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Bank-Intermediated Arbitrage

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Abstract

We argue that post-crisis banking regulations pass through from regulated institutions to unregulated arbitrageurs. We document that, once post-crisis regulations bind post 2014, hedge funds use a larger number of prime brokers and diversify away from GSIB affiliated prime brokers, and that the match to such prime brokers is more fragile. Tighter regulatory constraints disincentivize regulated institutions not only to engage in arbitrage activity themselves but also to provide leverage to other arbitrageurs. Indeed, we show that the maximum leverage allowed and the implied return on basis trades is considerably lower under post-crisis regulation, in spite of persistently wider spreads.

Key words: cost of capital, beta, bank regulation, Dodd-Frank act, banks

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To view the authors' disclosure statements, visit https://www.newyorkfed.org/research/staff_reports/sr858.html.

1 Introduction

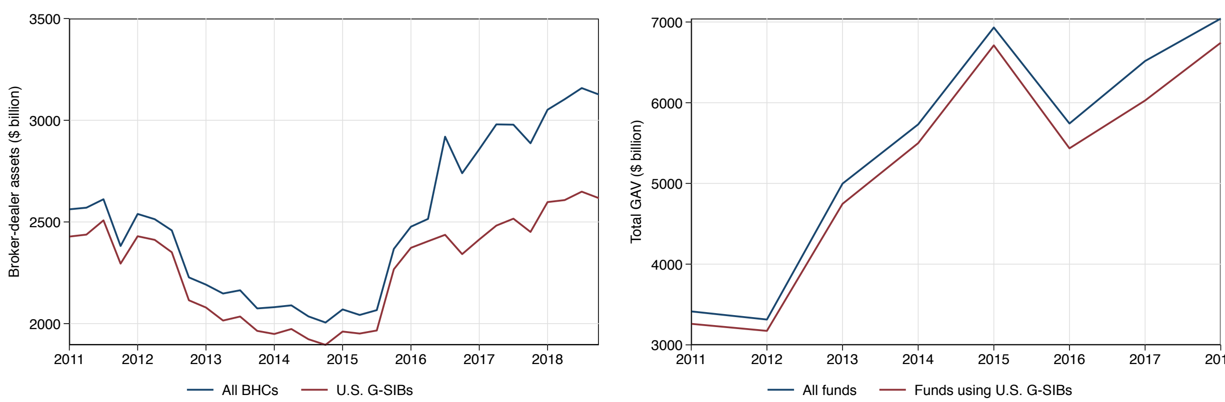
Arbitrageurs play a key role in the efficiency of financial markets. In practice, they rely on prime brokers and broker-dealers more broadly for a slew of services, such as trade execution, the extension of leverage, securities lending, and account centralization of cash and securities. Over time, prime brokerage has expanded from being primarily an equity-based product to encompassing the full range of fixed income, foreign exchange, derivatives, and futures products, making broker-dealers an integral part of the modern financial system. Consolidation of the banking system over time has led to the largest broker-dealers becoming part of bank holding companies and therefore subject to bank regulation. Despite their importance for arbitrage activity, little is known about the relationship between broker-dealers and their hedge fund clients, and how it is affected by regulation of a broker-dealer's bank holding company parent. In this paper, we study how bank regulations affect the match between a broker and its clients, and argue that regulations affecting incentives for banks to take on leverage pass-through to their hedge fund clients, increasing the overall "limits-to-arbitrage" in leverage-dependent arbitrage trades.

One of the innovations in our paper is to use data on the incidence of hedge fund–prime broker relationships from Form ADV, which is an annual regulatory filing by SEC-registered investment advisers with more than 15 U.S. clients or more than $25 million in assets under management. Form ADV thus provides us with a repeated panel of hedge fund–prime broker pairs, allowing us to study not only how the relationship between prime brokers and the hedge fund universe changes in aggregate over time, but also how the choice of clients for a *given* prime broker and the choice of prime brokers for a *given* hedge fund changes over time, including the probability of new match formation and the persistence of existing matches.

To illustrate the importance of observing pair-level variation, consider the evolution of the total net assets of broker-dealer subsidiaries of U.S. bank holding companies (Figure 1a) as a proxy for the amount of balance sheet space available to hedge fund clients and the evolution of the total gross asset value (GAV) of large U.S. hedge funds (Figure 1b) between 2011 and 2018.[1] Two features are striking about the aggregate trends plotted in Figure 1. First, the size (in terms of GAV) of the large hedge fund universe has grown almost monotonically during this period. Second, the total balance sheet space of U.S. banks devoted to brokerage activities declined noticeably between 2012 and the second half of 2015, but has grown since. If all prime brokers and hedge funds were homogeneous, these trends would suggest that leverage provision to hedge funds was declining or unchanged through the middle of 2015 but has increased since, while allowing for hedge fund clients to grow in almost every year of the sample.

Figure 1. Changing prime brokerage landscape. This figure plots the total net assets of broker-dealer subsidiaries of bank holding companies filling form FR Y9C (Figure 1a), together with the total gross asset value (GAV) of hedge funds submitting Form ADV (Figure 1b). "Total net assets of broker-dealer subsidiaries" includes assets of domestic and foreign subsidiaries engaged in underwriting or dealing securities, excluding intercompany assets and claims on subsidiaries.

(a) Net assets of broker-dealer subs **(b) Hedge fund GAV**



Instead, we find that prime brokers have fewer clients and are less likely to form new

[1]We use data on net assets of broker-dealer subsidiaries of bank holding companies filling form FR Y9C and data on hedge fund GAV from Form ADV which is available starting in 2011 only. The SEC ruling on Form ADV to implement provisions from the Dodd-Frank Act requires investment advisers to disclose regulatory AUM on a gross basis, without the deduction of outstanding debt or accrued but unpaid liabilities. For example, an adviser should not deduct securities purchased on margin when calculating AUM. The intent of using gross rather than net AUM is to include highly leveraged funds in systematic risk reports whose GAV is large.

client relationships in the post-2014 period, after the introduction of key Basel III banking regulations. Consistent with regulatory pressures passing through to broker-dealers' clients, hedge funds adjust through both the extensive and intensive margins, by splitting their business across a larger number of prime brokers and by reducing the overall size of their business. We argue that these changes are driven by regulation, in particular the supplementary leverage ratio (SLR), reducing the incentives for banks to provide balance sheet space to leveraged clients. The SLR requires that large financial institutions hold capital against their total leverage exposure, including on-balance sheet assets and off-balance sheet assets and exposures, with more stringent requirements for larger and more systemic institutions.[2] Consistent with this hypothesis, we further show that the prime broker–client relationships change the most for prime brokers affiliated with global systemically important banks (G-SIBs), which face the most stringent regulation, and for the largest hedge funds, which take up the most balance sheet space.

Why does the nature of the relationship between broker-dealers and their clients matter? Historically, both broker-dealers and hedge funds have acted as arbitrageurs in the largest asset markets in the world, taking on levered positions to reduce deviations from the law of one price across related markets. For broker-dealers that are part of bank holding companies, regulations that discourage taking on leverage on their own behalf as well as providing balance sheet space and leverage to hedge fund clients thus reduce the total amount of arbitrage capital available in the financial system. Focusing on *bank-intermediated* fixed income basis trades – which require a broker-dealer for execution or financing and are thus most likely to be affected by post-crisis changes to bank regulation – we show that the maximum implied leverage for such trades is much lower under the SLR than under the pre-crisis regulatory regime. We further show that, while risk-management constraints such

[2]The SLR applies to advanced approaches firms that have more than $250 billion in total consolidated assets or more than $10 billion of on-balance sheet foreign exposures including U.S. banking organizations and foreign banking organization, and U.S. intermediate holding companies. Total leverage exposure includes on-balance sheet assets and off-balance sheet exposures such as OTC derivatives, cleared derivatives, and repo transactions. U.S. G-SIB insured depository subsidiaries must maintain an enhanced supplementary leverage ratio of 6 percent to be considered well-capitalized during the paper's post-SLR sample period.

as value-at-risk (VaR) were more binding than regulatory constraints during the pre-SLR period, the SLR becomes the binding constraint once it's introduced, despite a concurrent decrease in the maximum leverage allowed by the VaR constraint in post-SLR period.

Taking into account the funding costs of both the long leg and the short leg of each trade, and the leverage requirement for all of the components of the trade, we document that the average implied return on equity (ROE) on the fixed income basis trades we consider is significantly smaller under SLR than the implied ROE under the risk-weighted capital requirement (RWA) and does not meet the 12% ROE that most large banks target. That is, even though the average absolute level of the bases is larger in the post-2014 period, regulatory changes imply that the basis trades are not sufficiently profitable from the perspective of regulated institutions. Comparing the pre- and post-2014 average levels, we document that the greatest (percentage) increases in the absolute level of the basis occur for trades that have the biggest change in balance sheet impact when moving from the RWA constraint to the SLR constraint. At the same time, there is a negative relationship between the (percentage) changes in the ROE on a basis trade and the balance sheet impact of the trade, so that trades with the biggest change in balance sheet impact have had the greatest reductions in the implied ROE that the trade generates. Thus, the increases in the level of the bases are insufficient to offset the increases in the balance sheet impact associated with executing the basis trades.

The rest of the paper is organized as follows. We review the related literature below. Section 2 describes the prime broker – client relationship in greater detail, summarizing how post-crisis changes in bank regulation affects the incentives to provide prime brokerage services. We document the post-SLR changes in the prime broker – client relationship in section 3. Turning to the effects on asset markets, section 4 lays out the components to the bank-intermediated arbitrage trades we consider in this paper, including funding costs and capital recognition. We show the decrease in the maximum allowed leverage for these trades in section 5, together with the implied changes in ROE. Section 6 concludes.

Related Literature This paper contributes to two recent and growing strands of literature. The first studies the institutional detail and behavior of hedge funds and their prime brokers.[3] The second studies the role that financing constraints play in the persistence of deviations of spreads from the no-arbitrage benchmark.

In the literature studying the interconnections between hedge funds and regulated institutions, the two papers closest to ours are Choi et al. (2019) and Mitchell and Pulvino (2012). Choi et al. study the CDS-bond basis in the wake of the Lehman bankruptcy and find that, contrary to wide-spread perception, the deviations in the basis arose as a result of hedge funds exiting their pre-crisis basis-narrowing trades, not from bond dealers unloading their inventory. Mitchell and Pulvino also study the performance of arbitrage trades during the financial crisis but focus on the funding provided by prime brokers to their hedge fund clients. They argue that prime brokers reduced the provision of leverage to hedge funds during the crisis, impairing the ability of arbitrageurs to engage in spread-narrowing trades. Ang et al. (2011) document the time-series and cross-sectional properties of hedge fund leverage more broadly and show that aggregate factors tend to predict changes in hedge-fund leverage better than fund-specific factors. Our paper differs from this prior literature by focusing on the effects of regulation on leverage provision by prime brokers to their clients and that it may limit the ability of arbitrageurs to correct mispricing even outside of crisis periods.

Very few papers study the institutional detail of prime brokerage and how it is affected by regulation. Kenny (2017) provides an overview of the institutional arrangements and changes post-crisis. Eren (2015) explores the benefits of internalization and rehypothecation and shows that the matching between hedge funds and prime brokers aims to exploit both. Infante (2019) models the terms of prime brokers' intermediation of credit to their hedge fund clients. Infante and Vardoulakis (2019) show theoretically that this intermediation exposes the prime brokers to a risk of assets-side runs by their hedge fund clients, similar to the traditional risk of liabilities-side runs. Gerasimova and Jondeau (2018) model the

[3]For a comprehensive survey of the academic literature on hedge funds, see Getmansky et al. (2015).

strategic interaction between hedge funds and prime brokers and speculate that Basel III leverage constraints on prime brokers may lead them to offer *more* leverage to hedge fund clients; prime brokers might soften their lending conditions to compensate for the effect of regulation on their own leverage. King and Maier (2009) advocate for indirect regulation of hedge funds via their prime brokers. Our paper focuses on how relationships between prime brokers and hedge funds have evolved before and after the financial crisis due to changes in regulation affecting the prime brokers.

The majority of papers studying the prime-brokerage relationship focus on their effects on hedge fund performance. Chung and Kang (2016) find a strong comovement in the returns of hedge funds sharing the same prime broker that might be explained by hedge fund trading based on information from the prime-broker; by the transmission of funding liquidity shocks across its clients when the prime broker's financial health deteriorates; or, by similar funds choosing to use the same prime-broker. Since the comovement is positively related to hedge fund performance, Chung and Kang argue for the information sharing hypothesis, consistent also with the evidence of Barbon et al. (2019), Di Maggio et al. (2019), and Kumar et al. (2019). Sinclair (2016) shows the role prime brokers play in connecting hedge funds with investors. There is also considerable evidence for the funding shock hypothesis in the spirit of Brunnermeier and Pedersen (2009): Klaus and Rzepkowski (2009) find that an increase in prime brokers' distress is associated with a significant decline in fund performance and that funds benefit from having multiple prime brokers. Boyson et al. (2010) use more indirect measures of liquidity shocks to hedge funds to document contagion across hedge funds. Kruttli et al. (2018) study counterparty risk management by prime brokers, and show that idiosyncratic liquidity shocks lead prime brokers to reduce credit supply to their hedge fund clients. Aragon and Strahan (2012) make use of the Lehman Brothers bankruptcy in 2008 and document the distress of hedge funds using Lehman as their prime broker. Similarly, Dahlquist et al. (2019) show that only the Lehman bankruptcy propagates to the returns to hedge fund clients, but the effect is mitigated for funds with multiple prime brokers.

Conversely, Faff et al. (2019) document the benefit to hedge funds of prime broking with a bank that receives a bail out during the crisis. Our paper focuses on how changes in the relationships between prime brokers and hedge funds impact cross-market liquidity rather than hedge funds' performance.

With respect to the existing literature on deviations from no-arbitrage, we innovate along two dimensions. First, we show how constraints faced by regulated institutions (i.e. prime brokers) translate into constraints faced by their clients (i.e. hedge funds). Second, instead of focusing on a particular type of arbitrage trade, we consider a broad set of trades. We show that trades that require the most intermediation by the regulated institutions – either because the regulated institutions are the marginal investors in the trade or because regulated institutions provide leverage financing to the marginal investors in the trade – are more sensitive to constraints faced by the regulated institutions.

A number of recent studies have focused on the role that the regulatory constraints faced by intermediaries play in perpetuating deviations from arbitrage. Avdjiev et al. (2019) document that deviations from covered interest rate parity (CIP) are strongly correlated to the dollar financing costs of global banks. In a related paper, Du et al. (2018) show that the expected profitability of CIP trades is much lower after proxying for banks' balance sheet costs, while Du et al. (2019) argue that deviations from CIP proxy for intermediary capital constraints. Similarly, Boyarchenko et al. (2018a,b) show that, after the introduction of SLR in the U. S., the break-even levels of Treasury-swaps spreads and credit bases are much lower (more negative) than prior to the crisis. In the equity market, Jylhä (2018) shows that tighter leverage constraints – induced by changing initial margin requirements – correspond to a flatter relationship between market betas and expected returns. In the sovereign fixed income market, Fleckenstein and Longstaff (2018) argue that the difference between the market repo rate on U. S. Treasuries and the implied repo rate from U. S. Treasury futures proxies for the balance sheet costs of regulated institutions in the U. S., and show that that spread is related to other fixed income bases, such as the Treasury-swap spread. Similarly, Pelizzon et al. (2018) study the sovereign bond-futures basis for European sovereigns, and argue that regulatory constraints on the banking sector prevent a market-neutral implementation of large scale asset purchase programs. More recently, Correa et al. (2020) study G-SIB's provision of dollar liquidity in repo and foreign exchange swap markets. On the other side of the bank relationships with other financial institutions, Anderson et al. (2019) study the effect of post-crisis reforms to money market funds on bank borrowing, and argue that the reduction in wholesale funding from money market funds to banks impedes banks' ability to participate in funding arbitrage trades. Finally, He et al. (2020) study the role of intermediary constraints in the COVID-19 related market dislocations in the Treasury markets in March 2020, while Liao and Zhang (2020) characterize the role of intermediaries in net external financial imbalances.

This recent literature builds on older studies of no-arbitrage deviations. In fixed-income markets, Duarte et al. (2007) consider the alphas generated by five types of fixed-income arbitrage trades that were prevalent prior to the financial crisis, and find that arbitrage trades that require the most leverage generate the highest alpha, consistent with arbitrageurs being compensated for using their limited capital. We refine the argument in our paper by focusing on the limits-to-arbitrage induced by banking regulation. Our paper also provides stylized facts for the theoretical limits-to-arbitrage literature (e.g., Gromb and Vayanos, 2002, Liu and Longstaff, 2004, Jermann, 2016, Biais et al., 2017, Hébert, 2018), both from the standpoint of the relationship between regulatory constraints and deviations from law of one price, and from the standpoint of the pass-through of regulation to unregulated entities through their relationships with regulated institutions.

2 Prime brokerage

We begin by describing the relationship between prime brokers and their clients, and how post-crisis changes in regulations affect the incentives of regulated institutions to provide prime brokerage services. We argue that prime brokerage acts as a conduit for regulation so that post-crisis regulatory changes targeted at banks are passed-through to their less regulated clients. Although we focus our discussion on the relationship between prime brokers and hedge funds, the regulatory pass-through we discuss would affect any client that relies on the prime broker and broker-dealers more broadly for leverage.

2.1 Brokerage services

Historically, prime brokers assisted clients such as hedge funds by executing trades as well as by tracking trades, consolidating positions, and calculating performance, regardless of which broker executed the trades. Over time, prime brokers have expanded their services, in particular as credit intermediaries: Since hedge funds may be too small or risky to borrow from other market participants directly, the prime broker steps in as a trusted counterparty to both.

Facing a hedge fund, the prime broker provides leverage against both long and short positions.[4] In the case of a hedge fund long position, the prime broker lends cash to the hedge fund and receives the security as collateral. The broker can then use this security as collateral to borrow from a third party (rehypothecation) or to lend to another hedge fund client that wants to take a short position. Figure 2a illustrates rehypothecation in a "matched-book repo" where the broker effectively intermediates between a hedge fund and a money market fund.

To facilitate a hedge fund client's short positions, the broker either uses its own positions, rehypothecates other clients' long positions, or borrows from securities lenders such as pension funds. In addition, the broker holds clients' free cash balances, generating a spread between the interest paid to the client and the return from using the cash balances for other purposes.

[4] The amount of leverage a hedge fund obtains from its prime brokers depends on the "financing platform" agreed upon. Financing platforms include "Regulation T," portfolio margining, and more bespoke arrangements. Each platform is governed by different regulations and offers the client different options and protections.

