Bank-Intermediated Arbitrage *

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Abstract

We argue that post-crisis bank regulation can explain large, persistent deviations from parity on basis trades requiring leverage. Documenting the financing cost and balance sheet impact on a broad array of basis trades for regulated institutions, we show that the implied return on equity on such trades is considerably lower under post-crisis regulation. In addition, although hedge funds would serve as natural alternative arbitrageurs, we document that funds reliant on leverage from a global systemically important bank suffer significant declines in assets and returns relative to unlevered funds. Thus, post-crisis regulation not only affects the targeted banks directly but also spills over to unregulated firms that rely on bank intermediation for their arbitrage strategies.

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1 Introduction

The law of one price – that the same exposure to the same source of risk should be priced the same no matter how that exposure is achieved – is one of the fundamental tenets of finance. Prolonged periods when prices of related assets deviate from each other suggest limits to arbitrage: failures of the law of one price represent profitable trading opportunities that would be exploited by unconstrained institutions. In this paper, we argue that the deviations from parity observed in a number of basis trades across asset classes since the financial crisis of 2007–2009 persist because post-crisis changes to regulation and market structure have increased the cost of participation in spread-narrowing trades for regulated institutions, creating limits to arbitrage. In the post-crisis regulatory environment, regulated broker-dealers not only are more constrained to participate in arbitrage trades themselves but also are less able to provide funding to their clients participating in these trades. This way the constraints imposed on regulated entities can pass through to unregulated arbitrageurs that rely on broker-dealers for funding.

To understand the role that regulation plays in the willingness of institutions to participate in basis spread trades, consider the on-the-run/off-the-run (OTR-OFR) basis trade, plotted as the solid blue line in Figure 1a. In the textbook OTR-OFR basis trade, a market participant would short the more expensive on-the-run Treasury and buy long the cheaper first off-the-run Treasury of similar maturity, earning the liquidity premium enjoyed by on-the-run securities. In practice, the short position in the on-the-run security would be taken through a reverse repurchase agreement, with the market participant lending cash and receiving the OTR Treasury as collateral, and the long position in the off-the-run security would be financed through a repurchase agreement, with the market participant borrowing cash and posting the OFR Treasury as collateral. Thus, the overall profit ("carry") that the participant makes by participating in the trade is the OTR-OFR basis, net of the difference between the interest rate paid on the OFR repo and the interest rate earned on the OTR repo, and net of the cost of financing repo haircuts (if any).

Under the pre-crisis regulatory regime, where regulated institutions treated the capital requirement based on risk-weighted assets (RWA) as the binding regulatory constraint, the OTR-OFR trade had almost no impact on the institutions' balance sheets. Since the reverse repo is collateralized by Treasury securities, its risk weight is 0; similarly, the repo position in the OFR Treasury affects the duration of the institution's liabilities but not the tier-1 capital of the institution. Thus, if the RWA ratio is the binding regulatory constraint, regulated institutions can lever their position in the OTR-OFR basis spread to an almost unlimited extent. In contrast, under the supplementary leverage ratio (SLR), regulated institutions must recognize the full notional of both the repo and the reverse repo position.[1] Thus, every dollar of trade exposure in the OTR-OFR basis is reflected as two dollars of leverage exposure on regulated institutions' balance sheets, severely limiting their ability to both participate in the trade on their own behalf and to provide funding for their clients wishing to engage in the trade.[2]

In this paper, we document the components of typical basis trades across a number of markets – U.S. nominal term structure of interest rates, foreign exchange, and U.S. credit. Most of the trades that we describe have at least one component that is a cash product – funded through the repo market – and one component that is a derivative. Thus, changes in the regulatory environment that discourage regulated institutions from participating in either repo or derivative markets also discourage these institutions from participating in spread-narrowing trades.

We then describe the regulatory changes that are most relevant for the markets that we consider. Though both Basel III and the Dodd-Frank Act introduced many regulatory changes that affect both the cash and derivative products involved in the trades we consider,

[1]Since both the on-the-run and the first off-the-run Treasuries trade "special" in repo, the repo and the reverse repo positions involved are bilateral and thus not nettable.

[2]If a client wishes to obtain funding for the trade from a regulated institution, the institution would enter into a repo agreement collateralized by the OTR Treasury and a reverse repo agreement collateralized by the OFR Treasury with the client.

the SLR seems to have had the greatest impact on the profitability of basis trades, as the SLR requirement increases the fraction of repo (and reverse repo) as well as derivative notional recognized in calculating the leverage ratio. We show that U.S. globally systemic banks (G-SIBs), subject to the strictest post-crisis regulations, have indeed adjusted their repo and derivative market activities in the period starting in January 2014 ("rule implementation"). In particular, U.S. G-SIBs have significantly reduced their activity in repo markets compared to the pre-crisis period and considerably more so than non-G-SIB banks. In derivative markets, we show that changes in the gross notional amount outstanding of non-centrally cleared OTC derivatives, most affected by post-crisis regulations, is positively correlated with the gross notional transacted interdealer and even more so since the regulations have come into effect around 2014.

We next study the funding costs of both the long leg and the short leg of each basis trade, and the leverage requirement treatment of all of the components of the trade under both the pre-crisis and the post-crisis regulatory environments. This allows us to calculate the implied return on equity (ROE) of the trade under both the risk-weighted capital requirement and the SLR. We show that the implied ROE under the SLR is significantly smaller than the implied ROE under the risk-weighted capital requirement and often does not meet the 12% ROE that most large banks target. That is, even though basis spreads have frequently been larger post-crisis than pre-crisis, regulatory changes imply that the basis trades are not sufficiently profitable from the perspective of regulated institutions, even at these elevated levels.

The question then, is why less regulated arbitrageurs such as hedge funds don't substitute for banks' lower arbitrage activity. Our hypothesis is that, to the extent that arbitrageurs rely on regulated institutions for funding, clearing, and execution services, even non-regulated arbitrageurs may be impacted by post-crisis regulations. Consistent with this hypothesis, we find evidence that levered funds using G-SIB prime brokers have been differentially affected in recent years. Using a difference-in-differences approach, we show that assets under management (AUM) has significantly declined in recent years for levered funds that use a G-SIB prime broker relative to unlevered funds that use a G-SIB prime broker, both in aggregate and at the level of the fund. We also find that, among levered funds, aggregate AUM has significantly declined for funds that use a G-SIB prime broker relative to funds that do not use a G-SIB prime broker, a result that reflects the declining number of levered funds using G-SIB prime brokers. Finally, we provide evidence that performance has also been affected. Alongside the overall decline in hedge fund performance in recent years, levered funds using G-SIB prime brokers have underperformed relative to unlevered funds using G-SIB prime brokers on a value-weighted basis. Overall, the results are consistent with the hypothesis that regulation is having an indirect impact on arbitrageurs as measured by AUM and abnormal returns.

Finally, it is important to note that we do not argue that the post-crisis regulatory changes themselves are the cause of deviations from parity. Instead, when exogenous factors move the basis spreads away from zero, regulatory requirements disincentivize market participants from entering into trades that would counteract the effects of such exogenous shocks. When such shocks do occur, they reveal the changed economics of spread-decreasing positions.

Related Literature This paper contributes to the recent and growing literature documenting the role that financing constraints play in the persistence of deviations of spreads from the no-arbitrage benchmark. We deviate from the existing literature on 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. (2016) show 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) argue that the expected profitability of CIP trades is much lower after proxying for banks' balance sheet costs. Similarly, Boyarchenko et al. (2018a) and Boyarchenko et al. (2018b) 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.

This recent literature builds on the older studies of deviations from no arbitrage in both fixed-income and equity 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. On the equity side, Mitchell and Pulvino (2001) examine the systematic risk priced in merger arbitrage strategies while Mitchell et al. (2002) study arbitrage in situations where both the parent company and a subsidiary are publicly traded. In both of these types of equity arbitrage strategies, the papers find evidence of limits to arbitrage. We refine the limits to arbitrage argument in our paper by focusing on the limits to arbitrage induced by banking regulation.

Our paper is also related to the literature studying the interconnections between hedge funds and regulated institutions. The two papers in this literature closest to ours are Choi et al. (2018) and Mitchell and Pulvino (2012). Choi et al. (2018) 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 (2012) 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. Mitchell and Pulvino 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. Our paper differs from this prior literature by showing that leverage provision by prime brokers to their clients may limit the ability of arbitrageurs to correct mispricing even outside of crisis periods. Finally, Giannetti and Kahraman (2017) and Franzoni and Giannetti (2017) study the trading behavior of funds with different funding structures. Giannetti and Kahraman (2017) show that open-end funds, which are more subject to limits-to-arbitrage frictions, are less likely to purchase underpriced stocks than closed-end funds. Similarly, hedge funds with high share restrictions, having a lower degree of open-ending, also trade against long-term mispricing to a larger extent than other hedge funds. Franzoni and Giannetti (2017) then argue that financial-conglomerate-affiliated hedge funds have more stable funding than other hedge funds and are able to take more risk and to purchase less liquid and more volatile stocks than other hedge funds during financial turmoil.

From a theoretical perspective, our paper is related to the limits-to-arbitrage literature. Gromb and Vayanos (2002) study the welfare implications of constraints faced by traders intermediating between two segmented markets for the same good – such as, for example, a derivative and a cash product loading on the same fundamental exposure. Similarly, Liu and Longstaff (2004) consider the optimal portfolio allocation of investors that face collateral constraints but would like to engage in arbitrage activities. More recently, Jermann (2016) argues that negative Treasury-swap spreads can arise in a partial equilibrium model where banks face costs of holding both Treasuries and pay-fixed swaps on their balance sheet. Biais et al. (2016) construct a model where differences in the ability to short physical and derivative assets and collateral requirements for shorting can lead to the derivative portfolio being priced below the price of the corresponding physical assets, creating an equilibrium basis spread.

2 Basis trades

We begin by describing the components of the basis trades we consider and document the historical behavior of these spreads. We are interested in basic types of bank-intermediated basis (arbitrage) spreads. Though the list presented here is by no means exhaustive, it covers some of the largest markets in the world. These trades are primarily fixed-income trades; the main distinguishing feature of these trades is that at least one of the legs of the trade either requires a broker-dealer to be executed or requires a prime-broker to be funded.

2.1 Treasury trades

We begin with basis trades that involve U.S. Treasury securities.

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 In the Treasury-interest rate swap trade, institutions exploit pricing differences between the nominal Treasury and the interest rate swap markets. When the basis is positive, so that Treasuries are relatively more expensive, an institution enters into a short position in the Treasury together with a pay-floating position in an interest rate swap of matched maturity. When the basis is negative, Treasuries are cheap relative to interest rate swaps, and an institution enters into the reverse trade, taking a long position in Treasuries, and a pay-fixed position in interest rate swaps. For more details on the UST-swap trade, see Boyarchenko et al. (2018a).

Cash-futures trade The cash-futures trade also exploits relative mispricing of nominal-rate linked securities but involves Treasury futures, which are exchange-traded, rather than interest rate swaps. An institution enters a long position in the cheapest-to-deliver Treasury eligible for delivery into a futures contract with a given maturity and sells the corresponding futures contract, with the notional of the futures contract adjusted for the futures conversion factor. For more details on the cash-futures trade, see Labuszewski et al. (2017).

