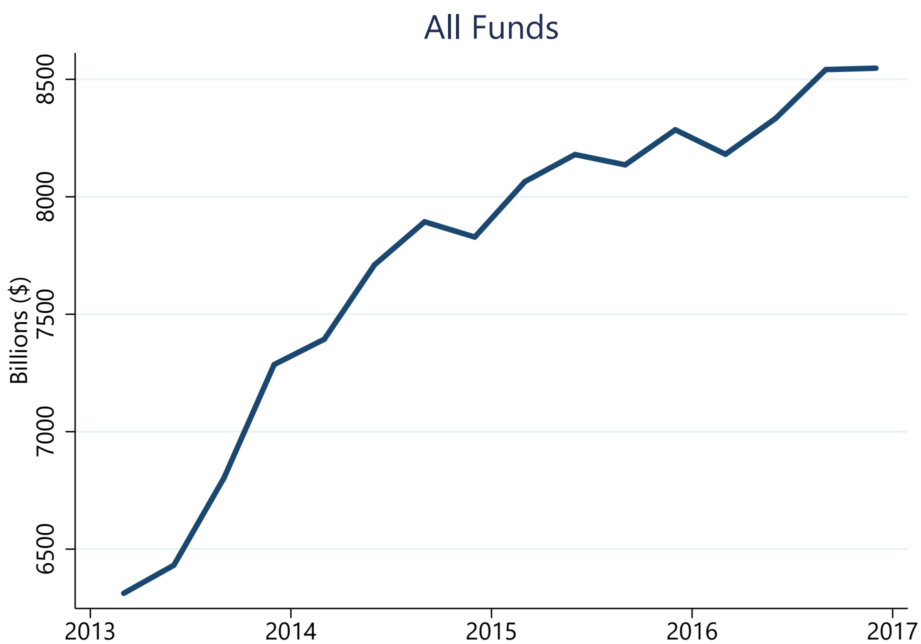


Figure 3 plots gross assets for publicly reporting and non-publicly reporting funds, separately, as well as their total.

Figure 4: Hedge Fund Industry Gross Assets (Form PF + Form ADV)