Prime brokers rely to a large extent on "internalization," e.g. using one client's long position to source another client's short position, or funding one client's debits with another client's credits. Figure 2b illustrates an example of internalization where the prime broker lends the security received as collateral from hedge fund 1 to hedge fund 2 and the cash received as collateral from hedge fund 2 to hedge fund 1. Since both hedge funds have to overcollateralize their trade with the prime broker, such a combination of trades is a net source of liquidity for the prime broker.

2.2 Regulatory impact

A prime broker faces two important risks: (i) credit risk, i.e. the risk that its client defaults and the value of the collateral posted is insufficient, and (ii) liquidity risk, i.e. the risk that the prime broker loses the funding generated through rehypothecation and internalization. The financial crisis highlighted in particular the liquidity risks of prime brokers (Duffie, 2010).[5] The experience of Bear Stearns and Lehman Brothers in 2008 also highlighted hedge funds' exposure to their prime brokers and led to a desire by the hedge funds to diversify across multiple prime brokers (Mackintosh, 2008).

The Basel III capital regulations have significantly impacted the activities of prime brokers that are part of bank holding companies. Given the key role of prime brokers as credit intermediaries, the supplementary leverage ratio (SLR) has had the biggest impact. Any matched-book repo, where the broker lends to a hedge fund and funds the loan by rehypothecating the collateral, increases the balance sheet and therefore the leverage ratio.[6] This is especially costly for low-margin intermediation using safe assets as collateral.[7]

Prime brokers and broker-dealers are also impacted by the Basel III liquidity regulations.

[5]See Aguiar et al. (2014) for detailed discussion of broker-dealers' funding risks.

[6]The leverage ratio calculation also includes several off-balance sheet exposures relevant to prime brokerage. For example, derivatives collateral received and pledged; written credit derivatives on a notional basis; off-balance sheet security financing transaction exposure; off-balance sheet unfunded lending commitments; off-balance sheet standby letters of credit and other guarantees. See, e.g. Citi Investor Services (2014) and J.P. Morgan Investor Services (2014) for details.

[7]See Kirk et al. (2014) for a detailed discussion of dealer activities involving multiple uses of collateral such as matched-book repo.

For hedge fund clients, the liquidity coverage ratio (LCR) assumes complete withdrawal of free credit balances and full draw-down of loan commitments (this is in contrast to lower run-off rates assumed for other client types). Further, the LCR assumes that the prime broker loses all of its collateralized funding with terms of less than 30 days. The net stable funding ratio (NSFR) affects prime brokers providing financing against collateral that is hard to rehypothecate, forcing them to fund such loans with a larger proportion of equity or long-term debt.

Finally, the regulatory treatment of brokers' activities, especially internalization, depends directly on allowable netting. As a rule of thumb, for two trades to net, they require the same counterparty, the same end date and the same settlement system. Historically, the netting had to be done only at low frequency reporting dates, e.g. quarter ends. However, some of the post-crisis regulation applies at significantly higher frequency which considerably reduces the scope for netting. For example, the LCR requires daily calculation with monthly reporting of the daily average and the Federal Reserve's stress tests (Comprehensive Capital Analysis and Review) use average daily balance sheet numbers. In addition, the LCR and NSFR limit netting in prime brokerage agreements to 50 percent of encumbered assets.

2.3 Possible effects

The regulatory impacts outlined above imply higher marginal costs for banks in providing brokerage services, both along the intensive and extensive margin. At the client level, we expect the prime brokers to target higher marginal profits, limiting hedge fund growth. Across clients, we expect the prime brokers to reduce their number of clients overall and to focus on clients generating high average profits. Further, we expect stronger responses by prime brokers affiliated with the most constrained institutions. In particular, since institutions designated as globally systemically important banks (G-SIBs) face additional capital requirements and supervisory scrutiny, prime brokers affiliated with G-SIBs should be the most affected by post-crisis changes in regulation.

It is not immediately clear what type of hedge fund is most affected by the post-crisis regulations. From the prime broker's perspective, a desirable client has long positions that are easy to fund, short positions that are easy to borrow, high internalization benefits (e.g. hard to borrow longs), and a balanced portfolio (longs equal to shorts). This suggests that unlevered long–short equity funds, for example, should be least impacted while levered fixed-income arbitrage funds should be most impacted. More generally, we expect funds to split their activity across more prime brokers than before and to rely less on G-SIB prime brokers. It is unclear how these effects should vary with fund size, especially if larger funds require more complex services that may only be available at a large G-SIB prime broker.

The resultant prime broker–client relationships are an equilibrium outcome balancing prime brokers' supply of balance sheet space with clients' demand for balance sheet space. Overall, we expect hedge funds to spread out more across prime brokers concurrent with a shift from relying on G-SIB prime brokers to relying on non-G-SIB prime brokers and a more specialized match in each prime broker–client relationship.

3 Post-crisis changes in prime broker-client relationships

Many of the regulations described in Section 2 were introduced, finalized and implemented concurrently,[8] making an event study approach to measuring the impact of individual regulations impossible. Instead, we follow prior literature and compare outcomes in different subperiods. Since the focus of our paper is on the effects of SLR on brokerage activities, we define the sub-period starting in January 2014 as the "post-SLR" period (also called "rule implementation period" in the literature).

[8]See e.g. Adrian et al. (2017) for a timeline of selected regulations.

3.1 Data description

We use data on hedge fund gross asset value (GAV) and prime broker relationships from 2011 to 2018 from Form ADV. Form ADV is an annual regulatory filing by investment advisers with more than 15 U.S. clients or more than $25 million in assets under management (AUM) registered with the SEC. Starting in 2011, the filing requirements encompass more registered investment advisers, including those advising hedge funds and other private funds, and filing of parts of the form by exempt investment advisers. We follow Jiang (2018) in cleaning the raw data, requiring that the primary business of the investment adviser be in advising private funds. In addition, we identify which reported prime brokers are affiliated with G-SIBs by manually matching the names of the reported prime brokers with the names of G-SIB bank-holding companies. Appendix A provides more details on Form ADV and the parts of Form ADV that we use in our analysis. Although the relationships are listed as those between clients and prime brokers, an examination of the data reveals that in the majority of cases, these prime brokers are in fact also broker-dealers. Indeed, prime brokers that are not registered SEC broker-dealers represent only 1 percent of the reported relationships in our sample. Thus, the prime broker relationships reported in Form ADV are in fact in general relationships with broker-dealers more broadly.

There are several advantages of using Form ADV instead of commercial databases such as Lipper TASS and HFR to study the relationship between hedge funds and prime brokers. First, our sample does not suffer from sample selection bias since advisers are required to file Form ADV annually once they pass the minimum AUM requirement while hedge funds submit data to commercial databases voluntarily. Second, we can track how the set of prime brokers that each hedge fund uses changes over time since advisers are required to report all of their prime broker relationships in every filing. Commercial databases instead only retain the most recent prime broker information submitted so previous research had to rely on repeated snapshots of the commercial data. Moreover, hedge funds report only a subset of their prime brokerage relationships to commercial databases. One potential concern with our empirical strategy – using within hedge fund variation over time – is that it requires the same hedge funds to file in both the pre-SLR and post-SLR sample. Table 1 shows that a large number of hedge funds appear in filings both pre- and post-SLR, with few prime broker exits prior to 2014. Instead, 181 prime brokers enter the sample after 2014, suggesting that there may be more scope for smaller, less regulated prime brokers to compete with the larger bank-affiliated players in the market. Indeed, the 2019 annual *Absolute Return* prime brokerage survey notes that smaller prime brokers have been able to gain market share in recent years, with prime brokerage as a whole becoming more commoditized.

Table 2 presents summary statistics for the number of hedge funds and their size and for the number of prime brokers and the number of reported relationships for each year in our sample. Overall, the characteristics of the panel seem stable over time, both in terms of the number of hedge funds, the GAV of the average fund, and the number of prime brokers used by the average hedge fund. The table does provide a first indication of the changing relationship between hedge funds and G-SIB prime brokers, with the fraction of G-SIB prime brokers out of all the prime brokers used by the average fund declining over time. We investigate this trend more formally in the next subsection.

3.2 Results

Number of prime brokers per hedge fund. We begin by investigating the number of prime brokers that each fund uses. Table 3 reports the estimated coefficients from the regression of the number of unique prime brokers reported by fund f in fiscal year y on a post-SLR dummy, fund size, their interaction, as well as year and fund fixed effects:

$$\#\,\text{PBs}_{f,y} = \alpha_f + \alpha_y + \beta_1\,\mathbf{1}_{\text{Post-SLR}} + \beta_2 \log \text{GAV}_{f,y} + \gamma\,\mathbf{1}_{\text{Post-SLR}} \times \log \text{GAV}_{f,y} + \epsilon_{f,y}$$

When β_1 is positive, hedge funds use more prime brokers starting in 2014. Similarly, when γ is positive, larger hedge funds increase their number of prime brokers more than the average hedge fund does. Table 3 shows that, on average, hedge funds have 0.34 more prime brokers after 2014 (column 1). This effect is both economically and statistically significant: prior to 2014, the average hedge fund had 3.5 prime brokers, so that the post-SLR increase represents 10 percent of the baseline. Comparing the cross-hedge-fund effect in column (1) to the within-hedge-fund-effect from column (2), we see that most of the increase comes from the within-fund variation and not a change in the composition of funds. Column (3) shows that bigger hedge funds increase the number of prime brokers they use more than smaller hedge funds: the top 10 percent of hedge funds by size increase the number of prime brokers they use by 0.11 more than the bottom 10 percent of hedge funds. Columns (5)–(8) show that the same results hold in logs. Thus, overall, hedge funds split their business amongst more prime brokers post-SLR, with larger funds increasing the number of prime brokers they use more than smaller funds, suggesting that they are under more pressure from their prime brokers.

Reliance of hedge funds on G-SIB prime brokers. We now consider the reliance of funds on the more regulated G-SIB prime brokers. Table 4 reports the estimated coefficients from the regression of the fraction of G-SIB-affiliated prime brokers among the unique prime brokers reported by fund f in fiscal year y on a post-SLR dummy, fund size, their interaction, as well as year and fund fixed effects:

$$\frac{\#\text{ GSIB PBs}_{f,y}}{\#\text{ PBs}_{f,y}} = \alpha_f + \alpha_y + \beta_1\,\mathbf{1}_{\text{Post-SLR}} + \beta_2 \log \text{GAV}_{f,y} + \gamma\,\mathbf{1}_{\text{Post-SLR}} \times \log \text{GAV}_{f,y} + \epsilon_{f,y}$$

When β_1 is positive, hedge funds have a larger number of G-SIB prime brokers as a fraction of the total number of prime brokers they use starting in 2014 and are thus more reliant on more constrained prime brokers. Similarly, when γ is positive, larger hedge funds increase their reliance on G-SIB prime brokers even more than the average fund does. Column (1) of Table 4 shows that, on average hedge funds reduce the fraction of G-SIB prime brokers by 4.79 percentage points post-SLR, relative to a pre-SLR average of 82 percent. Again, a large part of this effect is from within-fund variation (column 2). Turning to column (3), we see that, in the cross-section, larger hedge funds are more reliant on G-SIB prime brokers pre-SLR and that they reduce their reliance on G-SIB prime brokers less than smaller hedge funds: while the bottom 10 percent of hedge funds lower the fraction of G-SIB prime brokers by 3.47 percentage points, the top 10 percent of hedge funds lower the fraction of G-SIB prime brokers by only 2.60 percentage points. Thus, although both large and small hedge funds reduce their reliance on G-SIB prime brokers after the introduction of SLR, large hedge funds are less able to do so, suggesting that they are dependent on services that only a large G-SIB prime broker can provide.

A natural question is whether 2014 is the "right" break point in our sample. Figure 3 confirms this by showing cumulated effects of the previous two results: relative to the number of prime brokers reported in 2011, hedge funds have progressively increased the number of prime brokers they use starting in 2013-2014. At the same time, the fraction of G-SIB prime brokers declined during 2014-2016 relative to the fraction of G-SIB prime brokers reported in 2011 but has stabilized since.[9]

Hedge fund size. Consider now the average size of hedge funds. Table 5 reports the estimated coefficients from the regression of the log size of hedge fund f in fiscal year y on lagged size, a post-SLR dummy, the fraction of G-SIB prime brokers used by the fund, the interaction between the post-SLR dummy and the fraction of G-SIB prime brokers, as well

[9]More precisely, Figure 3 plots the year fixed effects α_y from the regressions

$$\Delta \# \text{ PBs}_{f,y} = \alpha_f + \alpha_y + \epsilon_{f,y} \quad \text{and} \quad \Delta \frac{\# \text{ GSIB PBs}_{f,y}}{\# \text{ PBs}_{f,y}} = \alpha_f + \alpha_y + \epsilon_{f,y},$$

with the changes computed relative to the 2011 levels.

as year and fund fixed effects:

$$\log \mathrm{GAV}_{f,y} = \alpha_f + \alpha_y + \rho \log \mathrm{GAV}_{f,y-1} + \beta_1 \mathbf{1}_{\text{Post-SLR}} + \beta_2 \frac{\#\ \text{GSIB PBs}_{f,y}}{\#\ \text{PBs}_{f,y}} + \gamma\, \mathbf{1}_{\text{Post-SLR}} \times \frac{\#\ \text{GSIB PBs}_{f,y}}{\#\ \text{PBs}_{f,y}} + \epsilon_{f,y}$$

When β_1 is positive, hedge funds are on average bigger in the post-SLR sample. Similarly, when γ is positive, hedge funds that use a larger fraction of G-SIB prime brokers increase their size more post 2014 than the average hedge fund does. Column (2) of Table 5 shows that, on average, hedge fund GAV is 0.64 log $ billion smaller in the post-SLR period, relative to a pre-SLR mean of -2.81 log $ billion. Turning to column (4), we see that this effect is particularly large for funds more reliant on G-SIB prime brokers: hedge fund GAV of a fund that only uses G-SIB prime brokers is 0.18 log $ billion lower than that of a fund that does not use any G-SIB prime brokers in the post-SLR period. Columns (5)–(8) confirm that the same results hold in changes instead of levels.

Number of hedge funds per prime broker. We now turn to adjustments made by prime brokers. Table 6 reports the estimated coefficients from the regression of the number of hedge funds reporting a prime brokerage relationship with broker b in year y on a post-SLR dummy, an indicator for brokers affiliated with G-SIBs, their interaction, as well as year and prime broker fixed effects:

$$\#\ \text{HFs}_{b,y} = \alpha_b + \alpha_y + \beta_1 \mathbf{1}_{\text{Post-SLR}} + \beta_2 \mathbf{1}_{\text{G-SIB}} + \gamma\, \mathbf{1}_{\text{Post-SLR}} \times \mathbf{1}_{\text{G-SIB}} + \epsilon_{b,y}.$$

When β_1 is positive, a larger number of hedge funds report a prime-brokerage relationship with prime broker b starting in 2014, i.e. the prime broker increases its number of clients in the post-SLR period. Similarly, when γ is positive, G-SIB prime brokers grow their client base more than other prime brokers. Table 6 shows that, on average, prime brokers in our sample reduced their number of clients in the post-SLR period by 72.7 (column 1), driven by within-prime broker variation (column 2). Turning to columns (3)–(4), we see that G-SIB prime brokers lose more of their clients in the post-SLR period, with the average G-SIB prime broker reducing its number of clients by an additional 108.

Overall, Tables 3–6 show that the adjustments in the prime broker–hedge fund relationship in the post-SLR period occur through increases in the number of prime brokers used by an individual fund, reductions in the number of clients per prime broker, decreases in the average fund size, and decreases in the reliance on G-SIB prime brokers. We turn now to the persistence of the prime broker–client match.

Probability of broker–client relationship. Table 7 investigates the persistence of the prime broker–client match. Columns (1)–(4) use no characteristics of either side. Columns (5)–(7) include broker characteristics and thus take the perspective of a hedge fund client, while Columns (8)–(10) include fund characteristics and thus take the perspective of a prime broker. Consider first the baseline effects from a linear probability model of a relationship between fund f and prime broker b in fiscal year y on a dummy indicating a relationship between the two in the previous fiscal year, a post-SLR dummy, their interaction, as well as year, fund and broker fixed effects:

$$\begin{aligned} \mathrm{Rel}_{f,b,y} = \alpha_f + \alpha_b + \alpha_y + \rho\,\mathrm{Rel}_{f,b,y-1} + \beta_1\,\mathbf{1}_{\text{Post-SLR}} \\ + \gamma_1\,\mathrm{Rel}_{f,b,y-1} \times \mathbf{1}_{\text{Post-SLR}} + \epsilon_{f,b,y} \end{aligned}$$

When β_1 is positive, the probability of a new relationship formed is higher in the post-SLR period. Similarly, when γ_1 is positive, an existing relationship is more persistent in the post-SLR period. Columns (1)–(4) of Table 7 show that, on average, the probability of forming a new prime broker–client relationship is lower during the post-SLR period ($\beta_1 < 0$). Conditional on an existing relationship, however, the match between a client and its prime broker is more persistent in the post-SLR period ($\gamma_1 > 0$), even when considering within-fund variation (column 2), within-broker variation (column 3), or variation within the fund-broker pair (column 4).

