Balance Sheet Constraints of Prime Brokers on Hedge Fund Performance: Evidence from GSIB Surcharge

Yueting Jiang* Yiwen Shen†

Abstract

Hedge funds often use leverage provided by prime brokers to enhance their investment returns. We investigate how prime brokers' capital constraints impact the performance of connected hedge funds. At the hedge fund level, we construct a measure for prime brokers' balance sheet constraints using the capital requirements under the Basel III framework. We document that tighter balance sheet constraints of prime brokers lead to lower future return, alpha, volatility, Sharpe ratio, and information ratio of the hedge funds. These findings are consistent with an analytical model in which prime brokers respond to balance sheet constraints by increasing leverage cost or decreasing leverage provision to hedge funds. The effects are generally stronger for smaller hedge funds and during more capital binding times. Our results reveal the real effects of bank regulation on connected financial institutions via the services of prime brokers.

Keywords: Hedge funds, prime brokers, Basel III regulation, bank capital requirements, leverage costs

1 Introduction

Hedge funds are major players in modern financial markets. By the end of 2023, the total assets under management of the hedge fund industry have reached about 5 trillion US dollars. Hedge funds often use leverage to enhance their returns. To obtain the funding for leverage, hedge funds mainly rely on the financing services provided by their prime brokers. In a typical financing agreement, a hedge fund borrows money from the prime broker using its financial assets (e.g., stocks) as collaterals. Such access to credit is crucial for hedge funds to achieve their target performance. In addition, prime brokers provide a set of other services to their

*The Chinese University of Hong Kong, yueting.jiang@link.cuhk.edu.hk
†The Hong Kong University of Science and Technology, yiwenshen@ust.hk

hedge fund clients, such as security lending, clearing, and custody. For these reasons, hedge funds usually have stable and persistent connections with their prime brokers.

In the prime brokerage industry, the most important players are usually affiliated to large investment banks (e.g., J.P. Morgan, Goldman Sachs) for their abundant capital and ability to perform complex services. After the global financial crisis in 2009, there has been increasing regulations on the financial condition of the large banks, with a goal of improving their resilience and reliability during adverse market scenarios. In the post-crisis era, one of the most important regulatory responses is the Basel III framework, which is initially proposed in 2010 and gradually implemented in subsequent years. In short, the Basel III framework asks banks to hold enough capital (e.g., common stocks and retained earnings) relative to its risk-weighted assets (RWA). See Bank for International Settlements (2017) for a detailed introduction of the Basel III framework. Furthermore, the framework identifies a set of Global Systemically Important Banks (GSIBs) that play major roles in the global financial system. Due to their systemic importance, the GSIBs are required to hold additional capital beyond the baseline level for all banks. The capital requirements imposed under the Basel III framework have been shown to limit banks' business and put pressure on their returns (e.g., Duffie, 2018, Benetton, 2021).

In this paper, we investigate how prime brokers' balance sheet constraints impact the performance of hedge funds they serve. This contributes to the burgeoning area that studies the real effects of bank regulations on connected financial institutions (see, e.g., Boyarchenko et al., 2018, Breckenfelder and Ivashina, 2021, Giannetti et al., 2023). For a bank, its capital requirement is evaluated at the consolidated level that includes the balance sheets of all prime brokers affiliated to it. As such, a bank-affiliated prime broker is also subject to the overall regulatory requirement of its parent bank. On the other hands, the financing business between prime brokers and hedge funds is counted as a bank's risk-weighted assets due to the credit and market risk embedded in it. When a bank faces tighter capital constraints, it tends to restrict or reduce the size of its risk-weighted assets as raising equity in short period is usually difficult and costly. Such response is expected to limit the financing service provided by the prime brokers, thus negatively affecting the performance of the connected hedge funds.

We first propose a theoretical model to reveal the potential channels. The model considers a hedge fund that invests in one risk asset. The fund obtains leverage from a prime broker up to a limit with a constant per unit cost, and maximizes its mean-variance utility by choosing the optimal leverage level. We assume that the prime broker responds to tighter capital constraints in two ways: increasing the leverage cost and/or decreasing the maximum leverage provision. Both responses have been observed by one of us when working at a major prime broker, as well as financial professionals in the hedge fund industry.[1] The model shows how the two channels affect the hedge fund performance. We find that both increasing leverage cost and decreasing maximum leverage provision reduce the expected return and volatility of the hedge fund. The increasing cost channel also predicts a drop in the Sharpe ratio, while the decreasing provision channel has the opposite impact. We estimate the plausible range of the model parameters using market data and evidence from literature. The model solution suggests that the increasing leverage cost channel tends to play a more dominant role than the decreasing maximum provision channel. Thus, we conjecture that tighter prime brokers' balance sheet constraints are associated with lower future return, volatility, and Sharpe ratio of the connected hedge funds.

We empirically test the hypothesis from our model using multiple data sets of hedge funds, prime brokers, and associated banks from 2012 to 2021. We use the GSIB surcharge as our main measure for prime brokers' balance sheet constraints. The GSIB surcharge is the additional requirement (capital over risk-weighted assets) for the major banks in the global financial system. The GSIB surcharge is firstly proposed in 2012 and gradually implemented (phased-in) between 2016 and 2019. The possible level ranges from 1% to 5.5% for the GSIBs, reflecting their degree of importance in the financial system (a more important bank usually has a higher surcharge). We focus on GSIB surcharge in our main setting as the GSIB-affiliated prime brokers account for most of the market share in the prime brokerage business for hedge funds. In addition, the GSIB surcharge represents the extra capital requirement imposed above the baseline, thus is more likely to be binding for the banks. For the identification, we observe sufficient variation in the GSIB surcharge both cross-sectionally and over time thanks to the heterogeneity in banks and the phase-in implementation.

We obtain the hedge funds returns and characteristics from the Lipper TASS data set and their prime broker information from the Form ADV. At the fund-month level, we construct a measure for the balance sheet constraints by averaging the GSIB surcharges of all its prime brokers. We find a negative relationship between the hedge fund future return and its prime brokers' average GSIB surcharge. The hedge funds in the top tercile of average GSIB surcharge has significantly lower return and risk-adjusted alpha than those in the bottom tercile. The results hold when we use a double-sort on both fund size and average surcharge. We control for other fund characteristics using Fama-Macbeth regression. It shows that a one-standard-deviation increase of average GSIB surcharge is associated with a 0.29% decrease in the hedge fund's next month return (3.48% annually).

Next, we use panel regression to investigate the impact of GSIB surcharge on multiple

[1]See a relevant survey in 2016 by Alternative Investment Management Association at https://www.aima.org/article/basel-iii-survey.html. Other anecdotal evidence can be found in Devasabai (2014) and Nicol (2015).

hedge fund performance metrics. Our specification includes the fund style × month fixed effects, similar to Franzoni and Giannetti (2019). This controls for the time-variant macroeconomic factors that may favor particular fund styles in certain periods, and rules out the concern that some fund styles are naturally more reliant on GSIBs. We find that the hedge funds with higher GSIB surcharge have lower excess return, alpha, volatility, as well as Sharpe and information ratio over the next year. These observations support our model predictions, and reveal how the prime brokers' balance sheet constraints affect the connected hedge funds. In another specification, we include both the style × month and fund fixed effects in the regression. This additionally controls for the unobserved, time-invariant fund characteristics. Our main findings still hold. The magnitudes of effects are economically substantial: a one-standard-deviation increase in GSIB surcharge decreases the hedge fund's monthly excess return and volatility by 0.28% and 0.53% respectively.[2] These results contrast with the findings in Favara et al. (2021), which show that GSIB surcharge has no real effect on firms' borrowing as they can switch to non-GSIB banks.

We further check the heterogeneity in the effects and make two findings. First, we find that the negative effects of prime brokers' balance sheet constraints are greater for small hedge funds than for large ones. For prime brokers, large hedge funds are valuable clients as they generate stable revenue and bring various types of business. Thus, brokers may reserve capital for large hedge funds or offer them favorable conditions when facing tighter capital constraints. This partially mitigates the negative impacts of the balance sheet constraints. Second, we observe stronger effects during the periods when banks are likely to face greater capital pressures. These include the last quarter of year and periods with high market volatility (VIX) or widened CDS spreads of major banks. In the binding periods, prime brokers may significantly cut the size of their financing services, thus limiting the leverage exposure of the connected hedge funds.

What are the possible responses of hedge funds? We consider two of them. First, hedge funds may switch to the prime brokers with lower capital requirements (e.g., smaller banks or non-bank institutions). Second, hedge funds may elevate their embedded leverage by investing in stocks with higher market beta. Using the data in Form ADV, we find that the relationships between hedge funds and prime brokers are relatively sticky: the proportion of the pairwise connections that experience a change in a year is about 12% and remains stable in our sample period. One explanation is that leveraged hedge funds usually require complex services from prime brokers, thus it is beneficial for them to have stable connections with reliable, large brokers, even if the leverage costs are higher. For the response in embedded leverage, we obtain

[2] The effects are smaller when we use the within-fixed-effect standard deviation change of average GSIB surcharge, as suggested in Breuer and Dehaan (2023) and Liu and Winegar (2023).

the equity holdings of the hedge fund families from the Thompson Reuters 13F database. We find that higher GSIB surcharge is indeed associated with higher future portfolio beta of the funds. Our results are consistent with the those in Kruttli et al. (2022). The paper shows that after a liquidity shock of a major bank, connected hedge funds are unable to quickly substitute their funding source and they tend to increase the embedded leverage of their portfolios.

We carry out several additional tests to support the validity of our main findings. First, we include both the capital requirement on Common Equity Tier 1 (CET 1) and the GSIB surcharge when constructing the balance sheet constraint measure. The expected effects on hedge fund performance, i.e., lower return, volatility, Sharpe and information ratio, still hold under the new measure. Second, using a DiD analysis, we find that the hedge funds that rely more heavily on GSIB-affiliated brokers further underperform the other ones after the implementation of the GSIB surcharge in 2016. Finally, we extract the textual information about a bank's capital situation from its earnings call. We identify a list of words that are closely relevant to banks' capital requirements using the word embedding algorithm. Then, we develop a capital-related sentiment score for a hedge fund's prime brokers using the FinBERT model in Huang et al. (2023), which is a state-of-the-art large language model tailored to the finance settings. The textual information again reveals the effects of the balance sheet constraints: when the prime brokers' parent banks are more sanguine about their capital situation, this predicts higher future return of the connected hedge funds.

In sum, we find that tighter balance sheet constraints of prime brokers lead to lower returns, volatility, as well as Sharpe and information ratios of the hedge funds they serve. The results are significant and robust in multiple settings. To our best knowledge, this is among the first works that examine the real effects of bank capital constraints on hedge fund performance. Our findings reveal an unintended consequence of the Basel III regulations in the capital market, and contribute to the on-going debate on the costs and benefits of strengthened capital regulations on banks (e.g., Aiyar et al., 2014; Kisin and Manela, 2016, Fraisse et al., 2020, Buchak et al., 2024). In particular, the results suggest that the bank capital requirements may have very different impacts on hedge funds and non-financial firms (e.g., Favara et al., 2021), as the former rely heavily on the services of prime brokers and are unable to easily switch their financing sources.

Our study also reveals a novel channel through which the banks' capital requirements affect the financial market: the transmission of balance sheet costs can hurt the hedge funds' profitability and lead to changes in their investment decisions. In existing literature, most works focus on how broker dealers' balance sheet constraints impact the asset prices in the market via their market-making and liquidity provision activities (Duffie, 2018, Du et al., 2018, Cenedese et al., 2021, He et al., 2022). We contribute to this line of literature by exploring another major function of the broker dealers — the financing business that provides funding for connected financial institutions. This can be a relevant factor for regulators when they evaluate the policy implications on financial intermediaries and overall markets.

The rest of the paper is organized as follows. In next section, we provide a brief review of relevant literature. Section 2 introduces the institutional background of Basel III regulation framework and the prime brokerage business. Section 3 develops an analytical model that captures the impact of prime broker balance sheet constraints on hedge funds. Section 4 describes our data set and control variable construction. We present our main empirical analysis in Section 5. In Section 6, we perform several additional studies to support our findings. Section 7 concludes.

1.1 Literature Review

Our work is related to the following three streams of literature: the impact of financial intermediaries' capital constraints on financial markets; the real effects of bank regulation in post-crisis era; the role of prime brokers in hedge fund industry.

We contribute to the fast-growing literature examining the implications of financial intermediaries' capital constraints on the financial markets (Duffie, 2018, Fleckenstein and Longstaff, 2018). In this line of literature, existing studies largely focus on the impact on different types of assets, such as foreign exchange (Du et al., 2018, Cenedese et al., 2021), interest rate futures (Fleckenstein and Longstaff, 2020), US treasury (He et al., 2022, Du et al., 2023), and ETFs (Hong et al., 2022). Du et al. (2018) and Cenedese et al. (2021) find that the deviations from the arbitrage-free price of covered interest rate parity can be explained by the banks' balance balance sheet constraints. Hong et al. (2022) reveal that the absolute ETF premiums (gap between ETF price and NAV) exhibit comovement when ETFs have the same lead market-makers. Fleckenstein and Longstaff (2020) show that the difference in the funding rates from the derivative contracts and cash markets can be explained by intermediaries' balance sheet cost. He et al. (2022) find that the severe illiquidity in US treasury markets during the COVID-19 crisis can be attributed to the balance sheet constraints of large dealers. In these works, the major channel of effects is the market-making function of the financial intermediaries. In this study, we investigate another novel implication of financial intermediaries' capital constraints by showing how they affect the performance of connected hedge funds, which are themselves important intermediaries in the market. The channel of our effects is the financing service of prime brokers. We find that prime brokers' balance sheet constraints tend to negatively affect the performance of their hedge funds.

Our study is also related to the ongoing debate on the costs and benefits of the strengthened bank regulations after the global financial crisis. Many studies have found that more stringent bank regulations have real effects on non-financial firms and retail clients. In general, higher capital requirements of banks can lead to reduced lending (Behn et al., 2016, Gropp et al., 2019, Fraisse et al., 2020) and increased interest rate (Benetton, 2021) for borrowers. Mixed results are also observed. Favara et al. (2021) find that GSIB surcharge has no real effect on firms' total borrowing, as they are able to find substitute funding from non-GSIB banks. Different from these works, we check the real effects of bank regulations on other financial institutions. In this aspect, Boyarchenko et al. (2018) find that after the introduction of the leverage ratio requirement under Basel III framework, both small and large hedge funds reduce their reliance on GSIB prime brokers. But large hedge funds are less likely to do so as they rely more on the sophisticated services by GSIB brokers. Giannetti et al. (2023) show that after the implementation of Basel III leverage ratio requirement, profits associated with liquidity provision in the corporate bond market are transferred to bond mutual funds. We complement this literature by checking the impact of the GSIB surcharge under the Basel III framework on multiple performance metrics of hedge funds. In addition, we develop a theoretical model to reveal the potential channels. The predictions from the model are in line with our empirical findings.

Finally, our work contributes to the growing field on the roles of prime brokers in the hedge fund industry. Prime brokers provide complex services to the hedge funds, and thus can have substantial impacts on their clients. Previous studies have identified various roles of prime brokers, including information sharing (Chung and Kang, 2016, Kumar et al., 2020), capital introduction (Sinclair, 2022), and manager selection for funds of funds (Aragon et al., 2022). We focus on the financing and credit provision role of prime brokers, which has not been widely investigated in existing literature. In recent works, Dahlquist et al. (2021) find that the intermediary risk factor in He et al. (2017) is a significant determinant of hedge fund returns, but not mutual fund returns. This suggests that hedge funds bear unique risks due to their reliance on prime brokers' financing. Kruttli et al. (2022) find that an adverse liquidity shock to a major prime broker (Deutsche Bank) decreases the credit offered to its connected hedge funds due to the supply reduction channel. However, they find no significant impact on the hedge fund returns after the event as hedge funds benefit from a bull market by increasing the embedded leverage of their portfolios. We differ from the existing literature by revealing the effects of prime broker balance sheet constraints on multiple hedge fund performance metrics. These effects are consistent with the response of increasing leverage cost by prime brokers when they face tighter capital requirements.

2 Institutional Background

To study the impact of prime brokers' balance sheet constraints on hedge fund performance, we focus on the regulatory capital requirements under the Basel III framework. In this section, we briefly present the institutional background of our empirical settings. We first introduce the relevant capital requirements under the Basel III framework. Then, we describe the prime brokerage business for hedge funds and how it is affected by the capital requirements.

2.1 Capital Requirements and GSIB Surcharge

The Basel III regulatory framework was proposed in November 2010 as a response to the financial regulation deficiencies revealed by the global financial crisis. It aims to strengthen the quality of banks' capital bases and reduce the systematic risk in the financial system. The wide range of regulatory reforms has led to significant implications on financial institutions and broad markets (e.g., Fleckenstein and Longstaff, 2018). The Basel III framework consists of three pillars: regulatory capital, supervisory review, and market disclosure. In this study, we focus on the first pillar regarding banks' regulatory capital, which is the central theme in the framework.

For a bank (or a bank holding company), the Basel III regulatory framework asks it to follow a set of minimum capital requirements in the form of (see also Favara et al., 2021):

$$\frac{\text{Regulatory capital}}{\text{Risk-weighted Assets}} \geq \text{Minimum capital ratio} + \text{GSIB surcharge}. \tag{1}$$

It requires that the bank must hold enough capital relative to its asset. We introduce each component in the formula in below. The risk-weighted assets (RWA) include the loans and other assets of a bank, weighted to reflect their respective level of risk (e.g., credit risk, market risk, and operational risk). For banks, their major RWAs are loan portfolios, such as mortgages, personal loans, and corporate loans.