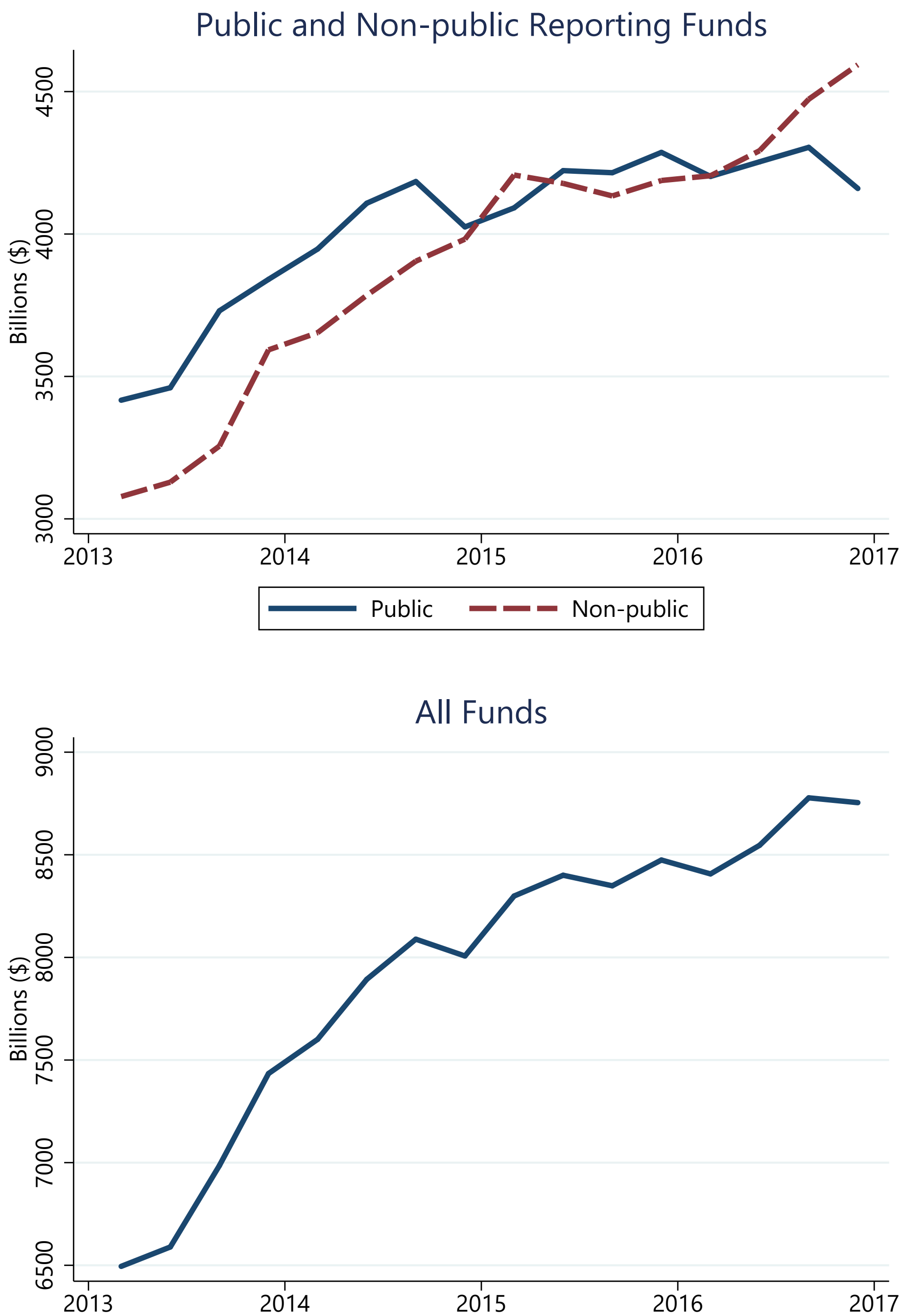
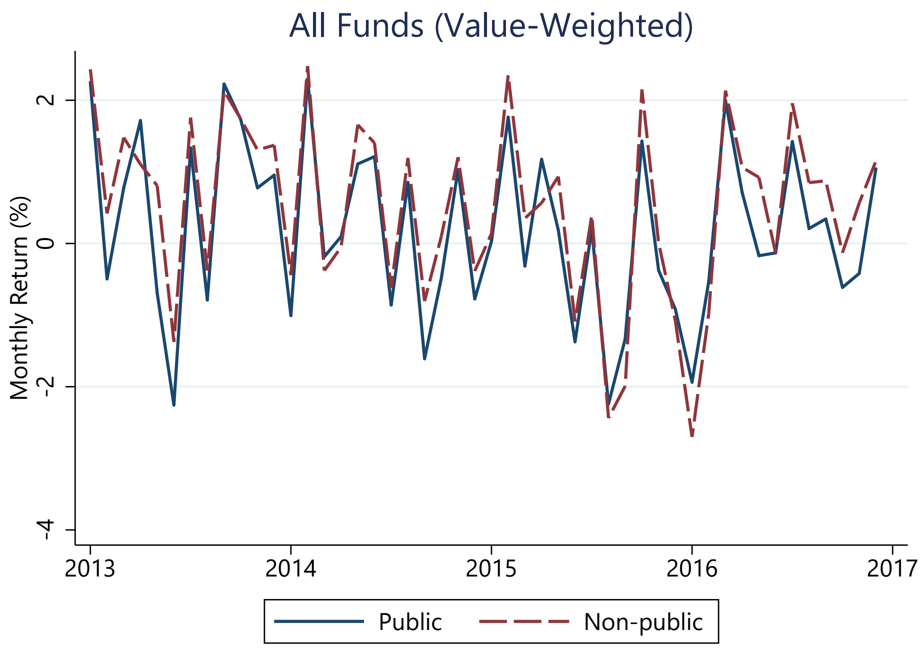
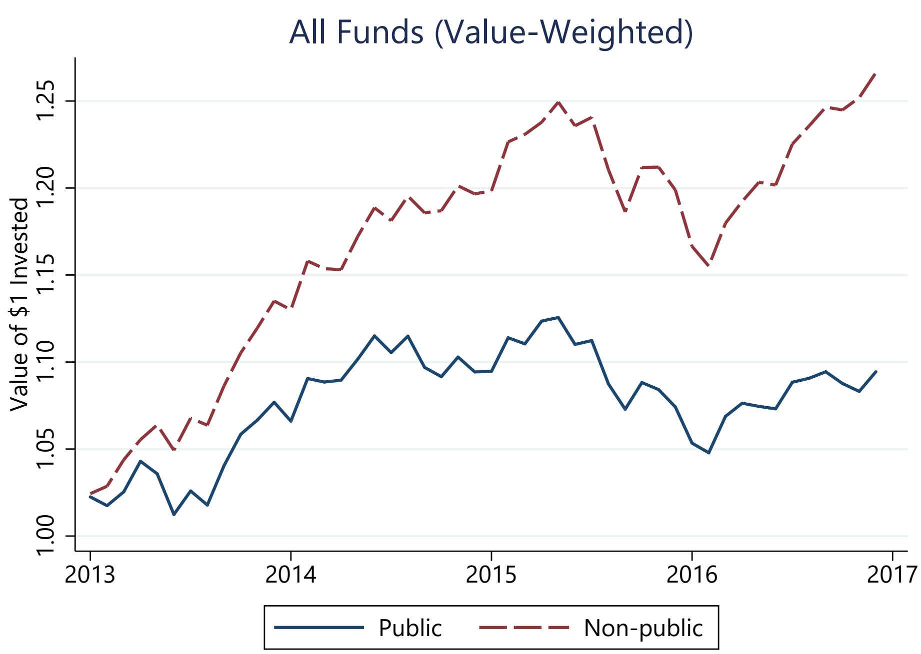


Figure 4 plots gross assets for publicly reporting and non-publicly reporting funds, separately, as well as their total. In this figure, gross assets include gross assets as reported on Form PF as well as reported on Form ADV, for funds that do not report gross assets to Form PF or any public database.

