Post-Crisis Bank Regulations and Financial Market Liquidity

Baffi Lecture

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Dedicated to Gertrude

Contents

Preface

This is the manuscript of the Baffi Lecture that I delivered at Banca d'Italia in September 2017. I address the implications for financial-market liquidity of post-crisis capital and failure-resolution rules for systemically important banks. I focus especially on over-the-counter (OTC) markets, which handle most of the world's trade in bonds, repos, swaps, commodities, and foreign exchange. The bulk of trade in these OTC markets is intermediated by roughly 15 large dealers that are regulated as banks or broker-dealer subsidiaries of bank holding companies. For the purpose of this lecture, I therefore make little distinction between "banks" and "dealers." Many small dealers are not affiliated with banks and come under different capital and failure-resolution regulations than those considered here. I simply neglect those smaller firms here, although they are important for other concerns. I also focus on the efficiency of traded financial markets, and not on conventional bank lending markets.

My main subject is not financial stability, and I am not addressing appropriate regulatory minimum levels of bank capital. Nevertheless, the form of regulatory capital requirements does play a significant role in the analysis, especially through the

impact of the leverage ratio rule. One of the implications of my analysis is that bank capital levels could actually be pushed higher while still improving the liquidity of markets for safe assets such as low-risk fixed-income instruments, including repos. This could be achieved by relaxing the leverage-ratio rule and increasing risk-based capital requirements. That is, the current rules do not place us close to the efficient frontier of potential levels of market efficiency and financial stability.

I will show that post-crisis capital regulations and new failure-resolution rules increase the funding costs that are borne by bank shareholders, and thus the cost to buy-side firms for access to space on the balance sheets of large banks. Another policy implication is therefore the encouragement of market infrastructure and trading methods that reduce the amount of space on bank balance sheets that is needed to conduct a given amount of trade.

Darrell Duffie
Stanford University, March, 2018.

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The Cost of Bank Balance Sheet Space

Space on the balance sheets of major dealer banks is much more expensive than before the Great Financial Crisis of 2007-2009. Increased regulatory capital requirements and much higher bank funding costs have added significant frictions to some important over-the-counter markets, especially those requiring collateral or involving the intermediation of low-risk assets. Pre-crisis, banks did not internalize the systemic risk associated with their excessively large balance sheets.

The higher cost of access to liquidity from large banks does not necessarily mean that there was "too much liquidity" before the crisis. Market liquidity is good, not bad. In the post-crisis environment, market forces and regulatory policies can improve liquidity by using bank balance sheets more sparingly. For example, banks should in some cases be disintermediated with greater use of all-to-all markets.

An important theme of this book is that the increased reluctance by big banks to use their balance sheets for intermediation is in many cases caused by increased funding costs that have nothing to do with regulatory capital requirements. Now that the creditors of big banks are less likely to be bailed out with government capital, they are requiring much higher credit spreads. Using models and evidence, I show that bank credits spreads set a lower bound on the extra return (above and beyond the fair market return) that banks must earn on their trading activities to compensate their shareholders for the use of their balance sheets. This frictional wedge on trade applies even if there are no regulatory capital requirements.

This chapter lays out the main ideas of the book, based largely on the concept of debt overhang. Chapter 2 goes into more depth regarding the implications of the leverage ratio rule for the intermediation of safe assets such as treasury repos. Chapter 3 explains the impact of funding costs on bank shareholders, with an illustrative case study of the implications for arbitrage bounds on the cross-currency basis. Chapter 4 discusses how markets can be redesigned in various ways to reduce the amount of bank balance sheet space required to handle a given amount of trade. Some of the recommended changes in market design will promote greater competition or netting efficiencies, making greater use of multilateral trade platforms and financial market infrastructure.

1.1 The setting

Dealers provide liquidity to financial markets by offering to buy what others wish to sell, and to sell what others wish to buy. Dealer intermediation is especially important in over-the-counter (OTC) markets, where ultimate investors may find it difficult or slow to arrange trades directly with each other. Most trade in bond, swap, and foreign exchange markets is intermediated by a small number of large dealer banks.

Before the financial crisis, dealers kept large market-making inventories and were ready to quickly make additional space on their balance sheets for clients who wished to liquidate their asset positions. Capital requirements, however, were too low. By absorbing so much risk relative to their capital, most major dealers were a menace to financial stability. When some of the largest U.S. dealers failed or had to be bailed out in 2008, legislators and regulators resolved to restore financial stability with significant increases in capital and liquidity requirements. These new rules reduced the socially inefficient incentives of large dealers to take risk. These poor incentives were caused mainly by being "too big to fail."