Consider next the client perspective in columns (5)–(7) by adding to the regression an indicator for G-SIB prime brokers and interactions with the previous relationship indicator and the post-SLR indicator:

$$\begin{aligned}\text{Rel}_{f,b,y} = {} & \alpha_f + \alpha_b + \alpha_y + \rho\,\text{Rel}_{f,b,y-1} + \beta_1\,\mathbf{1}_{\text{Post-SLR}} + \beta_2\,\mathbf{1}_{\text{G-SIB}} \\ & + \gamma_1\,\text{Rel}_{f,b,y-1} \times \mathbf{1}_{\text{Post-SLR}} + \gamma_2\,\text{Rel}_{f,b,y-1} \times \mathbf{1}_{\text{G-SIB}} + \gamma_3\,\mathbf{1}_{\text{Post-SLR}} \times \mathbf{1}_{\text{G-SIB}} \\ & + \delta_1\,\text{Rel}_{f,b,y-1} \times \mathbf{1}_{\text{Post-SLR}} \times \mathbf{1}_{\text{G-SIB}} + \epsilon_{f,b,y}\end{aligned}$$

We see in columns (5)–(7) that, pre-SLR there is a higher probability of forming a new relationship with a G-SIB prime broker than a smaller prime broker ($\beta_2 > 0$) but the difference in probability is lower in the post-SLR period ($\gamma_3 < 0$). Moreover, the persistence of an existing relationship with a G-SIB prime broker is lower during the post-SLR period ($\delta_1 < 0$), even when considering within-fund variation (column 6), or variation within the fund-broker pair (column 7).[10]

Turn now to the prime broker perspective. Columns (8)–(10) of Table 7 add to the baseline regression of columns (1)–(4) the size of the fund (in log GAV) and interactions with the previous relationship indicator and the post-SLR indicator:

$$\begin{aligned}\text{Rel}_{f,b,y} = {} & \alpha_f + \alpha_b + \alpha_y + \rho\,\text{Rel}_{f,b,y-1} + \beta_1\,\mathbf{1}_{\text{Post-SLR}} + \beta_3 \log \text{GAV}_{f,y} \\ & + \gamma_1\,\text{Rel}_{f,b,y-1} \times \mathbf{1}_{\text{Post-SLR}} + \gamma_4\,\text{Rel}_{f,b,y-1} \times \log \text{GAV}_{f,y} + \gamma_5\,\mathbf{1}_{\text{Post-SLR}} \times \log \text{GAV}_{f,y} \\ & + \delta_2\,\text{Rel}_{f,b,y-1} \times \mathbf{1}_{\text{Post-SLR}} \times \log \text{GAV}_{f,y} + \epsilon_{f,b,y}\end{aligned}$$

When γ_1 is positive, the prime broker-client match is more persistent in the post-SLR period

[10]Note that, since the coefficients on the interaction terms between the indicator for existing relationship and the indicator for a G-SIB broker in column (7) are identified off of variation in the G-SIB status of the prime broker over time for repeated client–G-SIB prime broker pairs, we have relatively little power in our sample to identify those coefficients. Although these coefficients in column (7) are not statistically significant, the signs of the point estimates coincide with the signs of the coefficients estimated in columns (5)–(6).

and, when δ_2 is positive, an increase in persistence post-SLR is bigger for matches between a larger hedge fund and its prime broker than for matches with smaller clients. Columns (8)–(10) of Table 7 show that, on average, the persistence of a prime broker–hedge fund match is higher for large clients ($\gamma_4 > 0$), though the probability of a new match forming is lower ($\beta_3 < 0$): larger hedge funds have a harder time finding a new prime broker but generate enough revenue for their prime brokers to make maintaining the relationship worthwhile. In the post-SLR period, the probability of a large client forming a new prime broker match is not differentially affected ($\gamma_5 = 0$), but the persistence of existing matches to large clients decreases ($\delta_2 < 0$).

In sum, considering the relationships between prime brokers and hedge funds, we find that in the post-SLR period fewer new relationships are formed each year and this effect is stronger for G-SIB prime brokers. In contrast, existing relationships are more persistent but this effect is weaker for G-SIB prime brokers and large hedge funds. These results are consistent with a shift away from relying on G-SIB prime brokers and a more specialized match in each prime broker-client relationship.

4 Basis trades

The previous section documents that the relationship between brokers and hedge fund clients changed after the introduction of the SLR in 2014, with constrained prime brokers less willing to provide balance sheet space to clients. For the rest of the paper, we examine whether post-SLR changes in how broker-dealers conduct business more generally – both in terms of executing trades on their own behalf and in terms of balance sheet provision to clients – affect market outcomes. We focus on standard fixed income arbitrage in the form of basis trades.[11] The list, though not exhaustive, covers some of the largest asset markets in the world. The main distinguishing feature of these trades is that they are *bank-intermediated*: at least one leg of the trade requires a prime brokerage relationship for either trade execution

[11]Note that these trades are not perfect risk-free arbitrages in the textbook sense.

or financing. In this section, we describe the mechanics of the basis trades, and how the funding costs and regulatory capital recognition for these trades changed under SLR. We summarize the direct impact of select post-crisis regulations on components of our basis trades in Table 8.[12]

4.1 Basis trade components

The trades we consider can be grouped into three categories: Treasury trades (OTR–OFR trade, UST–Swap, UST–Futures), covered interest rate parity trades (CIP), and U.S. credit trades (single name CDS–bond trade, Index–single name CDS trade).

OTR–OFR trade In the traditional on-the-run/off-the-run (OTR–OFR) trade, an institution tries to capitalize on the liquidity premium priced in newly issued nominal Treasuries by entering into a short position in the most recently issued nominal Treasury of a given maturity and a long position in the off-the-run security that has the closest duration match. See, e.g. Fontaine and Garcia (2011) for more details on the OTR–OFR trade.

UST–Swap trade The UST-swap trade exploits the relative pricing difference between nominal Treasuries and interest rate swaps. When the basis is positive, so that Treasuries are relatively expensive, an institution enters into a short position in the Treasury market and a long position (receive fixed, pay-floating) in an interest rate swap of matched maturity. When the basis is negative, an institution enters into the reverse trade. For more details on the UST–swap trade, see Boyarchenko et al. (2018a).

UST-Futures trade The cash–futures trade exploits relative pricing differences between cash Treasuries and exchange-traded Treasury futures. When the implied return from selling Treasury futures (implied repo rate) is higher than the funding cost of the cheapest-to-deliver

[12] Appendix B.3 describes the regulatory impact in greater detail, as well as providing some high-level results on how participation by regulated institutions changed after the introduction of SLR.

Treasury (CTD repo rate), an institution enters into a short position in the Treasury futures contract and a long position in the CTD with the notional of the futures contract adjusted for the futures conversion factor. When the implied repo rate is below the CTD repo rate, an institution enters into the reverse trade. For more details on the cash-futures trade, see Labuszewski et al. (2017) and Fleckenstein and Longstaff (2018).

CIP Trade The CIP trade exploits the costs of borrowing U.S. dollars in different currencies. When U.S. dollar funding is relatively expensive, an institution enters into a long position in a U.S. Treasury (receive dollar rate) and a short position in the foreign sovereign bond (pay foreign rate) with the same maturity that is swapped back into dollars with spot and forward foreign exchange trades. When U.S. dollar funding is relatively cheap, an institution enters into the reverse trade. For more details on the CIP trade, see Avdjiev et al. (2019) and Du et al. (2018).

Single name CDS–basis trade In the CDS-bond basis trade, institutions exploit differences in the cost of taking on credit risk exposure to individual entities through either the cash bond market or through the single-name CDS market. When the CDS-bond basis is positive, corporate bonds are relatively more expensive than single-name CDS, and institutions take advantage by selling protection in the single-name CDS market and shorting the corresponding corporate bond. When the CDS-bond basis is negative, corporate bonds are cheap relative to single-name CDS, and institutions enter into a long position in the corporate bond market and buy protection on the same reference entity in the single-name CDS market. For more details on the mechanics of the CDS-bond basis trade, see Boyarchenko et al. (2018b).

Index–single-name CDS trade In the index–single-name trade, institutions exploit differences in the cost of taking on credit risk exposure to a basket of corporate entities through either the single-name CDS market or the index CDS market. When the index-single-name basis is positive, index CDS are expensive relative to the basket of single-name CDS, and institutions sell protection in the index CDS market and simultaneously buy protection on the replicating basket of single-name securities. When the index-single-name basis is negative, index CDS are cheap relative to the basket of single-name CDS, and institutions buy protection in the index CDS market and simultaneously sell protection on the replicating basket of single-name securities.

Figure 4 plots the average level of the basis for 5 year U.S. nominal Treasury trades, 5 year CIP, and U.S. credit markets prior to January 1, 2014 (panel a) and after January 1, 2014 (panel b). As has been documented in prior literature, for most trades, the absolute value of the basis is significantly larger in the post-SLR period (period starting on January 1, 2014).

4.2 Funding costs and regulatory recognition

The practical execution of the basis trades described above requires funding of both legs of the trade and, for regulated institutions, recognition of the trades for regulatory leverage calculations. We now summarize the funding costs and regulatory recognition of the basic types of positions that underly our calculations of the trades under both risk-weighted assets (RWA) and the supplementary leverage ratio. Table 9 summarizes the components to the trade, as well as the associated funding costs and SLR regulatory recognition.

Cash products Long positions in cash products are traditionally funded through repurchase agreements (repos), assuming that the security is accepted as collateral in a repo contract.[13] For the trades described above, long positions in the on-the-run Treasury securities are funded through special agreement repurchase agreements ("repo specials"); off-the-run Treasury securities are funded through tri-party repos; sovereign bonds of other countries

[13] In some instances the long position is taken through a securities lending trade which is economically very similar to a repo.

and U.S. corporate bonds are funded through bilateral repos. In a repo, the institution borrows the market value of the security minus a haircut from the repo lender, posts the security as collateral in the agreement, and pays the repo interest rate on the loan. We assume that haircuts on the repo agreements are financed through unsecured loans, at an interest rate equal to the one-year overnight interest rate swap (OIS) rate. Similarly, short positions in cash products are covered through reverse repos (or securities borrowing). In a reverse repo, the institution lends cash against the market value of the security (minus the haircut) to the borrower, receives the security as collateral, and is paid the repo interest rate. See e.g. Euroclear (2009) for a discussion of the use of repo markets to finance long and short positions in cash products.

Under the risk-weighted asset capital requirement, repo positions do not affect the leverage ratio as these are liabilities on institutions' balance sheets and do not differentially affect the Tier 1 capital in the numerator of the ratio. For reverse repo positions, the impact depends on the collateral used in the transaction. For transactions collateralized with either U.S. government, U.S. agency or OECD government debt, the cash product positions have zero risk weight and thus do not affect risk-weighted assets. Repo transactions collateralized with either securities issued by non-depository institutions or depository institutions outside of the OECD have a 100 percent risk weight, so that the entire notional of the repo position is recognized. Repo transactions collateralized by all other types securities receive 20 percent risk weight.

In contrast, under the supplementary leverage ratio, the full notional of all repo transactions, regardless of which securities are used as collateral, is recognized in calculating the leverage exposure of the institution. Thus, relative to the pre-crisis regulatory regime, the supplementary leverage ratio requires significantly more capital against relatively low-risk, low-margin activities such as repo borrowing and lending against Treasury securities.

Derivatives For derivative positions that involve no transfer of money at the initiation of the contract, such as interest rate futures and swaps, institutions only need to finance the margin required on the position. For exchange-traded derivatives (e.g. futures), the exchange requires participants to post margin for each position. The dealer enters into a futures contract with the exchange, posting margin against the position. The dealer borrows the margin from a counterparty in the unsecured funding market, with the dealer receiving a cash loan in exchange for interest rate payments. At the maturity of the contract, the dealer and the exchange make cash payments as specified in the contract.

For OTC derivatives, prior to the crisis, dealers would often not be required to post margin in bilateral transactions but would collect margin from non-dealer customers. For those derivatives that are cleared on CCPs, the CCP collects margin on positions regardless of who the counterparty is, with the margin required on positions short in credit risk requiring half the margin that positions long in credit risk. According to market participants, prior to the introduction of mandatory clearing rules in March 2013, around 25 percent of OTC derivative transactions were centrally cleared. In the ROE calculations below, we thus assume that 25 percent of OTC derivatives required margin posted prior to March 2013.[14] For OTC derivatives not subject to central clearing, we assume that 25 percent of the positions required margin prior to the introduction of mandatory initial margin in September 2016.[15]

In addition to margins on the derivative positions, CDS positions after the crisis often require upfront payments between the buyer and the seller of protection, with a positive upfront payment corresponding to a payment made by the buyer of protection to the seller of protection.[16] As with haircuts on repo positions and derivative margins, we assume that upfront payments (if any) on derivatives are funded in unsecured funding markets.

For exchange-traded and centrally cleared derivatives, institutions recognize the current replacement value of the derivative position and an adjusted potential future exposure (PFE).

[14]See e.g. Prabhakar (2015) and Larah (2015).

[15]See Appendix C.2 for more details on mandatory initial margins.

[16]This occurs when the standardized fixed rate on the contract does not coincide with the floating-equivalent rate charged by the market.

The adjusted PFE is calculated as

$$\text{Adjusted PFE} = (0.4 + 0.6 \times \text{Net-to-gross ratio}) \times \text{Gross PFE},$$

where the Gross PFE is the total PFE of all the positions traded on the same exchange or cleared through a single CCP. Under the supplementary leverage ratio, the institution recognizes the total adjusted PFE and current replacement value of the position; under the risk-weighted capital ratio, institutions recognize up to 50 percent of the total (if the trade is with a non-dealer customer).

Finally, for bilateral derivatives, institutions recognize the current replacement value of the derivative position and the un-adjusted gross PFE of all the individual derivative positions. Under the supplementary leverage ratio, limited netting of bilateral positions is allowed, provided the positions are with the same counterparty, provide exposure to entities within the same Bloomberg industry, have the same spread, and fall within the same duration bucket.

5 Basis trade leverage

We now turn to the economics of basis narrowing trades, proceeding in two steps. First, we examine whether regulatory or risk management leverage requirements bind on average during different sub-periods in our sample. The more binding constraint is more likely to influence the regulated institutions' decisions with respect to engaging in basis-narrowing trades or intermediating them for hedge fund clients. Second, we examine whether the observed basis deviations are sufficiently large to induce regulated institutions to engage in spread-narrowing trades. Even without binding constraints, bases have to be sufficiently wide for the trade to be profitable after accounting for regulatory treatment.

5.1 Implied leverage limits

Consider first the leverage limit implied by regulatory constraints $\lambda_t = E_t/A_t$ where E_t is Tier-1 capital and (λ_t, A_t) is either the RWA constraint and risk-weighted assets,

$$\lambda_t^{\text{RWA}} = \frac{\text{Tier-1 capital}_t}{\text{Risk-Weighted Assets}_t},$$

or the SLR constraint and total leverage exposure,

$$\lambda_t^{\text{SLR}} = \frac{\text{Tier-1 capital}_t}{\text{Total Leverage Exposure}_t}.$$

If the regulatory constraint is binding, a new trade with notional N_t^{trd} that increases the denominator of the constraint by A_t^{trd} requires an increase in equity capital by the amount of $E_t^{\text{trd}} = \lambda_t \cdot A_t^{\text{trd}}$ and has a leverage limit of $N_t^{\text{trd}}/(\lambda_t \times A_t^{\text{trd}})$.

For example, consider the UST-swap trade for a 10-year maturity with a negative basis so that swap rates are below Treasury rates. In this case, an institution enters into a long position in the Treasury that is financed by a repo transaction and a short position in the swap (pay fixed, receive floating) that requires margin (see e.g. Boyarchenko et al., 2018a). The regulatory capital impact of the trade depends on the amount and recognition of the initial margin on the interest rate swap, the recognition of the repo notional and the amount of the repo haircut charged, and the potential future exposure (PFE) of the swap, as summarized in Table 10 for all the basis trades in Section 4.

The leverage limit for this trade under the assumption that a risk-weighted capital ratio of 3% binds is:

$$\text{Leverage}_{\text{RWA}} = \frac{1}{\underbrace{.03}_{\lambda_t^{\text{RWA}}} \times (\underbrace{.04}_{\substack{\text{Swap}\\\text{Margin}}} + \underbrace{.02}_{\substack{\text{Repo}\\\text{Haircut}}} + \underbrace{.015 \times .5}_{\substack{\text{Swap}\\\text{PFE}}} + \underbrace{0}_{\substack{\text{Repo}\\\text{Notional}\\\text{Recognized}}})} = 494$$

In contrast, the leverage limit under the assumption that the supplementary leverage ratio of 6% binds is:

$$\text{Leverage}_{\text{SLR}} = \frac{1}{\underbrace{.06}_{\lambda_t^{\text{SLR}}} \times (\underbrace{.04}_{\substack{\text{Swap}\\\text{Margin}}} + \underbrace{.02}_{\substack{\text{Repo}\\\text{Haircut}}} + \underbrace{.015 \times .4}_{\substack{\text{Swap}\\\text{PFE}}} + \underbrace{1}_{\substack{\text{Repo}\\\text{Notional}\\\text{Recognized}}})} = 15.6$$

Thus, the maximal leverage on the UST-swap trade allowed under the SLR constraint is dramatically lower than that under the RWA constraint. Comparing the components of the two leverage calculations, we see that the biggest difference is in the amount of the repo notional recognized: while the RWA recognizes none of the notional of the repo secured by the U.S. Treasury, the SLR recognizes the full repo notional. This difference is further amplified by the higher SLR leverage requirement overall.

In addition to regulatory leverage constraints, banks are also subject to risk management, or value-at-risk (VaR) constraints. Unlike regulatory leverage constraints, VaR constraints are meant to protect the institution from losses to the market value of trading positions. Given a time series of the basis b_t and of the unlevered book return ρ_t for a trade, we compute the realized one-day dollar return to the trade as

$$R_{t+1} \equiv \frac{\rho_t}{252} \times \text{Notional} - \Delta b_{t+1} \times \text{DV01}_t$$

where DV01_t is the dollar value of a basis point for the specified notional amount and Δb_{t+1}

is the one day change in the basis. The h-day holding period return is then computed as the sum of h one-day returns,

$$R_{t,t+h} \equiv \sum_{i=1}^{h} R_{t+i}.$$

We estimate the h-day, α-percent VaR $\omega(\alpha, h)$ as the solution to,

$$\mathbb{P}\left(\left|\omega(\alpha, h) \cdot R_{t,t+h}\right| > \text{Notional}\right) = \alpha, \tag{1}$$

which is updated each month using data from a rolling ten-year window. The estimate $\omega_t(\alpha, h)$ is the proxy for a leverage limit under the VaR constraint for each trade.

Figure 5 plots the average maximum leverage implied by regulatory constraints (top row) and VaR constraints (bottom row) for pre-SLR (left column) and post-SLR (right column) subperiods. Comparing first the average VaR-implied leverage during the pre-SLR period to the average VaR-implied maximum leverage during the post-SLR period, we see that the VaR-implied maximum has decreased slightly for most of our trades: although the average level of basis spreads is higher in the post-SLR period, the volatility of the basis is higher as well. The decrease in the VaR-implied maximum leverage is, however, small relative to the decrease in regulatory-implied maximum leverage of about two orders of magnitudes.

Across all four panels, we see that, in the pre-SLR period, the maximum leverage implied by the VaR constraint is lower than the maximum leverage implied by RWA, suggesting that risk management was the binding constraint on average. In contrast, in the post-SLR period, the regulatory capital constraint becomes binding, with the maximum leverage implied by SLR much lower than the VaR-implied maximum leverage.

5.2 Return to basis trades

Consider now the return to engaging in spread narrowing trades from the perspective of regulated institutions. We approach the economics of the basis trades from the viewpoint of the limits-to-arbitrage literature:[17] since basis trades involve transaction costs and use regulatory capital, regulated institutions are only willing to enter into such trades if the (levered) profit net of transaction costs is sufficiently large. The idea that transaction costs can help explain basis deviations is not new; for example, in the CIP literature, transaction costs have been proposed as an explanation going back to at least Frenkel and Levich (1975). The innovation in our paper is to take the funding and regulatory capital recognition seriously, across multiple markets, and show that the economic considerations for basis trades have changed in the wake of the post-crisis regulatory reform.