Figure 5: Cumulative Returns





The top panel of Figure 5 plots the monthly, weighted-average rate of return, net of fees, for funds that report to at least one public database and those that report only on Form PF. Returns are value-weighted by funds' net assets. The bottom panel plots the cumulative, total return over the full sample period for public and non-public funds, separately, based on the rate of return values reported in the top-panel.

Figure 6: Cumulative Returns by Strategy

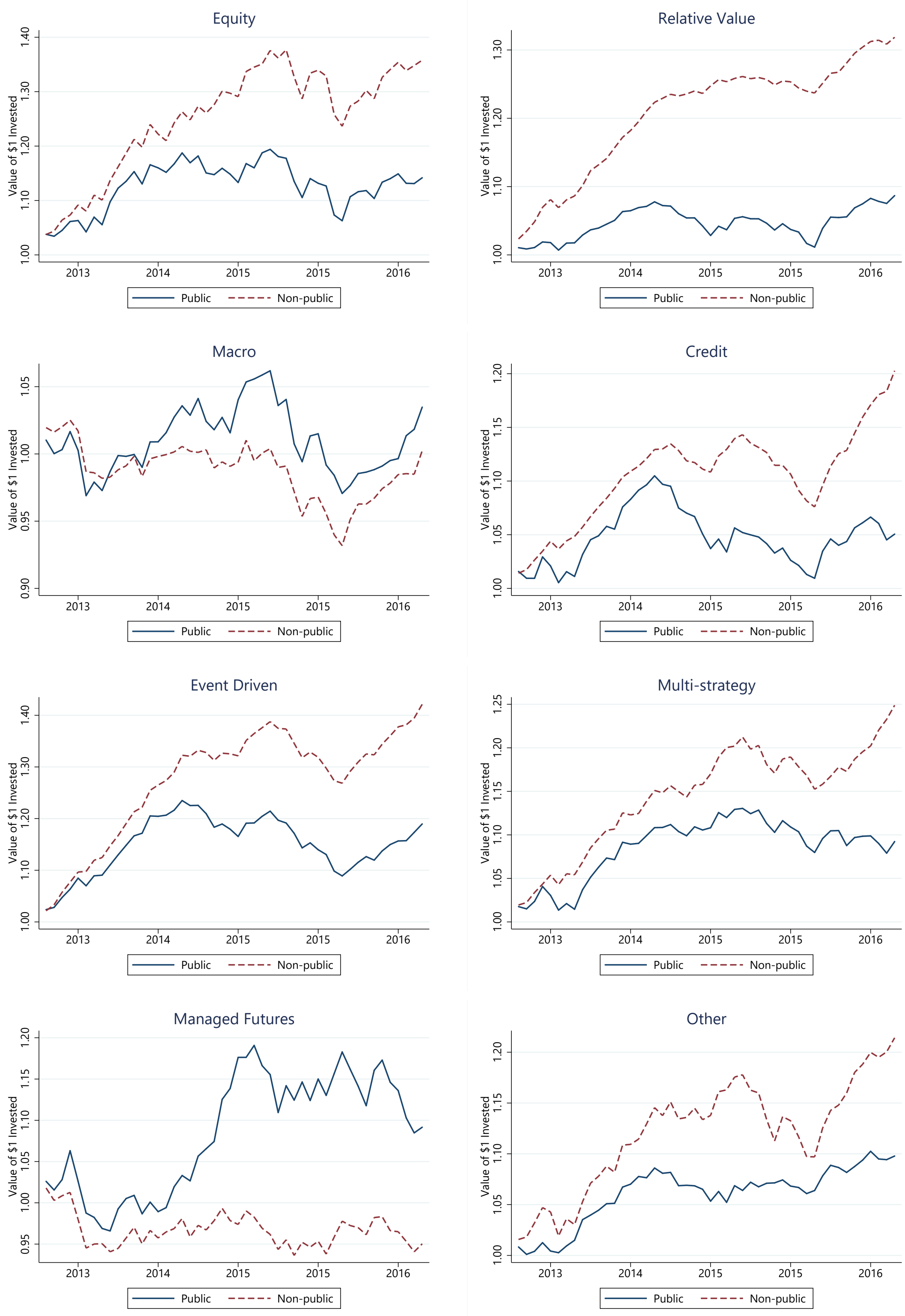


Figure 6 plots the monthly, weighted-average, cumulative total return over the full sample period for public and non-public funds, separately for each strategy category. Rates of return are weighted by funds' net assets within public/non-public, strategy, month and year.