Historical variation Figure 1a plots the time series evolution of the OTR-OFR spread, the Treasury-interest rate swap basis, and the cash-futures basis for securities with ten-year maturity. On average, the cash-futures basis has the largest deviations that spike down around the Treasury issuance cycle. Outside of these episodes, the cash-futures basis is positive, indicating that, on average, Treasuries are underpriced relative to the futures. The OTR-OFR spread is the closest to zero on average and, likewise, positive. Unsurprisingly, all three types of spreads have the largest deviations during the crisis, with the Treasury-swap basis turning negative. The Treasury-swap basis also turned negative during the second half of 2015, reaching almost a half of its crisis-period low.

2.2 Covered interest rate parity

In the covered interest rate parity (CIP) trade, an institution trades off the cost of borrowing in U.S. funding markets against the costs of borrowing in foreign markets and swapping the foreign funding into U.S. funding via a forward exchange rate swap. When the basis is positive, U.S. dollar funding is relatively cheap and institutions take advantage by entering into a long position in U.S. Treasuries, a pay-fixed forward exchange rate swap, and shorting a foreign sovereign security with the same maturity. When the basis is negative, U.S. dollar funding is relatively expensive, and institutions take advantage by shorting a U.S. Treasury security, entering into a pay-floating forward exchange rate swap, and buying a foreign sovereign security with the same maturity. For more details on the CIP trade, see

Avdjiev et al. (2016) and Du et al. (2018).

Historical variation Figure 1b plots the time series of the one year CIP trade for advanced economy currencies. Prior to the crisis, the CIP was consistently positive and around 20 basis points for all ten currencies. The CIP for most currencies turns negative during the crisis, with the basis for Danish krone reaching almost -200 basis points. Though the CIP levels have returned closer to zero after the crisis, the average magnitude is still significantly larger than prior to the crisis. Moreover, the CIP on all currencies except for the Australian and New Zealand dollars have remained negative.

2.3 Credit trades

The final type of bank-intermediated trade that we consider are those involving different credit instruments.

CDS-bond basis trade In the CDS-bond basis trade, institutions trade off 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 trade In the index-single-name trade, institutions trade off 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.

Historical variation Figure 1c plots the time series of the CDS-bond and index-single-name bases for investment grade and high yield U.S. corporate reference entities. Prior to the crisis, all four bases tended to be positive. During the crisis, the bases turn negative, with both the CDS-bond basis and the investment grade index-single-name basis remaining negative since. In the second half of 2015, all four bases once again turn negative, reaching a third of their respective crisis-period lows.

3 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 1 summarizes the expected impact of these regulations by asset class.

3.1 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.

3.2 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[3] 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.[4].

[3]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.

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

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 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.[5] 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

[5] 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.

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[6], and there is some empirical evidence that banks' intermediation in the corporate bond market has been adversely affected (e.g., Bao et al., 2016, Adrian et al., 2017, Bessembinder et al., 2018).

3.3 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.

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 2 plots the time series of gross notional borrowed in repo (Figure 2a) and lent in reverse repo (Figure 2b) 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.

To examine these trends more formally, in Table 2, we regress bank-level borrowing and lending in the repo market as a fraction of total assets on a sub-period indicator, bank

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

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 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.

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 3 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 4 plots the monthly changes in total open interest in Treasury futures (exchange-traded, Figure 4a) and in USD-denominated interest rate swaps (OTC, Figure 4b) 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 4b 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 3 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.

4 Return on equity

We now turn to the practical considerations involved in executing basis trades, including the costs of funding and the regulatory capital impact of different parts of the trades. We approach the basis deviations from the viewpoint of the limits-to-arbitrage literature:[7] since spread-narrowing trades involve transaction costs and use regulatory capital, regulated institutions are unwilling to enter into such trades unless the profit net of transaction costs, or carry, of the trade 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 costs seriously, across multiple markets, and show that the economic considerations for basis trades have changed in the wake of the post-crisis regulatory reform.

4.1 Funding costs

We begin with the funding costs associated with the spread-narrowing trades. Instead of describing the overall cost of each trade, we document the funding costs of the basic types of positions that underly each trade. Table 4 then summarizes the different legs to each trade and the funding components of each leg.

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. For the trades described in Section 2, 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 and U.S. corporate bonds are funded through bilateral repos. In a repo, the in-

[7]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).

stitution 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 (OIS) swap rate. Figure 5a outlines these components of a long-cash product position, and the market participants involved in the transaction. The dealer purchases the cash product in the cash product market in exchange for cash. They then post the cash product as collateral in the repo market, receive cash minus the repo haircut from, and pay the repo interest rate to, their secured funding market counterparty. The rest of the notional of the cash product is borrowed from a counterparty in the unsecured funding market, with the dealer receiving a cash loan in exchange for interest rate payments. We report representative haircuts in U.S. repo markets in Table 5. Unsurprisingly, riskier securities (corporate bonds instead of sovereign bonds; high yield corporate bonds instead of investment grade corporate bonds) require a higher haircut when used as collateral.

Similarly, short positions in cash products are covered through reverse repos. 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.

Figure 6 plots the time series of representative repo rates for U.S. Treasuries (Figure 6a), sovereign bonds (Figure 6b), and U.S. corporate bonds (Figure 6c), together with the unsecured funding rates (Figure 6d). As policy rates decline, both the secured and unsecured funding rates decline, with repo interest rates becoming negative for countries with negative policy rates. Repo positions collateralized by riskier securities, such as high yield corporate bonds, require a higher interest rate. Finally, the repo special interest rate exhibits downward spikes that coincide with the Treasury security issuance cycle.

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. We lay out the parties to the trade and the markets involved in an exchange-traded derivative contract in Figure 5b. 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. Figure 7a plots the time series evolution of the initial margin required by the CME for the 10 year Treasury futures contract. The margin increased during the crisis to around 2.25 percent but has since decreased to (almost) pre-crisis levels of around 1 percent.

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 around 25 percent of OTC derivatives required margin posted prior to March 2013.[8] Figure 5c lays out the parties to the trade in a cleared OTC derivative contract. The dealer enters into a bilateral contract with a trade counterparty, exchanging any required initial payment and fixed and floating payments over the life of the trade. The dealer then clears the transaction through a CCP, posting margin with the CCP. The margin is once again borrowed in the unsecured funding market, with the dealer receiving cash and making periodic interest rate payments while the position remains open.

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

For OTC derivatives not subject to central clearing, we assume that around 25 percent of the positions required margin prior to the introduction of mandatory initial margin in September 2016. See Appendix A.2 for more details on mandatory initial margins. We lay out the parties to the trade for a bilateral OTC derivative contract in Figure 5d. The dealer enters into a bilateral contract with a trade counterparty, exchanging any required initial payment and fixed and floating payments over the life of the trade. Both counterparties post margin to each other, with the party buying protection usually posting half of the margin posted by the party selling protection. The margin is once again borrowed in the unsecured funding market, with the dealer receiving cash and making periodic interest rate payments while the position remains open.

In addition to margins on the derivative positions, CDS positions after the crisis often require upfront payments[9] 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. As with haircuts on repo positions and derivative margins, we assume that upfront payments (if any) on derivatives are funded in unsecured funding markets. Figure 7b plots the time series of upfronts on the baskets underlying the CDX.NA.IG and CDX.NA.HY indices. The upfront on the investment grade basket is much closer to zero than the upfront on the high yield basket, indicating that investment grade CDS contracts tend to be valued close to the standardized fixed coupon rate of 100 basis points. Nonetheless, there is noticeable time variation in the upfront for both baskets, with both upfronts negative, so that the credit protection is valued cheaper than prescribed by the standardized fixed spread, in the most recent period.

4.2 Capital impact

As with the funding costs, instead of describing the capital impact of each individual trade, we focus on the capital impact of the basic types of positions that underly each trade. For

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

each position type, we describe the impact on both risk-weighted assets, which constitute the denominator of the RWA capital ratio, and on the "total leverage exposure," which constitutes the denominator of the supplementary leverage ratio. In addition to the leverage impact of the positions themselves, under both regulatory regimes, institutions recognize the face value of the unsecured loan for the either the haircut or the margin on the position, as appropriate. Table 6 summarizes the balance sheet impact of all the trades under the SLR.

Cash products Under the risk-weighted asset capital requirement, repo positions do not affect the 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.

Exchange-traded derivatives For exchange-traded derivatives, institutions recognize the current replacement value of the derivative position and the potential future exposure of the position. Under the risk-weighted capital requirement, positions on exchanges have a 20 percent risk weight, but a 40 percent weight under the supplementary leverage ratio.

Centrally-cleared derivatives As with exchange-traded derivatives, with centrally cleared derivatives, institutions recognize the current replacement value of the derivative position and an adjusted potential future exposure (PFE). 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 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 20 percent of the total.

Bilateral derivatives 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.

4.3 Return on equity

We are now ready to compute the return on equity (ROE) on the basis trades. The ROE on an individual trade is given by the levered carry of the trade. The carry on the trade is profit net of funding cost

$$\text{Carry}_t = \text{Basis}_t - \text{Funding cost}_t,$$

where Funding cost_t is the total funding cost of all legs of the trade as described in Section 4.1. To calculate the leverage implicit in the trade, recall that the risk-weighted leverage ratio is given by

$$\text{RWA leverage}_t = \frac{\text{Tier-1 capital}_t}{\text{RWA}_t},$$

and the supplementary leverage ratio is given by

$$\text{SLR}_t = \frac{\text{Tier 1 capital}_t}{\text{Leverage exposure}_t}.$$

The total leverage of the trade is then given by

$$\frac{1}{\text{Leverage}_t} = \text{Regulatory leverage}_t \times \text{Capital impact}_t,$$

where Capital impact$_t$ is the total capital impact of the trade, as described in Section 4.2, and Regulatory leverage$_t$ is the regulatory leverage constraint that binds at date t. Thus, for a given trade, the ROE on the trade is given by

$$\text{ROE}_t = \frac{\text{Basis}_t - \text{Funding cost}_t}{\text{Regulatory leverage}_t \times \text{Capital impact}_t}. \tag{1}$$

Equation (1) highlights that the higher frequency changes to an institution's ROE are due to changes in the funding costs associated with the trade, while lower frequency changes – such as the average level of spreads during a sub-period – are due to either changes in the regulatory leverage requirement that binds for the marginal institution or in how different legs of the trade affect the regulatory capital requirement. In computing the break-even spreads, we assume that the risk-weighted capital requirement of 3 percent is binding prior to January 2014, and the supplementary leverage ratio of 6 percent is binding afterwards.

Results The left column of Figure 8 plots the time series of implied ROE for our trades under the (counterfactual) assumption that the risk-weighted capital ratio is binding for the entire sample, while the right column of Figure 8 plots the time series of implied ROE for our trades under the (counterfactual) assumption that the supplementary leverage ratio is binding for the entire sample. For all the trades we consider, 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 percent ROE targets that most large financial institutions 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.

5 Hedge Fund Evidence

The previous section showed that the profitability of basis trades is significantly lower for regulated institutions under the current regulatory regime than under the pre-crisis regulatory regime. We now investigate whether there is evidence of regulation impacting hedge funds through their prime brokers using a difference-in-differences approach.

Focusing on the subset of hedge funds that use a G-SIB prime broker, we compare funds that use leverage to funds that do not use leverage. In addition, focusing on the subset of hedge funds that use leverage, we compare funds that use a G-SIB prime broker to funds that do not use a G-SIB prime broker. The null hypothesis in this analysis is that, all else equal, G-SIB prime brokers will be less willing to extend financing in the post-crisis regulatory environment which will differentially affect the funds that use leverage *and* have a G-SIB prime broker.