The too-big-to-fail incentives operated through two channels. First, there was the moral hazard of the managers and shareholders of large dealer banks, who knew that the insolvency risks they were taking were reduced by the likelihood that the government would step in with new capital when necessary to avert failure. Governments were frightened by the prospect of failure

spillover costs to the broader economy. Second, even if there was no moral hazard, the dealer banks were able to issue debt at interest rates that were artificially lowered through the expectations by creditors of government bailouts. The reduced debt funding costs allowed the shareholders of the big banks to earn positive returns on balance-sheet expanding trading strategies that would have generated negative shareholder returns if debt funding costs had reflected the expected default losses and risks that would have applied in the absence of government support.

Figure 1.1.1 illustrates the central role of dealers in bilateral OTC markets. Here, all of the trading needs of buy-side firms, shown in blue, are handled by dealers, shown in green. As depicted, dealers can also balance their positions by trading with each other. Wang (2017) shows that this core-periphery bilateral market structure arises naturally from the benefit to dealers of netting their buy and sell order flows, thus lowering their balance-sheet costs. Although the most efficient netting is obtained with a single monopolistic dealer, the equilibrium number of dealers is counterbalanced by the desire of buy-side firms for competition among dealers.

Chapter 4 considers hybrid market structures involving trade platforms on which buy-side firms can request quotes from multiple dealers. Although request-for-quote platforms improve competition relative to the fully bilateral trade arrangements shown in Figure 1.1.1, current trade-platform markets are inefficiently fragmented and usually do not permit all-to-all trade competi-
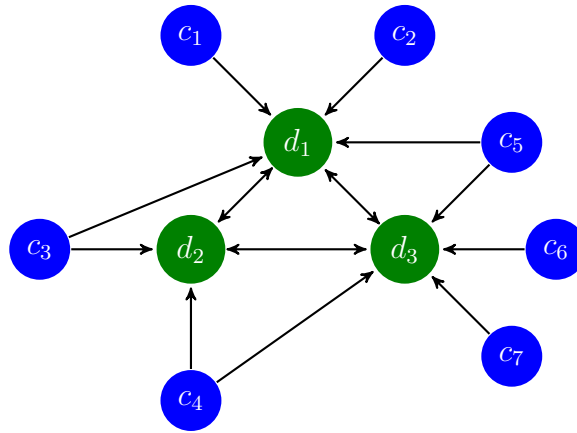
Figure 1.1.1: Schematic of bilateral trade in an OTC market.

tion. Even on relatively competitive all-to-all exchange-based markets, large dealers are a significant source of immediacy, as first modeled by Grossman and Miller (1988).

He, Kelly and Manela (2017) provide empirical evidence that risk premia across a range of asset markets depend significantly on dealer capital structure. In broad terms, when dealers are better capitalized, asset risk premia are lower. We will explore causes for this dependence.

1.2 Debt overhang has risen

Post-crisis financial reform has impinged on the liquidity of some key financial markets through the effect of debt overhang, a concept first explained by Myers (1977).

Figure 1.2.1 illustrates an example of debt overhang in which a bank expands its market-making inventory with funding provided by an issuance of equity. This improves the credit quality of the bank's debt, raising its value. The value of the legacy

equity is lowered by this transfer of value to creditors. For the new asset purchase to be profitable for legacy equity owners, the new assets must be purchased at a price sufficiently low relative to the value of the equity given up to new shareholders. For the scenario illustrated in Figure 1.2.1, the new assets are purchased at their market value and the new equity is raised at its market value. The legacy equity therefore declines in value. If the bank is run on behalf of shareholders, this transaction would be rejected. This disincentive for the bank to add to its market making inventory represents a loss in market efficiency.

A bank would almost never rely entirely on equity as a source of financing for incremental asset purchases. Shareholder value is better maintained by relying, to an extent that is prudent for shareholders or allowed by regulation, on repo or unsecured debt financing (in that order). Throughout this book, we will explore the implications for market liquidity of these alternatives sources of funds, and also the role of regulatory minimum levels of equity financing.

The benefits of a safer financial system associated with higher capital requirements have easily exceeded the associated market illiquidity costs. I will argue, though, that some improvements in market liquidity can be obtained, without sacrificing financial stability, by changing the form of capital requirements in a manner that leaves the overall level of capital in the banking system at least as high.