Figure 7: CDFs of Estimated Alphas

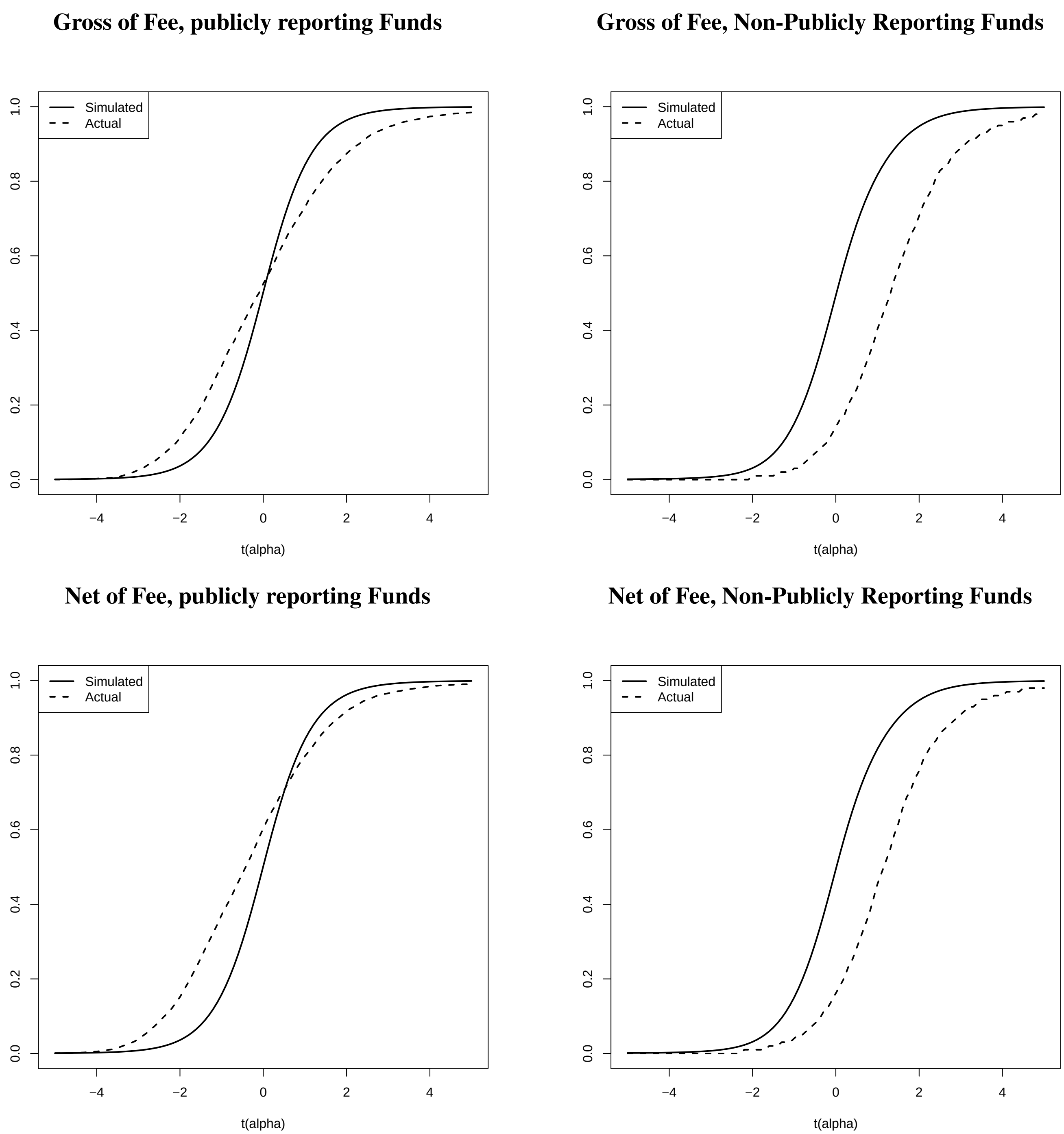


Figure 7 plots the empirical CDFs of alpha t-statistics from the actual data against the CDFs implied by the average values of alpha t-statistics at each quantile over the 10,000 bootstrapped samples. For data using Form PF, the empirical CDF is plotted by linearly interpolating between each of the 99 integer-valued percentiles of the distribution of the alphas. All plots include data from January 2013 – December 2016.