We assume that regulated banks target a minimum return on equity (ROE) in choosing whether to participate in a basis trade.[18] We define the ROE of the trade as the product of the unlevered net return on the trade and the maximum allowed leverage under the different constraints. Specifically, the unlevered net return on the trade is the trade basis net of funding costs

$$\rho_t = \text{Basis}_t - \text{Funding costs}_t,$$

where Funding cost_t is the total funding cost of all legs of the trade as described in Section 4.2.

[17]See, e.g. Shleifer and Vishny (1997) and Gromb and Vayanos (2002, 2010b), and the overview of the theoretical literature in Gromb and Vayanos (2010a).

[18]The fact that banks *do* target ROE in making investment decisions has been well documented in the literature (see e.g. Pennacchi and Santos 2018 for evidence on U. S. banks and Alessandri and Haldane 2009 for evidence on U.K. banks). The question of *why* banks target ROE is outside the scope of our paper; the literature has proposed both rational and irrational explanations. Pennacchi and Santos (2018), for example, argue that banks that maximize shareholder value should target ROE if they have fixed-rate deposit insurance and face increasing competition that erodes charter value. On the other hand, Begenau and Stafford (2016) argue that banks use leverage to manipulate ROE because investors' irrationally target ROE.

Given a maximum allowed level of leverage $\bar{\lambda}_t$, the implied ROE is then given by

$$\text{ROE}_t = \bar{\lambda}_t \rho_t. \tag{2}$$

Equation (2) highlights that the higher frequency changes to a trade's ROE are due to changes in the funding costs associated with the trade, while lower frequency changes are due to changes in the maximum allowed level of leverage. Since capital regulation affects primarily the later, we focus on low frequency changes in implied ROE. As in Section 3, we compare average pre-SLR returns (January 1, 2005–December 31, 2013, excluding the crisis years, January 1, 2007–December 31, 2009) to average post-SLR returns (January 1, 2014–January 31, 2018).

The left panel of Figure 6 presents the average absolute value of the implied ROE for our trades prior to January 1, 2014, with the implied ROE calculated under the assumption that the risk-weighted assets leverage requirement was relevant leverage requirement. For all the trades we consider, the average ROE is well above the 12-15 percent ROE target of most large financial institutions, suggesting that risk management constraints, such as value-at-risk (VaR), rather than regulatory capital constraints were the limiting factor prior to the introduction of post-crisis capital regulation.

In contrast, the average absolute value of the implied ROE in the post-SLR period, presented in the right panel of Figure 6 is below the 12-15 percent target for all trades. That is, despite the higher levels of the bases in the post-SLR period, the implied ROE under the supplementary leverage ratio is significantly smaller than the implied ROE under the risk-weighted capital requirement and often does not meet the 12-15 percent ROE target. Thus, in the post-SLR regulatory regime, institutions must either accept lower ROE when participating in basis trades or not participate until the absolute level of the trade reaches unusually high levels.

Comparing different types of trades in the market for the same kind of exposure, the implied ROE calculation highlights the disparity with which post-crisis regulation affects different markets. Consider, for example, the CDS-bond basis trade and the index-single-name trade. Implied ROE decreases substantially on the CDS-bond basis trade, for both credit rating categories, under SLR while the implied ROE on the index-single-name trade remains largely unaffected. The main reason is the recognition under the SLR of the full notional of the repo funding of a long corporate bond position involved in the CDS-bond basis trade (or the reverse repo funding of a short corporate bond position). Thus, while dealers are required to post substantially more margin on their OTC derivative positions than prior to the crisis and, in the case of the high yield index, cannot net either the margin or the potential future exposure of the derivative positions, the overall increase in the balance sheet impact of OTC derivatives is substantially smaller than the increase in the balance sheet impact of repo funding.

Indeed, as plotted in Figure 7a, the percentage change in the absolute level of the basis from pre-SLR period to the post-SLR period is positively related to the change in the capital impact of the trade in switching from the risk-weighted assets leverage requirement to the supplementary leverage ratio. Trades which saw the greatest increases in their capital impact – such as the OTR-OFR trade and the CIP trades – have also had the biggest (relative) increases in the average level of the basis. Figure 7b shows, however, that there is a *negative* relationship between the percentage change in the absolute level of ROE from pre-post-SLR period to the post-SLR period and the change in capital impact, so that trades with the biggest capital impact have had the biggest (relative) reductions in the implied ROE that the trade generates. Thus, the post-crisis increases in the level of the basis are insufficient to offset the post-crisis increases in the capital impact of basis trades.

6 Conclusion

In the aftermath of the financial crisis, a number of asset markets have experienced large, persistent deviations from the law of one price. We argue in this paper that these deviations persist because of limits-to-arbitrage engendered by post-crisis regulatory and market structure changes: such reforms increase the balance sheet impact of spread-narrowing trades for regulated financial institutions, reducing their ability both to participate in basis trades on their own behalf and to provide funding and balance sheet to their clients engaging in such trades. Consistent with this hypothesis, we document that the relationship between hedge funds and their prime brokers changed after the introduction of SLR in 2014, with hedge funds increasing the number of prime brokers they use and reducing dependence on more constrained prime brokers, and prime brokers decreasing the average number of clients and the average client size. From the perspective of regulated institutions, we document that the implied return on equity on basis trades is substantially lower in the new regulatory regime, with capital regulation, rather than risk-management incentives, becoming the binding constraints in choosing which trades institutions participate in. Taken together, these results suggest a pass-through of regulation from the directly affected sector to other parts of the financial sector that rely on the regulated sector for funding, execution, and clearing services.

In May 2018, the U.S. Congress passed revisions to the Dodd-Frank Act,[19] while, at the same time, federal bank regulators agreed on a revision to the implementation of the Volcker Rule.[20] Such changes are unlikely to reverse the economics described in this paper as Basel III is the regulation that has the biggest impact on the profitability of basis trades. For example, the supplementary leverage ratio disincentivizes institutions from participating in low margin activities; the liquidity coverage ratio provides incentives to hold more liquid securities; the net stable funding ratio, by requiring sufficient stable funding to cover asset losses over a one-year horizon, encourages institutions to reduce their use of short-term

[19]See, e.g. “Congress Approves First Big Dodd-Frank Rollback”, New York Times, May 22, 2018.
[20]See, e.g. “Big Banks to Get a Break From Limits on Risky Trading”, New York Times, May 30, 2018.

funding markets. Thus, while the global regulatory community adheres to the provisions of Basel III, basis trades will continue to have a significant impact on regulated institutions' balance sheets. Indeed, in the wake of Treasury market dislocations in early March 2020, the federal banking agencies temporarily excluded U.S. Treasury securities and deposits from the supplementary leverage ratio calculation, citing the purpose of the rule being "to allow bank holding companies, savings and loan holding companies, and intermediate holding companies subject to the supplementary leverage ratio increased flexibility to continue to act as financial intermediaries."[21]

This paper takes the first step in evaluating the pass-through of regulation from the directly-affected part of the financial sector to other parts of the financial sector. While regulation does seem to have increased limits-to-arbitrage in markets that rely on regulated institutions for either funding or execution (or both), the costs of deviations from law of one price have to be weighed against the increased resiliency of both the regulated sector and the financial system as a whole. We leave this full welfare calculation for future research.

[21]Federal Reserve Board: https://www.federalreserve.gov/newsevents/pressreleases/files/bcreg20200401a1.pdf

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Table 1: Number of years in sample. This table summarizes the number of years that individual advisers, hedge funds and prime brokers appear in Form ADV. "Pre-SLR" indicates that the institution only appears in filings with fiscal years prior to 2014; "Post-SLR" indicates that the institution only appears in filings with fiscal years starting in 2014; "Both" indicates that the institution appears in filing both pre- and post-2014.

(a) *Advisers*

Years in sample	Pre-SLR only	Both	Post-SLR only	Total
1	503	–	661	1164
2	259	100	480	839
3	101	144	307	552
4	–	236	208	444
5	–	181	177	358
6	–	330	–	330
7	–	433	–	433
8	–	601	–	601
Total	863	2025	1833	4721

(b) *Hedge funds*

Years in sample	Pre-SLR only	Both	Post-SLR only	Total
1	2547	–	2673	5220
2	1167	441	2031	3639
3	453	719	1280	2452
4	–	905	1075	1980
5	–	774	679	1453
6	–	1346	–	1346
7	–	1482	–	1482
8	–	1480	–	1480
Total	4167	7147	7738	19052

(c) *Prime brokers*

Years in sample	Pre-SLR only	Both	Post-SLR only	Total
1	31	–	96	127
2	19	12	36	67
3	4	13	20	37
4	–	19	23	42
5	–	25	6	31
6	–	17	–	17
7	–	27	–	27
8	–	70	–	70
Total	54	183	181	418

Table 2: Form ADV summary statistics. This table summarizes the properties of the Form ADV sample of hedge funds by year. Values reported are means within the year, with standard deviations reported in parentheses below the mean. Log gross asset values (GAV) reported in log $ billion terms.

	2011	2012	2013	2014	2015	2016	2017	2018
Number of advisers	1,634	1,686	2,101	2,185	2,151	2,193	2,271	2,250
Adviser HHI (GAV)	115.01	129.75	91.96	98.01	270.13	100.47	105.01	123.48
Number of funds	6,635	6,386	8,385	8,539	8,793	8,815	8,888	8,888
Fund HHI (GAV)	34.85	52.37	27.78	37.78	185.83	32.72	32.58	53.51
Log GAV	-2.66	-2.68	-2.53	-2.46	-2.47	-2.44	-2.33	-2.36
	(2.19)	(2.25)	(2.28)	(2.29)	(2.26)	(2.23)	(2.21)	(2.27)
Number of prime brokers	137	129	159	158	136	144	157	153
PB HHI (N. advisers)	858.49	874.23	843.95	821.51	795.06	755.71	748.56	751.67
PB HHI (N. funds)	773.61	869.64	802.75	763.83	755.40	735.29	704.87	702.59
Number of PB per fund	3.61	3.43	3.70	3.74	3.78	3.51	3.81	3.95
	(3.92)	(2.54)	(3.14)	(3.25)	(3.23)	(3.00)	(3.36)	(3.43)
Number of G-SIB PB	3.02	3.05	3.21	3.21	3.22	2.98	3.21	3.34
	(2.76)	(2.37)	(2.67)	(2.75)	(2.71)	(2.64)	(3.01)	(3.08)
Fraction of G-SIB PB	83.83	86.31	85.40	84.45	82.30	79.57	78.07	79.04
	(29.88)	(27.66)	(28.15)	(29.22)	(31.53)	(34.39)	(35.46)	(33.92)

Table 3: Larger number of prime brokers per fund. This table reports the estimated coefficients from a regression of the number of prime brokers (columns 1–4) and log number of prime brokers (columns 5–8) used by a hedge fund in a given fiscal year on a post-SLR indicator, equal to 1 for fiscal years starting in 2014. Log gross asset values (GAV) reported in log $ billion terms. All regressions include year fixed effects. Standard errors clustered at the fund level reported in parentheses below point estimates. *** significant at 1%, ** significant at 5%, * significant at 10%.

	Levels				Logs			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-SLR	0.34	0.28	0.39	0.35	0.09	0.06	0.10	0.08
	(0.05)***	(0.04)***	(0.06)***	(0.04)***	(0.01)***	(0.01)***	(0.01)***	(0.01)***
Log GAV			0.11	0.06			0.05	0.01
			(0.01)***	(0.01)***			(0.00)***	(0.00)***
Post-SLR × Log GAV			0.03	0.02			0.01	0.01
			(0.01)**	(0.01)**			(0.00)**	(0.00)***
Fund FE		✓		✓		✓		✓
Adj. R-sqr.	0.00	0.89	0.01	0.89	0.00	0.90	0.02	0.90
N. clusters	17709	13318	17709	13318	17709	13318	17709	13318
N. of obs	65329	60109	65329	60109	65329	60109	65329	60109

Table 4: Lower fraction of G-SIB prime brokers per fund. This table reports the estimated coefficients from a regression of the fraction of G-SIB prime brokers used by a hedge fund in a given fiscal year on a post-SLR indicator, equal to 1 for fiscal years starting in 2014. Log gross asset values (GAV) reported in log $ billion terms; fraction of G-SIB prime brokers measured in percentage terms (so that if a fund uses only G-SIB-affiliated prime brokers, fraction of G-SIB prime brokers = 100). All regressions include year fixed effects. Standard errors clustered at the fund level reported in parentheses below point estimates. *** significant at 1%, ** significant at 5%, * significant at 10%.

	(1)	(2)	(3)	(4)
Post-SLR	-4.79	-2.76	-3.47	-2.41
	(0.47)***	(0.38)***	(0.48)***	(0.37)***
Log GAV			2.46	-0.23
			(0.12)***	(0.09)***
Post-SLR × Log GAV			0.87	0.18
			(0.14)***	(0.08)**
Fund FE		✓		✓
Adj. R-sqr.	0.01	0.84	0.06	0.84
N. clusters	17709	13318	17709	13318
N. of obs	65329	60109	65329	60109

Table 5: Smaller hedge funds on average. This table reports the estimated coefficients from a regression of the log gross asset value (GAV) (columns 1 – 4) and year-over-year change in log GAV (columns 5 – 8) of a hedge fund in a given fiscal year on a post-SLR indicator, equal to 1 for fiscal years starting in 2014. Log gross asset values (GAV) reported in log \$ billion terms; fraction of G-SIB prime brokers measured in ratio terms (so that if a fund uses only G-SIB-affiliated prime brokers, fraction of G-SIB prime brokers = 1). All regressions include year fixed effects. Standard errors clustered at the fund level reported in parentheses below point estimates. *** significant at 1%, ** significant at 5%, * significant at 10%.

	Levels				Changes			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
L.Log GAV	0.98	0.49	0.98	0.49				
	(0.00)***	(0.02)***	(0.00)***	(0.02)***				
Post-SLR	-0.11	-0.64	-0.11	-0.49	-0.12	-0.64	-0.12	-0.54
	(0.02)***	(0.02)***	(0.03)***	(0.04)***	(0.02)***	(0.02)***	(0.03)***	(0.03)***
Fraction of G-SIB PBs			-0.04	0.06			-0.07	0.00
			(0.03)	(0.05)			(0.03)***	(0.04)
Post-SLR × Fraction of G-SIB PBs			0.00	-0.18			0.00	-0.12
			(0.03)	(0.04)***			(0.03)	(0.03)***
Fund FE		✓		✓		✓		✓
Adj. R-sqr.	0.83	0.89	0.83	0.89	0.00	0.10	0.00	0.10
N. clusters	13156	9785	13156	9785	13156	9785	13156	9785
N. of obs	44641	40945	44641	40945	44641	40945	44641	40945

Table 6: Fewer hedge fund clients per prime broker. This table reports the estimated coefficients from a regression of the number of hedge funds (columns 1 – 4) and log number of hedge funds (columns 5 – 8) reporting a relationship with the prime broker in a given fiscal year on a post-SLR indicator, equal to 1 for fiscal years starting in 2014. All regressions include year fixed effects. Standard errors clustered at the prime broker level reported in parentheses below point estimates. *** significant at 1%, ** significant at 5%, * significant at 10%.

	Levels				Logs			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Post-SLR	-72.70	-85.68	-39.75	-66.82	-0.83	-0.97	-0.69	-0.87
	(20.73)***	(25.07)***	(11.62)***	(18.63)***	(0.17)***	(0.18)***	(0.16)***	(0.17)***
G-SIB			499.12	164.31			3.58	0.30
			(119.68)***	(52.41)***			(0.46)***	(0.24)
Post-SLR × G-SIB			-107.33	-108.07			-0.58	-0.48
			(47.00)**	(36.11)***			(0.31)*	(0.21)**
Prime-broker FE		✓		✓		✓		✓
Adj. R-sqr.	0.01	0.67	0.32	0.68	0.02	0.82	0.35	0.82
N. clusters	418	291	418	291	302	220	302	220
N. of obs	1546	1419	1546	1419	1132	1050	1132	1050

Table 7: More fragile relationship with G-SIB prime brokers and larger clients. This table reports the estimated coefficients from a regression of an indicator of a relationship between a prime broker and a hedge fund existing in the current year on lagged relationship indicator, a post SLR indicator (equal to 1 for fiscal years starting in 2014), an indicator for a G-SIB affiliated prime broker and size of the hedge fund client. Log gross asset values (GAV) reported in log $ billion terms. All regressions include year fixed effects. Standard errors clustered at the fund level reported in parentheses below point estimates. *** significant at 1%, ** significant at 5%, * significant at 10%.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Rel. previous yr.	0.28	0.31	0.24	0.27	0.26	0.28	0.26	0.33	0.28	0.31
	(0.005)***	(0.005)***	(0.005)***	(0.005)***	(0.013)***	(0.012)***	(0.011)***	(0.007)***	(0.006)***	(0.007)***
Post-SLR	-0.23	-0.35	-0.19	-0.31	-0.18	-0.28	-0.25	-0.22	-0.18	-0.32
	(0.006)***	(0.008)***	(0.007)***	(0.008)***	(0.009)***	(0.010)***	(0.010)***	(0.008)***	(0.008)***	(0.008)***
Post-SLR × Rel. previous yr.	0.14	0.14	0.12	0.13	0.21	0.19	0.16	0.11	0.10	0.12
	(0.007)***	(0.006)***	(0.006)***	(0.006)***	(0.015)***	(0.013)***	(0.013)***	(0.009)***	(0.008)***	(0.008)***
G-SIB					0.22	0.18	0.06			
					(0.006)***	(0.005)***	(0.038)			
Rel. previous yr. × G-SIB					-0.01	0.02	0.01			
					(0.012)	(0.012)	(0.012)			
Post-SLR × G-SIB					-0.04	-0.08	-0.08			
					(0.007)***	(0.007)***	(0.007)***			
Rel. previous yr. × Post-SLR × G-SIB					-0.08	-0.04	-0.02			
					(0.014)***	(0.013)***	(0.013)			
Log GAV								-0.01	-0.01	-0.00
								(0.002)***	(0.002)***	(0.002)
Rel. previous yr. × Log GAV								0.02	0.02	0.02
								(0.002)***	(0.002)***	(0.002)***
Post-SLR × Log GAV								0.00	0.00	-0.00
								(0.002)	(0.002)	(0.002)**
Rel. previous yr. × Post-SLR × Log GAV								-0.01	-0.01	-0.01
								(0.003)***	(0.003)***	(0.002)***
Fund FE		✓		✓		✓	✓			✓
Prime broker FE			✓	✓			✓		✓	✓
Adj. R-sqr.	0.18	0.32	0.25	0.35	0.21	0.33	0.35	0.18	0.25	0.35
N. clusters	17709	16283	17705	16280	17709	16283	16280	17709	17705	16280
N. of obs	313782	311976	313771	311966	313782	311976	311966	313782	313771	311966

Table 8: Impact of key post-crisis regulations. This table summarizes the key post-crisis regulations that have a direct or indirect impact on the basis trades analyzed in this paper through either the cash or derivative leg, in addition to whether there is an impact on the associated securities financing transactions. The Basel III acronyms refer to risk-weighted assets (RWA), the supplementary leverage ratio (SLR), and the liquidity coverage ratio (LCR) which impose constraints on bank capital, leverage, and liquidity.