Andersen, Duffie and Song (2018) shows that the excess rate
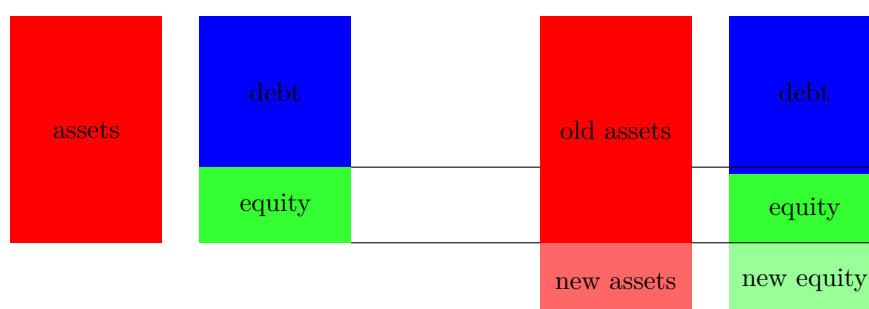
Figure 1.2.1: An example of debt overhang. Purchasing new assets funded by new equity improves the credit quality of the debt, raising its value. The value of the legacy equity position is lowered by this transfer of value to creditors. In the illustration, the new assets are purchased at their market value and the new equity is raised at its market value. In practice, for the asset purchase to be profitable for legacy dealer equity owners, the new assets must be purchased at a price lower than the amount of capital provided by new shareholders. This price wedge is manifested in wider bid-offer spreads, which reduce market liquidity.

of return on a balance-sheet-expanding trade that is required to overcome debt-overhang costs to shareholders is proportional to the bank's unsecured credit spreads. One might therefore have guessed that the impact of debt overhang on trading markets would be much reduced since the Great Financial Crisis by the significant increases in bank capitalization that have been mandated by regulators. These increases in capital have significantly lowered bank insolvency risk. Once a bank's debt has become safer, there should be less scope for bank creditors to profit from a further improvement in the credit quality of their claims associated with the financing of new asset purchases. Thus, debt overhang should now be lower. Instead, however, bank debt overhang is actually more severe now than before the Great Financial Crisis (GFC) because bank credit spreads are higher, not lower, than their pre-crisis levels.

Figure 1.2.2 shows the dramatic post-crisis increase in one-

year large-bank unsecured credit spreads, as proxied by the difference between one-year interbank offered rates (IBORs) and one-year overnight index swap (OIS) rates, for dollars and euros. A similar profile of increased major-bank credit spreads applies at all maturities. For example, five-year large-bank credit spreads, proxied by the credit default swap rates shown in Figure 1.2.3, have also risen dramatically since the GFC. Apparently, large banks are no longer assumed to be "too big to fail." Creditors have clearly absorbed this lesson and now demand higher compensation for absorbing potential future default losses. Atkeson, d'Avernasz, Eisfeldt and Weill (2018) and Berndt and Duffie (2018) provide strong empirical evidence for the post-crisis reduction of too-big-to-fail government subsidies.

New bail-in rules for bank failure resolution target long-term debt for losses.[1] As a systemically important financial institution nears insolvency, governments now have the legal ability under Dodd-Frank Act in the United States, and the European Union's Bank Resolution and Recovery Directive, to convert wholesale bank debt to equity, thus instantly recapitalizing the bank. (The same effect is achieved in the U.S. by transferring the assets of the failing bank to a new bank.) Governments have stated their firm intentions to use their new "bail-in" authorities, and have required large banks to have enough debt subject to bail-in rules to achieve a healthy recapitalization of the bank whenever necessary. Although one can question whether the

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[1]For the European Union setting, this approach is summarized by Center for Economic Policy Studies Task Force (2016).

government would actually use its new bail-in authority effectively, what matters for the debt overhang frictions that I have described is whether bank creditors *believe* that they would be bailed in, and thereby result suffer significant expected losses. With this belief, the yields on bank debt demanded by creditors in wholesale funding markets would rise accordingly.

Indeed, wholesale bank credit spreads are dramatically above their pre-crisis levels, despite improved levels of capital. For example, Berndt and Duffie (2018) show that, for a given probability of default, 5-year credit default swap rates for the largest banks have been well over twice as large in the post-crisis period, in comparison with the period 2001-2007. Credit spreads at short maturities are also significantly elevated, as shown in Figure 1.2.4, despite much higher levels and quality of bank capitalization. An exception applies at the one-month maturity point, where credit spreads are not much larger now than pre-crisis, perhaps because of the liquidity coverage ratio (LCR) rule, or the assumption that very short-term wholesale bank liabilities are likely to be protected from bail-in.