Figure 8: PDFs of Estimated Alphas

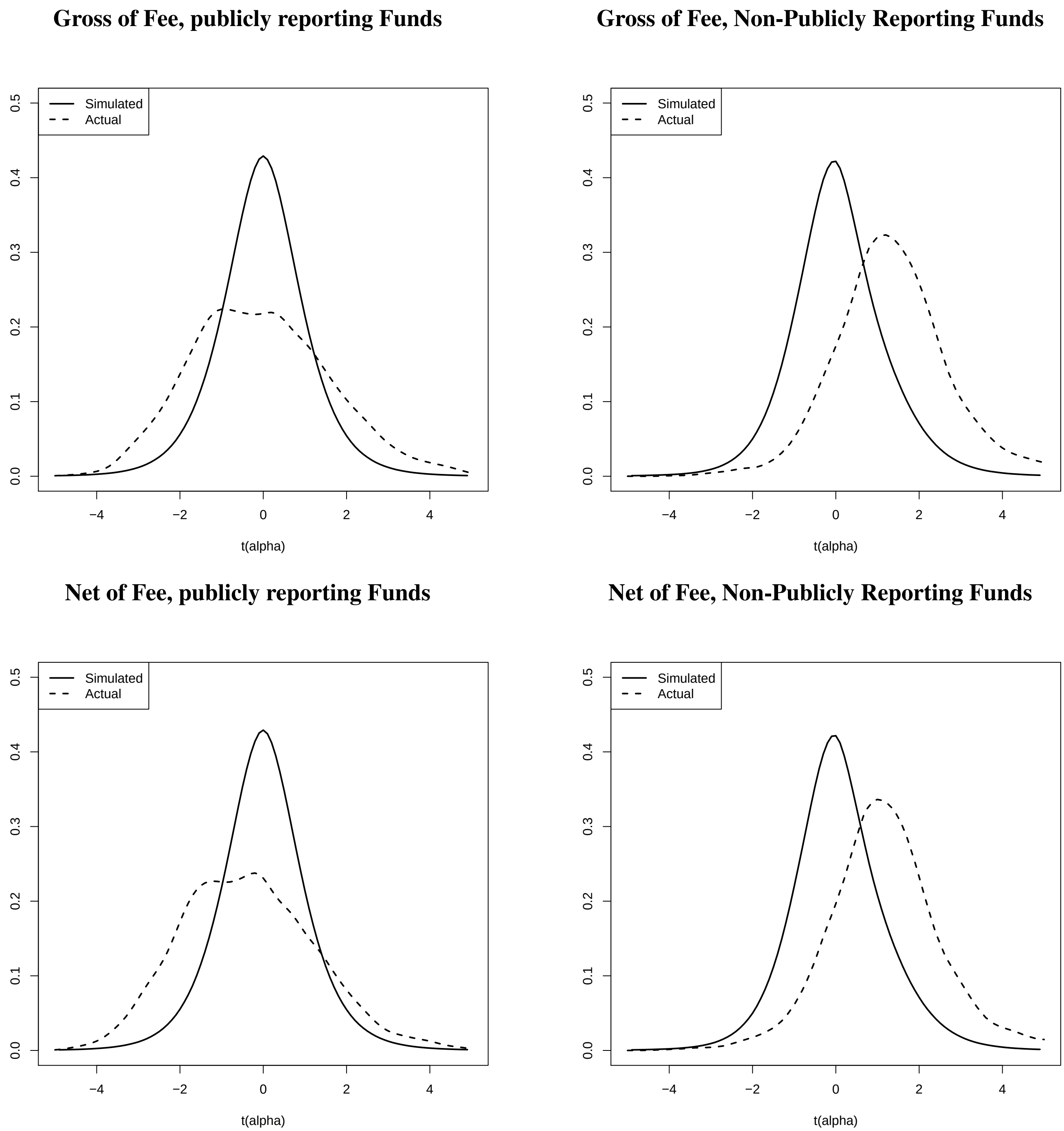


Figure 8 plots the empirical PDFs of alpha t-statistics from the actual data against the PDFs implied by the average values of alpha t-statistics at each quantile over the 10,000 bootstrapped samples. PDFs are calculated using kernel density estimation. For data using Form PF, the kernel density estimation is based on the 99 integer-valued percentiles of the distribution of the alphas. All plots include data from January 2013 – December 2016.