While we focus on hedge fund clients – as the prototypical example of unregulated institutions that traditionally act as arbitrageurs – it should be noted that regulatory spillovers, if any, would also affect other types of dealers' clients, such as insurance companies and mutual funds.

We first provide some institutional background on prime brokerage and how it has been affected by the post-crisis regulation. We then describe the data and present the results.

5.1 Prime Brokerage

Historically, prime brokers assisted clients such as hedge funds by executing trades as well as 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, the prime broker steps in as a trusted counterparty to both.

Facing the hedge fund, the prime broker provides leverage against both long and short positions.[10] In the case of a hedge fund long position, the prime broker lends cash to the fund customer, e.g. through a margin loan, and receives the security as collateral, which the prime broker can then rehypothecate in a repo or use as a source for short positions of other customers. Figure 9a illustrates rehypothecation in a "matched-book repo" where the prime

[10]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 customer different options and protections.

broker effectively intermediates between a hedge fund and a money market fund.

To facilitate a hedge fund customer's short positions, the prime broker either uses its own positions, re-hypothecates other customers' long positions, or borrows from securities lenders such as pension funds. In addition, the prime broker holds customers' free cash balances, generating a spread between the interest paid to the customer and the interest received by using the cash balances for other purposes.

Prime brokers rely to a large extent on "internalization," e.g. using one customer's long position to source another customer's short position, or funding one customer's debits with another customer's credits. Figure 9b 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.

Risks and regulation The prime broker faces two important risks: (i) credit risk, i.e. the risk that the hedge fund cannot meet its margin calls and the value of 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).[11] The experience of Bear Stearns and Lehman Brothers in 2008 also highlighted hedge funds' exposure to their prime brokers and led to a desire to diversify across multiple prime brokers (Mackintosh, 2008).

The Basel III regulations have significantly impacted prime brokers' activities. Given the key role of prime brokers as credit intermediaries, the SLR has had the biggest impact. Any matched-book repo where the prime broker lends to a hedge fund and funds the loan by rehypothecating the collateral increases the balance sheet and therefore the leverage ratio.[12]

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

[12] 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); J.P.

This is especially costly for low-margin intermediation using safe assets as collateral.[13]

Prime brokers are also impacted by the Basel III liquidity regulations. For hedge fund customers, the LCR assumes complete withdrawal of free credit balances and full drawdown of loan commitments (this is in contrast to lower run-off rates assumed for other customer types). Further, the LCR assumes that the prime broker loses all of its collateralized funding with terms of less than 30 days. The 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 prime brokers' activities, especially internalization, depends directly on allowable netting. As a rule of thumb, netting requires trades with the same counterparty, same end date and 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).

Possible effects There is only limited anecdotal evidence as to the effects of the post-crisis regulations on prime brokerage practice. Ernst & Young (2016), for example, reports that in 2006 the top two prime brokers, Goldman Sachs and Morgan Stanley, accounted for 52% of hedge fund assets, while in 2012 they accounted for less than 33%. Given that pre-crisis prime brokerage was a significant source of revenue for broker dealers, this anecdotal reduction in hedge fund reliance on prime brokerage funding might translate to banks' profits.[14]

Morgan Investor Services (2014) for details.

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

[14]According to Euromoney Magazine, Goldman Sachs' prime brokerage revenue before the Lehman bankruptcy in 2008 was up to $900 million per quarter, roughly 11 percent of its average quarterly revenues (Avery, 2008).

As banks optimize their balance sheet costs, the effects tend to line up with the expected incentives: shorter tenors in financing hedge funds (or higher rates for longer term financing); lower reliance on customers' cash balances for funding of other activities; less extension of credit lines (or at higher rates); customer-specific pricing of services based on actual impact on prime broker's balance sheet; shift towards synthetic prime brokerage, e.g. through swap trades; migration of hedge fund assets to non-bank dealers.

It is not entirely clear what type of hedge fund is most affected by the post-crisis regulations. From the prime broker's perspective, a desirable customer 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. For our empirical analysis, we will consider affected funds those using leverage and with a G-SIB prime broker.

5.2 Hedge Fund Data

We obtain data on hedge fund assets under management (AUM), returns, and prime brokerage relationships from 1994 to 2016 using the Lipper TASS database.[15] Our approach for cleaning the data closely follows Hu et al. (2013). We include observations of monthly returns that are reported net of fees for funds with at least \$10 million in AUM and at least 24 months of return history. In addition, we winsorize assets at \$5 billion and returns at 50% to mitigate the impact of outliers in our regression analysis.[16]

The TASS database provides a snapshot of the links between hedge funds and prime brokers as of the latest update in WRDS (we use the TASS version as of May 1st, 2018). We determine whether prime brokers are G-SIBs by performing a fuzzy string match on

[15] TASS created its graveyard database in 1994 to record the performance of both live funds and funds that have stopped reporting returns. We start the sample in 1994 to alleviate potential concerns related to survivorship bias. This does not address, however, the voluntary nature of reporting in the TASS database, which may raise selection concerns.

[16] The 1st and 99th quantiles for the raw return and AUM data satisfying the filters are -10.7% and 11.5% and \$10.6mn and \$4.1bn respectively.

company names and then manually review the match to remove errors or fill in gaps.[17] Of the 873 prime brokers in the database, we classify 238 as G-SIBs and 101 as U.S. G-SIBs. Merging this data with returns, we find that 47% (49%) of fund-month observations can be matched to at least one prime broker on an equal-weighted (asset-weighted) basis. The vast majority of these observations are only linked to one prime broker (92% equal-weighted and 85% asset-weighted). For the cases with multiple prime brokers, we set the G-SIB dummy to 1 if a fund has at least one G-SIB prime broker. Within this prime-broker-linked subset, we find that 68% (75%) of fund-month observations have at least one G-SIB prime broker on an equal-weighted (asset-weighted) basis.

Similarly, we obtain information on fund characteristics, including fund style and whether funds use leverage, as one-time snapshots. As a result, our analysis abstracts from changes in fund style, leverage, and prime broker relationships over time. For example, we do not see changes in prime brokerage relationships after the default of Lehman Brothers or changes in relationships in the post-crisis regulatory period, where anecdotal industry evidence suggests that some banks are changing their hedge fund client base.[18] This data limitation should be kept in mind when interpreting the results and potentially favors comparing the difference-in-difference coefficients over more recent time periods when the snapshot of prime broker to hedge fund links is likely to be more accurate.

Summary statistics for the full sample of hedge fund data satisfying the filters discussed above and for the subset with prime broker data are recorded in Table 7. Overall, the prime-broker-linked subset looks fairly representative of the full sample with a few minor differences. For example, while the percentage of observations in the "undefined" category is lower in the prime broker subset, other variables like fund size, fund age, and average returns are broadly

[17]We link domestic and international subsidiaries back to the parent company. For example, Goldman Sachs & Co., Goldman Sachs International, Goldman Sachs Execution & Clearing LP, Goldman Sachs (Asia) LLC, and Goldman Sachs Asset Management International are all linked to Goldman Sachs. The fuzzy string match is relatively accurate. We only change 5.6% of the matches manually, which primarily involves removing erroneous links. For example, we remove matches between Credit Suisse and Credit Lyonnais Rouse and Bank of America and Bank of Nova Scotia. We also manually link Citibank N.A. and related company names to Citigroup.

[18]For example, see "Picky banks play hardball with hedge fund clients," 9/15/15 Reuters.

similar.

Table 7 reports the average raw return $R_{i,t}$, excess return $Re_{i,t}$, and abnormal return $Ra_{i,t}$ by fund style. To measure performance, risk exposures are estimated by regressing monthly hedge fund excess returns onto contemporaneous and lagged market excess returns Rm_t in rolling regressions using up to five years of monthly data,

$$Re_{i,t} = \alpha_i + \beta_{0,i} \cdot Rm_t + \beta_{-1,i} \cdot Rm_{t-1} + e_{i,t}.$$

This approach follows Getmansky et al. (2004) to account for the high autocorrelation of hedge fund returns relative to other asset classes, which potentially reflects illiquidity and return smoothing at the fund level. To proxy for market returns, we use CRSP value-weighted returns in excess of the one-month Treasury bill rate obtained from Ken French's website. Hedge fund excess returns are defined as $Re_{i,t} = R_{i,t} - R_{f,t}$ using the one-month Treasury bill rate to proxy for the risk-free rate $R_{f,t}$. Abnormal returns are defined as,

$$Ra_{i,t} = Re_{i,t} - \hat{\beta}_{0,i} Rm_t - \hat{\beta}_{-1,i} Rm_{t-1}.$$

The estimated betas are backward looking or pre-ranking betas when funds have been in the sample for at least five years. Otherwise, the betas are full sample betas for the amount of time the fund has been in the sample. Some of the regression specifications below control for fund performance by including the estimated rolling alphas $\hat{\alpha}_i$ as control variables. Note that our notation omits the time-variation in the rolling alphas and betas $\hat{\alpha}_{i,t}$, $\hat{\beta}_{0,i,t}$, and $\hat{\beta}_{-1,i,t}$ for simplicity. As in average raw returns and excess returns, the subset of prime-broker-linked hedge funds has similar abnormal returns in relation to the full sample.

5.3 AUM

Table 8 reports the main difference-in-differences regressions for the AUM of hedge funds that use G-SIB prime brokers. Specifications 1 and 2 report the aggregate results by regressing total assets for levered and unlevered funds onto time period dummies and time period dummies interacted with a leverage dummy. The negative coefficient on the interaction term for 2014–2016 indicates that there has been a significant decline in assets of about $50 billion for levered funds relative to unlevered funds in comparison to the 1994–2006 pre-period. Moreover, the coefficients for the interaction terms indicate that assets for levered funds have steadily declined in recent years. Panel B reports the significance of this change from 2010–2013 to 2014–2016. Since the financial crisis, levered funds' assets have declined by about $52 billion relative to unlevered funds, a similar magnitude to the pre-period.

Table 8 builds on these results in specifications 3 to 5 by reporting regressions for fund level AUM. Specification 4 indicates that average assets per fund have declined by about $230 million relative to the 1994–2006 pre-period. Panel B confirms that there has also been a decline of about $140 million when comparing 2010–2013 to 2014–2016. These results are statistically and economically significant. For example, Table 7 indicates that average assets in the prime broker subset are on the order of $250 million. Moreover, specification 5 shows that the results are robust to including controls for fund style, fund age, and fund performance as measured by rolling CAPM alphas. Note also that the coefficients on these control variables have the expected sign. Assets are increasing in fund age and performance, which are z-scored for ease of interpretation. For example, a one–standard deviation increase in age and performance results in a $45 and $22 million increase in assets for the full sample results in Panel A.

Figure 10 illustrates these regression results graphically. The top plot reports total assets for levered versus unlevered funds with a G-SIB prime broker. The difference in green has steadily declined in recent years, consistent with the interaction terms in the regressions. As of 2016, levered funds manage about the same amount of assets as unlevered funds. This is a significant change compared to the years leading up to the financial crisis when levered funds managed over three times as much as unlevered funds. In addition to these aggregate results, Figure 10 also provides a breakdown by reporting the average assets per fund and the total number of funds over time. The results indicate that both the assets per fund and the total number of funds are declining for levered hedge funds relative to unlevered hedge funds, consistent with the hypothesis that regulations impacting G-SIB prime brokers are spilling over and impacting their hedge fund clients.