Under the Basel III framework, there are three types of regulatory capital with different liquidity and security levels: Common Equity Tier 1 (CET1) capital, Tier 1 capital, and total capital. Accordingly, the minimum capital ratio on the right-hand side of (1) varies for each of them. The CET1 capital includes the common shares, stock surplus, retained earnings, and other items. It has the highest quality among all types of regulatory capital, and can absorb losses immediately when they occur. The Tier 1 capital and total capital are less liquid than the CET1 capital, and include more items on the balance sheet. Their definitions can be found in Section OA.1 of the Online Appendix. For the three types of regulatory capitals, the minimum capital ratios are 4.5% for CET1 capital, 6% for Tier 1 capital, and 8% for the total capital. In Section 6.1, we use the CET1 ratio to show the robustness of our main findings.

After the global financial crisis, financial regulators have been increasingly aware of the importance of certain large banks to the global financial system. From November 2011, the list of Global Systemically Important Banks (GSIB) has been proposed by the Financial Stability Board (FSB). The GSIBs include some of the world's largest and most sophisticated financial institutions, such as J.P. Morgan Chase, Citigroup, Bank of America, and Goldman Sachs. Due to the importance of GSIBs, the Basel III framework requires them to follow more rigid capital standards than other non-GSIB banks. For a GSIB bank, it needs to hold additional capital over the minimum capital ratio required by the Basel III framework. The additional capital, in excess of the minimum requirement, is represented by the GSIB surcharge in (1).

The introduction of GSIB surcharge aims to improve the resilience of GSIBs during crisis and lower their probability of failure. If a bank is classified as a GSIB, its regulatory capital ratio must be higher than the sum of minimum capital ratio and the GSIB surcharge, as shown in (1). The surcharge for a GSIB is fixed in each year and independent of the type of regulatory capital (and corresponding minimum capital ratio) considered. It is calculated based on a set of quantitative indicators of the bank's systemic importance, and is released in advance for each year. The methodologies for calculating the GSIB surcharge are described in Section OA.1 of the Online Appendix. The surcharge varies across the GSIBs, with the minimum being 1% and maximum being 5.5%. Table 4 shows the GSIB list and their surcharges in 2021. In general, more important GSIBs have higher surcharge levels. For non-GSIB banks, the additional capital requirement does not apply and we set the GSIB surcharge as zero for them.

The GSIB surcharge was introduced gradually to give banks more time to adjust their business and strengthen their capital structure. It was implemented since January 2016, but was not fully effective until January 2019. During the phase-in period, only a proportion of the surcharge is applied to the capital ratio requirement (1). The effective surcharge in year t is given by:

$$\text{Effective Surcharge}_t = \text{Surcharge}_t \times \text{phase-in ratio}_t \tag{2}$$

where phase-in ratio_t is the proportion of GSIB surcharge that is effective in year t. Table 1 reports the phase-in ratio in each year. We see that an additional 25% of surcharge takes effect every year from 2016 to 2019. For example, if the surcharge of a GSIB is always 2% in the four years, then the effective surcharge for each year would be 0.5%, 1%, 1.5%, and 2% respectively. Figure 2 shows the release timeline and effective proportion of the GSIB surcharges over time. We see that the final surcharge level for each year is released one year before its implementation (in November of the year before last).

Table 1: GSIB surcharge phase-in ratio over time

Year	2015 and before	2016	2017	2018	2019 and after
Phase-in ratio	0%	25%	50%	75%	100%

[Insert Figure 2 here]

The capital requirements under the Basel III framework impose significant constraints on the banks' balance sheets. With a higher capital ratio, a bank has to hold more capital against a given level of RWA on its balance sheets. This increases the implicit cost of the bank's balance sheet, ceteris paribus. On the other hand, fixing the bank's regulatory capital level, tighter capital requirements make it more difficult for the bank to expand its business by increasing the RWA. In order to reach the target capital ratio, banks can either increase their regulatory capital or shrink their RWA. Empirical studies show that when banks face increased capital requirements, they usually do not raise equity capital. Instead, they are more likely to reduce their RWA and require more collateral on new loans (see Gropp et al., 2019, Degryse et al., 2021, and Favara et al., 2021).

As GSIBs are subject to higher capital requirement, the additional surcharge imposed on the minimum capital ratio is more likely to affect the business of these large banks. Despite the four year phase-in periods, the compliance pressure takes effect quickly since 2016.[3] We expect that GSIBs have to adapt quickly to satisfy the additional capital requirement. As noted by Jamie Dimon, the CEO of J.P. Morgan, the GSIB surcharge makes it more challenging for the bank to achieve higher return. In the 2021 annual letter, he mentioned that the additional capital requirements would effectively cut return on equity (ROE) by about 15% from whatever it would have been if the bank didn't have such a high GSIB charge.[4] From the management team perspective, GSIB surcharge clearly drags down the bank's performance by increasing its capital cost.

The Basel III framework also includes other capital requirements that do not depend on the risk level of different assets, which contrasts with the RWA used in (1). For example, the Supplementary Leverage Ratio (SLR) requirement asks banks to maintain a minimum amount of capital against the total leverage exposure, regardless of their risk levels.[5] In this study, we focus on the traditional security financing services provided by prime brokers to hedge funds (see next section), which contributes significantly to banks' RWA due to their

[3]The international framework for GSIB surcharge is established in 2012. The rule for determining surcharge for US GSIBs is finalized in July 2015.

[4]See https://www.fool.com/investing/2022/04/07/jamie-dimon-tells-investors-to-prepare-for-an-extr/.

[5]See https://www.bis.org/publ/bcbs270.pdf.

high counterparty credit risk. In addition, the capital requirements based on the RWA in (1) is usually more binding for the banks than those based on the total exposure. Thus, the effect of non-risk-based requirements is out of the scope in this paper.

2.2 Prime Brokerage Business

Prime brokerage is a set of services offered by large financial institutions, mainly investment banks, to hedge funds and other investment clients. The services include, but are not limited to, financing, security lending, capital introduction, clearing, custody, and execution (see, e.g., Boyarchenko et al., 2018, Kumar et al., 2020, Aragon et al., 2022). As hedge funds employ sophisticated trading strategies, they tend to rely on large bank affiliated brokers for complex services.

One of the main services provided by prime brokers is the financing service through which hedge funds are able to use leverage to enhance returns. Hedge funds usually use margin loan and repo financing to obtain leveraged exposure. Margin loans are cash loans obtained from prime brokers to finance the fund's long positions and are secured by collaterals. Repo financing is the agreement to sell securities combined with an agreement to repurchase those securities at a pre-arranged price on a future date. It works like a collateralized loan, with the securities being the collateral. Kruttli et al. (2022) show that margin loan and repo financing make up around 90% of all hedge fund borrowings. In addition, compared with corporate loans, financing agreements between prime brokers and hedge funds are more frequent and short-termed.

For a bank affiliated prime broker, its financing services are affected by the capital requirements on its parent bank. This is because the capital ratio for a bank is evaluated at the consolidated level, which includes the business of its prime broker. According to the Basel III framework, margin loan and repo financing are counted as banks' RWA due to their counterparty credit risk.[6] For example, the bank faces the risk that the hedge fund may default on a margin loan even the loan is collateralized. Thus, a higher capital requirement for the bank would impose tighter constraints on the bank-affiliated prime broker's balance sheet. This restrains the prime broker's financing services to hedge funds by putting a limit on its maximum allowable RWA.

In this study, we focus on GSIB-affiliated prime brokers and study how their capital constraints impact the hedge fund performances through the prime brokerage business. The GSIB prime brokers provide a suitable setting for answering this question. First, GSIB prime

[6] Counterparty credit risk is the risk that the counterparty to a transaction may default before the final settlement of the transaction's cash flows.

brokers are the most important players in the brokerage business (see the report from Preqin[7]). They represent the largest financial institutions and are capable of providing sophisticated services for the hedge funds. According to Boyarchenko et al. (2018), GSIB brokers account for 80% of all brokers used by hedge funds. This is also observed in our sample (see Section 4). Thus, we expect their capital constraints to have significant and broad impacts on the hedge fund performance. Second, GSIB surcharge requires extra regulatory capital on top of the minimum capital ratio shared by all banks. The additional capital requirement is more likely to be binding, as GSIBs are subject to stricter supervisory scrutiny. Finally, the different surcharge levels among GSIBs and the phase-in implementation over time provide enough cross-sectional and temporal variation in the balance sheet constraints of prime brokers, which can be used to identify how such constraints affect hedge fund performance.

We investigate how prime broker's balance sheet constraints, as measured by the GSIB surcharge, affect the hedge fund performance. In the next section, we develop a theoretical model to shed light on the potential channels. We conduct rigorous empirical analysis to reveal the effects in Section 5.

3 Theoretical Framework

In this section, we develop a theoretical model to investigate the impacts of prime broker's balance sheet costs on hedge fund performance. This reveals the potential channels and provides a foundation for our subsequent empirical analysis.

We consider a leveraged hedge fund that invests in one risky asset with expected return μ_r and σ_r^2. The fund gets financing for its leverage from a prime broker. The per unit leverage cost c is set by the prime broker. It includes potential financing and commission fees associated with the leverage. We assume that $c < \mu_r$, i.e. the leverage cost is smaller than the asset's expected return. With net leverage level δ, we can express the expected return and variance of the hedge fund's position as:

$$\mathsf{E}(R) = (1+\delta)\mu_r - \delta c \quad \text{and} \quad \mathsf{var}(R) = (1+\delta)^2\sigma_r^2, \tag{3}$$

where the term $-\delta c$ captures the leverage cost.

We assume the hedge fund maximizes the following mean-variance objective[8] by choosing

[7] See, for example, https://docs.preqin.com/reports/Hedge-Fund-Prime-Brokers-June-2018.pdf

[8] Hedge funds are risk averse as they usually have internal risk limits.

its leverage level δ:

$$\begin{aligned}\max_{\delta \geq 0} \quad & \mathsf{E}(R) - \frac{\gamma}{2}\mathsf{var}(R) \\ \text{s.t.} \quad & \delta \leq \overline{\delta},\end{aligned}$$

where γ is its risk-aversion coefficient. $\overline{\delta}$ is the maximum leverage that a hedge fund can obtain from its prime broker. It can reflect the internal risk limits faced by the prime broker, e.g., the leverage provided to one client cannot be too high.

By (3), we can solve the optimal leverage δ^* of the hedge fund. If there were no constraint $\delta \leq \overline{\delta}$, it is easy to derive the optimal leverage as

$$\delta^*_{UC} = \max\left\{\frac{\mu_r - c}{\gamma\sigma_r^2} - 1, 0\right\},$$

which decreases in the risk aversion γ. The optimal δ^* can be solved as

$$\begin{cases} \delta^* = \overline{\delta}, & \text{if } \gamma \leq \frac{\mu_r - c}{\sigma_r^2(1+\overline{\delta})}, \\ \delta^* = \delta^*_{UC} < \overline{\delta}, & \text{if } \frac{\mu_r - c}{\sigma_r^2(1+\overline{\delta})} \leq \gamma \leq \frac{\mu_r - c}{\sigma_r^2}, \\ \delta^* = 0, & \text{if } \gamma > \frac{\mu_r - c}{\sigma_r^2}. \end{cases} \tag{4}$$

In the first case, the hedge fund is very risk-taking with a relatively small γ. Thus it uses all the leverage that can be provided by the prime brokers, leading to a binding constraint $\delta^* = \overline{\delta}$. In the second case, the hedge fund is moderately risk-taking, and the optimal leverage is unbinding with $\delta^* < \overline{\delta}$. In the last case, the hedge fund is very risk averse such that it uses no leverage. We focus on the first two cases with $\delta^* > 0$, which are relevant for leveraged hedge funds. In addition, we show momentarily that they are more likely to happen in the market.

We now investigate how prime broker's balance sheet constraints may affect the investment performance of the hedge fund, including its expected return, variance, and Sharpe ratio. We assume there are two possible responses when the prime broker faces tighter balance sheet constraints. First, they may increase the leverage cost c. Second, they may decrease the maximum leverage $\overline{\delta}$ that can be provided. We refer the two channels as increasing cost channel and reducing provision channel respectively.

In the case with moderate risk aversion level, $(\mu_r - c)/(\sigma_r^2[1 + \overline{\delta}]) \leq \gamma \leq (\mu_r - c)/\sigma_r^2$, we have optimal leverage $\delta^* = \delta^*_{UC} < \overline{\delta}$. Plugging this into (3), the expected return, variance, and Sharpe ratio of the hedge fund at the optimal leverage level can be calculated as:

$$\mathsf{E}(R^*) = \frac{(\mu_r - c)^2}{\gamma\sigma_r^2} + c, \qquad \mathsf{var}(R^*) = \frac{(\mu_r - c)^2}{\gamma^2\sigma_r^2},$$

and

$$\mathsf{S}(R^*) = \frac{\mu_r - c}{\sigma_r} + \frac{\gamma\sigma_r c}{\mu_r - c}.$$

As the constraint $\delta \leq \overline{\delta}$ is unbinding in this case, the above metrics are only affected by the leverage cost c, but not the maximum leverage $\overline{\delta}$. Thus, only the increasing cost channel is at play when the prime broker becomes more balance sheet constrained. Given the admissible range of γ, we can show that the expected return $\mathsf{E}(R^*)$ and variance $\mathsf{var}(R^*)$ are both decreasing in the leverage cost c. For the Sharpe ratio $\mathsf{S}(R^*)$, we find that it also decreases in c if the additional condition $\gamma \leq (\mu_r - c)^2/(\sigma_r^2\mu_r)$ holds. The proofs are provided in Section OA.2 of the Online Appendix. Thus, as the prime broker increases the leverage cost, we expect the hedge fund would have a lower return, a smaller variance, and a lower Sharpe ratio (supposing $\gamma \leq (\mu_r - c)^2/(\sigma_r^2\mu_r)$).

In the case with low risk aversion level, $\gamma \leq (\mu_r - c)/(\sigma_r^2[1 + \overline{\delta}])$, the leverage constraint is binding with $\delta^* = \overline{\delta}$. The expected return, variance, and Sharpe ratio of the hedge fund at the optimal leverage level are given by:

$$\mathsf{E}(R^*) = (1 + \overline{\delta})\mu_r - \overline{\delta}c, \qquad \mathsf{var}(R^*) = (1 + \overline{\delta})^2\sigma_r^2,$$

and

$$\mathsf{S}(R^*) = \frac{\mu_r}{\sigma_r} - \frac{\overline{\delta}c}{1 + \overline{\delta}\sigma_r}.$$

In the binding case, the hedge fund performance is affected by both the increasing cost channel and decreasing provision channel. As shown in Section OA.2, both increasing c and decreasing $\overline{\delta}$ reduce the expected return $\mathsf{E}(R^*)$. The variance $\mathsf{var}(R^*)$ is independent of c and decreases in $\overline{\delta}$. For the Sharpe ratio, we find it is decreasing in both c and $\overline{\delta}$. Thus, the increasing cost channel (larger c) leads to a smaller Sharpe ratio, while the decreasing provision channel (smaller $\overline{\delta}$) increases it. The net effect is undetermined.

Table 3 summarizes the impact on hedge fund performance when the prime broker is more balance sheet constrained. We see that the expected return and variance always decrease. The Sharpe ratio also decreases if the leverage is unbinding (and risk aversion is not too high), or if the increasing cost channel dominates in the binding case.

In the model, we cannot determine whether the leverage constraint $\delta < \overline{\delta}$ is binding at the optimal solution, and which of the two channels is more dominant when prime brokers

Table 2: Summary of Impacts on Hedge Fund Performance

	Unbinding: $\frac{\mu_r - c}{\sigma_r^2(1+\overline{\delta})} \leq \gamma \leq \frac{\mu_r - c}{\sigma_r^2}$		Binding: $\gamma \leq \frac{\mu_r - c}{\sigma_r^2(1+\overline{\delta})}$	
Channels	Increasing c	Decreasing $\overline{\delta}$	Increasing c	Decreasing $\overline{\delta}$
$\mathsf{E}(R^*)$	$\downarrow$	N/A	$\downarrow$	$\downarrow$
$\mathsf{var}(R^*)$	$\downarrow$	N/A	N/A	$\downarrow$
$S(R^*)$	$\downarrow$ if $\gamma \leq \frac{(\mu_r - c)^2}{\sigma_r^2 \mu_r}$	N/A	$\downarrow$	$\uparrow$

become more balance sheet constrained. That said, we obtain some heuristic evidence using real-world data. We set the annual estimates $\mu_r = 11.1\%$ and $\sigma_r = 17.8\%$ based on the S&P 500 Index returns from 2010 to 2022. We assume the leverage cost is $c = 2\%$ annually based on typical margin loan spreads.[9] For the maximum leverage provision, we set it as $1+\overline{\delta} = 6.67$ following the portfolio margin rule.[10] With these parameters, we can find the ranges of risk aversion γ for the three cases of optimal leverage δ^* in (4). These are shown in Figure 1. Thus, if the risk aversion γ lies in $[0.43, 2.87]$, the leverage constraint is unbinding. Furthermore, if $0.43 \leq \gamma \leq 2.36$, the Sharpe ratio decreases in the leverage cost c. The leverage constraint becomes binding when the risk aversion is smaller than 0.43, and the net impact of the two channels on Sharpe ratio is indefinite.