	Basel III			Dodd-Frank			Other	
	RWA	SLR	LCR	Volcker Rule	OTC Derivatives Clearing	Swap Execution Facilities	Centrally Cleared Repo	Non-Centrally Cleared Margining
Securities								
Treasuries		x	x	x			x	
Corporate Bonds	x	x	x	x				
Single-Name CDS	x	x		x	x	x		x
Index CDS	x	x		x	x	x		x
FX Swap	x	x		x				x
Financing								
Repo		x	x				x	
Securities Lending		x	x	x			x	

Table 9: Bank-intermediated trades. This table summarizes the bank-intermediated basis trades considered in this paper, including both legs of the transaction the funding costs of the trades, and the balance sheet impact of the trade. A "long" position in a swap is a pay-floating position; a "short" position in a swap is a pay-fixed position. Legs laid out from the perspective of a positive basis trade.

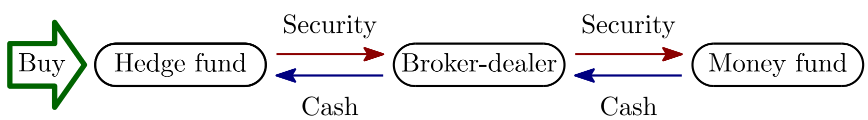
Trade	Long leg	Short Leg	Funding long	Funding short	Impact long	Impact short
U.S. Treasury spreads						
OTR-OFR	On-the-run Treasury	Off-the-run Treasury	Repo; Unsecured for repo haircut	Reverse repo	Repo notional; Haircut loan	Reverse repo notional
UST-swap	IR swap	Treasury	Unsecured for swap margin	Reverse repo	PFE of swap; Margin loan	Reverse repo notional
Cash-futures	CTD Treasury	Duration-adjusted future	Repo; Unsecured for repo haircut	Unsecured for futures margin	Repo notional; Haircut loan	PFE of future; Margin loan
Exchange rates						
CIP	Treasury; fwd exchange swap	Foreign sovereign	Repo; Unsecured for repo haircut and swap margin	Reverse repo	Repo notional; PFE of swap; Haircut and margin loans	Reverse repo notional
Credit risk spreads						
CDS-bond	SN CDS	Corporate bond	Unsecured for CDS margin	Reverse repo	PFE of swap; Net margin loan; Upfront if positive	Reverse repo notional
CDX-CDS	Basket of SN CDS	CDX	Unsecured for SN CDS margin	Unsecured for CDX margin	Net PFE of swap portfolio; Net margin loan; Upfront of swap portfolio if positive	–Upfront of index if negative

Table 10: Basis and trade return components. This table summarizes the calculation of the basis, the unlevered net book return, DV01, and regulatory capital impact for trades considered in this paper. $\hat{y}$ is the continuously-compounded yield-to-maturity; b is the basis; h is the repo haircut; m the derivatives margin; u the upfront payment on the derivative; p the PFE of the derivative; z_i is the continuously-compounded yield on a zero-coupon Treasury with time to maturity i years; F_i is the i year forward exchange rate; λ_{cds} (λ_{cdx}) is the risk-neutral default intensity implied by the spread on the single name CDS (index CDS). Book returns and regulatory capital impact reported for positive basis.

Trade	Basis (b)	Book return	DV01	RWA impact	SLR impact
U.S. Treasury spreads					
OTR-OFR	$\hat{y}_{ofr} - \hat{y}_{otr}$	$b_{otr} - (1 - h_{repo})\left(r_{repo}^{ofr} - r_{repo}^{otr}\right) - h_{repo} r_{3m}^{OIS}$	$\frac{1}{2}\sum_{i=1}^{2T} e^{-z_{\frac{i}{2}}\frac{i}{2}} \times 10^{-4}$	h_{repo}	$2 + h_{repo}$
UST-swap	$r_{cms} - \hat{y}_{cmt}$	$b_{cms} - r_{3mL} + (1 - h_{tpr})\, r_{tpr} - m_{cms} r_{3m}^{OIS}$	$\frac{1}{2}\sum_{i=1}^{2T} e^{-z_{\frac{i}{2}}\frac{i}{2}} \times 10^{-4}$	$m_{cms} + 0.5 p_{cms}$	$1 + m_{cms} + 0.4 p_{cms}$
Cash-futures	IRR_{fut}	$b_{fut} - (1 - h_{bond})\, r_{repo}^{ctd} - (m_{fut} + h_{bond})\, r_{3m}^{OIS}$	$\frac{1}{2}\sum_{i=1}^{2T} e^{-z_{\frac{i}{2}}\frac{i}{2}} \times 10^{-4}$	$m_{fut} + h_{bond} + 0.2 p_{fut}$	$1 + m_{fut} + h_{bond} + 0.4 p_{fut}$
Exchange rates					
CIP	r_{xccy}	$b_{xccy} - (1 - h_{tpr})\, r_{tpr} + (1 - h_{for})\, r_{for} - (m_{xccy} + h_{tpr})\, r_{3m}^{OIS}$	$\frac{1}{4}\sum_{i=1}^{4T} \frac{F_{\frac{i}{4}}}{S} e^{-z_{\frac{i}{4}}\frac{i}{4}} \times 10^{-4}$	$m_{xccy} + h_{tpr} + 0.5 p_{xccy}$	$2 + m_{xccy} + h_{tpr} + 0.4 p_{xccy}$
Credit risk spreads					
CDS-bond, IG	$r_{cds} - r_{bond}$	$b_{cds} + (1 - h_{IG})\, r_{tpr}^{IG} - (\max(u_{cds}, 0) + 0.5 m_{cds})\, r_{3m}^{OIS}$	$\frac{1}{4}\sum_{i=1}^{4T} e^{-\left(\lambda_{cds} + z_{\frac{i}{4}}\right)\frac{i}{4}} \times 10^{-4}$	$0.2 + \max(u_{cds}, 0) + 0.5 m_{cds} + 0.5 p_{cds}$	$1 + \max(u_{cds}, 0) + 0.5 m_{cds} + 0.4 p_{cds}$
CDS-bond, HY	$r_{cds} - r_{bond}$	$b_{cds} + (1 - h_{HY})\, r_{tpr}^{HY} - (\max(u_{cds}, 0) + 0.5 m_{cds})\, r_{3m}^{OIS}$	$\frac{1}{4}\sum_{i=1}^{4T} e^{-\left(\lambda_{cds} + z_{\frac{i}{4}}\right)\frac{i}{4}} \times 10^{-4}$	$1 + \max(u_{cds}, 0) + 0.5 m_{cds} + 0.5 p_{cds}$	$1 + \max(u_{cds}, 0) + 0.5 m_{cds} + p_{cds}$
CDX-CDS, IG	$r_{cds} - r_{cdx}$	$b_{cdx} - 0.5 m_{cds} r_{3m}^{OIS} - (-\min(u_{cdx}, 0) + \max(u_{cds}, 0))\, r_{3m}^{OIS}$	$\frac{1}{4}\sum_{i=1}^{4T} e^{-\left(\lambda_{cdx} + z_{\frac{i}{4}}\right)\frac{i}{4}} \times 10^{-4}$	$-\min(u_{cdx}, 0) + \max(u_{cds}, 0) + 0.5 m_{cds} + 0.5 p_{cds}$	$-\min(u_{cdx}, 0) + \max(u_{cds}, 0) + 0.5 m_{cds} + 0.4 p_{cds}$
CDX-CDS, HY	$r_{cds} - r_{cdx}$	$b_{cdx} - 0.5 m_{cds} r_{3m}^{OIS} - (-\min(u_{cdx}, 0) + \max(u_{cds}, 0))\, r_{3m}^{OIS}$	$\frac{1}{4}\sum_{i=1}^{4T} e^{-\left(\lambda_{cdx} + z_{\frac{i}{4}}\right)\frac{i}{4}} \times 10^{-4}$	$-\min(u_{cdx}, 0) + \max(u_{cds}, 0) + 0.5 m_{cds} + 0.5 p_{cds}$	$-\min(u_{cdx}, 0) + \max(u_{cds}, 0) + 0.5 m_{cds} + p_{cds}$

Figure 2. Prime broker services. This figure illustrates two types of services traditionally provided by prime brokers. Figure 2a illustrates an example of credit intermediation (matched-book repo) where the prime broker lends cash to the hedge fund to finance a long position and rehypothecates the collateral in a repo with a money market fund. Figure 2b illustrates an example of internalization where the prime broker offsets one hedge fund's long position with another hedge fund's short position. The prime broker lends the security received as collateral from hedge fund 1 to hedge fund 2 and the cash received as collateral from hedge fund 2 to hedge fund 1.

(a) Credit intermediation by prime broker



(b) Internalization by prime broker

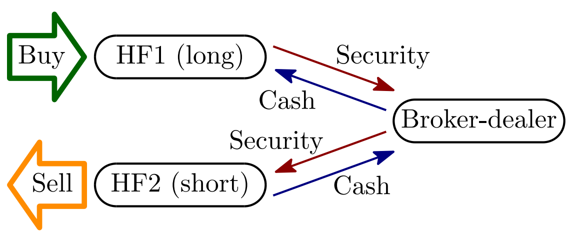
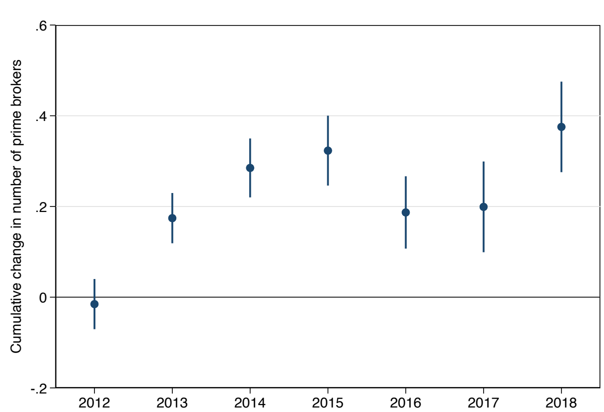


Figure 3. Cumulative changes. This figure plots the average cumulative changes in the number of prime brokers used by hedge fund clients (Figure 3a) and the fraction of G-SIB-affiliated prime brokers (Figure 3b). Error bars based on standard errors clustered at the fund level.

(a) Number of prime brokers



(b) Fraction of G-SIB prime brokers

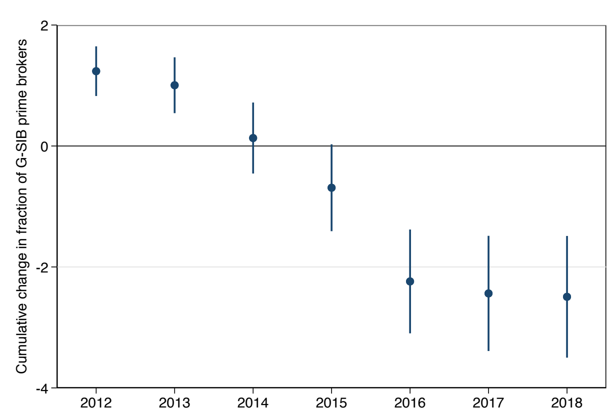


Figure 4. Basis spreads. This figure shows the average basis for 5 year U.S. nominal Treasury trades, 5 year CIP, and U.S. credit markets prior to January 1, 2014 (left column) and after January 1, 2014 (right column). See Table A.1 for the data sources.

(a) Average basis prior to January 1, 2014 **(b) Average basis after January 1, 2014**

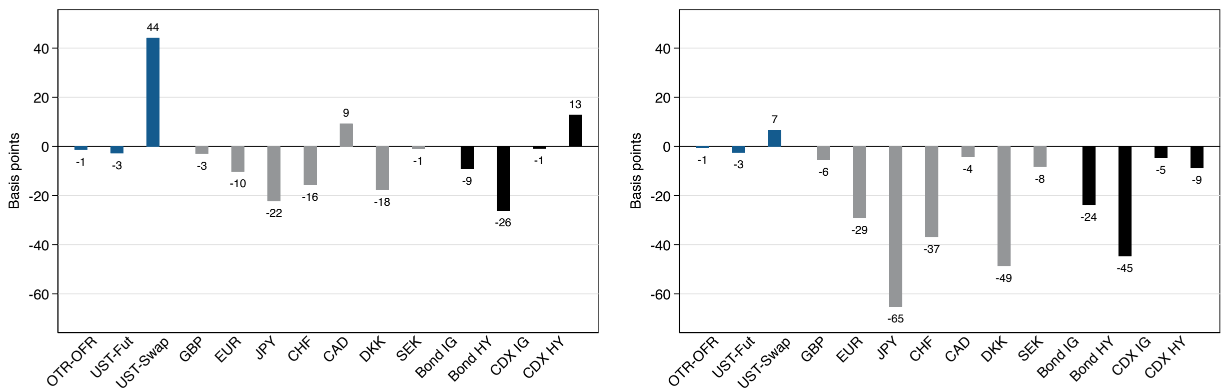


Figure 5. Implied maximum leverage. This figure plots the implied maximum leverage allowed by regulatory constraints (top row) and VaR constraints (bottom row) for 5 year U.S. nominal Treasury trades, 5 year CIP, and U.S. credit markets. Leverage implied by regulatory constraints computed under the assumption that a risk-weighted capital ratio of 3% binds prior to January 1, 2014 while a supplementary leverage ratio of 6% binds after January 1, 2014; VaR panels show sub-period averages of 10-day, 1 percent VaR computed using 10-year rolling windows. See Table A.1 for the data sources.

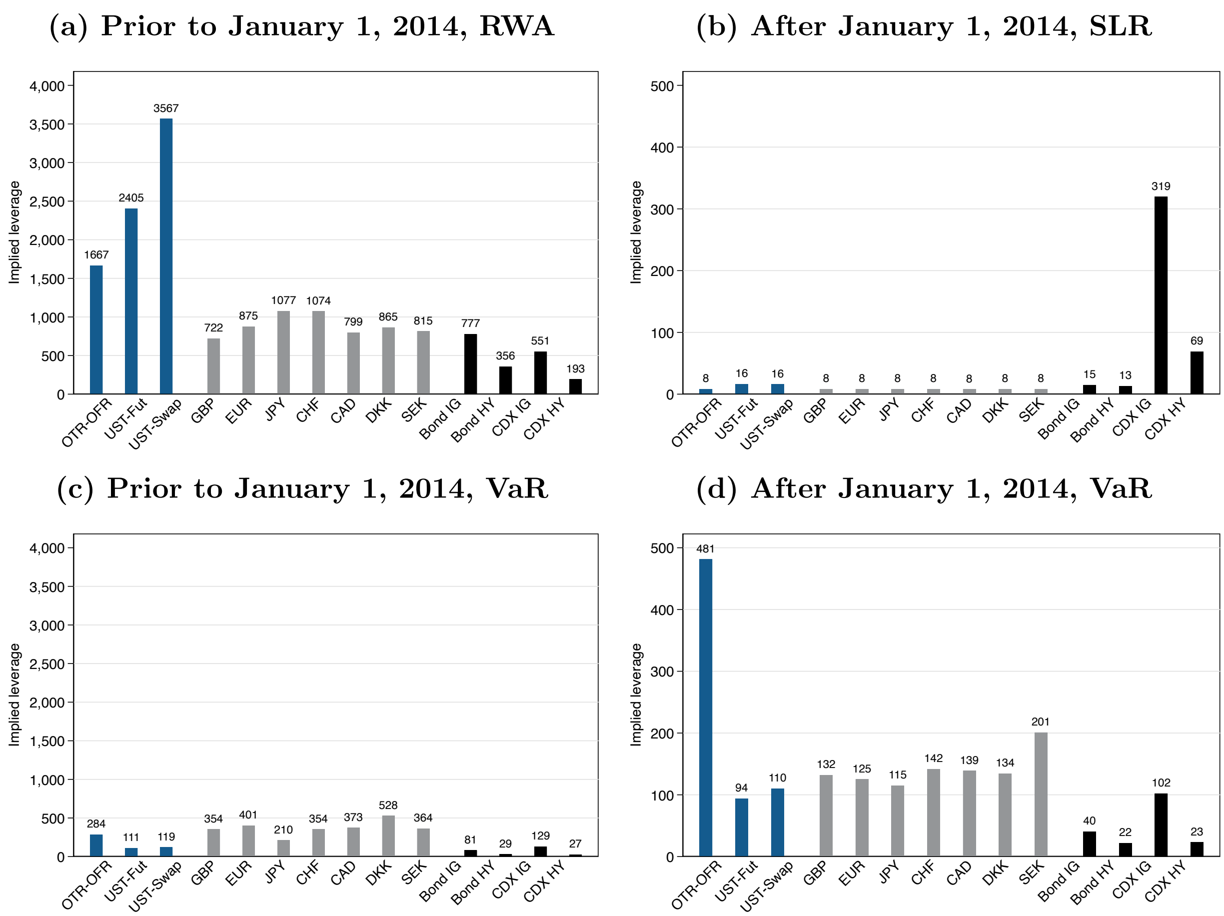
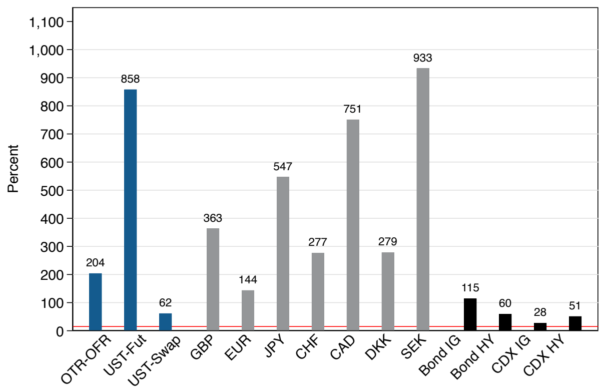


Figure 6. Return on equity. This figure shows the average absolute return-on-equity (ROE) for 5 year U.S. nominal Treasury trades, 5 year CIP, and U.S. credit markets prior to January 1, 2014 (Figure 6a) and after January 1, 2014 (Figure 6b) under the assumption that a risk-weighted capital ratio of 3% binds prior to January 1, 2014 while a supplementary leverage ratio of 6% binds after January 1, 2014. See Table A.1 for the data sources.