The results in Table 8 and Figure 10 consider funds using a G-SIB prime broker and then compare levered to unlevered funds. Building on these results, Table 9 and Figure 11 present the analogous analysis for funds that use leverage by comparing funds that use a G-SIB prime broker to funds that do not use a G-SIB prime broker. By focusing on the subset of funds that use leverage, this analysis attempts to isolate the funds that require financing for their strategies and then looks for a differential effect among the funds that also use G-SIB prime brokers. Similar to the previous results, Table 9 and Figure 11 indicate that there has been a significant decrease in total assets for levered funds using a G-SIB prime broker relative to levered funds that do not use a G-SIB prime broker. In contrast, there has not been a decline in fund level assets for levered funds using a G-SIB prime broker relative to levered funds that do not use a G-SIB prime broker. In this case, the decrease in total assets appears to be driven by a decrease in the number of levered funds using G-SIB prime brokers rather than a decrease in fund level assets.

5.4 Abnormal Returns

We now turn to hedge fund performance to provide an additional perspective.[19] The null hypothesis in this case is that post-crisis regulations are making it more difficult for levered hedge funds with G-SIB prime brokers to execute their trading strategies, leading to lower performance. Table 10 reports regressions of monthly fund level abnormal returns onto time period dummies and time period dummies with interaction terms for leverage and G-SIB

[19] The analysis in this section focuses on abnormal returns as measured by the model from Getmansky et al. (2004). In unreported results, we obtain similar findings for excess returns and abnormal returns relative to the CAPM (without a lagged market factor). In addition, we test for changes in risk exposures, including market betas and noise betas from Hu et al. (2013), and idiosyncratic volatility and find little evidence of differential change for leveraged funds with G-SIB prime brokers in recent years.

prime brokers. Panel A reports results for the subset of funds with G-SIB prime brokers, comparing levered versus unlevered funds. The results indicate that levered funds have underperformed unlevered funds by as much as 20 to 30 basis points for the 2010–2013 and 2014–2016 periods on a value-weighted basis. This magnitude is economically large in comparison to the average abnormal of 29 to 30 basis points in the summary statistics table. Moreover, this underperformance is statistically significant and robust to including fixed effects for fund style and controls for fund size. In addition, the negative relationship between fund size and performance is consistent with the literature (Berk and Green, 2004), indicating that a one-standard deviation move in log assets results in a 8 basis point decline in average monthly abnormal returns. The equal-weighted results are less significant but still exhibit the same sign with a negative and significant coefficient on fund size as before. In contrast to the value-weighted results, the equal-weighted results show a significant decline for all funds with G-SIB prime brokers in recent years.

Panel B builds on these results by reporting the analogous regressions for levered funds and compares the funds that use a G-SIB prime broker to funds that do not use a G-SIB prime broker. Similar to the AUM regressions, there is less fund level evidence of an impact when comparing levered funds with a G-SIB prime broker to levered funds that do not use a G-SIB prime broker. As in the equal-weighted results in Panel A, there is a decline in performance in recent years that is significant and large in magnitude.

Figure 12 illustrates these results by plotting fund level monthly abnormal returns as a two-year moving average on a value-weighted and equal-weighted basis. The top subplots compare levered and unlevered funds that use a G-SIB prime broker, similar to Panel A in Table 10. The bottom plots compare funds with and without a G-SIB prime broker that use leverage, similar to Panel B in Table 10. Dashed lines indicate the different time periods used in the regressions. The average difference for each period reported as the flat green line shows the decline in value-weighted abnormal returns for levered funds over time in the top left subplot.

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; this reduces their ability both to participate in basis trades on their own behalf and to provide funding and balance sheet to their clients engaging in basis trades. Consistent with this hypothesis, we document that the implied return on equity on basis trades is substantially lower under Basel III regulation than under Basel II, that the size of hedge funds obtaining leverage from prime brokers associated with G-SIBs has declined relative to hedge funds that use the same prime brokers but do not use leverage, and, finally, that the number of funds obtaining leverage from G-SIB-affiliated prime brokers has declined relative to the number of funds obtaining leverage from other types of prime brokers. 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,[20] while, at the same time, federal bank regulators agreed on a revision to the implementation of the Volcker Rule.[21] 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, such as repo; 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 funding markets, further discouraging them from repo activity. Thus, while the global

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

regulatory community adheres to the provisions of Basel III, basis trades will continue to have a significant impact on regulated institutions' balance sheets, representing a substantive shift in what levels of basis spreads are considered attractive to trade.

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.

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Table 1: Impact of key post-crisis regulations. This table summarizes the impact of key post-crisis regulations that have had direct or indirect impact on cash and derivatives securities involved in the basis trades we focus in this paper, as well as the impact on the associated securities financing transactions.

	Basel III			Dodd-Frank			Other	
	Capital	Leverage Ratio	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				
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 2: 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 3: 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.	0.970	0.358	1.436	0.200
	(0.948)	(0.167)**	(0.558)**	(0.113)*
Crisis	23.782	-0.169	-1.415	-0.268
	(3.743)***	(0.401)	(0.912)	(0.257)
Rule writing	22.175	-0.226	-1.993	-0.159
	(10.784)**	(1.184)	(0.817)**	(0.129)
Rule impl.	23.770	-0.117	-0.989	-0.179
	(11.617)**	(0.442)	(0.767)	(0.170)
Δ Interdealer	2.126	2.095	1.459	1.509
	(0.058)***	(0.102)***	(0.154)***	(0.348)***
Crisis $\times$ Δ Interdealer	-0.492	0.348	0.258	1.039
	(0.120)***	(0.118)***	(0.172)	(0.511)**
Rule writing $\times$ Δ Interdealer	-0.783	-0.499	0.544	0.866
	(0.715)	(0.351)	(0.587)	(0.534)
Rule impl. $\times$ Δ Interdealer	4.160	0.778	0.306	-0.849
	(1.464)***	(0.153)***	(0.377)	(0.487)*
Adj. R^2	0.478	0.886	0.923	0.749
N. obs	39	39	26	39

Table 4: Bank-intermediated trades. This table summarizes the bank-intermediated basis trades considered in this paper, including both legs of the transaction and the funding costs of the trades. A "long" position in a swap is a pay-floating position; a "short" position in a swap is a pay-fixed position.

Trade	Long leg	Short Leg	Funding long	Funding short
U.S. Treasury spreads				
OTR-OFR	Off-the-run Treasury	On-the-run Treasury	Repo; Unsecured for repo haircut	Reverse repo
UST-swap	Treasury	IR swap	Repo; Unsecured for repo haircut	Unsecured for swap margin
Cash-futures	CTD Treasury	Duration-adjusted future	Repo; Unsecured for repo haircut	Unsecured for futures margin
Exchange rates				
CIP	Foreign sovereign; forward exchange swap	Treasury	Repo; Unsecured for repo haircut and swap margin	Reverse repo
Credit risk spreads				
CDS-bond	Corporate bond	SN CDS	Repo; Unsecured for repo haircut	Unsecured for CDS margin
CDX-CDS	CDX	Basket of SN CDS	Unsecured for CDX margin	Unsecured for SN CDS margin

Table 5: 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 6: Balance sheet impact of bank-intermediated trades. This table summarizes the balance sheet impact of the bank-intermediated basis trades considered in this paper. A "long" position in a swap is a pay-floating position; a "short" position in a swap is a pay-fixed position.

Trade	Long leg	Short Leg	Impact long	Impact short
U.S. Treasury spreads				
OTR-OFR	Off-the-run Treasury	On-the-run Treasury	Repo notional; Haircut loan	Reverse repo notional
UST-swap	Treasury	IR swap	Repo notional; Haircut loan	PFE of swap; Margin loan
Cash-futures	CTD Treasury	Duration-adjusted future	Repo notional; Haircut loan	Par value of future; Margin loan
Exchange rates				
CIP	Foreign sovereign; forward exchange swap	Treasury	Repo notional; PFE of swap; Haircut and margin loans	Reverse repo notional
Credit risk spreads				
CDS-bond	Corporate bond	SN CDS	Repo notional; Haircut loan	PFE of swap; Net margin loan
CDX-CDS	CDX	Basket of SN CDS	Upfront; Notional net of PFE of swap; Margin loan	PFE of swap portfolio; Net margin loan

Table 7: Hedge Fund Summary Statistics. This table reports summary statistics for the Lipper TASS data by style from 1994 to 2016 including the number of fund-month observations N, total number of funds, live number of funds, and the average assets under management (AUM), raw return $R_{i,t}$, excess return $Re_{i,t}$, abnormal return $Ra_{i,t}^{lag}$, and beta $\beta^{lag} = \beta_0 + \beta_{-1}$ as well as the average volatility σ, skewness $\mathcal{S}$, and autocorrelation ρ across funds.

Panel A: Hedge Fund Data 1994-2016

Fund Style	N	Total	Live	AUM	Age	$R_{i,t}$	$Re_{i,t}$	$Ra_{i,t}^{lag}$	β^{lag}	σ	$\mathcal{S}$	ρ_1
Long Short Equity	125,913	1,659	276	227.75	53.66	0.73	0.55	0.32	0.50	4.17	-0.08	0.10
Fund of Funds	156,365	2,212	456	197.51	49.23	0.30	0.16	0.04	0.28	2.22	-0.85	0.20
Event Driven	35,675	446	73	287.32	56.75	0.71	0.51	0.34	0.34	2.52	-0.53	0.23
Emerging Markets	30,996	398	87	162.80	53.36	0.81	0.65	0.29	0.66	5.33	-0.46	0.19
Multi-Strategy	40,692	655	126	314.29	44.76	0.56	0.47	0.35	0.19	2.33	-0.48	0.15
Equity Market Neutral	19,050	282	33	286.43	45.32	0.48	0.30	0.26	0.09	2.07	-0.16	0.10
Other	19,034	291	99	309.00	46.35	0.69	0.58	0.46	0.16	2.43	-0.74	0.26
Global Macro	17,992	278	42	449.47	47.68	0.68	0.53	0.43	0.15	3.25	0.11	0.07
Convertible Arbitrage	12,140	165	12	206.50	50.56	0.51	0.30	0.20	0.18	2.44	-0.71	0.28
Fixed Income Arbitrage	15,886	210	22	390.31	53.09	0.55	0.36	0.33	0.05	2.06	-1.25	0.19
Undefined	76,044	933	744	199.31	46.57	0.82	0.78	0.72	0.06	1.56	-0.48	0.13
Dedicated Short Bias	1,621	27	1	47.40	36.50	0.11	-0.14	0.29	-1.01	5.86	0.29	0.09
Options Strategy	1,510	18	3	433.45	52.75	0.56	0.43	0.33	0.11	2.91	-0.49	0.12
Managed Futures	353	4	3	105.89	51.55	0.41	0.32	0.18	0.34	4.15	0.33	-0.02
All	553,271	7,578	1,977	238.05	50.09	0.59	0.45	0.30	0.29	2.81	-0.50	0.16