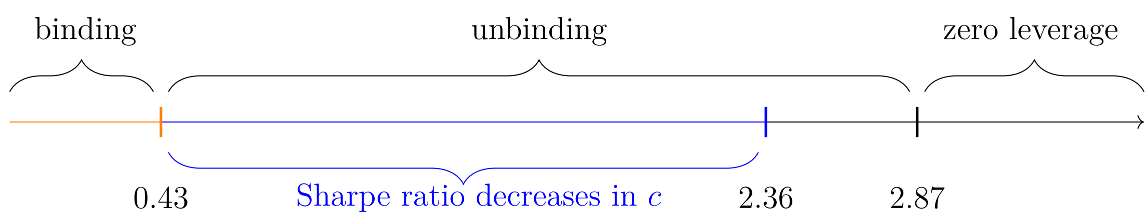

Figure 1: Range of risk aversion γ for the three cases of optimal leverage δ^*

We can estimate the risk aversion γ using empirically observed leverage levels, assuming they are already set at the optimal level by the hedge funds. For example, Kruttli et al. (2022) use Form PF, a confidential filling to SEC, to obtain the gross leverage ratio $(1 + \delta)$ for hedge funds with different styles. They find that the mean (median) leverage ratio ranges from 1.63 to 3.96 (1.31 to 2.47), which translates to an interval of 0.72 to 1.76 (1.16 to 2.19) for risk aversion γ using our parameters. Jiang (2023) uses Form ADV and shows that the mean (median) gross leverage ratio of hedge fund families falls between 1.4 and 2.98 (1.32

[9] We set the value of c based on the margin loan spread charged over the benchmark rate. The spreads for major currencies range from 0.5% to 3%; see https://www.interactivebrokers.hk/en/trading/margin-rates.php.

[10] By regulation, the minimum margin requirement for open-ended funds is 15%, translating to a maximum leverage of 6.67 (=100/15). See https://www.finra.org/rules-guidance/key-topics/portfolio-margin/faq.

and 2.48), with corresponding γ in $[0.96, 2.05]$ ($[1.16, 2.18]$). In Ang et al. (2011), the authors find a mean gross leverage ratio of 2.13 for the hedge funds in their sample, implying a risk aversion level of 1.35. In above examples, the estimated risk aversion γ all falls in the interval $[0.43, 2.87]$, leading to an unbinding constraint $\delta^* < \overline{\delta}$. Moreover, γ is smaller than 2.36 in most cases, suggesting the Sharpe ratio decreases in the leverage cost.

Based on above discussion, we conjecture that as prime brokers become more balance sheet constrained, their connected hedge funds would have lower expected return, volatility, and Sharpe ratio. We investigate this empirically using the hedge fund and prime broker data in subsequent sections.

4 Data and Descriptive Statistics

We combine several datasets for our analysis. First, we obtain GSIB surcharge data from Financial Stability Board website and 10-K fillings of US GSIBs. Second, we obtain hedge fund monthly return and fund-level characteristics data from Lipper TASS database. Third, we get hedge fund and prime broker relationships from Form ADV.[11] Our sample spans from 2013 to 2022, as the GSIB list is released in November 2012.

We first obtain the GSIB surcharge for each bank. For non-US GSIBs, their surcharges are set by the Financial Stability Board and the data can be obtained directly from the its official website.[12] For US GSIBs, their final surcharge levels are set jointly by the Financial Stability Board and Federal Reserve Board.[13] Thus, we hand collect the surcharges of US GSIBs from their 10-K fillings in each year. Table 4 shows the GSIBs and their surcharge levels in 2021. Figure 3 plots the surcharges for nine representative GSIBs between 2016 and 2022. We exploit the variation in the GSIB surcharges to study how prime brokers' balance sheet constraints affect hedge fund performance.

[Insert Table 4, Figure 3 here]

We obtain hedge fund monthly returns and fund-level characteristics from the Lipper TASS database. Lipper TASS is one of the most widely used database for research on hedge fund. Following the literature, we keep the funds that report the net-of-fee returns on a monthly frequency (Chen et al., 2021). For non-USD funds, we convert their asset under management

[11] The Form ADV can be downloaded in https://www.sec.gov/foia/docs/form-adv-archive-data. Hedge funds' prime brokers information is in Section 7B of Schedule D.

[12] See https://www.fsb.org/work-of-the-fsb/market-and-institutional-resilience/global-systemically-important-financial-institutions-g-sifis/.

[13] The Federal Reserve Board has another method for evaluating the proper surcharge level of US GSIBs. The final surcharge is set as the higher one of the levels proposed by Financial Stability Board and Federal Reserve Board.

to USD values using the spot foreign exchange rates from the Federal Reserve Bank of St. Louis. We exclude the fund of funds category in our analysis. A fund of funds invests in other funds. Thus, its performance can be affected by both its own brokers and those of its underlying funds, which is hard to disentangle empirically.

We classify hedge funds as leveraged or unleveraged as follows. First, we check the "leveraged" column in the database, which provides a binary classification. Second, the TASS database have four columns indicating which kinds of leverage are used by the hedge funds: futures, margin, derivatives, and FXcredit. We regard a hedge fund as unleveraged if none of the above fields indicates it uses leverage.[14] Otherwise, a fund is classified as leveraged. In our main analysis, we focus on the leveraged hedge funds as they are more likely to be affected by the prime broker's balance sheet constraints (see Section 5). The unleveraged funds are used for placebo tests.

We obtain the information on hedge funds' prime brokers from Form ADV. The Securities and Exchange Commission (SEC) requires all professional investment advisers (including hedge fund families) to submit Form ADV. The form must be updated annually[15] and made available as a matter of public record for companies that manage assets more than $25 million. We use Part 1A and Schedule D of Form ADV to collect the relationship information between hedge fund families and prime brokers over time. In Form ADV, one hedge fund family can have multiple prime brokers within the same bank holding company. For example, "J.P. Morgan ASIA Pacific Limited" and "J.P. Morgan Singapore" are all J.P. Morgan affiliated brokers. In our analysis, we manually map all subsidiary brokers to the bank holding company they belong to. This is because the balance sheet constraints (e.g., GSIB surcharge) are imposed on the bank holding company at a consolidated level.

As there is no common identifiers for investment advisors in Form ADV and management companies in TASS database, we manually merge the two datasets by matching the names of hedge fund families. We use the fuzzy string matching algorithm in Python. For each investment advisor name in Form ADV, we calculate its sub-string similarity score with all names in TASS. We keep the three fund management companies with the highest similarity scores as potential matches. The above matching procedure is similar to the ones used in Zheng and Yan (2021) and Franzoni and Giannetti (2019). We manually check the matched results through web search and keep the correct ones.

We use Form ADV instead of TASS to get the prime broker information (same as Boyarchenko et al., 2018). First, the prime broker information in TASS is a snapshot and does

[14]We classify leveraged and unleveraged funds using the two criteria since there can be some discrepancies between them in TASS. For example, the leveraged column shows zero but the margin column shows one. We manually checked some of such cases and found that the funds indeed use leverage.

[15]In unusual cases, investment advisers can also voluntarily update the form more than once in a year.

not contain historical changes (Chung and Kang, 2016). Second, we find that the number of prime brokers found in Form ADV is larger than that from TASS, as funds have to report all their prime brokers in Form ADV. Note that in TASS, we only see a number identifier for each fund and the hedge fund family it belongs to. Thus, we make a reasonable assumption that a hedge fund's prime brokers are the same as its parent fund family. Using the snapshot data in TASS, we find that more than 80% of hedge fund families have the same prime brokers across all of their funds.

We construct our main balance sheet constraint measure at the hedge fund level by averaging the GSIB surcharges of a fund's prime brokers. As we do not observe the actual balance sheet usage between the hedge fund and each of its prime brokers, we use a simple average as a proxy in our main setting. The average prime broker surcharge for fund i in month t is defined as:

$$AvgSurcharge_{i,t} = \frac{1}{N_{i,t}} \sum_{j} Surcharge_{j,t} \times \text{Phase-in ratio}_t, \tag{5}$$

where the average is taken over the $N_{i,t}$ prime brokers (including GSIB and non-GSIB ones) providing service to fund i in month t; $Surcharge_{j,t}$ denotes the GSIB surcharge level of broker j; Phase-in ratio_t is the phase-in ratio described in Section 2. If a broker is non-GSIB, we set its surcharge to zero. The average surcharge captures the degree to which a hedge fund is exposed to GSIB surcharge imposed on its prime brokers. In robustness checks, we also construct a rank-weighted average surcharge measure for each fund. Besides, we use an alternative balance sheet constraint measure for prime brokers by accounting for both the CET1 minimum ratio and the GSIB surcharge. The results are qualitatively similar and discussed in Section 6.

In addition, we control for standard risk factors for hedge fund returns in the literature. We mainly use the seven factors in Fung and Hsieh (2004): the equity market factor, the small-minus-big size factor, the change in the constant-maturity yield of the 10-year Treasury bond, the change in the yield spread between Moody's Baa bond and the 10-year Treasury bond, and three trend-following factors for bonds, currencies, and commodities. These factors are widely used to evaluate hedge fund performance (e.g., Teo, 2011, Zheng and Yan, 2021; Chen et al., 2021). In the robustness check, we also control for the liquidity factor in Pástor and Stambaugh (2003). We obtain the seven risk factors from David Hsieh's website and the liquidity factor from Robert F. Stambaugh's website.

Our final matched sample consists of 480 unique hedge funds (403 leveraged and 77 unleveraged) from 236 hedge fund families. Table 5 reports the number of hedge fund families that GSIB brokers and non-GSIB brokers serve in our sample. We see that more than 80% of the fund families use at least one GSIB prime brokers and more than 60% use only GSIB brokers. This shows that the GSIBs are indeed the major players in the brokerage business, consistent with academic and industry observations (e.g., Boyarchenko et al., 2018). Besides, a hedge fund tends to have multiple prime brokers: the average number is between two and three, and large hedge funds usually have more than five. While not reported in the table, we find that the relationships between hedge fund and prime brokers are relatively sticky. In our sample, the proportion of pairwise relations between prime brokers and hedge funds (include forming new ones and ending old ones) that change in a year is about 12%.

[Insert Table 5 here]

Table 6 presents the summary statistics for the leveraged funds sample used in our main analysis. All variables are winsorized at the 1% and 99% levels.[16] We have in total 17,683 fund-month observations. The fund monthly returns and characteristics are comparable to those in previous studies. For example, the mean and standard deviation of fund monthly excess returns in our sample are 0.42% and 3.68% respectively, which are close to those in Chen et al. (2021). We find substantial variation in the average surcharge, which is our variable of interest. It has a mean of 0.72% and a standard deviation of 0.95%. Table 7 further shows the correlation table for our main variables. We see that the correlations between the main variables in our analysis are low or mild.

[Insert Table 6, Table 7 here]

5 Main Empirical Analysis

In this section, we present our main empirical analysis on how balance sheet constrains of prime brokers impact the performance of connected hedge funds. We start our analysis using portfolio sorts and Fama-Macbeth regressions. Then, we perform panel regressions to control for the hedge fund characteristics and fixed effects. We further use interaction terms to investigate the heterogeneity in the effects. Finally, we explore how hedge funds respond to the tighter capital constraints of their prime brokers.

5.1 Portfolio Sorts and Fama-Macbeth Regressions

We first use portfolio sorts to examine the relation between average GSIB surcharge and hedge fund returns. Our portfolio analysis begins from January 2016, which is the time that GSIB surcharge was firstly implemented. For each month, we sort the leveraged hedge funds

[16] Our main findings are qualitatively similar with unwinsorized variables.

in our sample into three (tercile) portfolios by their average prime broker surcharge in (5). We hold the portfolios for a month and rebalance them on a monthly basis. The portfolio return is given as the equal-weighted average of the monthly returns of the hedge funds in it. We compute the average excess return (net of the one-month Treasury bill rate) of the three portfolios for each month in our sample period. In addition, we also estimate the portfolio alpha by regressing the time series of portfolio returns on the seven factor returns in Fung and Hsieh (2004) (see Section 4). The means of $AvgSurcharge$ in the three portfolios are 0.48%, 1.48%, and 1.94% respectively, indicating substantial variation in the prime broker balance sheet constraints faced by the hedge funds.

Panel A of Table 8 reports the excess return and alpha for the three portfolios, as well as the differences between the top and bottom tercile portfolios. The difference in monthly excess return between the top and bottom portfolios is −0.66% with a t-statistics of −3.60, which is economically large and significant at the 1% level. On a risk-adjusted basis, the difference in alpha spread between the top and bottom portfolios becomes smaller at −0.42% per month, but is still significant at the 5% level (t-statistics of −2.55). The results show that hedge funds facing higher average prime broker surcharge underperform those with lower ones, even after we adjust the return by risk factors. We find that the differences between the bottom and top surcharge portfolios mainly comes from the bottom portfolio, which has significantly positive excess return and risk-adjusted alpha. That is, hedge funds are more likely to achieve higher returns if they are less dependent on the prime brokers with high surcharge. This reflects the expected impact of prime brokers' balance sheet constraints on hedge fund performance. We also examine the impact of average surcharges on portfolio returns over longer holding periods and obtain similar results. As shown in Table 8, the difference in monthly alpha between the top and bottom portfolios is −0.40%, −0.41%, and −0.32% for holding period of three, six, and 12 months, respectively. All differences are significant at the 5% level or better.

To control for fund size effect, we further perform an independent double sort on fund size and average GSIB surcharge. In each month, we sort hedge funds into three groups by their average GSIB surcharge and two groups by their size (AUM). This yields six portfolios from the independent double sort. The portfolio results are reported in Panel B of Table 8. We find that the portfolio with high surcharge underperforms that with low surcharge in both small and large size groups. In the small size group, the average monthly excess return (resp. alpha) for high surcharge funds is 0.86% (resp. 0.53%) lower than that for low surcharge funds. In the large size group, the gaps decrease to 0.42% and 0.30%, but are still statistically significant. The average spread in return (resp. alpha) between high surcharge and low surcharge funds after controlling for their sizes is 0.64% (resp. 0.43%) per month, significant at the 1% level. The results again show that the balance sheet constraints of prime brokers negatively affect the hedge fund performance. The effect holds for both large and small funds, with a smaller magnitude for the large ones.

[Insert Table 8 here]

The portfolio-based analysis cannot simultaneously control for other fund characteristics that may also affect fund performance. For example, small hedge funds may not choose GSIB brokers and fund size can be negatively related to fund performance (e.g. Yin, 2016 shows the diseconomies of scale for hedge funds). To control for the fund-level characteristics, we run Fama-MacBeth cross-sectional regressions in the form of:

$$y_{i,t+1} = \beta_{0,t} + \beta_{1,t} AvgSurcharge_{i,t} + \beta_{2,t}^{'} X_{i,t} + \varepsilon_{i,t}, \tag{6}$$

where $X_{i,t}$ denotes the fund-level characteristics. It includes fund size (logarithm of AUM), fund age (logarithm of fund age in months), management fee, incentive fee, high-water mark dummy, personal capital dummy, minimum investment (logarithm of minimum investment plus one) , lockup period, redemption notice period, and fund style dummies. $y_{i,t+1}$ is the performance variable for fund i in next month. We run (6) for each month t using all available funds in our sample. Then we average over the estimated $\widehat{\beta}_{1,t}$ and $\widehat{\beta}_{2,t}$ over time to get the Fama Macbeth coefficients.

We consider both the excess return and risk-adjusted alpha as the dependent variable in (6). We follow Chen et al. (2021) to calculate the hedge fund alpha as follows. We perform the following regression in a rolling basis for fund i and month t if it has at least 24 observations in the prior 36 months:

$$r_{i,t} = \alpha_{i,t} + \beta_{i,t}^{\prime} f_t + \varepsilon_{i,t}, \tag{7}$$

where $r_{i,t}$ is the fund's excess return in month t, the vector f_t is the Fung-Hsieh seven factor returns. We estimate (7) using the data of fund i in the 36 months prior to t. Denote the estimated coefficient by $\widehat{\beta}_{i,t}$. Then, the alpha for fund i in month $t+1$ is obtained as:

$$\widehat{\alpha}_{i,t+1} = r_{i,t+1} - \widehat{\beta}_{i,t}^{\prime} f_{t+1},$$

where f_{t+1} denotes the realized factor returns in month $t+1$. The above procedure avoids look-ahead bias in the estimation.

Table 9 present the results for the Fama-Macbeth regression (6). In the first four columns, we use the $AvgSurcharge$ measure. In the last four columns, we standardize the $AvgSurcharge$ such that it has zero mean and unit cross-sectional standard deviation. The results reveal a strong negative relation between the average surcharge and the fund's excess return and alpha in next month, in both the univariate and multivariate settings. By columns (2) and (4), the coefficients of $AvgSurcharge$ for excess return and future alpha are -0.453 and -0.419 respectively, both significant at the 1% level. The coefficients of other covariates are in line with previous studies. For example, hedge funds with higher watermark and incentive fees tend to have better performance (e.g., Teo, 2011, Chen et al., 2021). Columns (5) - (8) report the results for standardized average surcharge measure, in which β_1 directly measures the impact of one-standard-deviation change in $AvgSurcharge$ on next month return and alpha. The coefficients range from -0.298 to -0.259, all significant at 1% level. The economic magnitude is meaningful. For example, a one-standard-deviation increase in average surcharge is associated with 0.29% decrease in monthly excess return (3.48% annually) .