Figure 9: Alpha and Betas for Publicly and Non-publicly Reporting Funds

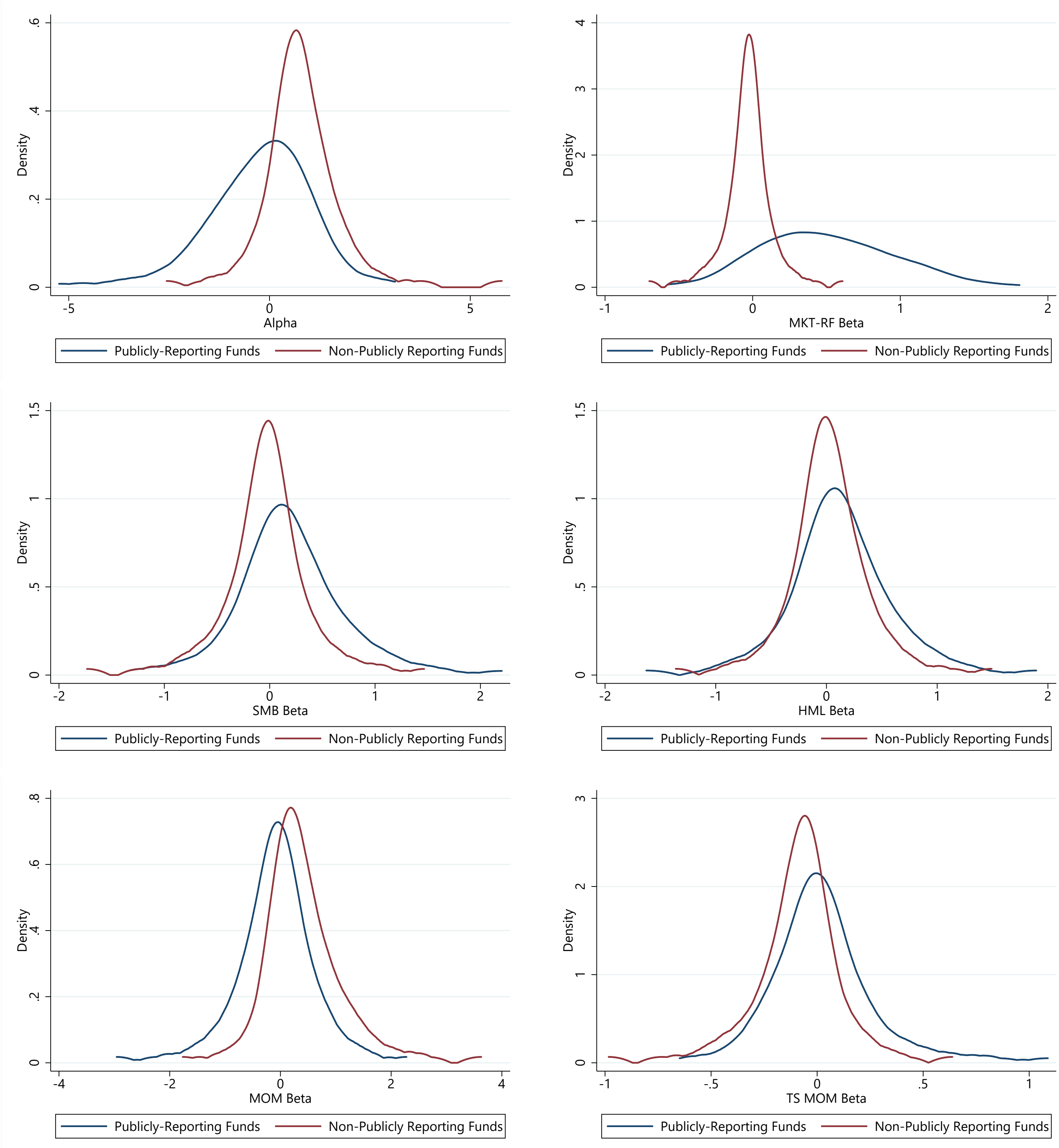


Figure 9: Alpha and Betas for Publicly and Non-publicly Reporting Funds

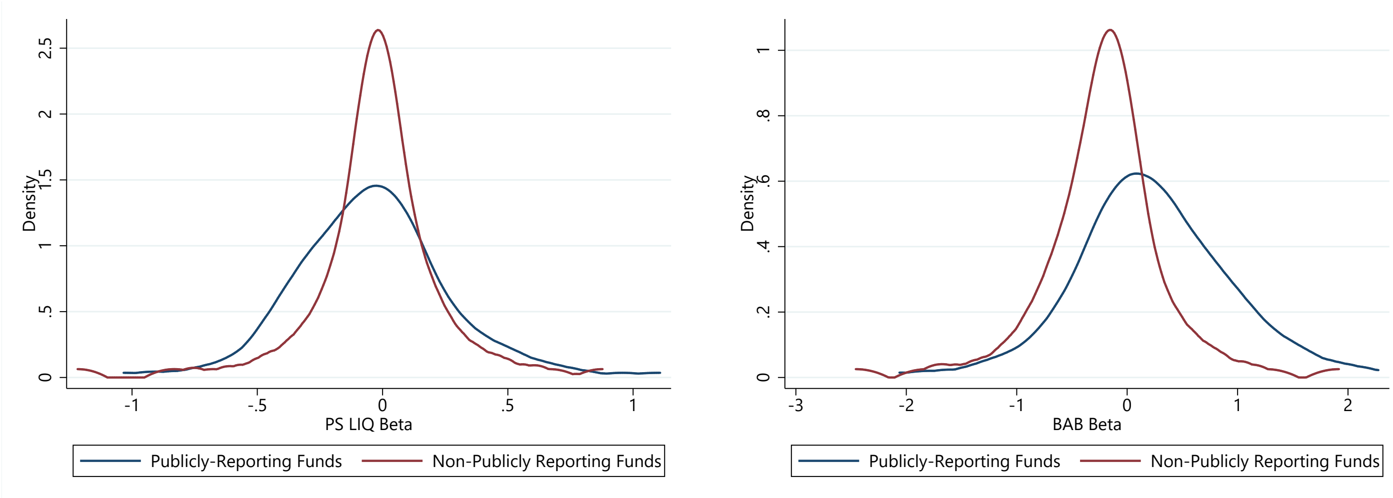
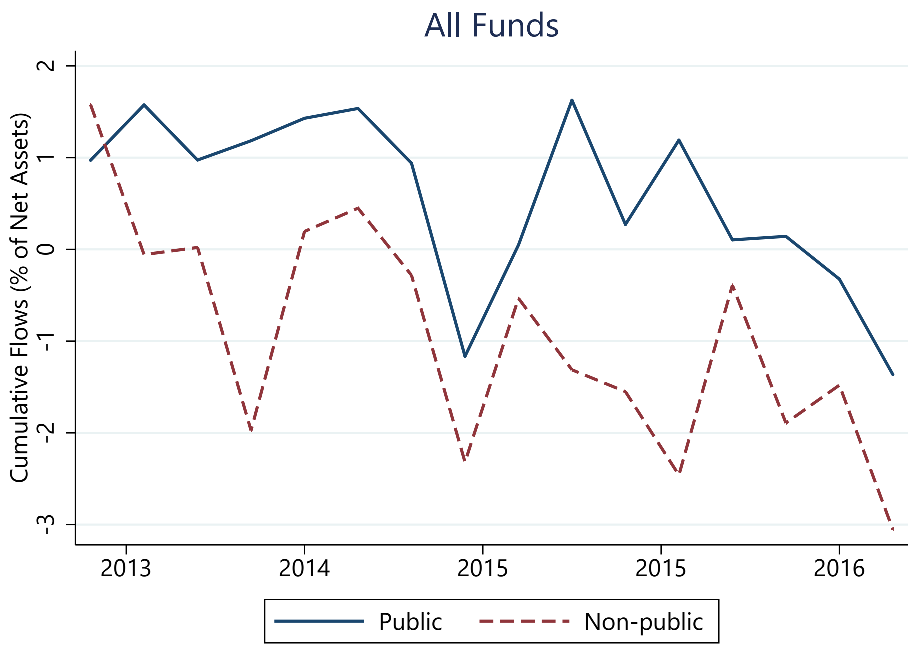