Panel B: Prime Broker Subset 1994-2016

Fund Style	N	Total	Live	AUM	Age	$R_{i,t}$	$Re_{i,t}$	$Ra_{i,t}^{lag}$	β^{lag}	σ	$\mathcal{S}$	ρ_1
Long Short Equity	101,064	1,327	197	229.36	54.01	0.74	0.56	0.35	0.49	4.23	-0.04	0.10
Fund of Funds	34,280	503	97	177.88	47.46	0.31	0.16	0.01	0.29	2.59	-0.64	0.16
Event Driven	27,991	345	56	249.73	57.29	0.71	0.51	0.34	0.33	2.46	-0.47	0.22
Emerging Markets	19,335	247	52	142.73	52.94	0.75	0.60	0.27	0.66	5.13	-0.43	0.18
Multi-Strategy	17,812	249	55	390.49	51.23	0.53	0.40	0.26	0.24	3.09	-0.37	0.15
Equity Market Neutral	14,214	199	18	283.89	47.08	0.46	0.28	0.23	0.09	2.20	-0.19	0.09
Other	11,109	156	52	355.02	50.83	0.69	0.58	0.46	0.16	2.64	-1.00	0.26
Global Macro	9,972	138	19	348.59	52.30	0.67	0.52	0.40	0.20	3.29	0.22	0.05
Convertible Arbitrage	9,295	132	7	232.60	48.00	0.51	0.31	0.23	0.17	2.58	-0.68	0.27
Fixed Income Arbitrage	8,984	123	11	310.60	51.04	0.58	0.39	0.35	0.08	2.27	-0.95	0.21
Undefined	5,691	74	60	232.83	43.44	0.63	0.60	0.40	0.18	2.21	-0.44	0.16
Dedicated Short Bias	1,090	19	0	47.05	33.93	0.47	0.22	0.59	-0.95	5.95	0.24	0.08
Options Strategy	1,069	13	2	569.05	51.76	0.47	0.34	0.29	0.03	3.03	-0.56	0.11
Managed Futures	216	2	1	135.68	58.95	0.56	0.45	0.41	0.31	4.14	0.37	0.01
All	262,122	3,527	627	245.71	52.03	0.63	0.46	0.29	0.36	3.41	-0.32	0.15

Table 8: AUM for Funds with a G-SIB Prime Broker This table reports difference-in-differences regressions for AUM comparing levered funds to unlevered funds that use a G-SIB prime broker. Specifications 1 and 2 report aggregate results. Specifications 3 to 6 report fund level results. Panel A reports full sample results from 1994 to 2016. Panel B reports the more recent period from 2010 to 2016.

Panel A: 1994-2016	(1)	(2)	(3)	(4)	(5)
2007-2009	117.00***	84.78***	106.44***	137.45***	121.79***
	(30.05)	(11.75)	(19.40)	(28.07)	(28.10)
2010-2013	73.41***	72.64***	102.36***	164.34***	132.40***
	(17.46)	(7.27)	(24.17)	(39.78)	(37.46)
2014-2016	44.40***	69.55***	224.01***	372.61***	311.81***
	(14.32)	(8.13)	(41.75)	(79.43)	(77.09)
Leverage		57.78**		71.91***	57.82***
		(24.14)		(20.85)	(21.23)
2007-2009 x Leverage		64.43*		-43.15	-43.35
		(34.90)		(33.66)	(33.54)
2010-2013 x Leverage		1.56		-90.98*	-95.26**
		(25.48)		(47.77)	(45.34)
2014-2016 x Leverage		-50.30*		-233.74***	-238.94***
		(26.16)		(89.90)	(86.11)
Age					45.01***
					(16.78)
Alpha					22.41**
					(8.74)
Observations	550	550	178855	178855	178855
Adjusted R^2	0.341	0.548	0.011	0.014	0.033
Fixed Effects			No	No	Style
Sample	Total (bn)	Total (bn)	Fund (mn)	Fund (mn)	Fund (mn)

Newey-West with 12 lags for Total AUM. Clustered by firm and month for Fund AUM.
Standard errors in parentheses. * $p<.10$, ** $p<.05$, *** $p<.01$

Panel B: 2010-2016	(1)	(2)	(3)	(4)	(5)
2014-2016	-29.02**	-3.09	121.65***	208.27***	187.49***
	(12.45)	(3.99)	(26.70)	(50.39)	(52.11)
Leverage		59.34***		-19.07	-55.34
		(8.21)		(47.01)	(45.66)
2014-2016 x Leverage		-51.86***		-142.77**	-129.73**
		(13.83)		(56.73)	(54.40)
Age					43.33
					(28.22)
Alpha					54.91**
					(21.35)
Observations	168	168	56669	56669	56669
Adjusted R^2	0.222	0.785	0.005	0.008	0.053
Fixed Effects			No	No	Style
Sample	Total (bn)	Total (bn)	Fund (mn)	Fund (mn)	Fund (mn)

Newey-West with 12 lags for Total AUM. Clustered by firm and month for Fund AUM.
Standard errors in parentheses. * $p<.10$, ** $p<.05$, *** $p<.01$

Table 9: AUM for Levered Funds This table reports difference-in-differences regressions for AUM comparing levered funds that use a G-SIB prime broker to levered funds that do not use a G-SIB prime broker. Specifications 1 and 2 report aggregate results. Specifications 3 to 6 report fund level results. Panel A reports full sample results from 1994 to 2016. Panel B reports the more recent period from 2010 to 2016.

Panel A: 1994-2016	(1)	(2)	(3)	(4)	(5)
2007-2009	87.92**	26.64***	85.12***	48.51*	29.17
	(38.76)	(10.25)	(19.65)	(28.06)	(26.99)
2010-2013	38.79	3.38	54.73**	-4.36	-26.83
	(25.68)	(7.76)	(23.05)	(33.13)	(31.73)
2014-2016	6.22	-6.81	114.28***	42.45	-6.18
	(20.93)	(7.99)	(34.65)	(49.02)	(47.13)
G-SIB PB		52.06**		41.81	35.77
		(24.25)		(29.00)	(29.98)
2007-2009 x G-SIB PB		122.57***		45.79	49.72
		(34.42)		(33.73)	(32.97)
2010-2013 x G-SIB PB		70.81***		77.72*	64.32
		(25.63)		(42.51)	(40.59)
2014-2016 x G-SIB PB		26.06		96.42	71.09
		(26.11)		(64.83)	(62.33)
Age					61.82***
					(14.17)
Alpha					27.15***
					(8.56)
Observations	550	550	166508	166508	166508
Adjusted R^2	0.161	0.565	0.004	0.008	0.033
Fixed Effects			No	No	Style
Sample	Total (bn)	Total (bn)	Fund (mn)	Fund (mn)	Fund (mn)

Newey-West with 12 lags for Total AUM. Clustered by firm and month for Fund AUM.
Standard errors in parentheses. * p<.10, ** p<.05, *** p<.01

Panel B: 2010-2016	(1)	(2)	(3)	(4)	(5)
2014-2016	-32.57	-10.19***	59.55***	46.81	36.22
	(26.85)	(3.39)	(21.78)	(30.75)	(30.08)
G-SIB PB		122.87***		119.53***	90.11*
		(8.33)		(41.26)	(46.86)
2014-2016 x G-SIB PB		-44.75***		18.70	10.49
		(13.67)		(41.16)	(39.73)
Age					66.44***
					(21.76)
Alpha					60.05***
					(16.50)
Observations	168	168	48326	48326	48326
Adjusted R^2	0.0743	0.942	0.002	0.009	0.052
Fixed Effects			No	No	Style
Sample	Total (bn)	Total (bn)	Fund (mn)	Fund (mn)	Fund (mn)

Newey-West with 12 lags for Total AUM. Clustered by firm and month for Fund AUM.
Standard errors in parentheses. * p<.10, ** p<.05, *** p<.01

Table 10: Hedge Fund Abnormal Returns This table reports difference-in-difference regressions for fund level monthly abnormal returns. Panel A compares levered and unlevered funds that use a G-SIB prime broker. Panel B compares funds with and without a G-SIB prime broker that use leverage.

Panel A: G-SIB PB Funds	(1)	(2)	(3)	(4)	(5)	(6)
2007-2009	-0.10	-0.03	0.04	0.03	0.05	0.07
	(0.23)	(0.22)	(0.21)	(0.24)	(0.22)	(0.22)
2010-2013	-0.24	-0.09	-0.07	-0.47***	-0.44***	-0.43***
	(0.15)	(0.15)	(0.15)	(0.13)	(0.13)	(0.13)
2014-2016	-0.26**	-0.09	-0.06	-0.51***	-0.43***	-0.41***
	(0.13)	(0.10)	(0.12)	(0.14)	(0.13)	(0.14)
Leverage		0.11	0.14		0.08*	0.07
		(0.09)	(0.09)		(0.05)	(0.05)
2007-2009 x Leverage		-0.10	-0.13		-0.02	-0.02
		(0.13)	(0.12)		(0.08)	(0.08)
2010-2013 x Leverage		-0.21	-0.22*		-0.05	-0.04
		(0.14)	(0.13)		(0.07)	(0.07)
2014-2016 x Leverage		-0.28**	-0.32**		-0.13	-0.13
		(0.12)	(0.12)		(0.08)	(0.09)
ln(AUM)			-0.08**			-0.08***
			(0.03)			(0.02)
Observations	178855	178855	178855	178855	178855	178855
Adjusted R^2	0.001	0.001	0.004	0.004	0.004	0.006
Fixed Effects	No	No	Style	No	No	Style
Weighting	VW	VW	VW	EW	EW	EW

Standard errors in parentheses clustered by firm and month.
* p<.10, ** p<.05, *** p<.01

Panel B: Levered Funds	(1)	(2)	(3)	(4)	(5)	(6)
2007-2009	-0.07	0.09	0.10	0.03	-0.00	0.01
	(0.24)	(0.24)	(0.24)	(0.24)	(0.22)	(0.22)
2010-2013	-0.25*	-0.14	-0.15	-0.44***	-0.36**	-0.36**
	(0.14)	(0.15)	(0.15)	(0.13)	(0.14)	(0.14)
2014-2016	-0.34**	-0.27*	-0.29*	-0.51***	-0.39***	-0.40***
	(0.14)	(0.15)	(0.17)	(0.13)	(0.13)	(0.13)
G-SIB PB		0.05	0.09		0.12**	0.09*
		(0.10)	(0.09)		(0.05)	(0.05)
2007-2009 x G-SIB PB		-0.20	-0.20		0.03	0.03
		(0.14)	(0.14)		(0.10)	(0.10)
2010-2013 x G-SIB PB		-0.15	-0.14		-0.13	-0.12
		(0.15)	(0.15)		(0.10)	(0.10)
2014-2016 x G-SIB PB		-0.09	-0.09		-0.17*	-0.15
		(0.17)	(0.17)		(0.09)	(0.09)
ln(AUM)			-0.07**			-0.07***
			(0.03)			(0.02)
Observations	166508	166508	166508	166508	166508	166508
Adjusted R^2	0.001	0.001	0.003	0.003	0.004	0.005
Fixed Effects	No	No	Style	No	No	Style
Weighting	VW	VW	VW	EW	EW	EW

Standard errors in parentheses clustered by firm and month.
* p<.10, ** p<.05, *** p<.01

Figure 1. Basis Spreads. This figure shows the time series evolution of basis trades for 10 year U.S. nominal Treasury trades, 1 year CIP, and U.S. credit markets. See Table 4 for a summary of the components of the trades and Table A.1 for the data sources.