[Insert Table 9 here]

Our findings from both portfolio sorts and Fama-Macbeth regressions suggest a significant and negative relation between average surcharge and hedge fund returns, even after controlling for common risk factors and fund characteristics. We also run the regression (6) using hedge fund performance metrics in next 12 months, including excess return, alpha, volatility, Sharpe ratio, and information ratio. The results are shown in Tables OA.3 and OA.4 of the Online Appendix, and are consistent with our theoretical predictions in Section 3. In particular, higher average surcharge decreases all these performance metrics. We further investigate such effects using panel regression in next section.

5.2 Panel Regression Analysis

In this section, we further investigate the impact of prime broker balance sheet constraints using panel regressions. We consider different hedge fund performance metrics in the regression to validate the theoretical framework in Section 3. In addition, by adding fixed effects, panel regression analysis allows us to examine the impact of average surcharge across and within funds. We estimate the following panel regression using the leveraged hedge fund sample:

$$y_{i,t+1,t+12} = \beta_0 + \beta_1 AvgSurcharge_{i,t} + \beta_2' X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}, \quad (8)$$

where $y_{i,t+1,t+12}$ is one of the following performance metrics: the average monthly excess return, Fung and Hsieh (2004) seven-factor adjusted monthly alpha, volatility, Sharpe ratios, and information ratios in the next 12 months. The volatility is calculated as the standard deviation of the monthly excess returns. The Sharpe ratio is defined as the mean excess return divided by the return volatility. Information ratio is defined as the fund's alpha divided by the standard deviation of the residuals (Chung and Kang, 2016). The fund-level characteristics

$X_{i,t}$ are the same as those included in the Fama-Macbeth regression; see Section 5.1.[17] The parameter of interest is β_1, which measures the effect of average GSIB surcharge exposure on hedge fund metrics.

We control for the style by time fixed effect ($\alpha_s \times \alpha_t$) in the panel regression (8). This controls for time-variant macroeconomic factors at the fund style level. In an alternative specification, we additionally include the fund fixed effect (α_i), which absorbs the unobservable, time-invariant heterogeneity across funds. With fund fixed effect, the identification captures the variation within each fund over times. As discussed in Section 4, average surcharge level exhibits temporal variation within a hedge fund due to the phase-in implementation of GSIB surcharge. We account for the serial correlation in dependent variable by clustering standard errors at the fund level. A similar approach is employed by Chung and Kang (2016) in their study on prime broker co-movement and future fund performance. In Section 6.4, we further use Discoll-Kraay standard errors to correct for the serial correlation. The results are largely similar.

Based on the theoretical framework in Section 3, we expect tighter balance sheet constraints of prime brokers would decrease the excess return, volatility, and Sharpe ratio for leveraged hedge funds. These effects are indeed observed in our empirical analysis. Table 10 reports the estimated β_1 from our panel regression for the five fund performance metrics. Panels A and B report the estimated coefficients for excess monthly return and alpha. Consistent with our hypothesis, hedge funds with higher average GSIB surcharge are associated with lower excess return and alpha. All coefficients are significantly negative at the 5 % level or better. The results hold after controlling for other fund characteristics and the two fixed effects considered.[18] In addition, the magnitudes of effects are quite stable across different specifications. For excess return (resp. alpha), the estimated β_1 ranges from -0.314 to -0.293 (resp. -0.338 to -0.297). When both fund and $Style \times Month$ fixed effects are included, a one-standard-deviation increase of average GSIB surcharge decreases hedge fund annualized return by 3.3% ($0.29 \times 12 \times 0.95$). We discuss the economic magnitude of effect momentarily.

[Insert Table 10 here]

Panels C to E of Table 10 report the effects of average surcharge on other hedge fund performance metrics. We find that funds with higher average surcharge are associated with lower future volatility, Sharpe ratio, and information ratio over the next 12 months, consistent

[17] When we add fund fixed-effect, the dummies for high-water mark and personal capital are dropped as they are fully absorbed by the fund fixed effect.

[18] Adding fund fixed effect can lead to look-ahead bias when the dependent variable is fund return or alpha. That said, we get consistent evidence on the negative impact of average surcharge on fund return and alpha by portfolio analysis and Fama-Macbeth regressions in Section 5.1.

with our hypothesis in Section 3. The effects are statistically significant at the 5% level in most cases. With both fixed effects included, a one-standard-deviation increase of average GSIB surcharge will decrease monthly return volatility by 0.53% (0.558×0.95). For Sharpe ratio, the coefficient is significant at the 1% level if we include the $Style \times Month$ effect, with a one-standard-deviation increase in average surcharge decreases the 12-month ahead Sharpe ratio by about 0.073 (0.077 × 0.95). However, the coefficient for Sharpe ratio becomes insignificant after we include the fund fixed effect.S This suggests that the negative relation between prime brokers' capital constraints and fund's Sharpe ratio mainly stems from the cross-sectional variation. Finally, we find that a one-standard-deviation increase in average surcharge decreases the 12-month ahead information ratio by about 0.09 (0.095×0.95), which is about 20% of its sample standard deviation.

Our results show that a one-standard-deviation increase in the average surcharge is associated with an about 3% decrease in the fund's annual excess return and alpha. The magnitude of effects seems large at first glance, but it can be interpreted as follows. First, we only include the leveraged hedge funds in our panel regression. Thus, the estimated effect applies to the leveraged return. Second, as noted in Breuer and Dehaan (2023) and Liu and Winegar (2023), when the regression includes specific fixed effects, the magnitude of coefficients can be interpreted accordingly. In our sample, the within-fixed-effect (both fund and $Style \times Month$) standard deviation of average surcharge is 0.34, which is much smaller than the sample counterpart (0.95). This translates to a decrease of about 1.18% (0.29×12×0.34) in hedge fund's annualized excess return and alpha. Finally, the phase-in period (2016 to 2019) of GSIB surcharge may force banks to increase their capital quickly for compliance purpose. Thus, our estimated coefficient represents the transitional instead of steady-state effect of GSIB surcharge.

5.3 Heterogenous Effects of GSIB Surcharge

In this section, we examine the heterogeneity in the effects of GSIB surcharge for different hedge funds and periods. The results shed lights on the underlying channels through which prime brokers' balance sheet constraints affect the hedge fund performance.

We first explore how the effects of GSIB surcharge depend on the fund size. We define a dummy variable $Large_{i,t}$ for each fund-month pair in our sample, which equals one if the size of fund is larger than the top tercile in the sample year. We interact this dummy with the average GSIB surcharge in the panel regression (8) for future hedge fund performance. The interaction regression is:

$$\begin{aligned} y_{i,t+1,t+12} &= \beta_0 + \beta_1 AvgSurcharge_{i,t} + \beta_2 AvgSurcharge_{i,t} \times Large_{i,t} \\ &+ \beta_3 Large_{i,t} + \beta_4^{'} X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}. \end{aligned}$$

The interaction coefficient β_2 indicates whether the fund size increases or decreases the effect of GSIB surcharge. Same as in Section 5.2, we set the dependent variable $y_{i,t+1,t+12}$ as the excess return, alpha, volatility, Sharpe ratio, and information ratio of the fund in next 12 months. Given the main coefficient β_1 is negative for all the performance metrics, a positive (resp. negative) value of β_2 implies that large hedge funds tend to get less (resp. more) impact from the prime brokers' balance sheet constraints.

The results for regression (9) are reported in Table 11, in which we control for the fund-level characteristics $X_{i,t}$ and both the $Style \times Month$ and fund fixed effects. We see that the coefficient β_2 is positive significant for the excess return, alpha, and Sharpe ratio, indicating that the effect of GSIB surcharge is smaller for large hedge funds. For example, we have $\beta_2 = 0.162$ for monthly excess return, which is significant at the 5% level. Thus, for a large hedge fund, the impact of its average GSIB surcharge is $-0.367 + 0.162 = -0.205$, which is 30% smaller than the average effect -0.293 in Table 10. Similar impacts are also observed for risk-adjusted alpha and Sharpe ratio. On the other hand, the effects of GSIB surcharge are larger for small funds. The heterogeneity in effects by fund size is consistent with our findings from the portfolio analysis with double sorts in Section 5.1.

The above results suggest that the negative effects of prime brokers' balance sheet constraints are partly mitigated for the large hedge funds. This can be potentially explained as follows. First, from the prime broker's perspective, large hedge funds are more valuable clients as they generate stable and intensive usage of the balance sheets. In addition, long-term relationship with large clients can bring other businesses to the broker. Thus, prime brokers are more likely to reserve their balance sheets for large hedge funds and offer more favorable financing arrangements.[19] Second, large hedge funds tend to have more prime brokers. Such diversification may bring them more bargaining power in the negotiations with prime brokers. For these reasons, the prime brokers' balance sheet constraints have a smaller impact for the large hedge funds.

[Insert Table 11 here]

Next, we check how the effects of GSIB surcharge vary during the time periods in which prime brokers are more likely to have binding capital constraints. We estimate the following panel

[19] Such behavior is indeed observed when one of the authors was working in a major prime broker.

regression with interaction:

$$\begin{aligned} y_{i,t+1,t+12} &= \beta_0 + \beta_1 AvgSurcharge_{i,t} + \beta_2 AvgSurcharge_{i,t} \times BindingPeriod_t \\ &+ \beta_3^{'} X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}, \end{aligned}$$

where $BindingPeriod_t$ is is a dummy variable that takes the value of one if month t belongs to a type of binding periods (defined in below). We omit the variable $BindingPeriod_t$ in the regression as it is fully absorbed by style by time fixed effect. We expect the impacts of GSIB surcharge on hedge fund performance to be more pronounced during the binding periods, i.e., the coefficient β_2 is negative.

We consider three types of binding periods. First, the year-end periods include the months in the last quarter of each year. During the year-end periods, banks may engage in window-dressing activities and shrink their balance sheets to lower their systematic importance.[20] Second, we define the high VIX periods as the months with end-of-month VIX higher than the top decile of our sample period. This includes the time with elevated market volatility, which can put pressure on banks' balance sheets. Lastly, we consider the periods with high CDS spreads of the main prime brokers. We calculate the average CDS spread of the five-year senior bonds from Citigroup, Goldman Sachs, J.P. Morgan Chase, Morgan Stanley, Credit Suisse Group, and Bank of America. The high CDS spread periods include the months with the average CDS spread higher than the top decile in our sample, indicating tightening credit conditions for brokers. We obtain the VIX and CDS spreads data from Bloomberg.

Table 12 presents the results for regression (9) with both $Style \times Month$ and fund fixed effects.[21] The results largely support our conjecture that the effects of GSIB surcharge are more pronounced during the binding periods. For year-end periods, the coefficient β_2 is negative and significant at the 5% level or better when the dependent variable is future excess return or volatility. Relative to the rest of time, a one-standard-deviation increase in average surcharge in year-end months leads to an additional decrease of 0.6% (0.05×0.95×12) in annual excess return. We observe consistent effects for the high VIX and high CDS spread periods (Panels B and C). For the high VIX (resp. high CDS spread) periods, the coefficient β_2 is significantly negative for excess return, volatility, and Sharpe ratio (resp. excess return, alpha, and volatility). The economic magnitude is large. For example, when the average CDS spread of main prime brokers is in its top decile, a one-standard deviation increase in average GSIB surcharge is associated with an additional 3.2% (0.28×0.95×12) decrease in

[20]See, e.g., the working paper by Naylor et al. (2024).

[21]The results are qualitatively similar, although a bit weaker, when we use quarter-end months or define high VIX and high CDS spread periods using the top quintile.

annual risk-adjusted alpha,[22] which almost doubles the average effect in Table 10. Such large impact can be explained as when a prime broker's CDS spread is relatively high, it tends to suggest that the broker is facing some serious liquidity problems. In these cases, the broker may need to intensively cut down the balance sheets allocated to the hedge funds.

[Insert Table 12 here]

We find that the impact of GSIB surcharge on hedge fund performance is more pronounced for the binding periods. On the other hand, the effects are still significant for the normal periods, with magnitudes similar to those in the full sample (Table 10). This suggests that our results are not solely driven by the more stressful periods. The heterogeneity in the effects again shows how the prime brokers' balance sheet constraints can negatively affect the hedge fund performance.

5.4 What are Hedge Funds' Responses?

We have shown that the prime brokers' balance sheet constraints can decrease the return of leveraged hedge funds. In this section, we discuss potential responses from the hedge funds. We consider two possible responses. First, hedge funds may change the relationships with their prime brokers, especially the GSIB brokers that face tighter capital constraints. Second, hedge funds may adjust their portfolio positions, e.g., increasing their holdings of the high beta stocks to elevate return.

The increased capital constraints for banks can affect the service relationship between prime brokers and hedge funds. Boyarchenko et al. (2018) find that after the implementation of Supplementary Leverage Ratio (SLR) rule in 2015, fewer new connections are formed between prime brokers and hedge funds each year. Such effect is stronger for GSIB brokers. In addition, after the SLR rule, large hedge funds tend to have more non-GSIB brokers. This suggests that the capital constraints of prime brokers limit their ability to serve new clients.

We check the connections between leveraged hedge fund families and prime brokers using the data from Form ADV. For each year, we compute the proportion of connections that experience a change, including the newly formed ones and ended ones. Figure 4 plots the changing proportion in our sample period. We see that the changing proportion is relatively low and stable over time, suggesting that the relationships between leveraged hedge funds and prime brokers are sticky. This can be explained as follows. First, leveraged hedge funds usually require complex services from their prime brokers, and access to financing is just one of them.

[22] The magnitudes would be smaller if we consider one within-fixed-effect standard deviation change; see the discussion in Section 5.2. In addition, the impact of GSIB surcharge is likely to be more short-term and abrupt during the binding periods than for the entire horizon, leading to a larger coefficient.

For example, prime brokers can provide informational advantage to their clients (Kumar et al., 2020). Second, after the global financial crisis, hedge funds are more aware of the importance of counter-party stability. Thus, they tend to maintain stable relationships with financially stable, well-capitalized prime brokers. These factors may outweigh the increased financing costs due to capital constraints.

Next, we investigate whether hedge funds respond to their prime brokers' balance sheet constraints by adjusting their portfolio. We obtain the quarterly US stock holdings data for the hedge fund families (management companies) from the Thomson Reuters 13F database,[23] and match them with the sample from Form ADV using the link table provided in Jiang (2023). The merged dataset contains the stock holdings of 246 distinct equity hedge fund families in 2013 to 2022. Note that the Thomson Reuters 13F only covers the holdings of US stocks. Thus, our portfolio analysis applies to the hedge fund families that report their US equity investment in the database.

We focus on the market beta of the equity portfolios held by the hedge fund families. Intuitively, when hedge funds' leverage is constrained by their prime brokers, they can mitigate the negative impact on their returns by investing in stocks with higher embedded leverage. Thus, hedge funds may increase their positions the high beta stocks, which move more dramatically with the market cycles. We examine this in below. At each quarter end, we first calculate the market beta for each stock using its daily returns in the past one year window. The market return is obtained from the Kenneth French's website. Then, we compute the portfolio beta for each hedge fund family as the value-weighted average of the betas of its stock positions. The weight for each stock is proportional to the market value held by the hedge fund family (see more details in Section OA.4 of the Online Appendix).

Denote the portfolio beta of fund family i in quarter q by $\text{FundBeta}_{i,q}$. We use the following regression to see how it is affected by the GSIB surcharge:

$$\text{FundBeta}_{i,q+1} = \beta_0 + \beta_1 AvgSurcharge_{i,q} + \beta_2 EquityMV_{i,q} + \alpha_i + \alpha_q + \varepsilon_{i,q+1}, \tag{9}$$

where $AvgSurcharge_{i,q}$ denotes the average GSIB surcharge for the fund family. We also control for the market value of the fund family's equity positions at the end of the quarter. We include the time fixed effect (α_q) to control for the time-variant macroeconomic factors. In an alternative setting, we additionally include the fund family fixed effect (α_i), which absorbs the unobservable time-invariant heterogeneity across the fund families. The standard errors are clustered at the fund family level. The coefficient β_1 measures how the future portfolio beta of a hedge fund family is affected by its average GSIB surcharge.

[23] The Thomson Reuters 13F database does not have fund-level holding data. Thus we perform the analysis on the hedge fund family level. This is same as in Kumar et al. (2020).

The estimation results are reported in Table 13. By columns (1) and (2), we see that β_1 is positive and significant no matter we add the fund family fixed effect or not. Thus, higher average surcharge exposure is associated with higher future portfolio beta. With both time and fund family fixed effects, a one-standard-deviation increase in $AvgSurcharge$ is associated with a 0.049 increase in next-quarter portfolio beta, which accounts for about 18% of the sample standard deviation of $\text{FundBeta}_{i,q}$. Thus, the magnitude of effect is economically meaningful. As an additional test, we replace the $AvgSurcharge_{i,q}$ in (9) by $RatioGSIB_{i,q}$, which represents the ratio of a hedge fund family's number of GSIB prime brokers divided by its total number of prime brokers. Thus, a higher $RatioGSIB_{i,q}$ means the hedge fund family is more dependent on GSIB brokers. The estimation results for $RatioGSIB_{i,q}$ are reported in columns (3) and (4). Again, the coefficient β_1 is positive and statistically significant. Specifically, for a hedge fund family, switching from using no GSIB brokers to fully relying on GSIB brokers is associated with a 0.130 increase in its portfolio beta.