(a) Average ROE prior to January 1, 2014



(b) Average ROE after January 1, 2014

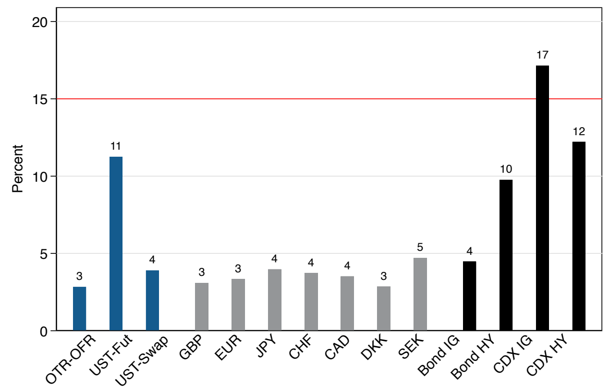
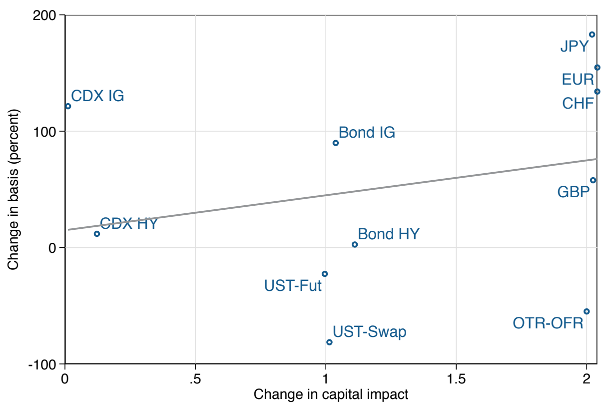
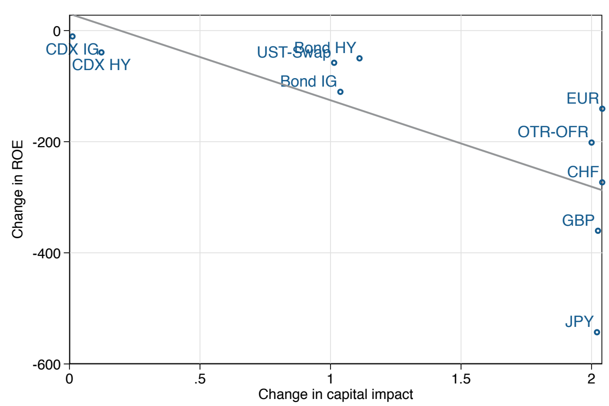


Figure 7. Changes in equity cost and profitability. This figure shows the percentage change in average absolute basis (Figure 7a) and average absolute return-on-equity (ROE, Figure 7b) for U.S. Treasury, CIP, and U.S. credit market trades for a five-year maturity as a function of the change in the capital impact of basis trades from the period ending on January 1, 2014 to the period starting on January 1, 2014. ROE computed under the assumption that a risk-weighted capital ratio of 3% binds prior to January 1, 2014 while a supplementary leverage ratio of 6% binds after January 1, 2014. See Table A.1 for the data sources.

(a) Change in average absolute basis



(b) Change in average ROE



Appendix

A Form ADV

Form ADV is the uniform form used by investment advisers to register with both the Securities and Exchange Commission (SEC) and state securities authorities. The Form is updated each year by filing an annual updating amendment within 90 days after the end the firm's fiscal year. Firms must also file the ADV form in the event of material changes, including changes to ownership.

A.1 Who is required to submit Form ADV?

The Investment Advisers Act of 1940 (Advisers Act) requires all investment advisers with at least 15 US clients and at least $25 million in assets under management to register with the SEC. Investment advisers encompass mutual funds, pension funds, private equity funds, hedge funds, and other types of pooled investment vehicles.

On June 22, 2011, the SEC adopted several rules implementing changes to the Advisers Act made by title IV of the Dodd-Frank Act. Under the new rules, many previously unregistered advisers, such as advisers to private funds, are required to registered with the SEC absent an exemption from registration. Moreover, under the new rules, even advisers that are exempt from registration are required to file a subset of the information requested by Form ADV, transforming Form ADV to both a registration and reporting form for registered advisers and a reporting form for exempt reporting advisers. So, advisers newly registering with the SEC or reporting as exempt reporting advisers were required to file Form ADV by March 30, 2012, and annually henceforth.

Exempt reporting advisers include private fund advisers taking advantage of (1) venture capital fund adviser exemption under Section 203(l) of the Investment Advisers Act; (2) private fund adviser exemption under Section 203(m)-1 of the Investment Advisers Act (investment adviser acts solely as an investment adviser to one or more qualifying private funds, and manages private fund assets of less than $150 million); (3) small adviser exemption (asset under management of under $25 million) under Section 203A(a)(1)(A) of the Investment Advisers Act.

A.2 What is being reported?

The ADV Form contains information about an investment adviser and its business operations. It contains four parts:

1. **Part 1A** provides basic information about the investment adviser, such as its legal name, its principal place of business, number of employees, assets under management, persons who own and control the firm, and the persons who provide investment advice on the firm's behalf.

   Part 1A also contains several supplemental schedules. Specifically:

- **Schedule A** includes information regarding direct owners and executive officers.
- **Schedule B** lists the indirect owners of the firm.
- **Schedule C** is used by paper filers to update the information required by Schedules A and B.
- **Schedule D** asks for additional information for certain items in Part 1A, including a list of other business locations, other locations of record, previously non-listed control persons, and the limited partnerships in which the firm participates.
- **Schedule R** asks for additional information about relying advisers.
- **Disclosure Reporting Pages (DRPs)** are schedules that ask for details about disciplinary events involving the investment adviser or its advisory affiliates.

All advisers registering with the SEC or any of the state securities authorities must complete Part 1A. Exempt reporting advisers that are not also registering with any state securities authority are required to complete only parts of the form.[22] Exempt reporting advisers that are registering with any state securities authority, however, must complete all parts of Form ADV.

2. **Part 1B** asks additional questions **required by state securities authorities**. Part 1B contains three additional DRPs. Advisers applying for SEC registration or who are registered only with the SEC, do not have to complete Part 1B.

3. **Part 2A** requires advisers to create narrative **brochures** containing information about the advisory firm. The requirements in Part 2A apply to all investment advisers registered with or applying for registration with the SEC, but do not apply to exempt reporting advisers.

4. **Part 2B** requires advisers to create **brochure supplements** containing information about certain supervised persons. The requirements in Part 2B apply to all investment advisers registered with or applying for registration with the SEC, but do not apply to exempt reporting advisers.

In 2018, 1697 registered investment advisers and 772 exempt reporting advisers submitted all or parts for Form ADV to the SEC.

A.3 Our Form ADV sample

Several papers in recent years have exploited different information from Form ADV to explore a broad set of questions. For example, Brown et al. (2008) use Form ADV information to measure operational risk. They construct a operational risk indicator for funds whose adviser reports any prior legal or regulatory violations, and they show that it can predict funds' returns and failures. Chen et al. (2013) use Schedules A, B, and C of Form ADV to identify

[22] Exempt reporting advisers are require to complete: Item 1 – Identifying Information, Item 2 – Identification of Exemption, Item 3 – Form of Organization, Item 6 – Other Business Activities, Item 7 – Financial Industry Affiliations and Private Fund Reporting, Item 10 – Control Persons, Item 11 – Disciplinary Events.

direct, and indirect ownership, and other affiliate relationships of mutual funds. They use this information to establish whether a mutual fund family outsources the management of their funds to advisory firms. Jiang (2018) derives leverage (GAV divided by NAV) of equity hedge funds from From ADV Part 1A (Gross Asset Value) and Part 2B (Net Asset Value is disclosed by some advisers). Using this leverage measure, he finds that an increase in the leverage used by hedge funds is associated with a subsequent increase in the stock's likelihood of a crash.

In this paper, we use Part 1A, and Schedule D to collect information about the relationships between advisers and prime brokers over time. Our sample encompasses observations for each adviser at each Fiscal Year it was registered with the SEC.

The raw data reflects the changes that were made to Form ADV over the years and its expanded coverage. The following steps detail how we cleaned the raw data downloaded from the SEC website before constructing our sample.

It is important to note that the SEC updates the information on the investment adviser website as soon as new information becomes available. Thus, the data downloaded in the future will not match exactly the data used in this paper.

1. Downloaded the raw files from the SEC website. There are two zip files where the submitters are registered advisers (files have `ria` suffix), and two zip files where the submitters are exempt registered advisers (files have `era` suffix). Each zip file contains csv and excel files that reference different parts and schedules of Form ADV. The current sample is based on a download from January 2001 to December 31, 2018.

2. Each submission is identified by a `FilingID` variable, which can be found in Part 1A. This variable is the key to linking files.

   The information provided in Part 1A is at the adviser-level.

3. Similar to Jiang (2018), to filter filers that are not hedge funds, we require an adviser to have more than 80% of assets under management from its hedge funds.

Regulatory assets under management (Item 5.F) Under the instructions of Form ADV, when determining regulatory assets under management the adviser is required to include all gross assets without any deduction for debt or leverage and all uncalled capital commitments. All assets are valued at their market value or fair value. Market value is determined the same method used to report account values to client, or to calculate fees for investment advisory services.

B Regulations affecting arbitrage

The financial crisis of 2007–2009 demonstrated shortcomings in the regulatory framework for financial institutions. Institutions experienced both solvency and liquidity problems during the crisis, motivating subsequent regulatory reforms of both institutions and markets. In this section, we provide a brief overview of key regulations in the U.S. that have either direct or indirect impact on funding, cash-product or derivative markets. Table 8 summarizes the expected impact of these regulations by asset class.

B.1 Basel III

The Basel III regulatory framework aims at improving the resilience of the global banking system by both improving the regulatory capital framework and by introducing liquidity regulation. The capital reforms, which raise both the quantity and quality of the regulatory capital base, are underpinned by a leverage ratio that serves as a backstop to the risk-based capital measures. Basel III introduced back in 2010 the SLR, an unweighted capital requirement intended as a safeguard against model risk and measurement error in the risk-based capital requirements. The U.S. version of SLR, which was proposed in July 2013 and finalized in 2014, is defined as Tier I capital divided by on-balance sheet assets and specific off-balance sheet assets, including derivatives exposures, ignoring the risk intensity of assets. In the U.S., banks must hold a minimum 3 percent Tier I leverage ratio from 2018, with the largest U.S. institutions subject to an additional 2 percent supplement.

Basel III also includes two liquidity regulations, the Liquidity Coverage Ratio (LCR) and the Net Stable Funding Ratio (NSFR). The LCR requires banks to have sufficient liquid assets to cover loss of funding over a 30-day period. This buffer reduces banks' vulnerability to a run. The NSFR complements the LCR by requiring sufficient stable funding, equity or long-term debt, to cover assets over a one-year horizon.

B.2 Dodd-Frank Act

In addition to the Basel reforms, U.S. banks and some foreign banks operating in the U.S. are subject to various rules that came into effect under the umbrella of the Dodd-Frank Wall Street Reform and Consumer Protection Act (DFA) signed in July 2010. We focus on the leading parts in DFA that affected the use of swaps and the cost of hedges: "Title VII: Wall Street Transparency and Accountability", and the Volcker Rule (Section 619 of DFA).

OTC Derivatives Clearing and Trading Title VII of DFA mandated transparency in the standardized swap markets, specifically for CDS and interest rate swaps, through transactions reporting, dissemination to the public, electronic execution on Swap Execution Facility (SEF), and central clearing. Rule writing responsibilities were divided between the SEC, which assumed rule making responsibilities for security-based swaps (i.e., single-name CDS), while the CFTC codified DFA Title VII requirements for CDS Indices and interest rate swaps. FX swaps and FX forwards have been exempted from the "swap" definition, and therefore were not subject to the clearing mandate.

Central clearing is intended to reduce systemic risk in the financial system. Instead of bilateral trades, the participants face only the clearinghouse rather than each other. For standard swaps, the clearinghouse imposes initial margin and variation margins. Initial margin is calculated at the portfolio level traded on the CCP. The variation margin is posted based on the mark-to-market value of open positions. In case a CCP member defaults, the clearinghouse will use the posted margins, as well as any additional funding in the guarantee funds. Non-standard swaps continue to be cleared bilaterally but each side is required to post initial margin with a third party and variation margin must be exchanged. The initial margin for non-standard transactions is based on ten-day movements in market variables in stressed market conditions. It is interesting to note that Basel III rules interact with the clearing mandate under DFA, as the former favor cleared interest rate derivatives transactions.

The CFTC phased in the implementation of mandatory clearing by registered derivatives clearing organizations during 2013, starting with mandatory clearing of swaps between major swap dealers[23] in March 2013 and ending with all entities subject to mandatory clearing on September 2013. Rules for single-name CDS, which are regulated by the SEC, have not yet been finalized.

Under CFTC rules, mandatory cleared swaps where at least one major participants is U.S.-based are required to trade on SEFs or designated contract markets. The SEFs must offer a central limit order book (CLOB), where traders can ex-ante observe buy and sell quotes and executed trades then become public. Trading protocols, such as, request-for-quote and request-for-streaming are also offered by SEFs (for more details, e.g., Benos et al., 2016, and Riggs et al., 2017). SEFs for North American CDX and iTraxx indices, and interest rate swaps came live on October 2013. According to statistics published by ISDA, the majority of interest rate derivatives and index CDS are cleared and traded on SEFs in recent years.[24]. In 2017, 88 percent of interest rate derivatives traded notional were cleared, and 55 percent were traded on SEFs. Similarly, 80 percent of traded notional of index CDS were cleared in 2017, and SEF-traded index CDS represented 75 percent of notional amount.

The differential treatment of standard and non-standard swaps translates to higher capital cost for non-standard swaps. As for the capital cost for standard swaps, although the transition to CCPs affects the cost of trading across the board, it impacts more participants who bet on one side of the market than participants, such as dealer banks, that trade both long and short in the same security. Being on both sides allows these participants to benefit from netting when the trades are cleared in the same CCP. The non-uniform impact of clearing on market participant was expected. The extent to which it manifested in a cross-CCPs basis, however, was not. Since 2015, identical interest rate cleared swap contracts trade 2-5 basis points more expensive at the CME than at LCH, both are the largest CCPs for U.S. swaps. The basis emerged as LCH utilizes a portfolio approach to margining, attracting interdealer trades, whereas CME allows netting for cleared OTC derivatives against exchange-traded futures, attracting participants who take directional trades.

Volcker Rule The impact of Section 619, the Volcker Rule, on OTC derivatives was another contentious debate around DFA. The Volcker rule prohibits institutions with access to FDIC insurance or to the Federal Reserve's discount window from engaging in proprietary trading. The Volcker Rule defines proprietary trading as engaging as a principal for the trading account of the banking entity or non-bank systemically-significant financial institution in buying or selling certain covered instruments, including any security, derivative or contract

[23]As prescribed by the Dodd-Frank Act, the CFTC has defined the swap dealer de minimis threshold to be set at $8 billion until December 31, 2019. See `https://www.cftc.gov/PressRoom/PressReleases/pr7632-17` for further details.

[24]See `https://www.isda.org/a/IhhEE/SwapsInfo-Full-Year-and-Q4-2017-Review.pdf` for further details.

of sale of a commodity for future delivery, as well as any option on any of these and any other security or instrument that the federal banking agencies, the SEC and the CFTC may determine.[25] To determine if a bank is engaged in proprietary trading, quantitive metrics, such as, inventory turnover, customer facing trade ratio, and standard deviation of daily trading profits and losses, are required to be reported (Schultz, 2017). Banks were required to comply by July 21, 2015, except for banks with significant trading activities, which were required to report quantitative metrics on their trading activities beginning July 2014.

Some activities that were identified as critical to supplying liquidity and to raising capital, such as market making and underwriting, were exempted from the proprietary trading prohibition. Distinguishing between market-making and proprietary trading is not straightforward. Market making desks have to justify position limits based on "the reasonably expected near-term demand of clients, customers, or counterparties." To the determine the future demand of clients a backward– (e.g., past clients' demand) and forward– (e.g., expected market conditions) looking "demonstrable" analysis is required. In response, several banks announced spin-offs and closures of their proprietary trading desks[26], and there is some empirical evidence that banks' intermediation in the corporate bond market has been adversely affected (e.g., Bao et al., 2018, Adrian et al., 2017, Bessembinder et al., 2018).

B.3 Impact of regulations

We now show high-level results on the effects of post-crisis regulations on bank incentives to participate in repo and derivative markets.

Effect on repo activity The SLR reduces the profits from low-margin, balance-sheet intensive businesses, such as repo and market-making in highly rated sovereign bonds, providing incentives for regulated institutions to decrease their participation in such business. Figure A.4 plots the time series of gross notional borrowed in repo (Figure A.4a) and lent in reverse repo (Figure A.4b) agreements by bank holding companies (BHCs) of different types. Though the overall participation of BHCs in both sides of the repo market has declined since the crisis, U.S. G-SIBs have reduced their participation the most.

In Table A.7, we examine these trends more formally and regress bank-level borrowing and lending in the repo market as a fraction of total assets on a sub-period indicator, bank type indicator and the interaction between the two. The four sub-periods we identify are: pre-crisis (Q1 2002–Q4 2006), crisis (Q1 2007–Q4 2009), rule writing (Q1 2010–Q4 2013), and rule implementation (Q1 2014–Q4 2017); we characterize BHCs into U.S. G-SIBs, BHCs subject to regulatory stress tests that are not G-SIBs (U.S. CCAR, ex-GSIB), foreign banking organizations (FBOs), and others. We can see that, prior to the crisis, U.S. G-SIBs, on average, borrowed 5.76 percent of assets more than smaller BHCs and lent 6.83 percent less. During the crisis, they reduced their borrowing by 4.5 percent of total assets, and their lending by 1.91 percent. Though the repo market activity by U.S. G-SIBs rebounded somewhat during the rule-writing period, the repo borrowing activity by U.S. G-SIBs is, on

[25] Trading U.S. obligations and foreign government obligations by banking entities that are U.S.-based or operate within the issuing foreign sovereign are exempt from the rule.