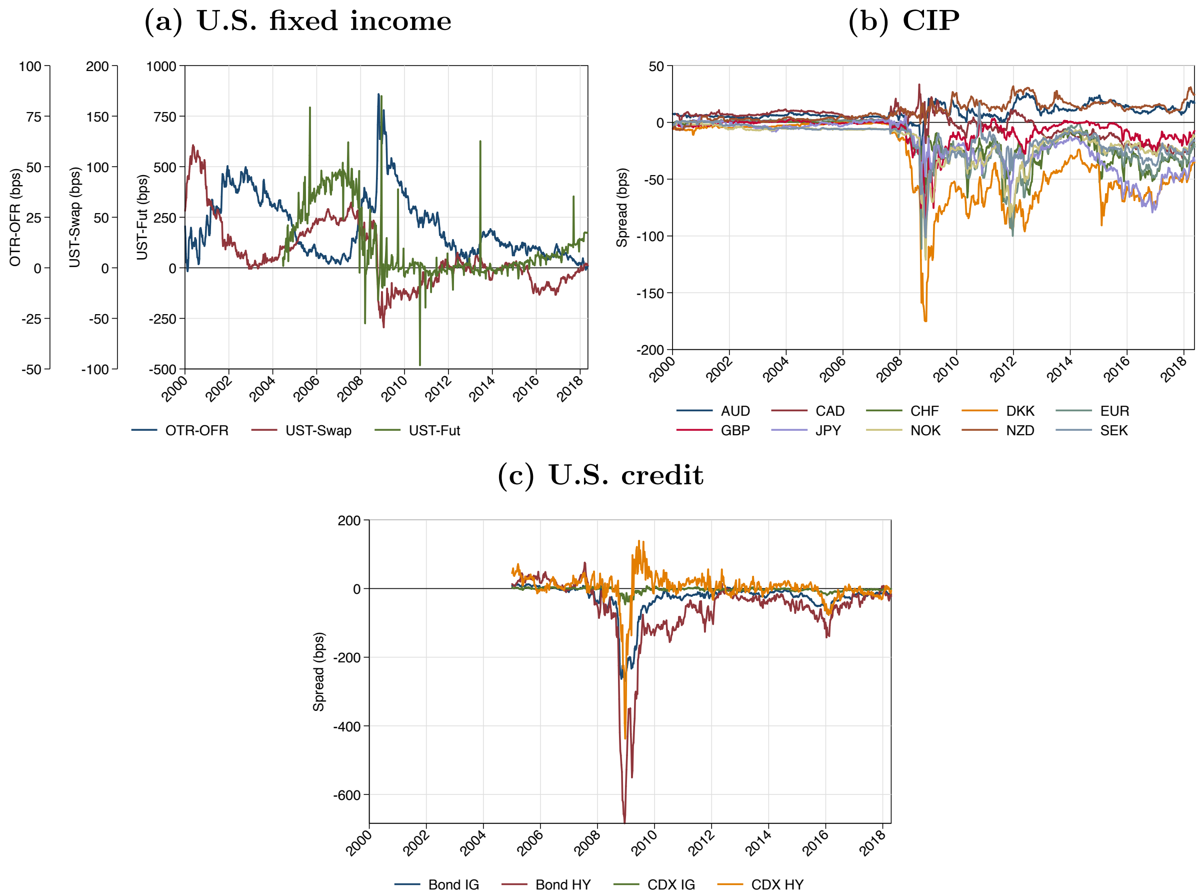
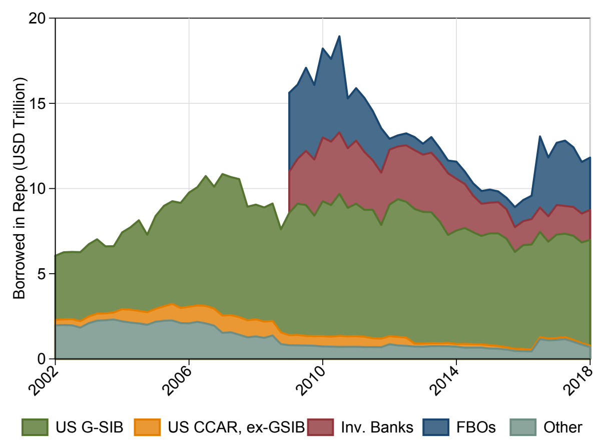


Figure 2. Securities Funded Through Repurchase Agreements. This figure shows the total amount of securities sold under agreements to repurchase (Figure 2a) and the total amount of securities bought under agreement to resell (Figure 2b) by bank type. "U.S. G-SIBs" are U.S. bank holding companies that 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

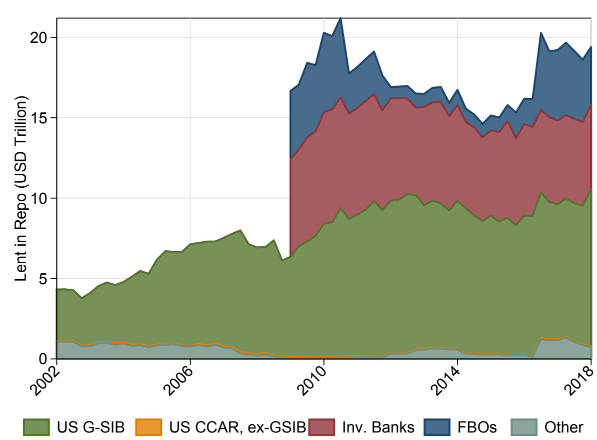


Figure 3. Gross Notional by Risk Category. This figure shows the gross notional outstanding in USD equivalent for interest rate, foreign exchange, credit, equity and commodity over-the-counter derivatives. Source: BIS OTC semi-annual derivative statistics.

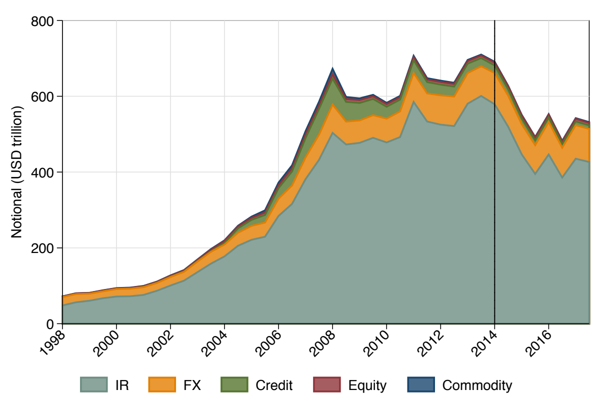
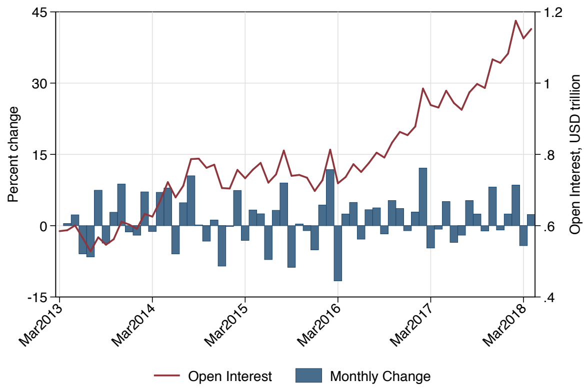


Figure 4. Open Interest in OTC and Exchange-Traded Derivatives. This figure shows the monthly change in total open interest in Treasury futures (4a) and in USD interest rate swaps (4b). Treasury futures open interest includes open interest in 2 year, 5 year, 10 year, and ultra-10 year Treasury futures. 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

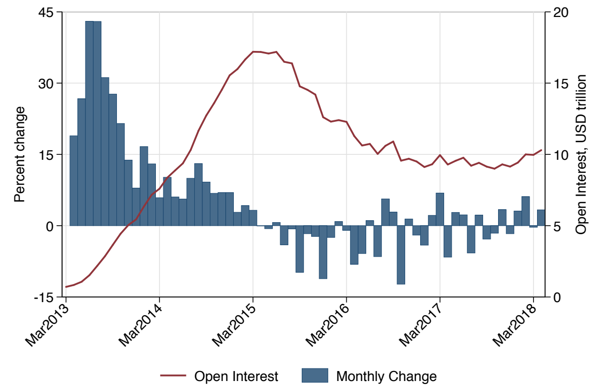
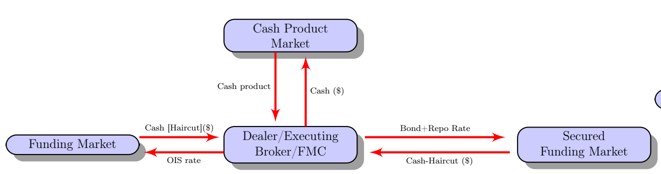
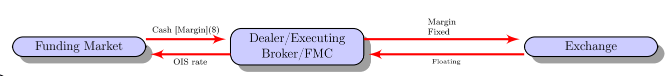


Figure 5. Trade Schematics. This figure shows the mechanics of a long cash-product position, an exchange-traded traded derivative position, a bilateral OTC derivative position, and a centrally-cleared OTC derivative position.

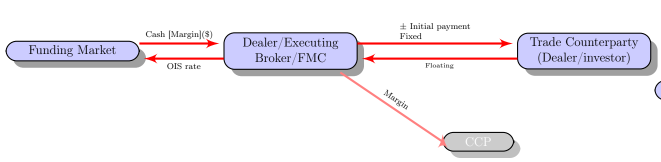
(a) Cash-product



(b) Exchange-traded



(c) OTC, cleared



(d) OTC, bilateral

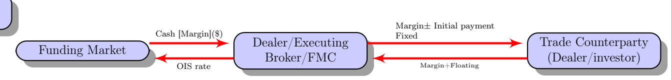


Figure 6. Funding Rates. This figure shows the time series evolution of representative interest rates for repurchase agreements collateralized by Treasury securities, sovereign bonds and U.S. corporate bonds, and unsecured funding rates. See Table A.1 for the data sources.