[Insert Table 13 here]

Our results suggest that, although the connections between hedge funds and prime brokers are relatively sticky, hedge funds tend to increase their portfolio beta in response to tighter capital requirements of their prime brokers. This interpretation is consistent with the findings in Boguth and Simutin (2018), who show that the aggregate market beta of actively managed mutual fund can be used to measure the tightness of their leverage constraints. The response of increasing embedded leverage by hedge funds may partially mitigate the negative impacts on their returns due to higher leverage costs, but can increase the risk of the hedge funds. In this study, we focus on how prime brokers' balance sheet constraints affect the hedge fund performance. We defer further investigation on the responses of hedge funds and their implications to future research.

6 Additional Empirical Tests

In previous sections, we show that tighter capital constraints of prime brokers can negatively affect the performance of hedge funds they serve. We further conduct three empirical tests to support the robustness of our findings, including panel regressions based on banks' CET1 requirements, a DiD analysis using the implementation of GSIB surcharge, and a textual analysis with state-of-the-art natural language processing (NLP) methods.

6.1 CET1 Ratio as Balance Sheet Constraint Measure

In our main analysis, we use the effective GSIB surcharge to measure prime brokers' balance sheet constraints. The reasons for doing so are discussed in Section 2.2. One limitation of the GSIB surcharge is that it only affects GSIB prime brokers, as non-GSIB brokers have a surcharge of zero. In this section, we consider an alternative measure for brokers' balance sheet constraints, which applies to all bank brokers.

We use the CET1 capital requirement under the Basel III regulatory framework (see Section 2). The CET1 requirement is the sum of two parts: the minimum CET1 ratio and a mandatory capital conservation buffer. In our sample, the minimum CET1 ratio starts at 3.5% in 2013 and increases to 4.5% by 2015.[24] The mandatory capital conservation buffer (CCB) is implemented in 2016 at an initial level of 0.625% and increases to 2.5% by 2019. The values of the CET1 ratio and the CCB in each year are reported in Table 15.[25] The CET1 capital requirement is uniform to all banks, but does not apply to non-bank institutions.

For fund i in month t, we define the prime brokers' balance sheet constraint measure based on the CET1 requirement as:

$$AvgCET1_{i,t} = \frac{1}{N_{i,t}} \sum_{j} (CET1_{j,t} + Surcharge_{j,t} \times \text{Phase-in ratio}_t), \tag{10}$$

which is analogous to (5). In above, the first term $CET1_{j,t}$ is the CET1 capital requirement (minimum ratio plus CCB) of broker j; the last term denotes the effective GSIB surcharge as described in Section 2.1. For GSIB brokers, both the two terms are positive. For non-GSIB bank-affiliated brokers, only the first term is positive. Non-bank affiliated brokers are not subject to the CET1 or GSIB capital requirement, i.e., having a ratio of zero in the right hand side of (10). We then estimate the following panel regression:

$$y_{i,t+1,t+12} = \beta_0 + \beta_1 AvgCET1_{i,t} + \beta_2' X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}, \tag{11}$$

where $y_{i,t+1,t+12}$ is one of the following hedge fund performance metrics over the next 12 months: excess return, risk-adjusted alpha, volatility, Sharpe ratio, and information ratio. The regression is set up in the same way as (8) except that we now measure the broker's balance sheet constraints by $AvgCET1_{i,t}$ instead of $AvgSurcharge_{i,t}$.

Table 14 presents the regression results for (11) based on the CET1 capital requirement.

[24] https://www.bis.org/bcbs/basel3/basel3_phase_in_arrangements.pdf

[25] There is another buffer called countercyclical capital buffer. The Basel III countercyclical capital buffer is calculated as the weighted average of the buffers in effect in the jurisdictions to which banks have a credit exposure. This buffer is zero in United States till 2023. Since it is based on banks worldwide credit exposure in different jurisdiction, we drop this buffer in the analysis.

The findings are consistent with those in Table 10 using the GSIB surcharge as the balance sheet constraint measure. In general, higher $AvgCET1_{i,t}$ tends to decrease the fund's return, alpha, volatility, Sharpe ratio, and information ratio in the next 12 months. The results hold both with and without the fund fixed effects, suggesting the impact of CET1 capital requirement arises from both cross-sectional variation among funds and within-fund variation over time. By column (2), the coefficient β_1 is -0.088 for monthly excess return (with a t-statistics of 1.92). Thus, a one-standard-deviation increase in $AvgCET1_{i,t}$ is associated with a 2.8% (0.088×12×2.64) decrease in the hedge fund's annualized return. This magnitude is similar to that of $AvgSurcharge$ (about 3.3%) discussed in Section 5.2. By columns (3) and (4), $AvgCET1_{i,t}$ negatively impacts the risk-adjusted alpha. The effects are slightly larger and significant at the 5% level.

As shown in columns (5) - (10), the hedge funds with higher average CET1 requirement are associated with lower future volatility, Sharpe ratio, and information ratio. The effects are statistically significant at the 5% level in most cases. With both fixed effects included, a one-standard-deviation increase in $AvgCet1_{i,t}$ decreases the monthly return volatility by 0.41% (0.157×2.64). With only $Style \times Month$ fixed effect, a one-standard-deviation increase in $AvgCET1_{i,t}$ is associated with a 0.042 (resp. 0.047) drop in the 12-month ahead Sharpe ratio (resp. information ratio), which is about 7.8% (resp. 10.9%) of its sample standard deviation.

Using the CET1 capital requirements faced by all banks, we find consistent evidence on how prime brokers' balance sheet constraints affect the hedge fund performance. The results are similar to those obtained with the GSIB surcharge in our main specification, and are in line with the theoretical model developed in Section 3.

[Insert Table 14, Table 15 here]

6.2 Difference-in-Difference Analysis

In this section, we use a difference-in-difference (DiD) study to reveal the impact of GSIB surcharge on hedge fund's future return. As shown in Figure 2, the GSIB surcharge is implemented since 2016. Thus, we expect the dependence on GSIB prime brokers to have a larger (negative) impact on fund return after 2016. We investigate this as follows.

For each month t, we classify the leveraged hedge funds in our sample to two groups. We compute a hedge fund's GSIB-broker ratio as its number of GSIB brokers divided by the number of all its brokers. We define the GSIB-dependent (resp. non GSIB-dependent) group as the hedge funds with the GSIB-broker ratio above (resp. below) the median in each month. Note that the GSIB list is determined by the Financial Stability Board in 2012. Thus, the

GSIB status of brokers can be determined in advance before 2016.

We then compare the difference in excess return between the two groups before and after the implementation of the GSIB surcharge in 2016. We perform the following DiD analysis:

$$y_{i,t+1} = \beta_0 + \beta_1 \times \text{Treat}_{i,t} \times \text{Post}_t + \beta_2' X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}, \tag{12}$$

where $y_{i,t+1}$ is the fund's excess return or alpha in next month; the treatment group dummy $\text{Treat}_{i,t}$ equals one if fund i is in the GSIB-dependent group in month t and zero otherwise;[26] Post_t is a dummy which takes value of one if month t is in or after 2016; $X_{i,t}$ denotes fund-level control variables, which are the same as those in Sections 5.1 and 5.2. We include both the fund and the $Style \times Month$ fixed effects. We expect the coefficient β_1 to be negative, i.e., the hedge funds in the GSIB-dependent group are associated with a larger decrease in their returns after the implementation of GSIB surcharge.

The estimation results are reported in Table 16. We see that the coefficient β_1 is indeed significantly negative for both excess return and alpha (at the 5% level). This shows that the implementation of GSIB surcharge decreases the return of the hedge funds that are more dependent on the GSIB brokers relative to those that are not. The magnitude is -0.79% (resp. -0.60%) for excess return (resp. alpha). This is inline with our main findings given the $AvgSurcharge_{i,t}$ is about 1.65 and 0.65 for the GSIB-dependent and non GSIB-dependent groups after 2016. Thus, the DiD analysis again shows that the balance sheet constraints of prime brokers are associated with lower future returns of their hedge funds.

The DiD analysis in (12) relies on the assumption that the hedge fund returns in the GSIB-dependent and non GSIB-dependent groups exhibit similar trends prior to the implementation of GSIB surcharge. We validate such assumption by estimating the dynamic effects of being more dependent on the GSIB brokers. We perform the following regression:

$$y_{i,t+1} = \Sigma_{\tau=2013,\tau\neq 2015}^{2021} \beta_\tau \times \text{Treat}_{i,t} \times \mathbb{1}\{t \in \text{Year}_\tau\} + \beta_2' X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}, \tag{13}$$

where $\text{Treat}_{i,t}$ and $X_{i,t}$ are defined as in the DiD analysis (12); $\mathbb{1}\{t \in \text{Year}_\tau\}$ is a dummy variable that takes value of one if month t is in year τ. In (13), we allow the treatment effect to vary for each year τ via the interaction terms $\text{Treat}_{i,t} \times \mathbb{1}\{t \in \text{Year}_\tau\}$. To avoid multi-collinearity issue, we exclude the year 2015 and use it as the base year for comparison. Same as our DiD analysis, we include both the fund and the $Style \times Month$ fixed effects.

Figure 5 plots the estimated β_τ's and their 95% confidence intervals with the dependent

[26] As the connections between prime brokers and hedge funds are sticky. the treatment status for a hedge fund is relatively stable (see discussion in Section 5.4). The proportion of changed treatment status between adjacent months is about 5% in our sample.

variable being the excess return in (13). We see that the coefficients of the interaction term are statistically indifferent from zero in the years prior to 2016. That is, the effect of being in the GSIB-dependent group does not show up before the implementation of GSIB surcharge, suggesting no pre-trends in the excess returns of the two groups. By contrast, for most of the years after 2015, the estimated β_τ is significantly negative at the 5% level (for 2017, β_τ is negative and insignificant). These patterns are in line with our DiD analysis. They show that after the implementation of GSIB-surcharge, relying more on the GSIB brokers tends to decrease the hedge fund's future return. This again reflects the impact of prime brokers' balance sheet constraints on hedge fund performance.

[Insert Figure 5, Table 16 here]

6.3 Balance Sheet Information from Earnings Calls

In this section, we analyze the impacts of prime brokers' balance sheet constraints using natural language processing (NLP) methods on the textual data from banks' earnings calls. The earnings calls generally occur on a quarterly basis and represent an important channel for regular communication between investors and a bank's management team (e.g., Li et al., 2021, Sautner et al., 2023; Mamaysky et al., 2023). Thus, earnings calls are likely to contain valuable information about the bank's capital condition and regulatory stress, if they are discussed by the management team or analysts in the calls. This complements our main analysis based on the capital ratios, which are determined in advance by the regulatory body.

We focus on the major bank holding companies that provide prime brokerage services in our sample. The selected banks are listed in Table OA.1. We see that most of them are GSIBs. We download their earnings calls between January 2013 and November 2021 from the Capital IQ database. We include both the presentation and Q&A sections in the analysis, as they may contain different types of information. We describe the data cleaning and processing steps in Section OA.5 of the Online Appendix.

A major challenge for analyzing the capital-related information from earnings calls is that the call transcripts are usually very long (e.g., 10,000 words), and many contents may contain little capital-related information. To address this, we develop a way to identify a set of words and phrases that are closely related to a bank's capital condition, and focus our analysis on the sentences that mention these words and phrases. The final output of our text model is a sentiment score for each earnings call that measures its capital condition. We briefly describe the major steps in below. More details are provided in Section OA.5 of the Online Appendix.

We start from the two terms "balance sheet" and "capital" and use the word embedding algorithm to identify a set of tokens that are mostly related to the two terms in the context of earnings calls. Similar to Li et al. (2021), we train the word2vec model in Python's `gensim` package using all earnings calls in our sample. Then, we select the sentences in the earnings calls that contain at least one of the capital-related tokens identified in the previous step. We expect these sentences to contain information relevant to a bank's capital condition. The other parts of the earnings call are ignored.

We use the FinBERT model to obtain the sentiment score of each selected sentence. FinBERT is developed by Huang et al. (2023) as a state-of-the-art large language model tailored to the finance field. It is based on the BERT model (Devlin et al., 2018) but further tuned using a large text dataset in finance and accounting, including corporate fillings, analyst reports, and earnings conference call transcripts. Huang et al. (2023) show that FinBERT outperforms other models in finance-related tasks. For an input sentence, the FinBERT model returns a sentiment label (positive, negative, neutral) and an intensity score (a number between zero and one). We use the signed intensity as the sentiment score for the sentence. A more positive score implies that the message delivered in the sentence is more sanguine. Finally, we set the sentiment score for each earnings call as the average of the scores of its capital-related sentences.

For each hedge fund, we construct a measure for its prime brokers' balance sheet constraints using the sentiment scores of their earnings calls:

$$AvgSentiment_{i,t} = \frac{1}{N_{i,t}} \sum_{j} \text{SentimentEC}_{j,t}, \tag{14}$$

where the average is taken over the fund's major prime brokers with earnings calls; $\text{SentimentEC}_{j,t}$ denotes the sentiment score of the earnings call from broker j's parent bank in month t. This measure is analogous to the average GSIB surcharge and CET1 requirement in (5) and (10). To avoid look-ahead bias, we defer the available time of each earnings call to the end of next calendar quarter.[27] For months without earnings call, we use the sentiment from the most recent one. The measure $AvgSentiment_{i,t}$ represents the average capital-related sentiment from a hedge fund's prime brokers. We then estimate the following regression similar to (8) and (11):

$$y_{i,t+1,t+12} = \beta_0 + \beta_1 AvgSentiment_{i,t} + \beta_2' X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}, \tag{15}$$

where the dependent variable is set as average monthly excess return or alpha in the next 12 months. We use the same fund-level control variables $X_{i,t}$ and include both fund and

[27]For example, the earnings call for a firm's first-quarter performance is considered to be available at the end of June.

$Style \times Month$ fixed effects.

We briefly discuss the results from our text model in below. First, Table OA.2 of the Online Appendix lists the identified tokens that are close to the words "capital" and "balance sheet" in the word embedding. We see that most of the selected tokens are economically meaningful and closely related to the bank's capital requirements (e.g., risk-weighted assets, tier one, basel iii). This shows the advantage of selecting words in a data-driven way, instead of using a pre-defined dictionary. For the sentence sentiment score, we provide two examples in below:

> *"We also continued to make significant progress against our capital targets, with a CET1 ratio of 9.8%; firm-wide and bank supplementary leverage ratios of 5.4% and 5.6%, respectively, ..., all while returning $3 billion of capital to shareholders this quarter,..."* (J.P. Morgan, 2014 Q3)

and

> *"Rather than the expected flat RWA versus last – end of last year, we're now targeting a EUR 15 billion to EUR 20 billion decline in risk-weighted assets for 2016."* (Deutsche Bank, 2016 Q2)

The sentiment score is 0.99 for the first sentence and -0.98 for the second one. Clearly, the first sentence shows that the management team is satisfactory with the bank's capital condition, while the second sentence implies that the capital requirement is limiting the bank's business via the level of risk-weighted assets.

Table 17 reports the estimation results for regression (15). We see that the coefficient of interest β_1 is positive and significant at the 5% level in all specifications. Thus, when the earnings calls suggest a fund's prime brokers are facing tighter balance sheet constraints, this is associated with lower future returns for the fund. With fund fixed effect, β_1 is 0.849 for excess return and 0.928 for alpha. In terms of economic magnitude, a one-standard-deviation increase in average sentiment decreases the fund's annualized return by 0.8% ($0.849\times12\times0.08$). The result from the textual analysis provides further evidence on how the hedge fund return is negatively affected by its prime brokers' balance sheet constraints. This complements our main findings based on the GSIB surcharge.

[Insert Table 17 here]

6.4 Robustness Checks

In this section, we perform several robustness checks for the effects of prime brokers' balance sheet constraints on hedge fund performance.

First, we use alternative methods to construct the prime brokers' GSIB surcharge measure faced by the hedge funds. For our main measure (5), we take the simple average of the GSIB surcharges of a hedge fund's prime brokers, as we do not observe the actual financing amount provided by each broker. As an additional check, we consider a rank-based weighted average measure for the GSIB surcharge of a hedge fund:

$$WAvgSurcharge_{i,t} = \frac{1}{\sum_j Rank_{j,t}} \sum_j Rank_{j,t} \times Surcharge_{j,t} \times \text{Phase-in ratio}_t, \qquad (16)$$

where $R_{j,t}$ is the rank of prime broker j when we sort the brokers in ascending order based on how many fund families they serve in the given year. The idea is to assign more weight to the larger prime brokers in the market. We then use the weighted average measure $WAvgSurcharge_{i,t}$ in the panel regression (8). The results are reported in Table OA.5 of the Online Appendix. We see that the results are largely similar to our main specification, with higher surcharge associated with lower excess return, alpha, volatility, and Sharpe/information ratio.

Second, we consider different timings for constructing the GSIB surcharge measure. We use the concurrent GSIB surcharge in our main analysis, as it is announced in the November of the year before the last (e.g., the GSIB surcharge for 2016 is announced in November 2014). We now consider two alternative timings for the GSIB surcharge in (5). In the first one, we use the GSIB surcharge level announced for next year, which is already available when we calculate $AvgSurcharge_{i,t}$ in the current year. In the second one, we do a linear interpolation for each month using the GSIB surcharge levels for the current and next year.[28] We replace $Surcharge_{j,t}$ in (5) with the two alternative measures to construct $AvgSurcharge_{i,t}$, and then use it in regression (8). Table OA.6 reports the estimation results for future excess return and alpha. We see that the coefficients are all negative and statistically significant. In addition, the magnitudes are very similar to our main specification.