[26] For example, Citigroup, JP Morgan, Goldman, Morgan Stanley and RBC announced the closure of their prop trading desks between 2010 and 2014.

average, 7.04 percent lower than prior to the crisis, and the repo borrowing activity is 2.48 percent lower. In contrast, other U.S. BHCs subject to regulatory stress tests only reduce their repo borrowing by 1.61 percent on average, relative to the pre-crisis period, and their repo lending by 0.1 percent. Kotidis and van Horen (2018) find similar effects of the leverage ratio on repo market functioning in the U. K., with dealers subject to a more binding leverage ratio reducing liquidity provision in the repo market in response to the switch from monthly to daily average reporting for leverage ratio purposes in January 2017.

We study whether more constrained institutions differentially reduce their securities financing transactions exposure to particular types of counterparties or for transactions collateralized with particular types of collateral in Table A.8. We measure how constrained an institution is using the supplementary leverage ratio that the bank holding company reports on form FR Y-9C,[27] with institutions with higher supplementary leverage ratios more constrained. We obtain information on institutions' securities financing transactions (SFTs) exposure form for FR Y-14Q, Schedule L.5, which collects information about exposure to top 25 counterparties, G-7 sovereign and CCPs through SFTs at the position netting level, together with collateral posted and received into these SFTs at the netting agreement level. The schedule also collects information on the counterparties themselves, such as location and industry (or type of counterparty). Prior to 2015, the submitters were not required to separately report exposures to G-7 sovereigns and CCPs; thus, to make the submissions comparable across form versions, we re-rank the counterparties in the later submissions to also include the exposures to G-7 sovereigns and CCPs in the ranking and retain the top 25 counterparties from this overall ranking.

Table A.8a reports the estimated coefficients from the regression contemporaneous regression of measures of total BHC exposure to SFTs, as a fraction of BHC total assets, on the reported SLR for the BHC, controlling for quarter fixed effects. The table shows that, in the cross-section, institutions with higher reported SLR have lower overall SFT exposure, with a one percentage point higher SLR corresponding to 16 percentage point lower gross SFT exposure. Turning next to the information at the counterparty-collateral type[28] level, Table A.8b reports the estimated coefficients from the regression

$$\begin{aligned}\frac{\text{Exposure}_{b,i,c,t}}{\text{Assets}_{bt}} &= \beta_0 \text{SLR}_{bt} + \beta_i \text{SLR}_{bt} \times \text{CP type}_{it} + \beta_c \text{SLR}_{bt} \times \text{Coll. type}_{ct} \\ &\quad + \beta_{ic} \text{SLR}_{bt} \times \text{CP type}_{ct} \times \text{Coll. type}_{ct} + \alpha_t + \alpha_i + \alpha_c + \alpha_{ic} + \epsilon_{b,i,c,t}.\end{aligned}$$

Consistent with SLR reducing profit for low-margin, balance-sheet-intensive businesses, we find that BHCs with higher SLRs have lower exposures to securities financing transactions overall (2.35% lower average counterparty-collateral exposure), but particularly so when the transactions are done with customers (1.65% lower) or CCPs (3.10% lower), or when collateralized by cash (3.33% lower) or central government debt (3.22% lower).

[27] Advanced approaches holding companies must report the supplementary leverage ratio in FR Y-9C, Schedule HC-R line item 45.

[28] We group counterparties into "Banks", "CCPs", and "Customers" (non-banks, non-CCPs); we group collateral types into cash (regardless of the currency), central government debt (which includes debt obligations issued by a sovereign entity or a government-sponsored enterprise, include U. S. agency mortgage-backed securities), corporate bonds and equity (which includes non-agency MBS) and other.

Effect on derivatives activity The SLR also impacts the profitability of derivative positions by recognizing both the total replacement value of the derivative position and the potential future exposure generated by the derivative position. These regulatory changes in particular affect over-the-counter, non-centrally cleared derivatives, as there is only limited netting accorded such derivatives under Basel III. Indeed, Figure A.5 shows that, although the gross notional outstanding in some OTC derivatives declined in the wake of the financial crisis, the biggest decreases in gross notional outstanding occur in the second half of 2013.

At the same time, consistent with regulations having the greatest impact on OTC derivatives, volumes traded in exchange-traded derivatives do not seem to have been affected to the same extent. Figure A.6 plots the monthly changes in total open interest in Treasury futures (exchange-traded, Figure A.6a) and in USD-denominated interest rate swaps (OTC, Figure A.6b) on the Chicago Board of Trade since the introduction of mandatory clearing for interest rate swaps in the U.S. on March 11, 2013. Figure A.6b shows that, while there is an initial increase in the open interest posted with the CCP as trading activity migrated to centrally clearing, open interest in interest rate swaps has on average been decreasing since March 2015. Open interest in Treasury futures has instead been on average increasing, though the overall open interest in interest rate swaps still far exceeds the open interest in Treasury futures ($10.3 trillion in swaps; $1.15 trillion in futures as of May 2018). Commentary by market participants (see e.g. Greenwich Associates, 2015) suggests that, as the cost of capital for regulated institutions increases, such institutions will charge their clients higher clearing fees, leading to some reallocation of trading activity from over-the-counter products to exchange-traded products. Kreicher et al. (2017) note, however, that, in the global market, interest rate swaps continue to become the more prevalent interest rate derivative contract at the long end of the curve.

We evaluate in Table A.9 the importance of the dealer sector for the OTC derivative market as a whole by regressing the semi-annual change in gross notional outstanding on the semi-annual change in gross notional outstanding on interdealer positions, the sub-period indicator described above and interaction between the two. For all four derivatives categories for which interdealer positions are reported – interest rate, foreign exchange, credit and equity – there is a positive and statistically significant relationship between changes in the total gross notional and in the gross notional traded interdealer. Moreover, for interest rate and foreign exchange derivatives, this relationship becomes stronger in the rule implementation period; for equity derivatives, the relationship is somewhat weaker in the rule implementation period. Thus, decreases in total gross notional outstanding are associated with decreases in gross notional traded between dealers, and even more so in the rule implementation period.

C Derivatives details

C.1 Potential Future Exposure

The potential future exposure (PFE) is an estimate of the value of a derivative contract at future points in time, usually within a specified confidence interval such as 95 or 99 percent. It is essentially an estimate of the future replacement cost of the contract via a distribution of potential values rather than a single point estimate. Although representative of the estimated future distribution, the PFE is defined as the upper bound of the forecasted credit exposures at the given level of confidence over a specified period of time. On the other hand, the current credit exposure is the greater of the present fair value of the contract and zero; it is known with certainty since it captures only the current market value. The PFE is not known with certainty, though, as it estimates this market value in the future.

There are various methodologies used to calculate PFE including creating simulations of future paths of the inputs used to calculate the replacement value and using a constant exposure method which is based on a fixed percentage of the effective derivative notional value of the contract. The Basel Accord utilizes the latter methodology, calculating PFE by multiplying the notional value of the derivative contract with a fixed percentage that is based on the PFE Add-on Factor as indicated in the Accord; this factor is based on the asset class and remaining maturity of the derivative contract. Table A.4 lists the PFE factor by asset class and maturity.

C.2 Standardized Initial Margin

One of the major reforms to OTC derivatives markets in the wake of the financial crisis was the introduction of mandatory minimal initial margins for derivative contracts not cleared through a CCP. These margin requirements serve to achieve two goals: reduction of systemic risk generated by bilateral derivative exposures and the promotion of central clearing for products that are eligible but not required for clearing. Initial margin requirements went into effect in the U.S. on September 1, 2016 and globally for the other G20 countries on March 1, 2017. The required amount of initial margin is calculated either using a quantitative portfolio margin model or a standardized margin schedule. If a quantitative model is used, the margin must be sufficient to cover an increase in the value of the instrument that is consistent with a one-tailed 99 percent confidence interval over a ten day horizon, with the confidence interval calibrated based on historical data that incorporates a period of significant financial stress. In this paper, we compute the financing costs and the implied breakeven basis based on the standard initial margin schedule for uncleared derivatives. Table A.5 lists the standardized initial margin schedule by asset class.

Table A.1: Data Sources

Source	Data
Bloomberg	XCCY, OIS, IBOR, currency spot rates, international repo rates, currency forwards, futures prices, futures conversion factors
Haver	Nominal yields, TIPS breakevens, on-the-run yield, first off-the-run yield
JP Morgan	CDS-bond basis, CDX-CDS basis
Markit	SN upfront
Federal Reserve Bank of New York	Repo haircuts
FICC	U. S. GCF repo rates, repo specials, reverse repo off-the-run
CME	Futures margins

Table A.2: Bank-intermediated trades; negative basis. This table summarizes the bank-intermediated basis trades considered in this paper, including both legs of the transaction the funding costs of the trades, and the balance sheet impact of the trade. A "long" position in a swap is a pay-floating position; a "short" position in a swap is a pay-fixed position. Legs laid out from the perspective of a negative basis trade.

Trade	Long leg	Short Leg	Funding long	Funding short	Impact long	Impact short
U.S. Treasury spreads						
OTR-OFR	Off-the-run Treasury	On-the-run Treasury	Repo; Unsecured for repo haircut	Reverse repo	Repo notional; Haircut loan	Reverse repo notional
UST-swap	Treasury	IR swap	Repo; unsecured for repo haircut	Unsecured for swap margin	Repo notional; haircut loan	PFE of swap; Margin loan
Cash-futures	Duration-adjusted future	CTD Treasury	Unsecured for futures margin	Reverse repo	PFE of future; Margin loan	Reverse repo notional
Exchange rates						
CIP	Foreign sovereign	Treasury; fwd exchange swap	Repo; Unsecured for repo haircut	Reverse repo; Unsecured for swap margin	Repo notional; Haircut loan	Reverse repo notional;PFE of swap; Margin loan
Credit risk spreads						
CDS-bond	Corporate bond	SN CDS	Repo; Unsecured for repo haircut	Unsecured for CDS margin	Repo notional; Haircut loan	PFE of swap; Net margin loan; –Upfront if negative
CDX-CDS	CDX	Basket of SN CDS	Unsecured for CDX margin	Unsecured for SN CDS margin	Net PFE of swap portfolio; Net margin loan; Upfront of index if positive	–Upfront of swap portfolio if negative

Table A.3: Basis and trade return components; negative basis. This table summarizes the calculation of the basis, the unlevered net book return, DV01, and regulatory capital impact for trades considered in this paper. $\hat{y}$ is the continuously-compounded yield-to-maturity; b is the basis; h is the repo haircut; m the derivatives margin; u the upfront payment on the derivative; p the PFE of the derivative; z_i is the continuously-compounded yield on a zero-coupon Treasury with time to maturity i years; F_i is the i year forward exchange rate; λ_{cds} (λ_{cdx}) is the risk-neutral default intensity implied by the spread on the single name CDS (index CDS). Book returns and regulatory capital impact reported for negative basis.

Trade	Basis (b)	Book return	DV01	RWA impact	SLR impact
U.S. Treasury spreads					
OTR-OFR	$\hat{y}_{ofr} - \hat{y}_{otr}$	$-b_{otr} + (1-h_{repo})\left(r^{ofr}_{repo} - r^{otr}_{repo}\right) - h_{repo} r^{OIS}_{3m}$	$\frac{1}{2}\sum_{i=1}^{2T} e^{-z_{\frac{i}{2}}\frac{i}{2}} \times 10^{-4}$	h_{repo}	$2 + h_{repo}$
UST-swap	$r_{cms} - \hat{y}_{cmt}$	$-b_{cms} + r_{3mL} - (1-h_{tpr})\, r_{tpr} - (h_{tpr} + m_{cms})\, r^{OIS}_{3m}$	$\frac{1}{2}\sum_{i=1}^{2T} e^{-z_{\frac{i}{2}}\frac{i}{2}} \times 10^{-4}$	$h_{tpr} + m_{cms} + 0.5p_{cms}$	$1 + h_{tpr} + m_{cms} + 0.4p_{cms}$
Cash-futures	IRR_{fut}	$-b_{fut} + (1-h_{bond})\, r^{ctd}_{repo} - m_{fut} r^{OIS}_{3m}$	$\frac{1}{2}\sum_{i=1}^{2T} e^{-z_{\frac{i}{2}}\frac{i}{2}} \times 10^{-4}$	$m_{fut} + 0.2p_{fut}$	$1 + m_{fut} + 0.4p_{fut}$
Exchange rates					
CIP	r_{xccy}	$-b_{xccy} + (1-h_{tpr})\, r_{tpr} - (1-h_{for})\, r_{for} - (m_{xccy} + h_{for})\, r^{OIS}_{3m}$	$\frac{1}{4}\sum_{i=1}^{4T} \frac{F_{\frac{i}{4}}}{S} e^{-z_{\frac{i}{4}}\frac{i}{4}} \times 10^{-4}$	$m_{xccy} + h_{for} + 0.5p_{xccy}$	$2 + m_{xccy} + h_{for} + 0.4p_{xccy}$
Credit risk spreads					
CDS-bond, IG	$r_{cds} - r_{bond}$	$-b_{cds} - (1-h_{IG})\, r^{IG}_{tpr} - (h_{IG} - \min(u_{cds},0) + 0.5m_{cds})\, r^{OIS}_{3m}$	$\frac{1}{4}\sum_{i=1}^{4T} e^{-\left(\lambda_{cds}+z_{\frac{i}{4}}\right)\frac{i}{4}} \times 10^{-4}$	$h_{IG} - \min(u_{cds},0) + 0.5m_{cds} + 0.5p_{cds}$	$1 + h_{IG} - \min(u_{cds},0) + 0.5m_{cds} + 0.4p_{cds}$
CDS-bond, HY	$r_{cds} - r_{bond}$	$-b_{cds} - (1-h_{HY})\, r^{HY}_{tpr} - (h_{HY} - \min(u_{cds},0) + 0.5m_{cds})\, r^{OIS}_{3m}$	$\frac{1}{4}\sum_{i=1}^{4T} e^{-\left(\lambda_{cds}+z_{\frac{i}{4}}\right)\frac{i}{4}} \times 10^{-4}$	$h_{HY} - \min(u_{cds},0) + 0.5m_{cds} + 0.5p_{cds}$	$1 + h_{HY} - \min(u_{cds},0) + 0.5m_{cds} + p_{cds}$
CDX-CDS, IG	$r_{cds} - r_{cdx}$	$-b_{cdx} - 0.5m_{cds} r^{OIS}_{3m} - (-\min(u_{cds},0) + \max(u_{cdx},0))\, r^{OIS}_{3m}$	$\frac{1}{4}\sum_{i=1}^{4T} e^{-\left(\lambda_{cdx}+z_{\frac{i}{4}}\right)\frac{i}{4}} \times 10^{-4}$	$-\min(u_{cds},0) + \max(u_{cdx},0) + 0.5m_{cds} + 0.5p_{cds}$	$-\min(u_{cds},0) + \max(u_{cdx},0) + 0.5m_{cds} + 0.4p_{cds}$
CDX-CDS, HY	$r_{cds} - r_{cdx}$	$-b_{cdx} - 0.5m_{cds} r^{OIS}_{3m} - (-\min(u_{cds},0) + \max(u_{cdx},0))\, r^{OIS}_{3m}$	$\frac{1}{4}\sum_{i=1}^{4T} e^{-\left(\lambda_{cdx}+z_{\frac{i}{4}}\right)\frac{i}{4}} \times 10^{-4}$	$-\min(u_{cds},0) + \max(u_{cdx},0) + 0.5m_{cds} + 0.5p_{cds}$	$-\min(u_{cds},0) + \max(u_{cdx},0) + 0.5m_{cds} + p_{cds}$

Table A.4: PFE Add-on Factors. Source: Basel III leverage ratio framework and disclosure requirements, January 2014 (`http://www.bis.org/publ/bcbs270.pdf`)

Remaining Maturity	Interest rates	FX and gold	Credit (Inv. Grade)	Credit (Non-inv. Grade)	Equities	Precious metals except gold	Other commodities
One year or less	0.0%	1.0%	5.0%	10.0%	6.0%	7.0%	10.0%
Over one year to five years	0.5%	5.0%	5.0%	10.0%	8.0%	7.0%	12.0%
Over five years	1.5%	7.5%	5.0%	10.0%	10.0%	8.0%	15.0%

Table A.5: Standardized Initial Margin Schedule. Initial margin listed as percent of notional. Inflation swaps treated as interest rate products for initial margin purposes. Source: Margin requirements for non-centrally cleared derivatives, March 2015 (`https://www.bis.org/bcbs/publ/d317.pdf`)

Asset Class	Initial margin
Credit: 0 – 2 year duration	2
Credit: 2 – 5 year duration	5
Credit 5+ year duration	10
Commodity	15
Equity	15
Foreign exchange	6
Interest rate: 0 – 2 year duration	1
Interest rate: 2 – 5 year duration	2
Interest rate: 5+ year duration	4
Other	15

Table A.6: Representative haircuts. This table reports median haircuts for U. S. Treasuries, international securities, and U. S. corporates. Haircuts reported in percent of notional. Source: Federal Reserve Bank of New York haircut survey.

Security	Haircut
U. S. Treasuries	2
Internation securities	2
Investment grade U. S. corporate	5
High yield U. S. corporate	8

Table A.7: Bank participation in repo markets. This table presents the estimated coefficients from an OLS regression of fraction of total assets funded in repo and fraction of total assets against which banks provide funding in repo markets on an indicator of bank type, indicator for the sub-period and interaction between the two. The four subperiods are: pre-crisis (start of sample – Dec. 31, 2006), crisis (Jan. 1, 2007 – Dec. 31, 2009), rule writing (Jan. 1, 2010 – Dec. 31, 2013), and implementation (Jan. 1, 2014 – end of sample), with the pre-crisis treated as the omitted category in the regressions. Banks are split into four categories: U.S. globally systemically important banks (G-SIBS), U.S. bank holding companies subject to CCAR stress tests that are not G-SIBs, foreign banking organizations (FBOs), and other U.S. bank holding companies, with the other category treated as the omitted category in the regressions. Standard errors clustered at bank and year reported in parentheses below point estimates; both regressions include bank fixed effects. *** significant at 1%, ** significant at 5%, * significant at 10%.