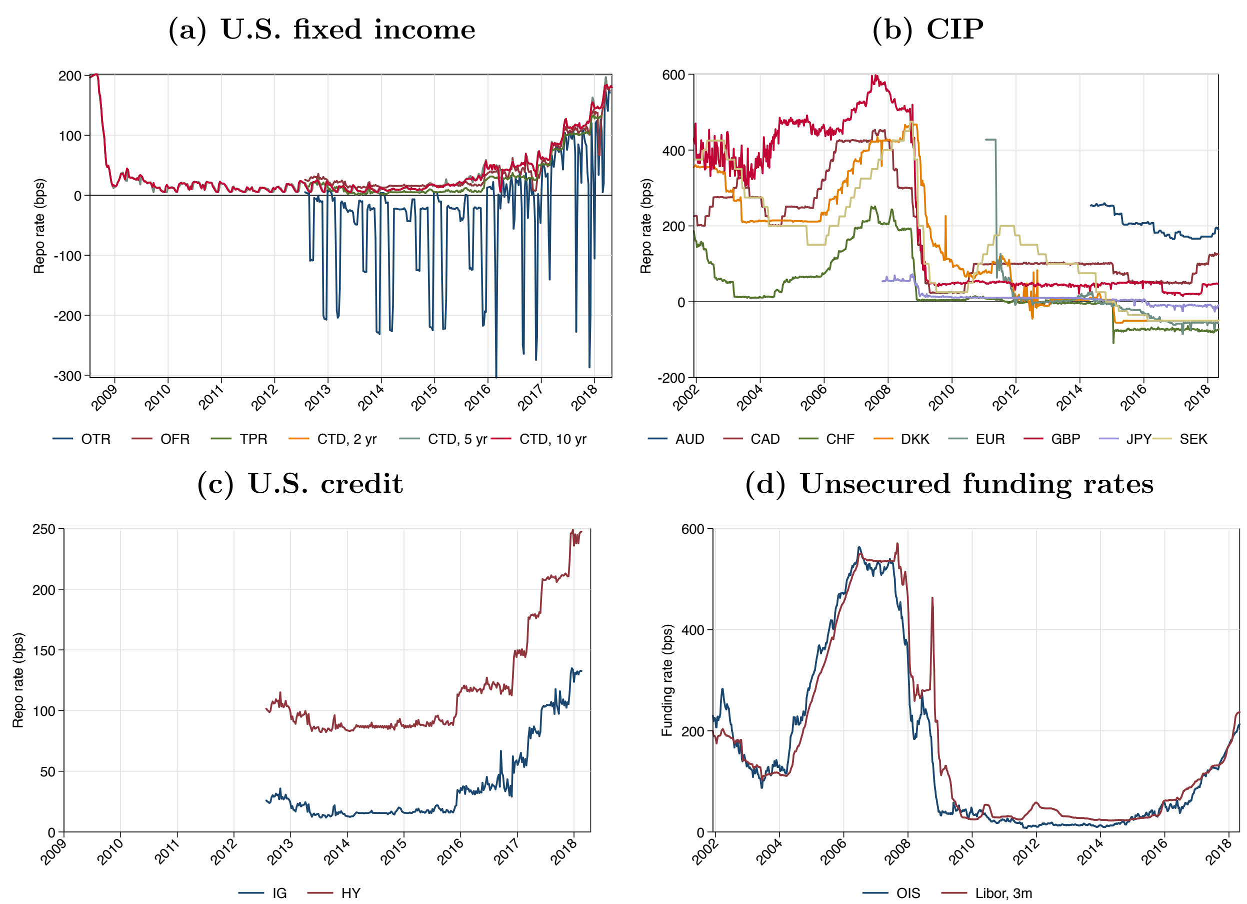


Figure 7. Margins and Upfronts. This figure shows the time series evolution of the margin on 10 year Treasury futures (Figure 7a) and of the upfront on the single-name baskets underlying the CDX.NA.IG and CDX.NA.HY indices (Figure 7b). Source: CME, Markit.

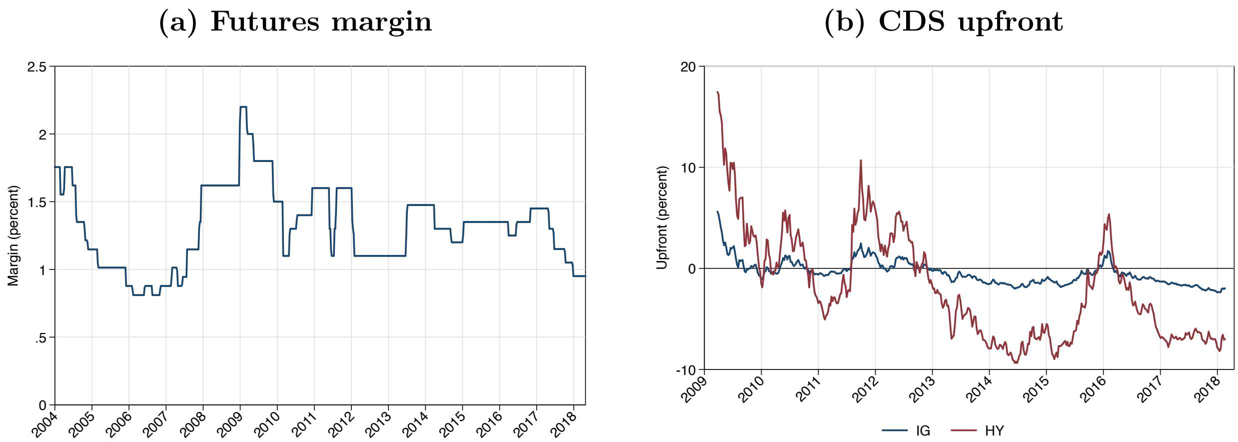


Figure 8. Return on Equity. This figure shows the time series evolution of return-on-equity (ROE) for 10 year U.S. nominal Treasury trades, 1 year CIP, and U.S. credit markets under the assumptions that a risk-weighted capital ratio of 3% binds for the full sample (left column) and that a supplementary leverage ratio of 6% binds for the full sample (right column). See Table A.1 for the data sources.

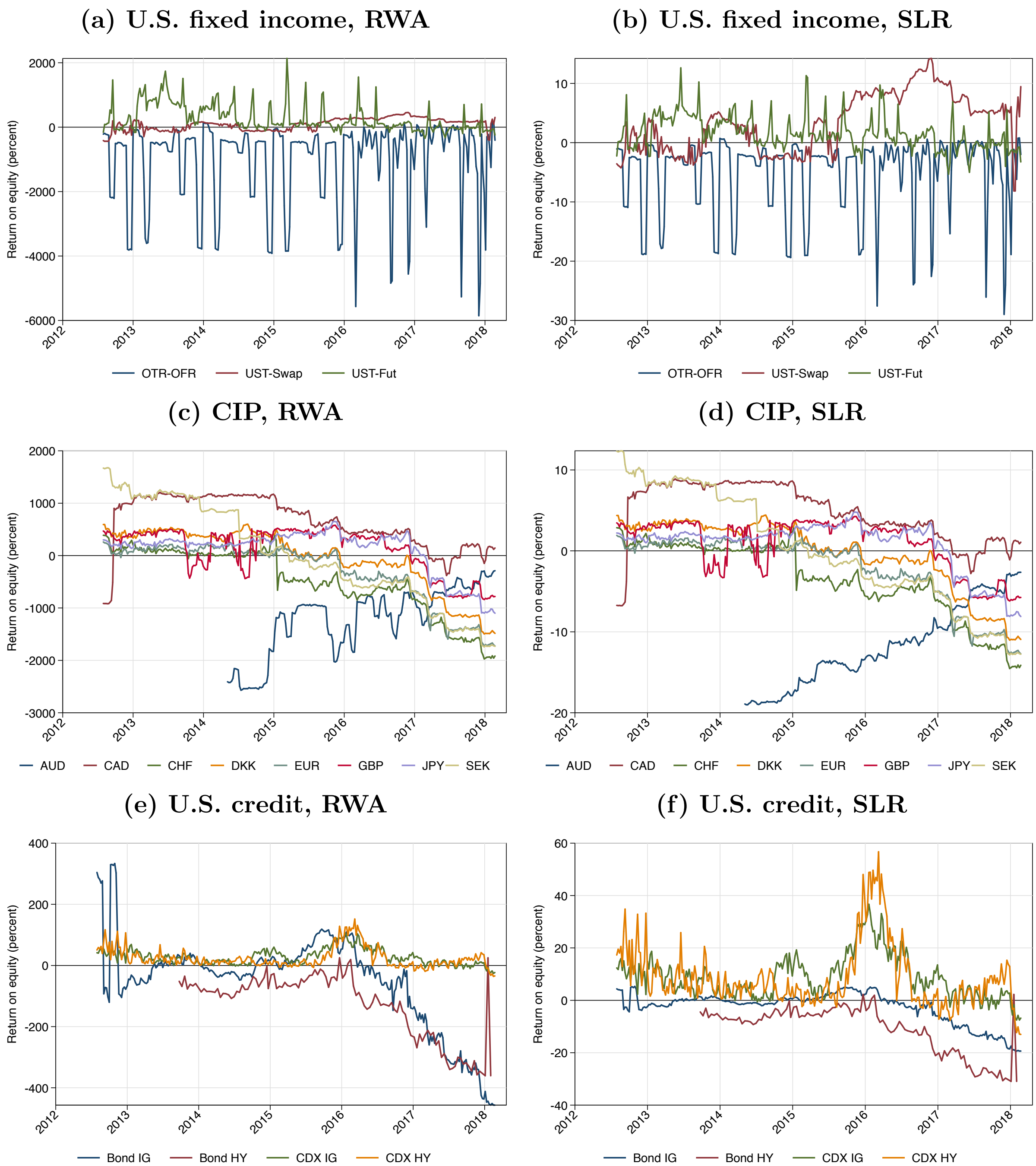
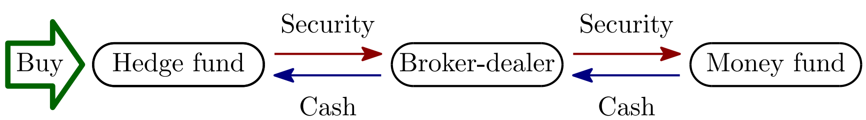


Figure 9. Prime broker services. This figure illustrates two types of services traditionally provided by prime brokers. Figure 9a illustrates an example of credit intermediation (matched-book repo) where the prime broker lends cash to the hedge fund to finance a long position and rehypothecates the collateral in a repo with a money market fund. Figure 9b 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

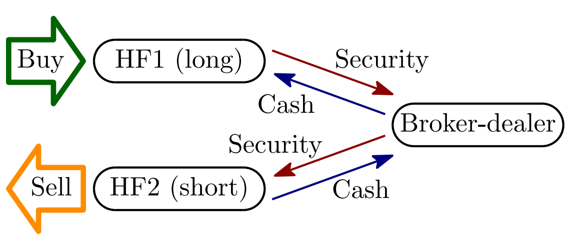


Figure 10. AUM for Funds with a G-SIB Prime Broker. The top figure reports the total AUM for hedge funds that use a G-SIB prime broker comparing funds that use leverage to funds that do not use leverage. The bottom figures report the average assets per fund over time and the total number of funds over time for each of the categories. The difference between funds that use leverage versus funds that do not use leverage is reported in green with the flat lines indicating the average differences over the time periods.