Next, we conduct the same set of analyses using stratified samples. Recall that we focus on the leveraged hedge funds in our main analysis, as they are more likely to be affected by prime brokers' balance sheet constraints. As a robustness check, we run regression (8) using the sample of all hedge funds, including both leveraged and unleveraged ones. The results are presented in Table OA.7 of the Online Appendix. The findings are largely similar to our main

[28]For the k-th month in a year, we set its surcharge level as: $(13-k)/12 \times$ Surcharge for current year $+ (k-1)/12 \times$ Surcharge for current year.

results in Table 10 — higher average GSIB surcharge is associated with lower hedge fund's excess return, alpha, volatility, and Sharpe/information ratio in next 12 months.

As a placebo test, we run the regression in (8) using the sample of unleveraged hedge funds only. We expect the unleveraged funds to be less affected by the balance sheet constraints of their brokers, as they do not need to use additional financing to support their leveraged positions. This is indeed seen in Table OA.8. It shows that the coefficient of average surcharge is insignificant for all outcome variables of the unleveraged funds. This provides additional evidence for how the prime brokers' balance sheet constraints affect hedge fund performance.

We further use an additional test to show how the impacts of prime brokers' balance sheet constraints vary for hedge funds that are likely to use high physical leverage. We use the fund snapshots in the TASS dataset to identify the hedge funds with high leverage, and then run an interaction regression similar to the one in (9). The implementation details and estimation results are discussed in Section OA.3 of the Online Appendix. We find that the negative impact of GSIB surcharge on future excess return is larger for the hedge funds with high leverage. This is in line with our findings as high leverage funds tend to be more dependent on the financing from their brokers.

We then show that the impact of GSIB surcharge is not driven by the Covid-19 period or the defunct funds. First, we run regression (8) using the sample from January 2013 to December 2019 before the Covid-19 pandemic. Second, we limit our sample to the hedge funds that are still live according to the TASS database. The information can be obtained from TASS in the "Live/Graveyard" field. The regression results for excess return and alpha are reported in Table OA.9 for the two subsamples. The coefficient of average surcharge remains significantly negative, with magnitudes largely similar to our main findings.

We also check the impact of average surcharge on hedge fund performance over different horizons. We run regression (8) for the hedge fund's excess monthly return and alpha over the next one, three, and six months. The results are presented in Table OA.10 of the Online Appendix. We see that the coefficient of $AvgSurcharge$ is significantly negative at the 5% level in all cases. Besides, the magnitudes of impacts are similar to our main specification. Thus, the impact of GSIB surcharge on returns still holds for alternative horizons.

In our main analysis, we use the seven factors in Fung and Hsieh (2004) to obtain the risk-adjusted alpha. As a robustness check, we additionally include the liquidity factor in Pástor and Stambaugh (2003) in the calculation of alpha, as it is shown to explain hedge fund returns (Teo, 2011). We run regression (8) for the newly defined eight-factor alpha and report the results in Table OA.11 of the Online Appendix. The coefficients of average surcharge are still significantly negative and the magnitudes are similar to our main specification.

Finally, we try other ways for clustering the standard errors in regression (8). We cluster the standard errors by the fund family level or by the fund and month level. We also use the Driscoll and Kraay (1998) standard errors with lags of 12 to account for the auto-correlation. The results are shown in Table OA.12. We see that our main findings are unaffected in all settings.

[Insert Table OA.5 - Table OA.12 here]

7 Conclusion

This paper investigates how prime brokers' balance sheet constraints impact the performance of connected hedge funds. Using the fund-broker relationship data, we construct a measure of the balance sheet constraints faced by a fund's prime brokers based on the GSIB surcharge under the Basel III framework. We find that higher average GSIB surcharge of prime brokers is associated with lower return, alpha, volatility, Sharpe ratio, and information ratio of the connected hedge funds in next twelve months. The effects are economically significant and robust in multiple settings. The empirical findings are consistent with the predictions from our model, in which the prime brokers increase the leverage cost or decrease the leverage provision when facing tighter balance sheet constraints. Several additional tests further show the validity of our results, including a DiD analysis based on the GSIB-dependence of hedge funds and a textual analysis using banks' earnings calls.

Our study reveals the real effects of Basel III regulations on performance of bank-connected financial institutions. The increased capital costs of banks are also born by their prime brokers and thus impair the profitability of connected hedge funds. In addition, hedge funds can respond to increased leverage cost by investing in stocks with higher market betas, i.e., increasing their embedded leverage. Such implications should be considered by regulators when designing regulatory policies. In future research, it would be interesting to investigate the impact of bank capital constraints on other financial institutions, such as mutual funds, pension funds, and insurance companies. Another potential direction is to explore how the impacts on hedge funds are further transmitted to downstream assets via their investment decisions. Finally, the increased capital requirements in the post-crisis era can also affect the interconnectedness between banks and non-bank financial institutions. The implications of such shift on asset pricing and market efficiency may be studied in future research.

References

Aiyar, Shekhar, Charles W Calomiris, John Hooley, Yevgeniya Korniyenko, Tomasz Wieladek. 2014. The international transmission of bank capital requirements: Evidence from the uk. *Journal of Financial Economics* **113**(3) 368–382.

Ang, Andrew, Sergiy Gorovyy, Gregory B Van Inwegen. 2011. Hedge fund leverage. *Journal of Financial Economics* **102**(1) 102–126.

Aragon, George O, Ji-Woong Chung, Byoung Uk Kang. 2022. Do prime brokers matter in the search for informed hedge fund managers? *Management Science* .

Bank for International Settlements. 2017. Basel III: Finalising post-crisis reforms. Available at https://www.bis.org/bcbs/publ/d424.pdf .

Behn, Markus, Rainer Haselmann, Paul Wachtel. 2016. Procyclical capital regulation and lending. *Journal of Finance* **71**(2) 919–956.

Benetton, Matteo. 2021. Leverage regulation and market structure: A structural model of the uk mortgage market. *The Journal of Finance* **76**(6) 2997–3053.

Boguth, Oliver, Mikhail Simutin. 2018. Leverage constraints and asset prices: Insights from mutual fund risk taking. *Journal of Financial Economics* **127**(2) 325–341.

Boyarchenko, Nina, Thomas M Eisenbach, Pooja Gupta, Or Shachar, Peter Van Tassel. 2018. Bank-intermediated arbitrage. *FRB of New York Staff Report* (858).

Breckenfelder, Johannes, Victoria Ivashina. 2021. Bank balance sheet constraints and mutual fund fragility. *Working Paper* .

Breuer, Matthias, ED Dehaan. 2023. Using and interpreting fixed effects models. *Journal of Accounting Research* .

Buchak, Greg, Gregor Matvos, Tomasz Piskorski, Amit Seru. 2024. Beyond the balance sheet model of banking: Implications for bank regulation and monetary policy. *Journal of Political Economy* **132**(2) 616–693.

Cenedese, Gino, Pasquale Della Corte, Tianyu Wang. 2021. Currency mispricing and dealer balance sheets. *Journal of Finance* **76**(6) 2763–2803.

Chen, Yong, Bing Han, Jing Pan. 2021. Sentiment trading and hedge fund returns. *Journal of Finance* **76**(4) 2001–2033.

Chung, Ji-Woong, Byoung Uk Kang. 2016. Prime broker-level comovement in hedge fund returns: information or contagion? *Review of Financial Studies* **29**(12) 3321–3353.

Dahlquist, Magnus, Valeri Sokolovski, Erik Sverdrup. 2021. Hedge funds and financial intermediaries. *Swedish House of Finance Research Paper* (19-8).

Degryse, Hans, Artashes Karapetyan, Sudipto Karmakar. 2021. To ask or not to ask? bank capital requirements and loan collateralization. *Journal of Financial Economics* **142**(1) 239–260.

Devasabai, Kris. 2014. Hedge funds face higher prime broker charges under Basel III. Available at https://www.risk.net/regulation/basel-committee/2349066/hedge-funds-face-higher-prime-broker-charges-under-basel-iii .

Devlin, Jacob, Ming-Wei Chang, Kenton Lee, Kristina Toutanova. 2018. Bert: Pre-training of deep bidirectional transformers for language understanding. *arXiv preprint arXiv:1810.04805* .

Driscoll, John C, Aart C Kraay. 1998. Consistent covariance matrix estimation with spatially dependent panel data. *Review of Economics and Statistics* **80**(4) 549–560.

Du, Wenxin, Benjamin Hébert, Wenhao Li. 2023. Intermediary balance sheets and the treasury yield curve. *Journal of Financial Economics* **150**(3) 103722.

Du, Wenxin, Alexander Tepper, Adrien Verdelhan. 2018. Deviations from covered interest rate parity. *Journal of Finance* **73**(3) 915–957.

Duffie, Darrell. 2018. Financial regulatory reform after the crisis: An assessment. *Management Science* **64**(10) 4835–4857.

Favara, Giovanni, Ivan Ivanov, Marcelo Rezende. 2021. Gsib surcharges and bank lending: Evidence from us corporate loan data. *Journal of Financial Economics* **142**(3) 1426–1443.

Fleckenstein, Matthias, Francis A Longstaff. 2018. Shadow funding costs: Measuring the cost of balance sheet constraints. Tech. rep., National Bureau of Economic Research.

Fleckenstein, Matthias, Francis A Longstaff. 2020. Renting balance sheet space: Intermediary balance sheet rental costs and the valuation of derivatives. *Review of Financial Studies* **33**(11) 5051–5091.

Fraisse, Henri, Mathias Lé, David Thesmar. 2020. The real effects of bank capital requirements. *Management Science* **66**(1) 5–23.

Franzoni, Francesco, Mariassunta Giannetti. 2019. Costs and benefits of financial conglomerate affiliation: Evidence from hedge funds. *Journal of Financial Economics* **134**(2) 355–380.

Fung, William, David A Hsieh. 2004. Hedge fund benchmarks: A risk-based approach. *Financial Analysts Journal* **60**(5) 65–80.

Giannetti, Mariassunta, Chotibhak Jotikasthira, Andreas C Rapp, Martin Waibel. 2023. Intermediary balance sheet constraints, bond mutual funds' strategies, and bond returns. *Swedish House of Finance Research Paper* (23-10).

Gropp, Reint, Thomas Mosk, Steven Ongena, Carlo Wix. 2019. Banks response to higher capital requirements: Evidence from a quasi-natural experiment. *Review of Financial Studies* **32**(1) 266–299.

He, Zhiguo, Bryan Kelly, Asaf Manela. 2017. Intermediary asset pricing: New evidence from many asset classes. *Journal of Financial Economics* **126**(1) 1–35.

He, Zhiguo, Stefan Nagel, Zhaogang Song. 2022. Treasury inconvenience yields during the covid-19 crisis. *Journal of Financial Economics* **143** 57–79.

Hong, Claire Yurong, Frank Weikai Li, Jiang Luo, Avanidhar Subrahmanyam. 2022. Financial intermediaries and comovement in market efficiency: The case of etfs. *Working Paper* .

Huang, Allen H, Hui Wang, Yi Yang. 2023. Finbert: A large language model for extracting information from financial text. *Contemporary Accounting Research* **40**(2) 806–841.

Jiang, Wenxi. 2023. Leveraged speculators and asset prices. *Review of Finance* .

Kisin, Roni, Asaf Manela. 2016. The shadow cost of bank capital requirements. *Review of Financial Studies* **29**(7) 1780–1820.

Kruttli, Mathias S, Phillip J Monin, Sumudu W Watugala. 2022. The life of the counterparty: Shock propagation in hedge fund-prime broker credit networks. *Journal of Financial Economics* .

Kumar, Nitish, Kevin Mullally, Sugata Ray, Yuehua Tang. 2020. Prime (information) brokerage. *Journal of Financial Economics* **137**(2) 371–391.

Li, Kai, Feng Mai, Rui Shen, Xinyan Yan. 2021. Measuring corporate culture using machine learning. *Review of Financial Studies* **34**(7) 3265–3315.

Liu, Zack, Adam Winegar. 2023. Economic magnitudes within reason. *Working Paper* .

Mamaysky, Harry, Yiwen Shen, Hongyu Wu. 2023. Credit information in earnings calls. *Working Paper* .

Naylor, Matthew, Renzo Corrias, Peter Welz. 2024. Banks' window-dressing of the G-SIB framework: causal evidence from a quantitative impact study. *BCBS Working Paper* .

Newey, Whitney K., Kenneth D. West. 1987. A simple, positive semi-definite, heteroskedasticity and autocorrelation consistent covariance matrix. *Econometrica* **55**(3) 703–708.

Nicol, Drew. 2015. Managers double down on PB against rising costs. Available at https://www.securitiesfinancetimes.com/securitieslendingnews/industryarticle.php?article_id=220217&navigationaction=industrynews. *Securities Finance Times* .

Pástor, L'uboš, Robert F Stambaugh. 2003. Liquidity risk and expected stock returns. *Journal of Political Economy* **111**(3) 642–685.

Sautner, Zacharias, Laurence Van Lent, Grigory Vilkov, Ruishen Zhang. 2023. Firm-level climate change exposure. *Journal of Finance* **78**(3) 1449–1498.

Sinclair, Andrew J. 2022. Do prime brokers intermediate capital? *Journal of Financial Intermediation* 101004.

Teo, Melvyn. 2011. The liquidity risk of liquid hedge funds. *Journal of Financial Economics* **100**(1) 24–44.

Yin, Chengdong. 2016. The optimal size of hedge funds: Conflict between investors and fund managers. *Journal of Finance* **71**(4) 1857–1894.

Zheng, Lingling, Xuemin Yan. 2021. Financial industry affiliation and hedge fund performance. *Management Science* **67**(12) 7844–7865.

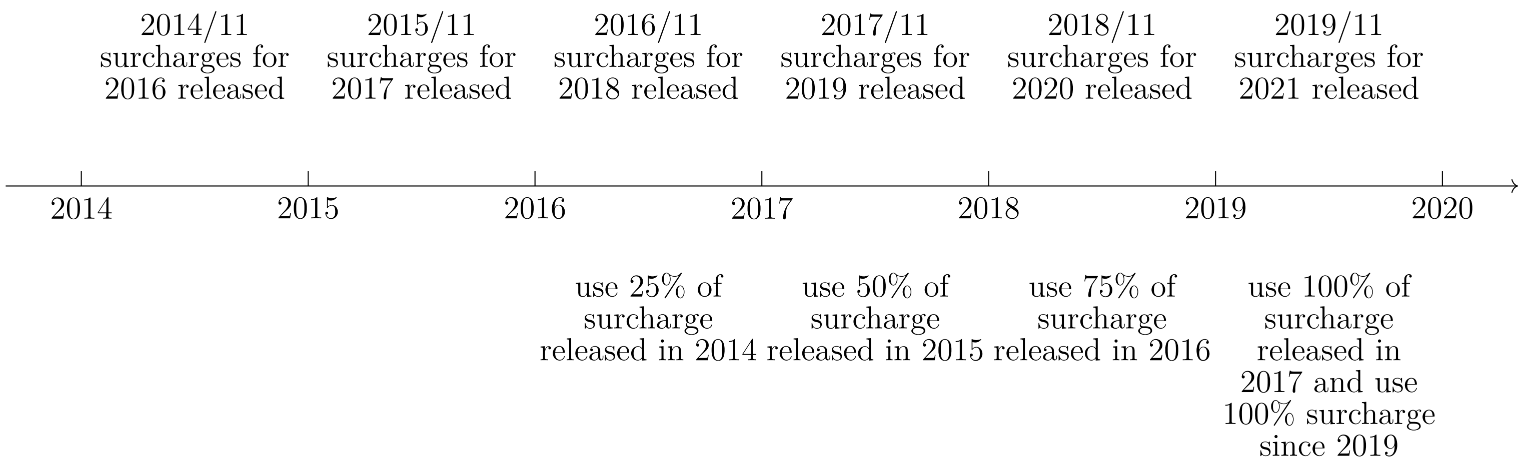

Figure 2: GSIB Surcharge Timeline

This diagram shows the timeline of the GSIBs surcharges from the Financial Stability Board (international framework). On November 2012, the Financial Stability Board firstly published GSIB list and corresponding surcharges. The Federal Reserve Board finalized its capital surcharge rule for US-GSIBs on July 2015. Source: Financial Stability Board.

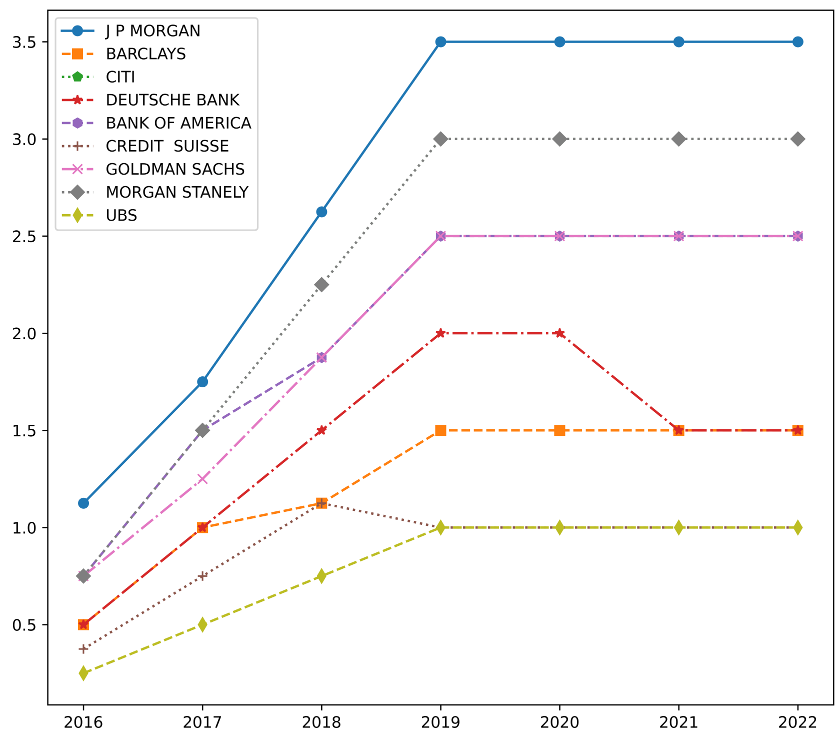

Figure 3: Effective GSIB Surcharge of Selected Banks

This figure shows the time series of effective GSIB surcharges for selected banks. Source: Financial Stability Board and 10-K.