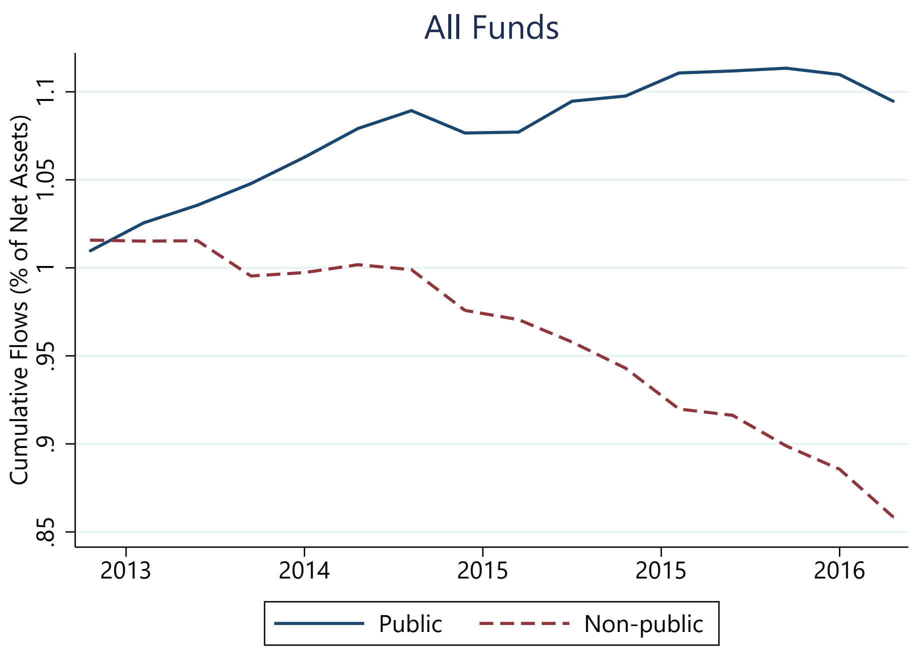


Figure 9 plots the empirical PDFs of alpha factor betas estimated from equation (1), for both publicly and non-publicly reporting funds. For non-publicly reporting funds, PDFs are constructed as linearly interpolated values between the 1^{st} and 99^{th} percentiles.