	Borrowed in Repo	Lent in Repo
Crisis	0.24**	-0.02
	(0.11)	(0.03)
Rule writing	-0.19	-0.05*
	(0.13)	(0.03)
Rule impl.	-0.82***	-0.11**
	(0.20)	(0.04)
US G-SIB	5.76*	-6.83
	(3.09)	(4.87)
US CCAR	9.11**	-8.47
	(4.04)	(5.23)
FBOs	5.48**	-8.30*
	(1.90)	(4.27)
Crisis × US G-SIB	-4.50*	-1.91
	(2.29)	(1.29)
Crisis × US CCAR	-1.42**	-0.03
	(0.62)	(0.08)
Crisis × FBOs	-1.87	0.17
	(1.82)	(0.57)
Rule writing × US G-SIB	-4.32	-1.21
	(2.96)	(2.06)
Rule writing × US CCAR	-1.87***	-0.20**
	(0.49)	(0.08)
Rule writing × FBOs	-1.58	0.52
	(3.19)	(1.82)
Rule impl. × US G-SIB	-7.04**	-2.48
	(3.16)	(2.18)
Rule impl. × US CCAR	-1.61***	-0.10
	(0.44)	(0.10)
Rule impl. × FBOs	0.55	2.89
	(4.01)	(3.09)
Adj. R-sqr.	0.77	0.88
N. of obs.	79558	79454

Table A.8: SLR and securities financing transactions exposure. This table presents the estimated coefficients from an OLS regression of measures of securities financing exposure (SFT) on reported supplementary leverage ratios. MtM posted (received) reflect the total mark-to-market value of securities posted to (received from) the top 25 SFT counterparties, as reported on FR Y14Q, Schedule L.5. Gross counterparty exposure (gross CE) is the sum of mark-to-market (MtM) value of securities posted and received; net counterparty exposure (net CE) is the sum of counterparty parent level net CE, calculated as the maximum between 0 and the difference between MtM posted to and MtM received from the counterparty. "Customers" are non-bank, non-CCP counterparties; "Central gvt. debt" includes U. S. agency securities; "Corp bonds and equity" includes corporate bonds, non-agency MBS, and equity. Omitted categories are banks (for counterparty type) and other (for collateral type). Exposures measured in percentage of assets terms. All regressions include quarter fixed effects; counterparty-collateral level regressions also include counterparty type, collateral type, and counterparty-collateral type fixed effects. Heteroskedasticity-robust standard errors reported in parentheses below point estimates. *** significant at 1%, ** significant at 5%, * significant at 10%.

(a) At the BHC level

	Gross CE	Net CE	MtM Posted	MtM Received
SLR	-16.04***	-0.28***	-8.11***	-7.93***
	(3.54)	(0.06)	(1.79)	(1.75)
Adj. R-sqr.	0.27	0.22	0.27	0.27
N. of obs.	36	36	36	36

(b) At the counterparty-collateral type level

	Gross CE				Net CE			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
SLR	-2.35***	-0.77***	-0.30***	-0.07	-0.36***	-0.19***	-0.02	-0.01
	(0.20)	(0.10)	(0.07)	(0.05)	(0.07)	(0.06)	(0.01)	(0.02)
CCPs × SLR		-3.10***				-0.50***		
		(0.51)				(0.17)		
Customers × SLR		-1.65***				-0.01		
		(0.24)				(0.11)		
Cash × SLR			-3.33***	-0.77***			-1.22***	0.00
			(0.51)	(0.18)			(0.21)	(0.02)
Central gvt. debt × SLR			-3.22***	-0.44**			0.13**	0.14**
			(0.44)	(0.18)			(0.05)	(0.06)
Corp bonds and equity × SLR			-1.66***	-1.59***			-0.26***	-0.84***
			(0.25)	(0.19)			(0.07)	(0.12)
CCPs × Cash × SLR				-6.75***				-2.71***
				(1.01)				(0.43)
CCPs × Central gvt. debt × SLR				-6.32***				-0.13**
				(0.85)				(0.06)
CCPs × Corp bonds and equity × SLR				0.73***				0.86***
				(0.26)				(0.12)
CCPs × Other × SLR				-0.08				-0.00
				(0.09)				(0.02)
Customers × Cash × SLR				-1.65***				-0.99***
				(0.40)				(0.26)
Customers × Central gvt. debt × SLR				-2.68***				0.07
				(0.37)				(0.13)
Customers × Corp bonds and equity × SLR				-1.64***				0.87***
				(0.53)				(0.12)
Customers × Other × SLR				-0.62***				-0.02
				(0.12)				(0.03)
Adj. R-sqr.	0.67	0.70	0.70	0.79	0.46	0.47	0.53	0.63
N. of obs.	432	432	432	432	432	432	432	432

Table A.9: OTC total notional and interdealer-traded notional. This table presents the estimated coefficients from an OLS regression of semi-annual changes in total gross notional outstanding on the semi-annual change in gross notional traded interdealer, indicator for the sub-period, and interaction between the two. The four subperiods are: pre-crisis (start of sample – Dec. 31, 2006), crisis (Jan. 1, 2007 – Dec. 31, 2009), rule writing (Jan. 1, 2010 – Dec. 31, 2013), and implementation (Jan. 1, 2014 – end of sample), with the pre-crisis treated as the omitted category in the regressions. Newey-West (2 lags) standard errors reported in parentheses below point estimates. *** significant at 1%, ** significant at 5%, * significant at 10%.

	IR	FX	Credit	Equity
Avg.	0.039	0.013	0.141	0.044
	(0.012)***	(0.006)**	(0.048)***	(0.028)
Crisis	0.022	-0.010	-0.141	-0.054
	(0.016)	(0.008)	(0.050)***	(0.038)
Rule writing	0.003	-0.010	-0.165	-0.038
	(0.025)	(0.017)	(0.050)***	(0.029)
Rule impl.	0.063	-0.010	-0.201	-0.039
	(0.036)*	(0.008)	(0.061)***	(0.034)
Δ Interdealer	0.650	0.767	0.335	0.504
	(0.118)***	(0.055)***	(0.098)***	(0.149)***
Crisis $\times$ Δ Interdealer	0.050	0.180	0.469	0.319
	(0.133)	(0.058)***	(0.111)***	(0.206)
Rule writing $\times$ Δ Interdealer	-0.348	-0.142	0.538	0.316
	(0.265)	(0.125)	(0.240)**	(0.205)
Rule impl. $\times$ Δ Interdealer	0.639	0.425	-0.126	-0.252
	(0.316)**	(0.072)***	(0.252)	(0.181)
Adj. R^2	0.635	0.872	0.890	0.640
N. obs	39	39	26	39

Figure A.1. Trade Schematics. This figure shows the mechanics of a long cash-product position, an exchange-traded traded derivative position, a bilateral OTC derivative position, and a centrally-cleared OTC derivative position.

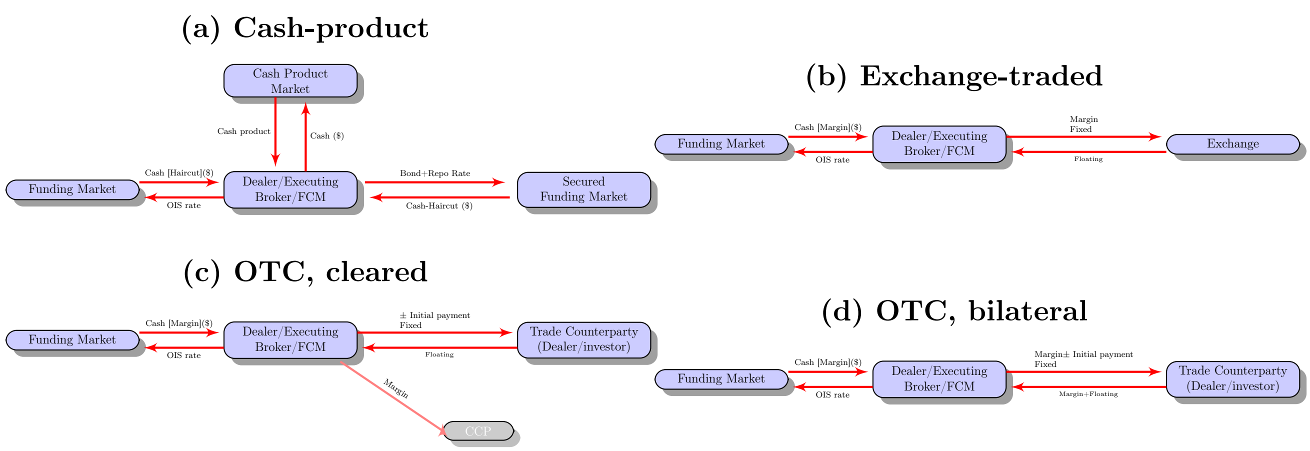


Figure A.2. Funding Rates. This figure shows the time series evolution of representative interest rates for repurchase agreements collateralized by Treasury securities, sovereign bonds and U.S. corporate bonds, and unsecured funding rates. See Table A.1 for the data sources.

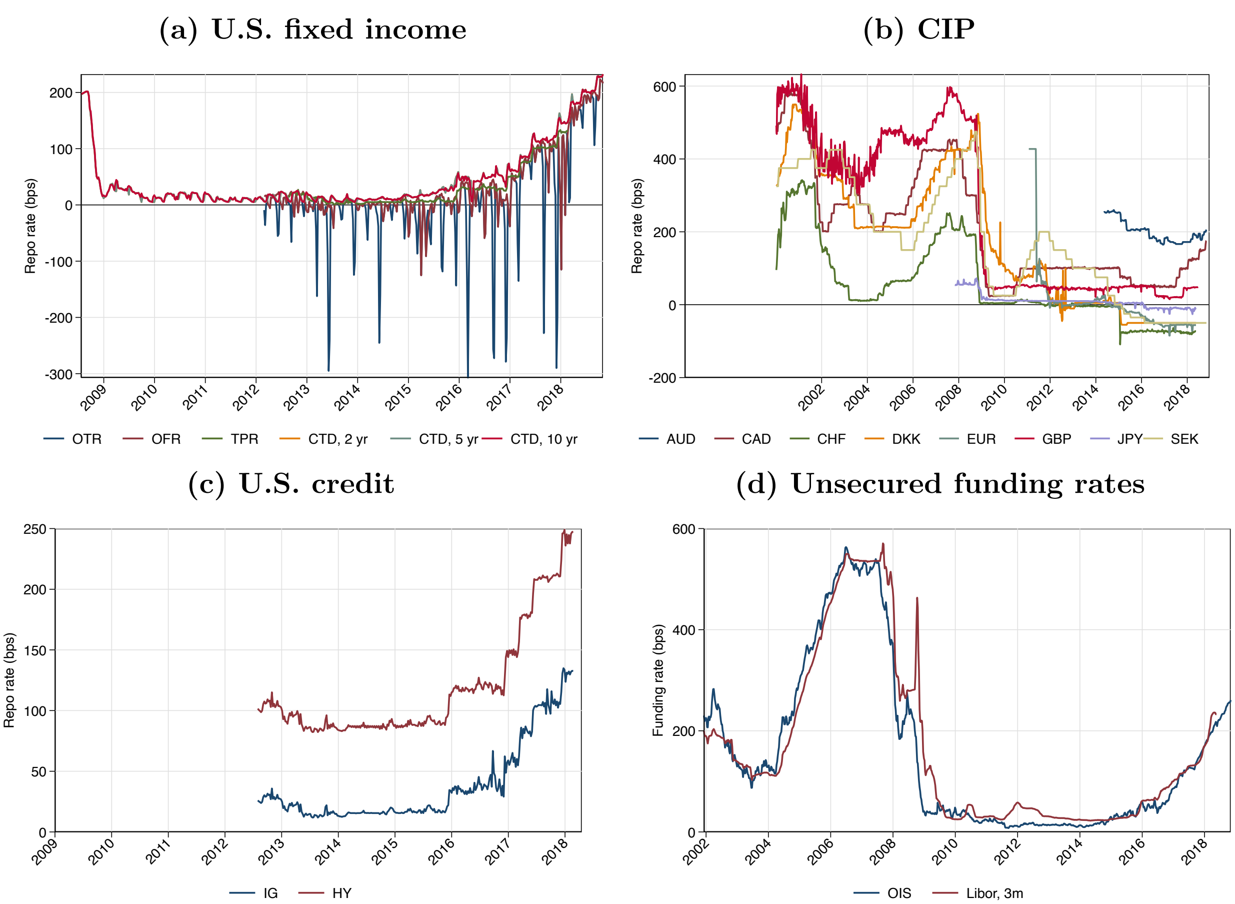


Figure A.3. Margins and Upfronts. This figure shows the time series evolution of the margin on 10 year Treasury futures (Figure A.3a) and of the upfront on the single-name baskets underlying the CDX.NA.IG and CDX.NA.HY indices (Figure A.3b). Source: CME, Markit.

(a) Futures margin **(b) CDS upfront**

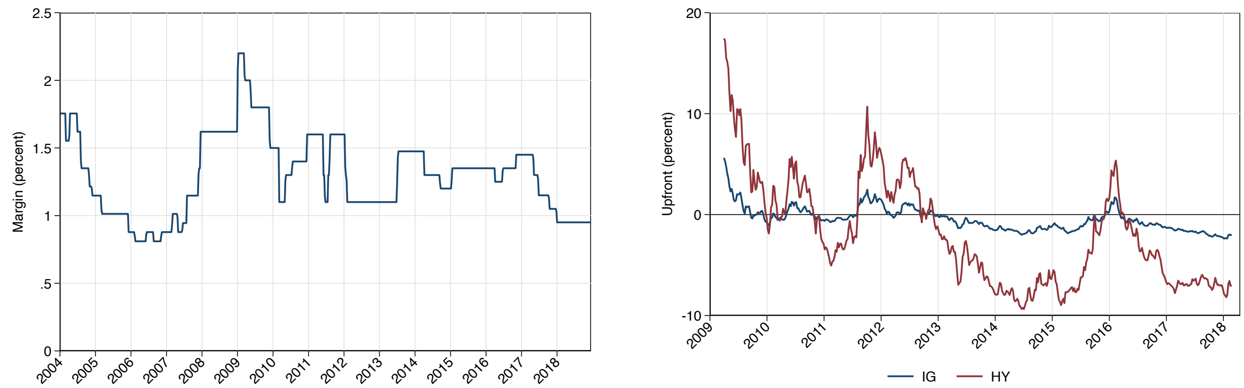


Figure A.4. Securities Funded Through Repurchase Agreements. This figure shows the total amount of securities sold under agreements to repurchase (Figure A.4a) and the total amount of securities bought under agreement to resell (Figure A.4b) by bank type. "U.S. G-SIBs" are U.S. bank holding companies that are classified as global systemically important banks (G-SIBs) in at least one quarter in the sample; "U.S. CCAR, ex-GSIB" are U.S. bank holding companies that participate in CCAR stress tests in at least one quarter in the sample that are not classified at G-SIBs; "Inv. banks" are banks that historically were investment, rather than commercial, banks; "FBOs" are foreign banking organizations. Source: FR Y-9C.

(a) Repurchase agreements **(b) Reverse repurchase agreements**

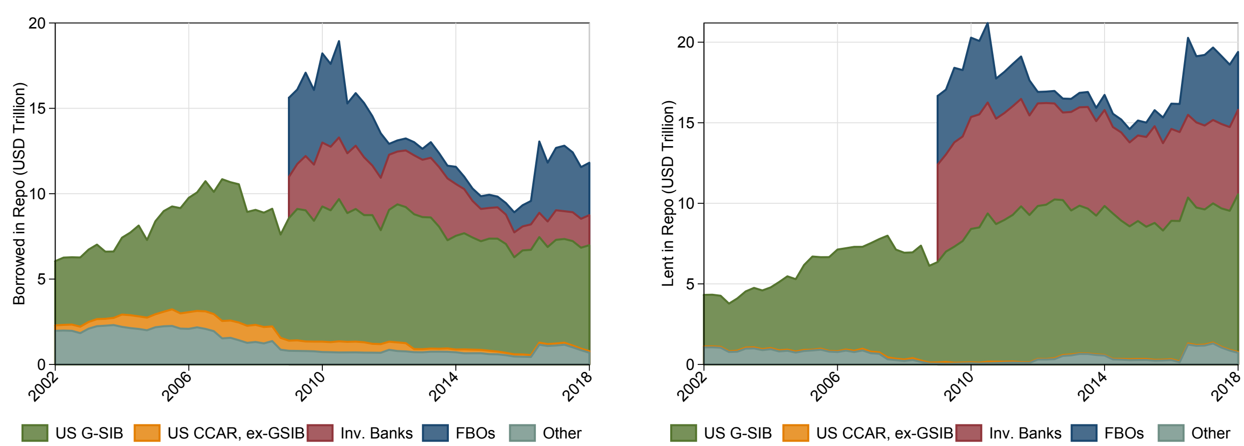


Figure A.5. Gross Notional by Risk Category. This figure shows the gross notional outstanding in USD equivalent for interest rate, foreign exchange, credit, equity and commodity over-the-counter derivatives. Source: BIS OTC semi-annual derivative statistics.

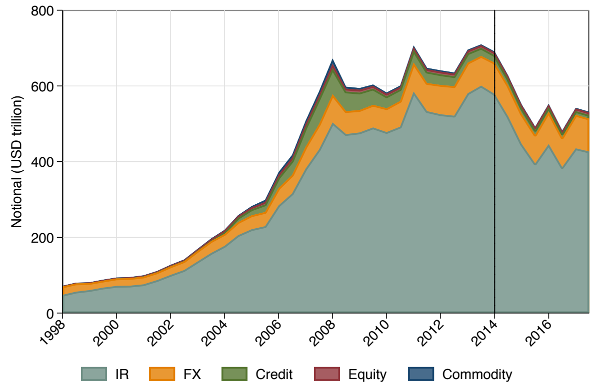
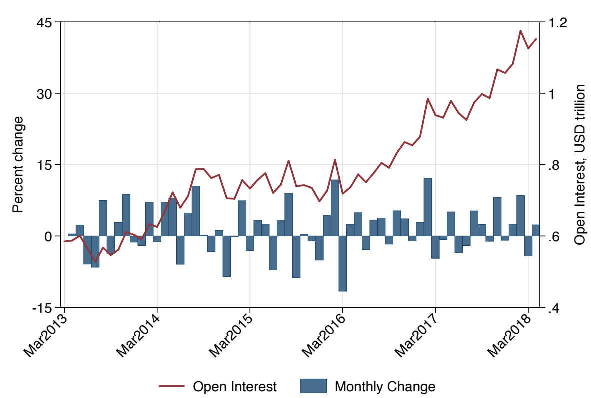


Figure A.6. Open Interest in OTC and Exchange-Traded Derivatives. This figure shows the monthly change in total open interest in Treasury futures (A.6a) and in USD interest rate swaps (A.6b). Treasury futures open interest includes open interest in 2 year, 5 year, 10 year, and ultra-10 year Treasury futures. USD interest rate swap open interest includes 5 year and 10 year maturity interest rate swaps. Source: CME.

(a) Treasury Futures



(b) USD Interest Rate Swaps