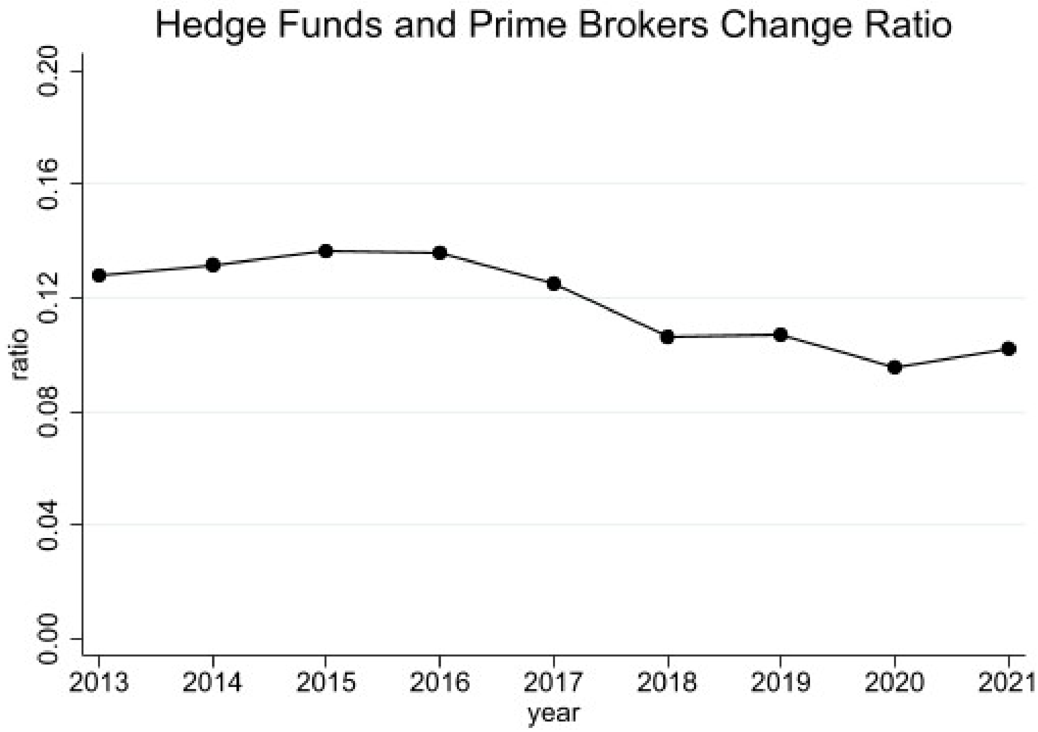

Figure 4: Changing Proportion of Hedge Fund and Prime Broker Connections

The figure plots the changing proportion of hedge fund and prime broker connections in each year. It is calculated as follows. Note that our merged sample of Form ADV and Lipper TASS includes the prime broker information on the hedge fund family level. Let $b_{ij,t}$ be the binary variable that takes value of one if fund family i uses broker j in month t. The changing proportion is calculated as:

$$\text{ChangeRatio}_t = \frac{1}{N_t} \sum_{i \in F_t, j \in B} |b_{ij,t} - b_{ij,t+1}|.$$

Here F_t is the set of leveraged hedge fund families that appear in our sample in both months t and $t+1$, B is the set of brokers, and $N_t := \sum_{i \in F_t, j \in S} |b_{ij,t} + b_{ij,t+1}|/2$ is the (average) total number of binary connections. We then sum the ratio for the months in a year.

Table 3: Variable Definition

This table presents definitions of the variables used in the paper. The first column gives the variable name. The second column includes a short description and data source.

Variable	Definition
Dependent Variables	
Excess return	Monthly hedge funds return less T-bill return. The data is obtained from the Lipper TASS database.
Alpha	Monthly hedge funds excess returns adjust by Fung and Hsieh seven factor.
Volatility	12-month hedge funds excess returns volatility.
Sharpe Ratio	12-month hedge funds average excess returns divided by volatility.
Information Ratio	12-month hedge funds average alpha divided by alpha's volatility.
Independent Variables	
AvgSurcharge	For each hedge fund, we average surcharges of its all prime broker's bank holding company. If a prime broker's bank holding company is non-GSIB, the surcharge is zero. The prime broker and hedge fund relationship is obtained from Form ADV. Surcharges for Non-US banks are from Financial Stability Board. Surcharges for US banks are from 10-K fillings.
AvgCET1	For each hedge fund, we calculate the average CET1 minimum capital requirement across all of the fund's prime broker banks. If a broker bank is designated as a GSIB, the bank's CET1 minimum requirement is increased by the applicable GSIB surcharge. CET1 minimum capital requirement is obtained from BIS website.
AvgSentiment	For each hedge fund, we calculate the average text-based sentiment score derived from the earnings call transcripts of the fund's prime broker banks. The sentiment score is based on the signed score output from the FINBERT model, applied specifically to sentences discussing capital-related topics. The earnings calls' data is from Capital IQ.
log_AUM	Logarithm of hedge fund asset under management (in USD).
log_age	Logarithm of hedge fund age in months.
ManagementFee	Management fee in percentage point.
IncentiveFee	Incentive fee in percentage point.
LockUpPeriod	Lock up period.
HighWaterMark	An indicator variable takes one if the fund is high water mark.
PersonalCapital	An indicator variable takes one if the fund uses personal capital.
log_minInvest	Logarithm of the sum of minimum investment amount and one.
RedemptionNoticePeriod	Redemption Notice Period (in days).

Table 4: Surcharges for GSIB as of 2021

The table shows surcharges as of year 2021 for Global Systemically Important Banks (GSIBs). There are currently eight US GSIBs. The US GSIB surcharge is calculated according to two methodologies, commonly referred to as Method 1 and Method 2. Method 1 was set by the Financial Stability Board (FSB) in consultation with the Basel Committee on Banking Supervision (BCBS). Method 2 was set by the Federal Reserve Board for US GSIBs. Non-US GSIBs meet the requirement of surcharge in Method 1. The final GSIB surcharge for US GSIBs is equal to the greater of the Method 1 surcharge and the Method 2 surcharge. The resulting surcharge of US-GSIBs can be found in 10-K.

Surcharge	G-SIBs
(3.5%)	JP Morgan (US)
(3.0%)	Citigroup (US), Morgan Stanley (US)
(2.5%)	Goldman Sachs (US), Bank of America (US)
(2.0%)	HSBC, Wells Fargo (US)
(1.5%)	Bank of China, Barclays, Deutsche Bank, Industrial and Commercial Bank of China, Mitsubishi UFJ FG, Bank of New York Mellon (US), BNP Paribas
(1.0%)	Agricultural Bank of China, Credit Suisse, Groupe BPCE, Groupe Crédit Agricole, ING Bank, Mizuho FG, Royal Bank of Canada, Santander, Société Générale, Standard Chartered, State Street (US), Sumitomo Mitsui FG, Toronto Dominion, UBS, UniCredit, China Construction Bank

Table 5: GSIB Prime Broker Market Share

The table shows the summary statistics for prime brokers and investment advisors in the merged sample. Fund characteristics data are obtained from the Lipper TASS Hedge Fund Database. Prime brokers are obtained from Form ADV filings with the SEC. We match hedge fund management companies from Lipper TASS with registered investment advisers (fund families) from Form ADV filings based on their names. Panel A reports the number of unique investment advisors (hedge fund investment company level) that use at least one GSIB prime broker and at least one non-GSIB broker for the merged sample. N Advisors is the unique number of investment advisors in the merged sample in the analysis. Panel B reports the number of unique GSIB brokers and non-GSIB brokers for the merged sample each year. All brokers are mapped to bank holding company level if the broker is bank-affiliated. The statistics are obtained annually as of January 31st, covering the period from 2013 to 2021.

Year	2013	2014	2015	2016	2017	2018	2019	2020	2021
Panel A: The number of funds use G-SIB and non G-SIB prime brokers									
N Advisors	236	247	242	223	214	209	198	183	169
Use G-SIB	221	229	223	200	187	180	170	154	144
Use Non G-SIB	48	54	58	56	60	68	65	61	54
Use GSIB-only	188	193	184	167	154	141	133	122	115
Use Non-GSIB only	15	18	19	23	27	29	28	29	25
Average number of PB	2.32	2.39	2.37	2.37	2.44	2.54	2.63	2.65	2.79
Panel B: The number of G-SIB and non G-SIB prime brokers									
Non G-SIB	30	30	28	31	25	25	26	31	34
G-SIB	14	16	14	15	17	18	18	16	16

Table 6: Summary Statistics

The table shows the summary statistics of fund characteristics for the main sample in the analysis. The observations are at the fund-month level. The sample period spans from January 2013 to November 2021.

	N	Mean	Std. Dev.	P10	P25	Median	P75	P90
Excess Return (%)	17683	0.42	3.68	-2.87	-0.82	0.41	1.66	3.73
FH-seven factor Alpha (%)	17683	0.11	3.65	-3.29	-1.14	0.18	1.41	3.34
Volatility (%)	17683	2.80	2.26	0.69	1.33	2.25	3.53	5.65
Sharpe Ratio	17683	0.25	0.54	-0.31	-0.09	0.17	0.48	0.86
Information Ratio	17683	0.10	0.43	-0.39	-0.17	0.07	0.32	0.63
Average Surcharge (%)	17683	0.72	0.95	0.00	0.00	0.00	1.31	2.25
Average CET1 capital minimum requirement (%)	17683	5.16	2.64	2.25	3.50	4.50	7.08	9.08
log_AUM	17683	18.35	1.93	15.89	17.19	18.38	19.60	20.56
log_age	17683	4.85	0.51	4.16	4.50	4.87	5.19	5.52
Management Fee (%)	17683	1.48	0.47	0.90	1.00	1.50	2.00	2.00
Incentive Fee (%)	17683	18.14	4.57	10.00	20.00	20.00	20.00	20.00
LockUpPeriod	17683	4.94	7.08	0.00	0.00	0.00	12.00	12.00
HighWaterMark	17683	0.83	0.38	0.00	1.00	1.00	1.00	1.00
PersonalCapital	17683	0.31	0.46	0.00	0.00	0.00	1.00	1.00
log_minInvest	17683	13.24	1.43	11.51	12.43	13.64	13.82	15.42
Redemption Notice Period (day)	17683	46.51	34.93	10.00	30.00	30.00	60.00	90.00

Table 7: Correlation Matrix

This table presents the correlation coefficients between the main variable of interest and the other explanatory variables. All variables are winsorized at the 1% and 99% levels. The sample period spans from January 2013 to November 2021.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
AvgSurcharge	1.000														
ExcessRet	-0.050	1.000													
alpha	-0.061	0.748	1.000												
vol12	0.021	-0.002	-0.012	1.000											
SR	-0.158	0.045	0.039	-0.296	1.000										
IR	-0.171	0.045	0.046	-0.224	0.784	1.000									
logAUM	-0.004	0.001	0.008	-0.113	0.019	0.039	1.000								
logAge	0.313	-0.024	-0.023	0.130	-0.148	-0.128	0.038	1.000							
MngFee	-0.005	-0.013	0.007	-0.069	0.079	0.091	0.011	-0.030	1.000						
IncentFee	-0.076	0.004	0.023	0.003	0.013	0.061	-0.063	0.047	0.385	1.000					
LockUp	-0.059	0.003	0.004	0.063	-0.020	0.009	-0.104	0.007	0.101	0.048	1.000				
HWM	0.041	0.021	0.019	-0.065	0.041	0.081	0.174	-0.148	-0.011	0.113	0.027	1.000			
PersK	-0.127	0.010	0.011	0.125	-0.028	0.002	0.030	0.114	-0.035	0.107	0.163	0.150	1.000		
logminInv	0.020	-0.000	0.006	-0.074	0.014	0.046	0.432	-0.015	-0.016	0.020	0.127	0.139	0.083	1.000	
RNP	-0.063	0.022	0.016	-0.023	0.100	0.089	0.063	-0.110	0.204	0.198	0.343	-0.059	0.113	0.295	1.000

Table 8: Portfolio Sorting Results

In Panel A, we sort funds into terciles based on their average exposure to GSIB surcharge of past month. Portfolios are re-balanced every month and held for 1, 3, 6, or 12months. For the three-month holding period, for example, one-third of the portfolio is revised in each month. The portfolios are equal-weighted. The table reports the results for excess returns and Fung and Hsieh (2004) seven factors alpha respectively. In Panel B, we implement independent double sorts on both fund size and average surcharge. The column HML presents the difference between the high surcharge fund portfolio and low surcharge fund portfolio within same size group. The average row reports the average of portfolio returns across size groups. t-Statistics are based on Newey and West (1987) standard errors with two lags. The time period is from January 2016 (when GSIB surcharge took effect) to November 2021. $*$, $**$, and $***$ indicate that the coefficients estimated are statistically significant at the 10%, 5%, and 1% level, respectively.

Panel A: Portfolio Sorting on Average Surcharge

	return (monthly %)				alpha (monthly %)			
	1m	3m	6m	12m	1m	3m	6m	12m
P1 (Low)	0.814***	0.820***	0.821***	0.831***	0.260**	0.275**	0.280***	0.284**
	(2.69)	(2.71)	(2.72)	(2.75)	(2.49)	(2.64)	(2.71)	(2.62)
P2	0.179	0.190	0.225	0.277	-0.131	-0.127	-0.089	-0.030
	(0.97)	(1.02)	(1.20)	(1.46)	(-1.25)	(-1.23)	(-0.83)	(-0.31)
P3 (High)	0.153	0.165	0.180	0.246	-0.164	-0.138	-0.121	-0.034
	(0.78)	(0.85)	(0.93)	(1.37)	(-1.03)	(-0.86)	(-0.75)	(-0.25)
P3-P1	-0.661***	-0.655***	-0.641***	-0.585***	-0.424**	-0.413**	-0.401**	-0.318**
	(-3.60)	(-3.57)	(-3.48)	(-3.26)	(-2.55)	(-2.49)	(-2.41)	(-2.12)

Panel B: Double Sorting on Fund Size and Surcharge

portfolio return	Surcharge 1 (Low)	Surcharge 2	Surcharge 3 (High)	HML
Small	0.836***	0.093	-0.026	-0.862***
	(2.82)	(0.42)	(-0.12)	(-3.89)
Large	0.753**	0.230	0.338	-0.415**
	(2.39)	(1.30)	(1.64)	(-2.51)
Average	0.795***	0.162	0.156	-0.639***
	(2.64)	(0.85)	(0.78)	(-3.64)

portfolio alpha	Surcharge 1 (Low)	Surcharge 2	Surcharge 3 (High)	HML
Small	0.215*	-0.240	-0.348	-0.563**
	(1.71)	(-1.33)	(-1.56)	(-2.33)
Large	0.285***	-0.053	-0.013	-0.297**
	(2.79)	(-0.55)	(-0.10)	(-2.37)
Average	0.250**	-0.146	-0.180	-0.430***
	(2.50)	(-1.24)	(-1.16)	(-2.66)

Table 9: Fama-MacBeth Regressions

This table reports results of the Fama-MacBeth regression of hedge fund performance on prime brokers average surcharge. *AvgSurcharge* measures hedge funds' average exposure to capital surcharges on GSIB-affiliated prime brokers. *std.AvgSurcharge* is a standardized average surcharge measure with mean of zero and standard deviation of one for each month. The time period is from January 2016 (when GSIB surcharge took effect) to November 2021. t-Statistics are based on Newey and West (1987) standard errors with two lags. $*$, $**$, and $***$ indicate that the coefficients estimated are statistically significant at the 10%, 5%, and 1% level, respectively.