Even if credit spreads had held constant rather than going up, a given amount of market-making inventory now requires a greater amount of equity capital, other things equal. Raising this equity improves the position of legacy debt, thus causing any increase in market-making inventories to be more expensive for bank shareholders. An alternative, which banks have tended to follow, is to conserve on equity and maintain smaller market-
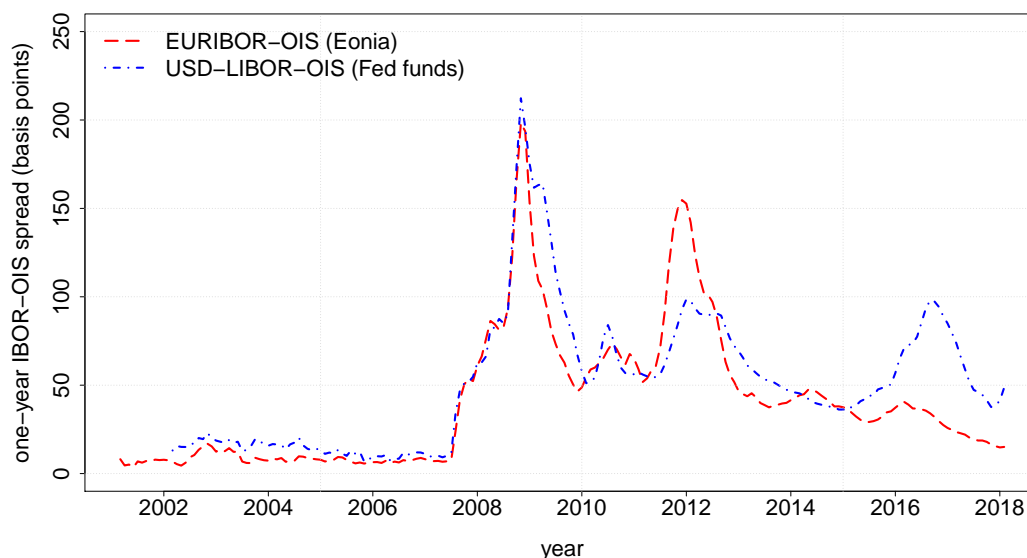
Figure 1.2.2: Spreads between one-year interbank offered rates (IBORs) and one-year overnight index swap (OIS) rates, a proxy for risk free rates. EURIBOR is spread to OIS based on Eonia overnight rates. US dollar LIBOR is spread to OIS based on the Federal Funds rate.

making inventories.[2] This reduces market liquidity by making it less likely that a given asset will be available in the bank's inventory when requested by a customer, and less likely that a bank is willing to accept an asset onto its balance sheet that a customer wishes to liquidate through a sale to the bank. The shadow price of access to a dealer's balance sheet, in this sense, is described by some practitioners as the "cost of balance sheet space."

We are now in a strange middle ground in which credit spreads are much higher than before the crisis, implying greater scope for debt overhang, while capital requirements are much higher, also

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[2]See Comerton-Forde, Hendershott, Jones, Moulton and Seasholes (2010).
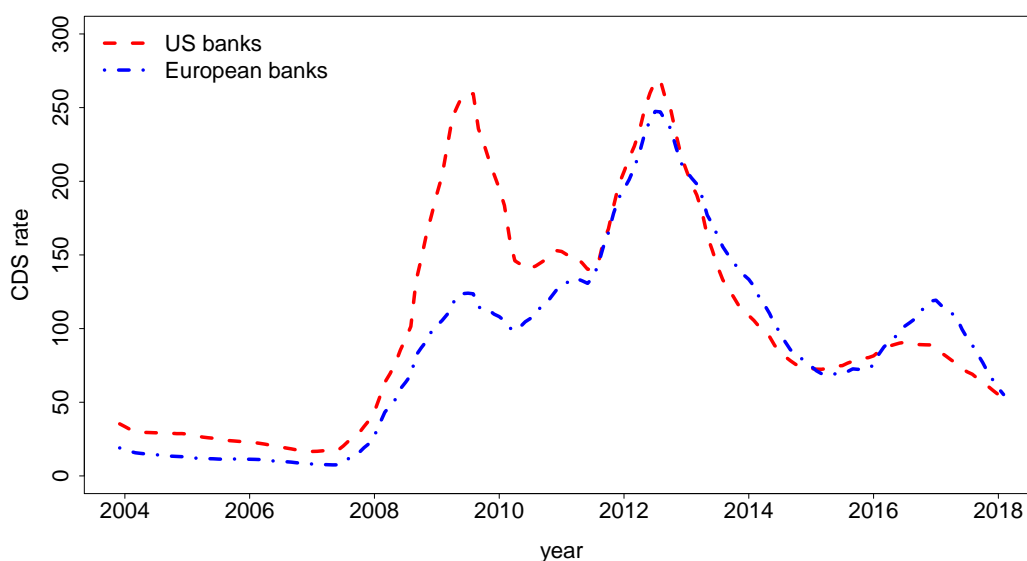
Figure 1.2.3: Five-year CDS rates of major dealers. Averages of the 5-year CDS rates of five large U.S. banks (JPM, Citi, BAML, MS, GS) and of five large European banks (Deutsche Bank, BNP, SocGen, Barclays, RBS). Data source: Bloomberg.