Figure 10: Cumulative Flows





The top panel of Figure 10 plots the monthly, weighted-average (net) investor flows for funds that report to at least one public database and those that report only on Form PF. Net flows are value-weighted by funds' net assets. The bottom panel plots the cumulative, total flow over the full sample period for public and non-public funds, separately, based on the net flows reported in the top-panel.

Figure 11: Cumulative Flows by Strategy

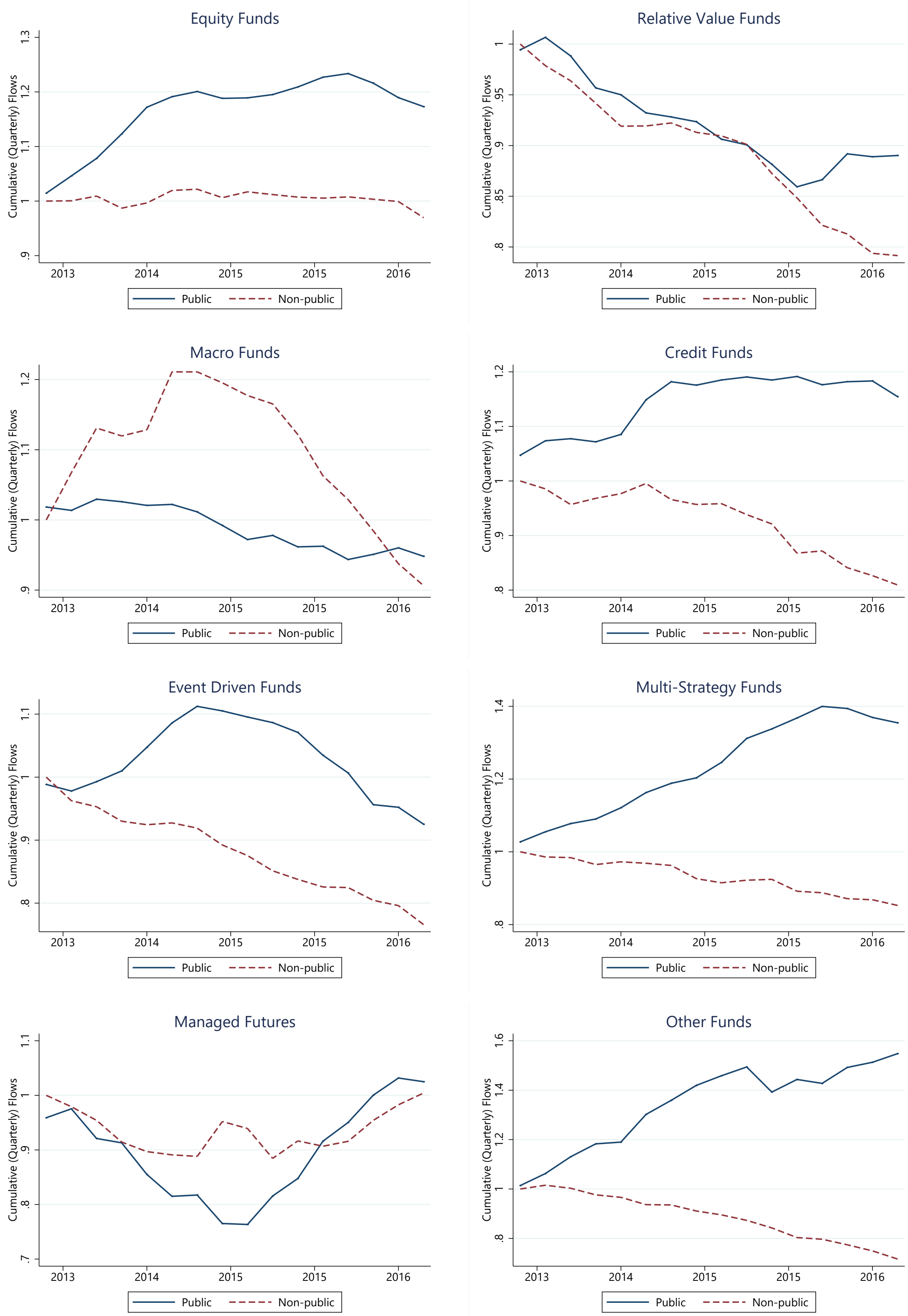


Figure 11 plots the monthly, weighted-average, cumulative total (net) investor flows over the full sample period for public and non-public funds, separately for each strategy category. Net flows are weighted by funds' net assets within public/non-public, strategy, month and year.