	(1) return	(2) return	(3) alpha	(4) alpha	(5) return	(6) return	(7) alpha	(8) alpha
AvgSurcharge	-0.433***	-0.453***	-0.306**	-0.419***				
	(-3.70)	(-4.11)	(-2.60)	(-3.42)				
std. AvgSurcharge					-0.295***	-0.291***	-0.259***	-0.298***
					(-3.22)	(-4.25)	(-2.84)	(-3.30)
log_AUM		-0.060**		-0.004		-0.060**		-0.004
		(-2.39)		(-0.18)		(-2.39)		(-0.18)
log_age		0.086		-0.002		0.086		-0.002
		(0.91)		(-0.03)		(0.91)		(-0.03)
ManagementFee		-0.278*		-0.208		-0.278*		-0.208
		(-1.76)		(-1.13)		(-1.76)		(-1.13)
IncentiveFee		0.009		0.029*		0.009		0.029*
		(0.50)		(1.90)		(0.50)		(1.90)
LockUpPeriod		-0.003		0.007		-0.003		0.007
		(-0.36)		(0.90)		(-0.36)		(0.90)
HighWaterMark		0.283**		0.248		0.283**		0.248
		(2.17)		(1.62)		(2.17)		(1.62)
PersonalCapital		0.041		-0.150		0.041		-0.150
		(0.31)		(-1.05)		(0.31)		(-1.05)
log_minInvest		0.025		0.000		0.025		0.000
		(0.63)		(0.00)		(0.63)		(0.00)
RedemptionNoticePeriod		0.002		0.000		0.002		0.000
		(0.85)		(0.06)		(0.85)		(0.06)
Style Dummy	No	Yes	No	Yes	No	Yes	No	Yes
Observations	9705	9705	9705	9705	9705	9705	9705	9705
Adjusted R^2	0.019	0.058	0.023	0.054	0.019	0.058	0.023	0.054

Table 10: Hedge Fund 12-month performance on Average GSIB Prime Broker Surcharge Exposure

This table reports the panel regression to examine the effects of hedge funds' average exposure to GSIB surcharges on fund's performance. The dependent variable is average excess return, average alpha, volatility, sharpe ratio, and information ratio over 12 months. *AvgSurcharge* measures hedge funds' average exposure to capital surcharges on GSIB-affiliated prime brokers. t-statistics in parenthesis are based on standard errors clustered at fund level. $*$, $**$, and $***$ indicate that the coefficients estimated are statistically significant at the 10%, 5%, and 1% level, respectively.

$$y_{i,t+1,t+12} = \beta_0 + \beta_1 AvgSurcharge_{i,t} + \beta_2^{'} X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t},$$

Panel A: Average excess return

	(1)	(2)	(3)
AvgSurcharge	-0.314***	-0.313***	-0.293**
	(-4.54)	(-4.29)	(-2.52)
Fund FE	No	No	Yes
Style × Month FE	Yes	Yes	Yes
Controls	No	Yes	Yes
Observations	17500	17500	17483
Adjusted R^2	0.235	0.246	0.365

Panel B: Average alpha

	(1)	(2)	(3)
AvgSurcharge	-0.338***	-0.349***	-0.297**
	(-4.73)	(-4.66)	(-2.39)
Fund FE	No	No	Yes
Style × Month FE	Yes	Yes	Yes
Controls	No	Yes	Yes
Observations	17500	17500	17483
Adjusted R^2	0.128	0.136	0.323

Panel C: Volatility of excess return

	(1)	(2)	(3)
AvgSurcharge	-0.605**	-0.565**	-0.558***
	(-2.31)	(-2.30)	(-3.70)
Fund FE	No	No	Yes
Style × Month FE	Yes	Yes	Yes
Controls	No	Yes	Yes
Observations	17500	17500	17483
Adjusted R^2	0.218	0.264	0.737

Panel D: Sharpe ratio

	(1)	(2)	(3)
AvgSurcharge	-0.074***	-0.077***	-0.069
	(-4.97)	(-4.31)	(-1.54)
Fund FE	No	No	Yes
Style × Month FE	Yes	Yes	Yes
Controls	No	Yes	Yes
Observations	17500	17500	17483
Adjusted R^2	0.328	0.350	0.528

Panel E: Information ratio

	(1)	(2)	(3)
AvgSurcharge	-0.096***	-0.104***	-0.095***
	(-6.10)	(-5.57)	(-2.79)
Fund FE	No	No	Yes
Style × Month FE	Yes	Yes	Yes
Controls	No	Yes	Yes
Observations	17500	17500	17483
Adjusted R^2	0.215	0.240	0.454

Table 11: Hedge Fund Performance on Average PB Surcharge Exposure: Heterogeneous Effect on Fund Size

This table reports the panel regression to examine how the effects of GSIB surcharge depend on the fund size. The dependent variable is average excess return, average alpha, volatility, sharpe ratio, and information ratio over 12 months. *Large* is a dummy variable that equals one if AUM of a hedge fund is in the top tercile of the sample year. t-statistics in parenthesis are based on standard errors clustered at fund level. $*$, $**$, and $***$ indicate that the coefficients estimated are statistically significant at the 10%, 5%, and 1% level, respectively.

$$\begin{aligned} y_{i,t+1,t+12} &= \beta_0 + \beta_1 AvgSurcharge_{i,t} + \beta_2 AvgSurcharge_{i,t} \times Large_{i,t} \\ &+ \beta_3 Large_{i,t} + \beta_4^{'} X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}, \end{aligned} \tag{17}$$

	(1) return	(2) alpha	(3) volatility	(4) sharpe	(5) IR
AvgSurcharge	-0.367***	-0.362***	-0.514***	-0.097**	-0.111***
	(-3.08)	(-2.69)	(-3.12)	(-2.08)	(-2.99)
AvgSurcharge × Large	0.162**	0.137*	-0.102	0.064**	0.032
	(2.15)	(1.77)	(-1.04)	(2.00)	(1.07)
Large	-0.215	-0.256*	0.021	-0.051	-0.068
	(-1.55)	(-1.70)	(0.12)	(-0.87)	(-1.26)
Fund FE	Yes	Yes	Yes	Yes	Yes
Style × Month FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	17483	17483	17483	17483	17483
Adjusted R^2	0.368	0.326	0.737	0.529	0.455

Table 12: Hedge Fund Performance on Average PB Surcharge Exposure in Periods of More Binding Capital Constraints

This table reports the panel regression to examine how the effect of GSIB surcharge vary in the periods of more binding capital constraints. The dependent variable is average excess return, average alpha, volatility, sharpe ratio, and information ratio over 12 months. YearEnd is a dummy which takes one if the month is in the fourth quarter. VIX_HI is a dummy which takes one if VIX is higher than the top decile for the sample period. IBCDS_HI is a dummy which takes one if IBCDS is higher than the top decile for the sample period. IBCDS index is calculated as the average credit default swap (CDS) spreads on 5-year senior bonds of the following institutions: Citigroup Inc, Goldman Sachs, JPMorgan, Morgan Stanley, Credit Suisse, and Bank of America.

$$\begin{aligned} y_{i,t+1,t+12} &= \beta_0 + \beta_1 AvgSurcharge_{i,t} + \beta_2 AvgSurcharge_{i,t} \times BindingPeriod_t \\ &+ \beta_3^{'} X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t} \end{aligned} \tag{18}$$

Panel A: Year-end effect

	(1) return	(2) alpha	(3) volatility	(4) SR	(5) IR
AvgSurcharge	-0.283**	-0.289**	-0.536***	-0.070	-0.093***
	(-2.49)	(-2.41)	(-3.65)	(-1.58)	(-2.77)
AvgSurcharge × YearEnd	-0.050**	-0.041	-0.107***	0.004	-0.011
	(-2.16)	(-1.32)	(-3.41)	(0.52)	(-1.55)
Fund FE	Yes	Yes	Yes	Yes	Yes
Style × Month FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	17483	17483	17483	17483	17483
Adjusted R^2	0.365	0.324	0.737	0.528	0.454

Panel B: VIX high period (VIX≥ Top Decile)

	(1) return	(2) alpha	(3) volatility	(4) SR	(5) IR
AvgSurcharge	-0.220**	-0.254**	-0.474***	-0.057	-0.089***
	(-2.30)	(-2.33)	(-3.24)	(-1.25)	(-2.59)
AvgSurcharge × VIX_HI	-0.352**	-0.207	-0.398*	-0.057*	-0.030
	(-2.04)	(-1.52)	(-1.91)	(-1.93)	(-1.27)
Fund FE	Yes	Yes	Yes	Yes	Yes
Style × Month FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	17483	17483	17483	17483	17483
Adjusted R^2	0.369	0.325	0.738	0.528	0.455

Panel C: CDS high period (CDS≥ Top Decile)

	(1) return	(2) alpha	(3) volatility	(4) SR	(5) IR
AvgSurcharge	-0.281**	-0.290**	-0.549***	-0.068	-0.095***
	(-2.46)	(-2.34)	(-3.65)	(-1.52)	(-2.78)
AvgSurcharge × IBCDS_HI	-0.504***	-0.284**	-0.328*	-0.038	-0.012
	(-2.63)	(-1.98)	(-1.71)	(-1.12)	(-0.45)
Fund FE	Yes	Yes	Yes	Yes	Yes
Style × Month FE	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes
Observations	17483	17483	17483	17483	17483
Adjusted R^2	0.367	0.324	0.737	0.528	0.454

Table 13: Hedge Fund Family Equity Holding on Average PB Surcharge

This table reports the panel regression to examine the effects of hedge funds' average exposure to GSIB surcharges on fund family equity holding beta. We match hedge fund management companies is Thomson Reuters 13F database with registered investment advisors from Form ADV filings based on the merging table in Jiang (2023). The observations are at fund-quarter level. The dependent variable is fund family's portfolio beta of quarterly equity holdings. t-statistics in parenthesis are based on standard errors clustered at fund family level. $*$, $**$, and $***$ indicate that the coefficients estimated are statistically significant at the 10%, 5%, and 1% level, respectively.

$$\text{FundBeta}_{i,q+1} = \beta_0 + \beta_1 AvgSurcharge_{i,q} + \beta_2 EquityMV_{i,q} + \alpha_i + \alpha_q + \varepsilon_{i,q+1},$$

	(1) beta	(2) beta	(3) beta	(4) beta
AvgSurcharge	0.107***	0.049**		
	(3.12)	(2.35)		
GSIB_ratio			0.137**	0.130*
			(2.07)	(1.70)
log_AUM_equity	0.010	0.001	0.008	0.000
	(1.31)	(0.12)	(1.10)	(0.01)
YearQuarter FE	Yes	Yes	Yes	Yes
Fund Family FE	No	Yes	No	Yes
Observations	6642	6638	6642	6638
Adjusted R^2	0.093	0.523	0.078	0.521

Table 14: Hedge Funds Performance on Average CET1 requirement

This table reports the panel regression to examine the effects of hedge funds' average exposure to Common Equity Tier 1 capital requirement on fund's performance. We estimate the following regression equation: $y_{i,t+1,t+12} = \beta_0 + \beta_1 AvgCET1_{i,t} + \beta_2^{'} X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}$. The dependent variable is average excess return, average alpha, volatility, sharpe ratio, and information ratio over 12 months. $AvgCET1_{i,t}$ measures hedge funds' average exposure to Common Equity Tier 1 capital requirement on bank-affiliated prime brokers. GSIB surcharge is included in CET1 requirement if the broker is also GSIB-affiliated. t-statistics in parenthesis are based on standard errors clustered at fund level. $*$, $**$, and $***$ indicate that the coefficients estimated are statistically significant at the 10%, 5%, and 1% level, respectively.

	(1) return	(2) return	(3) alpha	(4) alpha	(5) volatility	(6) volatility	(7) SR	(8) SR	(9) IR	(10) IR
AvgCET1	-0.079***	-0.088*	-0.083***	-0.103**	-0.176**	-0.157***	-0.016***	-0.022	-0.018***	-0.029**
	(-4.69)	(-1.92)	(-4.54)	(-2.21)	(-2.38)	(-2.75)	(-3.19)	(-1.20)	(-3.96)	(-2.10)
Fund FE	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes
Style × Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	17500	17483	17500	17483	17500	17483	17500	17483	17500	17483
Adjusted R^2	0.244	0.362	0.130	0.321	0.271	0.733	0.348	0.527	0.231	0.452

Table 15: Common Equity Tier 1 (CET1) Minimum Requirement and Conservation Buffer

This table shows minimum requirement and capital conservation buffer for CET1 ratio. Capital conservation buffer is established above the regulatory minimum capital requirement. Capital distribution constraints will be imposed on a bank when capital levels fall into the conservation range. The capital conservation buffer achieves full implementation by 2019.

Year	2013	2014	2015	2016	2017	2018	2019
Minimum CET1 ratio	3.5	4	4.5	4.5	4.5	4.5	4.5
Capital conservation buffer (CCB)	0	0	0	0.625	1.25	1.875	2.5
Minimum CET1 + CCB	3.5	4	4.5	5.125	5.75	6.375	7

Table 16: GSIB Broker Dependence and Hedge Fund Performance: Difference-in-Difference Analysis

This table reports results of difference in difference estimation. We estimate the following equation: $y_{i,t+1} = \beta_0 + \beta_1 \times \text{Treat}_{i,t} \times \text{Post}_t + \beta_2^{'} X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}$, where α_i and $\alpha_s \times \alpha_t$ capture fund and style by month fixed effects, respectively. $\text{Treat}_{i,t}$ takes value of one if a hedge fund's GSIB-affiliated prime brokers ratio are greater than cross-sectional median. Post_t takes value of one if the year of the month is greater equal than 2016. The dependent variable is the fund's next month excess return or alpha. t-statistics in parenthesis are based on standard errors clustered at fund level. $*$, $**$, and $***$ indicate that the coefficients estimated are statistically significant at the 10%, 5%, and 1% level, respectively.

	(1) return	(2) alpha
Treat × Post	-0.789***	-0.604***
	(-4.35)	(-3.44)
Fund FE	Yes	Yes
Style × Month FE	Yes	Yes
Controls	Yes	Yes
Observations	17442	17442
Adjusted R^2	0.174	0.074

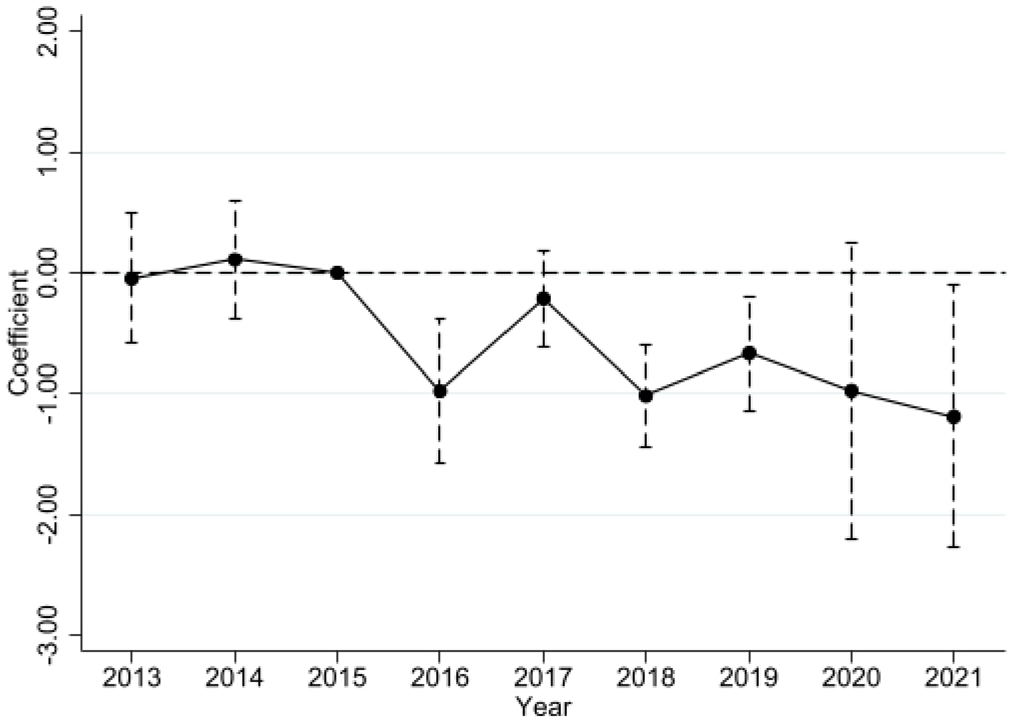

Figure 5: Dynamic effect of GSIB broker dependency on Hedge fund returns

This figure compares hedge fund monthly excess return by GSIB dependent and non-GSIB dependent hedge funds. It displays the estimates of β_τ for in the following equation: $y_{i,t+1} = \Sigma_{\tau=2013,\tau\neq 2015}^{2021}\beta_\tau \times \text{Treat}_{i,t} \times \mathbb{1}\{t \in \text{Year}_\tau\} + \beta_2' X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}$, where α_i and $\alpha_s \times \alpha_t$ capture fund and style by month fixed effects, respectively. $\text{Treat}_{i,t}$ is an indicator that is equal to 1 if hedge fund i proportion of GSIB prime brokers is greater than median at month t. $\mathbb{1}\{t \in \text{Year}_\tau\}$ is a dummy variable that takes value of one if month t is in year τ. 95 percent confidence intervals are computed using standard errors clustered at fund level.

Table 17: Sentiment of PB balance sheet on HF performance

This table reports the panel regression results for hedge fund performance on average PB balance sheet sentiment. The dependent variable is average excess return and average alpha over 12 months. The t-statistics are reported in parentheses. *AvgSentiment* is average sentiment score of balance sheet related sentences from the last quarter's earnings call. The informative words are selected by word2vec method. t-statistics in parenthesis are based on standard errors clustered at fund level. $*$, $**$, and $***$ indicate that the coefficients estimated are statistically significant at the 10%, 5%, and 1% level, respectively.

$$y_{i,t+1,t+12} = \beta_0 + \beta_1 AvgSentiment_{i,t} + \beta_2' X_{i,t} + \alpha_i + \alpha_s \times \alpha_t + \varepsilon_{i,t}$$

	(1) return	(2) return	(3) alpha	(4) alpha
AvgSentiment	0.937***	0.849**	1.349***	0.928**
	(3.05)	(2.38)	(3.76)	(2.25)
Style × Month FE	Yes	Yes	Yes	Yes
Fund FE	No	Yes	No	Yes
Controls	Yes	Yes	Yes	Yes
Observations	15450	15438	15450	15438
Adjusted R^2	0.243	0.380	0.157	0.354