implying more debt overhang than before. The corresponding reductions in market liquidity caused by higher debt overhang could be cured in the long run by imposing extremely high regulatory minimum capital ratios. At that point, the scope for debt overhang is essentially eliminated. Although this outcome would be socially beneficial, transition to this improved world would be costly to bank shareholders, given the implied transfers in value to their creditors. The interim impact on market liquidity would therefore be adverse unless mitigated by other changes in practice or regulation. This discussion sets aside the political realities of how to arrange for the large additional increases in bank capital that would be required to significantly reduce debt overhang.
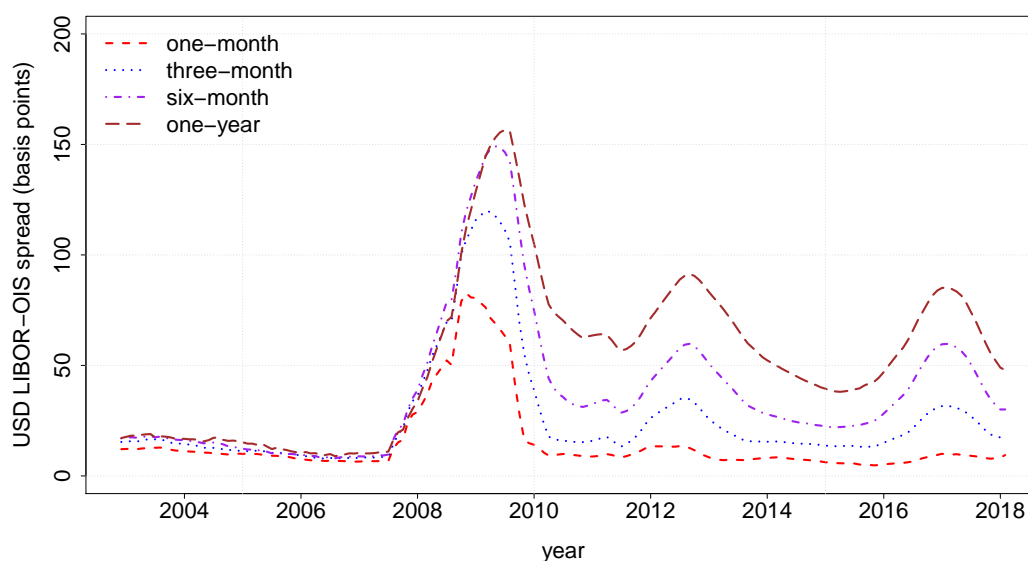
Figure 1.2.4: Spreads of US dollars LIBOR relative to overnight-index swap (OIS) rates (based on the underlying one-day federal funds rate) at maturities of one month, three months, six months, and one year. Data source: Bloomberg.

1.3 Liquidity provision by dealers

In the remainder of this chapter,[3] I will focus on the implications of more costly access to dealer-bank balance sheets for specific trading practices and markets.

Since about 2012, dealer banks have been assessing "funding value adjustments" (FVAs) to the market values of their swap books. This has the benefit, from the viewpoint of bank shareholders, of discouraging dealer swap desks from entering positions that require significant financing of margin and up-front payments.

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[3]Some of the remainder of this chapter is based on my Gallatin Lecture, Duffie (2017), presented at New York University in May 2016.

As will be discussed in Chapter 4, dealers have also dramatically increased their use of financial-engineering methods, such as swap compression trading, that economize on the amount of balance sheet space needed to intermediate a given amount of swap trades. To further reduce their balance sheets, dealers have "fired" large numbers of their less-profitable prime-brokerage clients.

Despite increased costs for access to dealer balance sheets, bid-ask spreads have not become wider in many OTC markets. In the corporate bond market, for example, bid-ask spreads have actually narrowed a bit, even relative to their pre-crisis levels, as explained by Mizrach (2015) and Adrian, Fleming, Shachar and Vogt (2016).