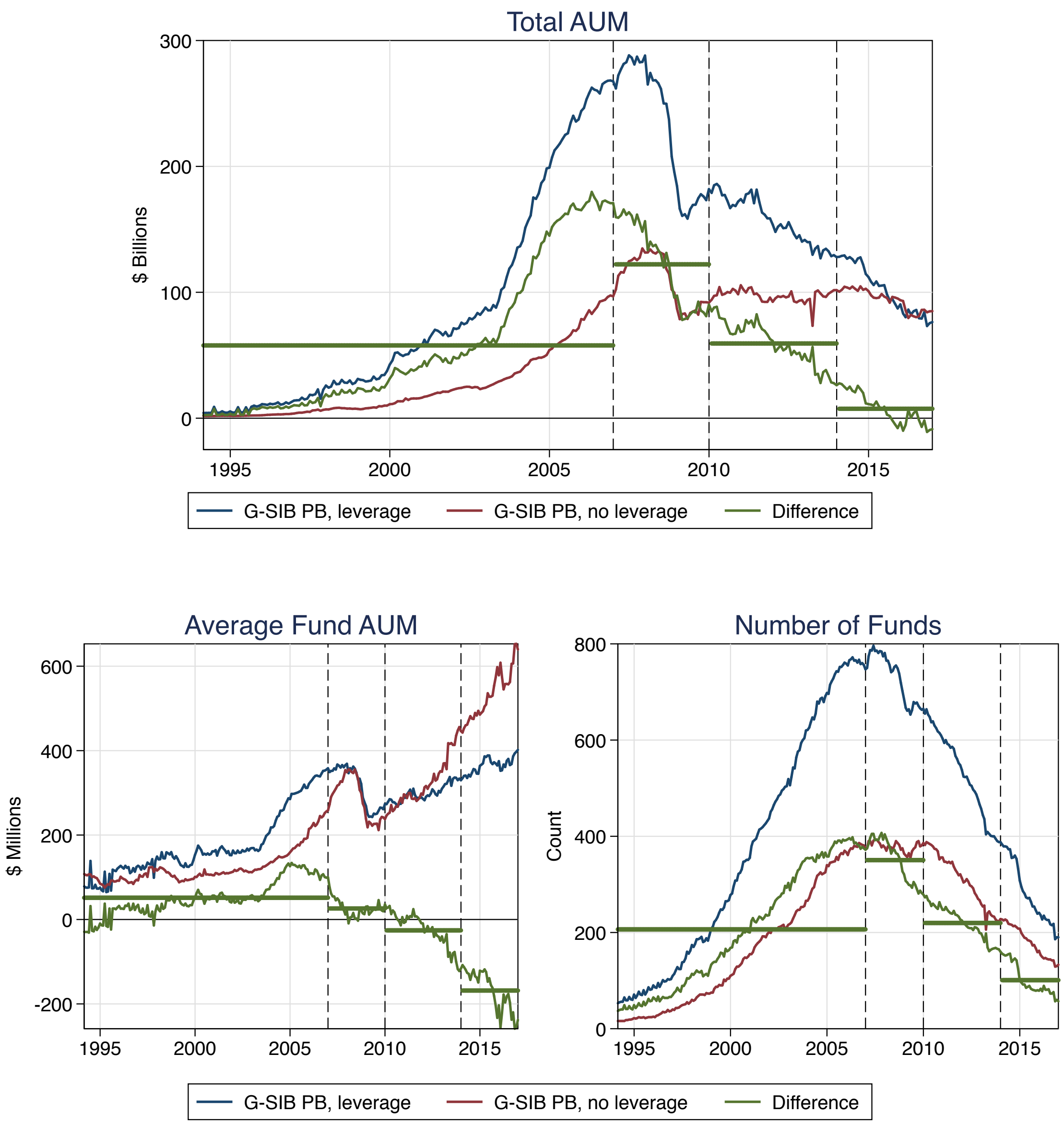


Figure 11. AUM for Levered Funds. This figure is analogous to Figure 10 comparing levered funds that use a G-SIB prime broker to levered funds that do not use a G-SIB prime broker. As before, there has been a significant decline in aggregate assets for levered funds that use G-SIB prime brokers relative to the comparison group. In contrast to the previous results, there has not been a decline in fund level assets, which potentially highlights an interesting difference in the way that regulation is potentially affecting levered funds with G-SIB prime brokers.

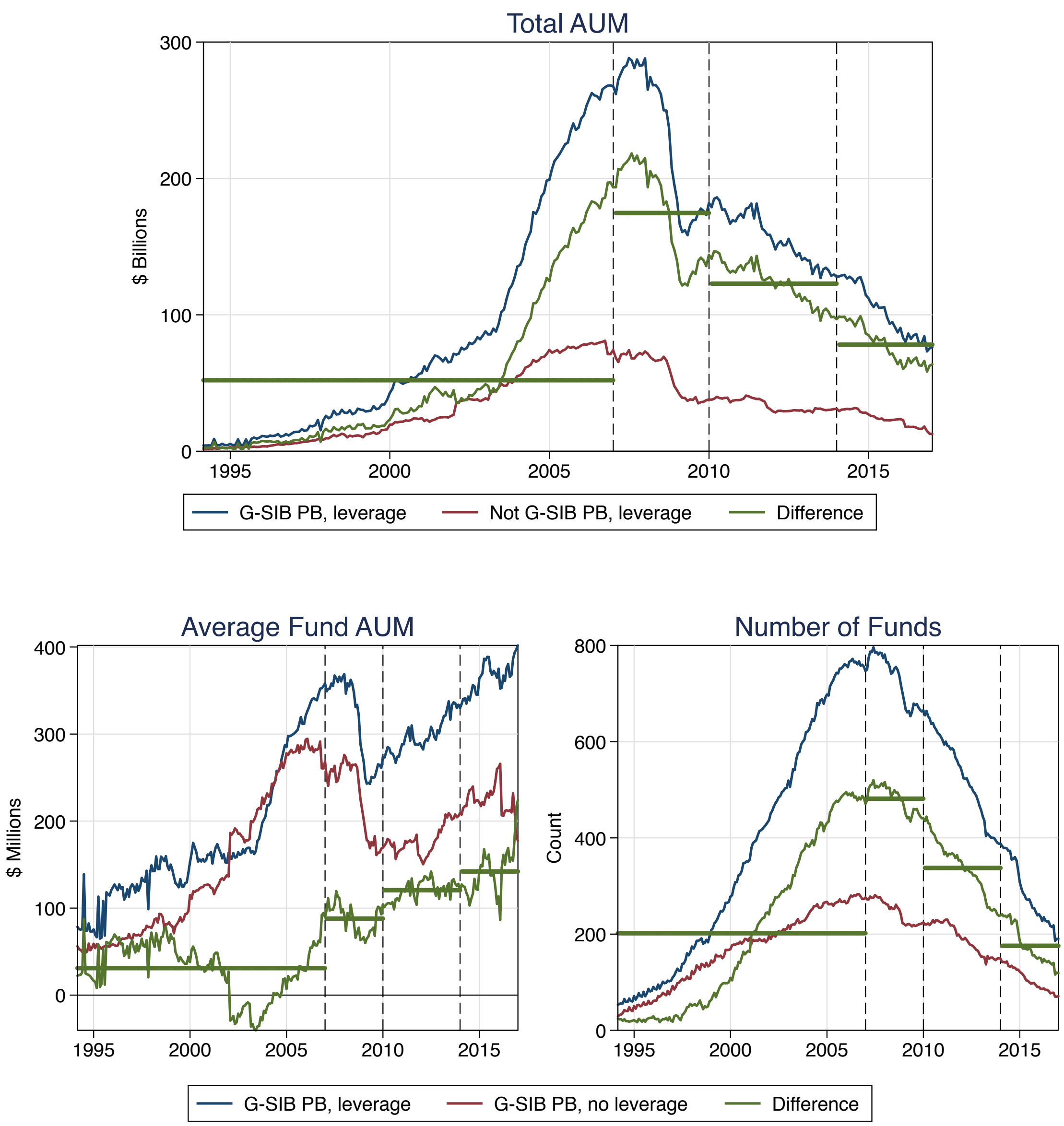
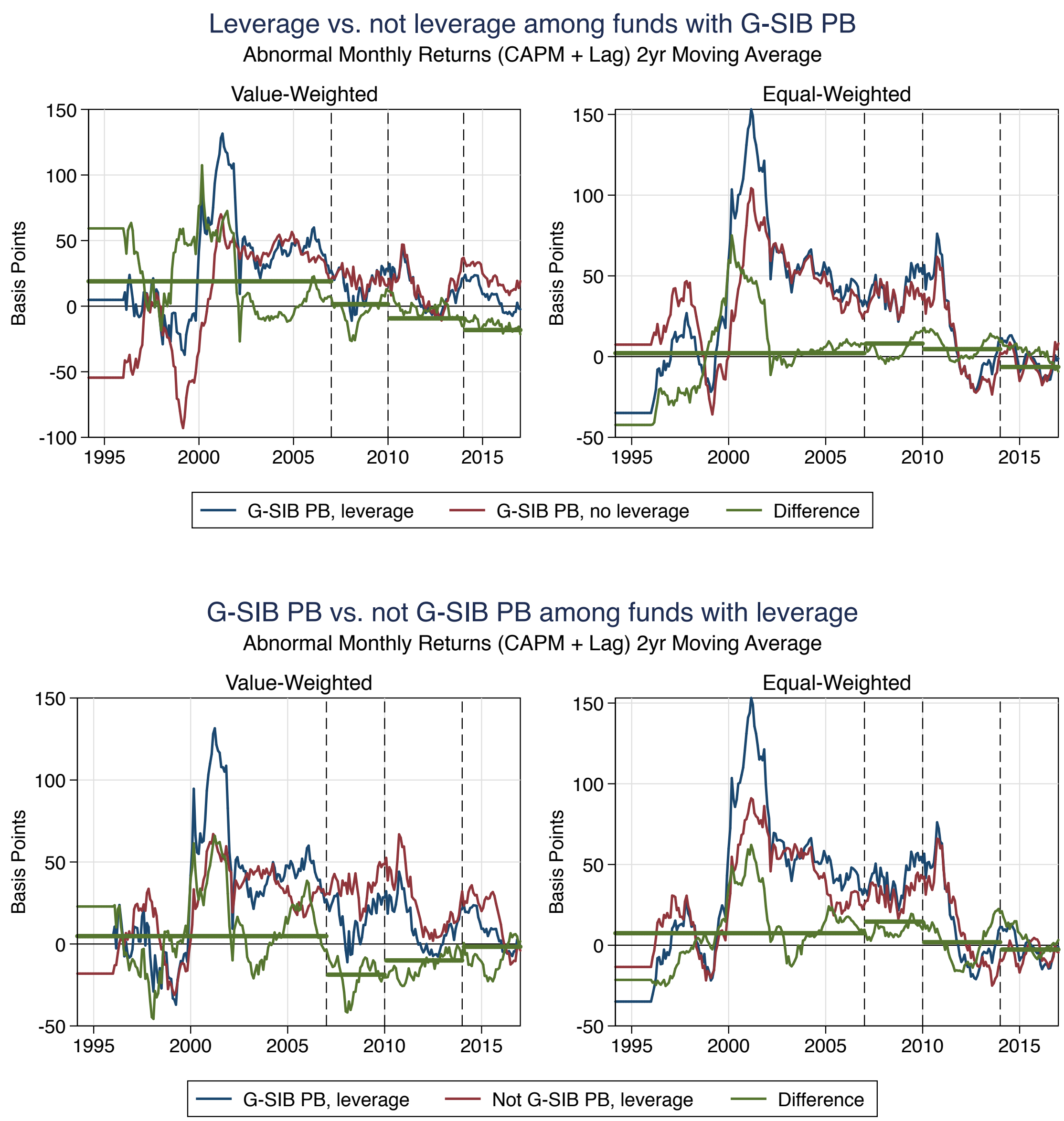


Figure 12. Hedge Fund Abnormal Returns. This figure reports fund level monthly abnormal returns as a two-year moving average on an equal-weighted and value-weighted basis. The top subplots compare levered and unlevered funds that use a G-SIB prime broker. The bottom plots compare funds with and without a G-SIB prime broker that use leverage. Dashed lines indicate the different time periods used in the regressions. The average difference for each period is reported as the flat green line.



A Derivatives Details

A.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.2 lists the PFE factor by asset class and maturity.

A.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.3 lists the standardized initial margin schedule by asset class.

Table A.1: Data Sources

Source	Data
Bloomberg	IRS, ZC Inflation, 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: 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.3: 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

Figure A.1. Hedge Fund Total AUM in Lipper TASS Database. This figure reports the total AUM for all funds in the TASS database relative to the total AUM for the funds in the prime broker subset, the levered funds that use a G-SIB prime broker, and the unlevered funds that use a G-SIB prime broker. The sharp drop and reversal in total AUM in March 2013 is driven by funds in the undefined category which are less frequent in the prime broker subset.