However, as pointed out by Bessembinder, Jacobsen, Maxwell and Venkataraman (2018), Choi and Huh (2017), and Dick-Nielsen and Rossi (2017), dealers are not absorbing large block trades as readily and corporate bond turnover has declined. Further, Helwege and Wang (2016) show that issuers of "mega-bonds" have responded by reducing the sizes of their largest issues.

When intermediating corporate bond trade requests, dealers are now more likely to offer agency or riskless-principal trades,[4] which delay the execution of a client's request to sell until the dealer can find a matching buyer. Again, this reduces the amount of balance sheet space required to handle a given amount of

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[4]See Ederington, Guan and Yadav (2015), Harris (2015), Trebbi and Xiao (2018), and An and Zheng (2016).

trade. In effect, dealers are relying more heavily on inventory held on their clients' balance sheets, and less on inventory that they hold themselves. For example, based on data on the U.S. corporate bond market presented by SIFMA (2016), in 2007, dealer inventories exceeded 5% of the total outstanding principal. By the end of 2015, this ratio had declined to less than 0.5%.

These effects go beyond the impact of the Volcker Rule,[5] which is less concerned with insolvency risk than with prohibiting speculative trading motives. As I have explained in Duffie (2012), the main impediment to liquidity associated with the Volcker Rule is the difficulty of separating legitimately exempted market making from prohibited speculative trading that isn't intended to make markets. The empirical analysis of Bao, O'Hara and Zhou (2018) suggests that the Volcker Rule has also reduced the liquidity of the U.S. corporate bond market.

1.4   Modigliani-Miller and asset substitution

The suggestion that capital structure matters for financial market liquidity is not a violation of the famous "MM" theorem of Modigliani and Miller (1958). The most relevant part of the MM Theorem states that the total market value of a firm's assets does not depend on the firm's capital structure. Even under its own assumptions, however, MM does not speak to the incentives of a firm to add new positions to its balance sheet. Whenever a

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[5]The Volcker Rule is stated in the Federal Register (2014).

dealer adds a new market-making position, even at zero trading profit, the market value of the bank's equity can be affected by a change in the riskiness of the bank's balance sheet. This point was emphasized by Miller (1995), who famously[6] likened the attitude of bank shareholders toward equity issuance to Mickey Rooney's aversion to "pumping gas into another man's car."

As I will explain in Chapter 3, adding a sufficiently risky position, even before considering any trading profit, can benefit a bank's shareholders at the expense of its creditors, because the limited liability of shareholders allows them to walk away from insolvency at no cost. This leaves creditors with a weaker claim. Jensen and Meckling (1976) used the term "asset substitution" to describe this method of exploiting the divergent interests of creditors and shareholders. Even if no single trade has a big impact, the incremental effects can add up over successive trades. Capital requirements reduce or block the asset-substitution incentives of shareholders.

In the context of banks dealing in capital markets, it is somewhat surprising, at least relative to the previous focus of economists, that debt overhang can also represent a significant friction in the case of debt issuance, and not just equity issuance. This point is modeled in Chapter 3.

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[6]I am grateful to Rainer Masera for bringing Miller's remarks to my attention.

1.5   Impact on swap markets

As explained earlier in this chapter, debt overhang implies that a trade with a positive mark-to-market dealer profit can sometimes imply a negative return for the bank's equity. An example of this is a pair of back-to-back swaps that fully hedges each other, but requires the dealer to post an additional amount of margin that must be financed. Financing the additional safe margin assets, which are available in default to the dealer's creditors rather than its shareholders, worsens the value of the bank's equity.

For instance, a buy-side investor may wish to enter a swap with a dealer. The dealer will often hedge the new position in the inter-dealer market. Buy-side firms frequently post no collateral with the dealer, but the dealer is now required to post collateral for the inter-dealer swap, whether to a central counterparty or to another dealer. Financing additional collateral causes a bank's creditors to benefit from improved margin backing, at the expense of the bank's legacy shareholders. Even if, as is common in practice, the required up-front payment for the swap and the collateral are funded with unsecured debt, the effective cost to the bank's shareholders is significant and equal to an amount known in industry practice as the funding value adjustment (FVA). More details concerning dealer FVA practice and implications are provided in Chapter 3, based on results from Andersen, Duffie and Song (2018).

A dealer should enter into such a trade only if it compensates

its shareholders with a sufficiently large trading profit, which can be obtained by widening its bid-offer spread. Of course, widening the bid-offer spread reduces market liquidity. An analogous "capital value adjustment," sometimes known in the dealer community as a "KVA," may also be required to compensate shareholders for using up some of the bank's headroom (available slack) under its regulatory capital requirements. Market-making capital requirements have increased significantly with the Basel III fundamental review of the trading book.

Although FVA practice was first introduced by swap dealers, the implications of funding costs for dealer intermediation extend to many other asset classes. For example, Chapter 3 explores the impact of funding costs for the cross-currency basis, a violation of the law of one price in cross-currency borrowing and foreign-exchange (FX) derivatives markets. Roughly speaking, the cross-currency basis must exceed a dealer's funding spreads before the dealer's shareholders would earn a positive return on arbitraging the basis. Not surprisingly, therefore, large violations of covered interest parity are now routine, but were rare in the pre-crisis period when dealer credit spreads were tiny.

Chapter 4 discusses some methods to reduce these adverse impacts on market liquidity.

1.6 Strategic implications for dealers

Debt overhang is smaller for more highly capitalized banks, therefore giving them an important advantage in competing for

trades. In order to overcome shareholder losses associated with
debt overhang, dealers with higher credit spreads must charge
their clients larger effective trading costs. Clients are often will-
ing to accommodate these additional costs because they have
motives to trade, such as hedging, that dominate the dealer's
debt overhang costs. For example, if Bank A has a credit spread
that is half of that of Bank B, then the shareholders of Bank A
can break even with a widening of bid-ask spreads for debt over-
hang costs that is only about half the corresponding widening of
bid-ask spreads that Bank B must quote to its customers. This
would tend to cause buy-side firms to prefer to trade with Bank
A over Bank B, other things equal. Of course, buy-side firms
are also averse to counterparty risk, so have an additional reason
to prefer to trade with better capitalized dealers. On the other
hand, frictions associated with customer-to-dealer relationships,
specialization of dealers by product category, search costs, and
OTC market opaqueness, may often prevent the best capitalized
dealer from "winning" a given trade.

In some markets, the debt-overhang advantage to better cap-
italized dealers in attracting more trades is further magnified
by the increased degree of netting of buy orders against sell or-
ders that would be expected with a larger number of clients, as
explained by Wang (2017). Some trades, however, release fund-
ing back to the dealer, conveying a significant funding *benefit*
to dealer shareholders. In swap markets, this is called a fund-
ing benefit adjustment (FBA). The dealer with the *higher* credit

spread would in this case be expected to benefit most from the trade, and to bid more aggressively. This may explain recent aggressive bidding by dealers for cross-currency swaps, because of their typically high funding benefits to dealers, as explained by Wood (2016). Another example of a funding benefit is the case of a swap trade that can be netted against the dealer's position in a central counterparty (CCP), thus reducing the amount of initial margin posted by the dealer with the CCP.

Dealers should encourage their trading desks to consider FVAs as a cost to the dealer's shareholders. These costs (or funding benefits) should be reflected in quoting practice, and in the choice of counteparty or central counterparty. To create appropriate incentives, the variable component of traders' compensation could be based on their trading P&L, *less* an estimate of the incremental impact of their trading on the firm's FVAs. In the case of swaps, as explained by Andersen, Duffie and Song (2018), dealers have instead simply applied downward adjustments for FVAs to the marked market values of their swap books. While this has a similar incentive effect on traders, the valuation practice is not consistent, as explained by Andersen, Duffie and Song (2018) and others cited in Chapter 3. An FVA does not actually change the market value of the acquired position. Instead, an FVA is a transfer in value from equity to debt.

Some major dealers have initiated "XVA optimization" programs.[7] Other dealers have significantly reduced their swap intermediation businesses. One of these, Deutsche Bank, elimi-

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[7]See Sherif (2016) and Sherif (2017).

nated most of its single-name CDS trading, although the precise motive for this decision was not reported. Debt overhang costs to shareholders are roughly proportional to dealer credit spreads, as shown in Chapter 3. Deutsche Bank has recently had relatively high credit spreads relative to other major dealers, and therefore should have a natural focus on structuring its intermediation business in light of its higher funding costs.

1.7   Asset pricing implications

Adrian, Etula and Muir (2014) and Brunnermeier and Pedersen (2009) have examined the impact of dealer capital structure on asset price behavior. Empirical studies by Adrian, Moench and Shin (2011) and He, Kelly and Manela (2017) have also shown that the expected returns of traded assets are sensitive to dealer capitalization and to the sizes of dealer market-making inventories.

Debt overhang has specific theoretical and practical implications for asset pricing. Chapter 2 illustrates the implications for the pricing of treasury repos. In Chapter 3, we discuss the impact of debt-overhang funding costs on interest rate swaps, credit default swaps, and violations of covered interest parity. Song (2016) shows that "no-arbitrage" put-call-parity pricing relationships in options markets frequently break down to an economically important degree in the presence funding costs to derivatives dealers' shareholders for carrying and hedging dealing inventory. In particular, Song (2016) shows that put-call

parity must be adjusted significantly for longer-dated options in order to obtain reasonable synthetic pricing for equity dividend strips. He shows that a failure to do so may have lead to a potentially important bias in prior research on the term structure of S&P 500 equity risk premia.

1.8   The leverage ratio rule

The leverage-ratio rule is a parallel system of Basel-based capital requirements that are not sensitive to the riskiness of a bank's assets. Under the U.S. supplementary leverage-ratio rule (SLR), for example, the largest U.S. broker dealers are subject to a 5% leverage ratio. This means that for every $100 million of additional assets, a dealer is required to have an additional $5 million of capital, regardless of the riskiness of the assets. Under this rule, intermediating safe assets such as U.S. Treasury repos requires a lot of capital relative to the tiny risks involved, and thus improves the position of the bank's unsecured legacy creditors.

As explained in Chapter 2, under the leverage-ratio rule, dealers should increase their bid-ask spreads on repo intermediation enough to overcome the debt-overhang cost to their shareholders. That is exactly what they have been doing. Since the introduction of the SLR, bid-ask spreads in the U.S. Treasury repo market have increased from around 3 basis points to over 16 basis points in late 2016, then dropping somewhat with the reform of money market mutual funds. As a consequence, volumes of trade in treasury repos have dropped precipitously, especially in

the inter-dealer repo market, as shown by Martin (2016).

Perhaps the leverage-ratio rule has also dampened the incentives for U.S. dealers to provide robust levels of liquidity to U.S. Treasury securities markets. At least, there is some question concerning the causes of the apparent episodic loss of liquidity in this market. This was in evidence, for example, with the "flash rally" on October 15, 2015, in the 10-year Treasury-note market.

1.9 European versus U.S. banks

European dealer banks have recently given up some of their market-making franchises, or at least some market share, to their American competitors. This is a natural consequence of the relatively stronger capitalization of U.S. banks, which implies that the shareholders of U.S. banks bear lower debt-overhang cost than their European counterparts for allocating balance sheet space to market making. This is related to the ratchet effect associated with debt overhang.[8]

For example, in 2016 Barclays sold its substantial "non-core" swap portfolio to J.P. Morgan.[9] In Chapter 3, we show that this novation trade can be motivated by the fact that the associated funding costs to J.P. Morgan's shareholders are lower than those to Barclay's shareholders, given that J.P. Morgan's credit spreads are significantly lower. Another motive for the novation

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[8]See Admati, DeMarzo, Hellwig and Pfleiderer (2018).

[9]See Morris (2016) and Parsons (2016).

could be JP Morgan's relatively better netting efficiencies, given its higher trade volumes.

At low levels of dealer capitalization, accommodating new client positions by adding capital (or using up some of the headroom available before additional capital must be raised) is more costly to shareholders than it would be if the bank's capitalization is already high. At very high levels of capital, there is almost no debt overhang cost to shareholders for additional market making because creditors are already so safe that there isn't much more market value that shareholders could transfer to creditors by adding even more capital.

1.10 Competition and price transparency

The adverse effects on the liquidity of OTC markets caused by debt overhang and the Volcker Rule are partly offset by regulations that have improved OTC market competition. Chief among these are regulations in support of price transparency. Various empirical studies suggest that the imposition in 2003 of post-transaction reporting in U.S. corporate bond markets, through the Trade Reporting and Compliance Engine (TRACE), has generally lowered execution costs for the buy-side customers of dealers.

Although greater price transparency improves competition and lowers search costs, the narrower bid-offer spreads generally promoted by TRACE could actually have had an adverse effect on market liquidity in some segments of the corporate bond

market. Asquith, Covert and Pathak (2013) speculate, based on their empirical results, that the reduction of dealer trading rents caused by TRACE may have reduced the intensity of intermediation services offered by dealers in smaller, riskier bond issues.

Regulation has also supported competition by forcing the migration of market-making services for some standardized products, such as plain-vanilla interest rate swaps, onto multi-dealer electronic trade platforms, where dealers must post prices in direct simultaneous competition with each other. Prior to regulation, multi-dealer OTC-market trade platforms were used primarily for inter-dealer trade. In the European Union, the Markets in Financial Instruments Directives require platform-based dealer competition across a wider range of markets, including bonds and swaps.

Chapter 4 emphasizes that the introduction of trade competition has not gone far enough. Dealers are still on at least one side of almost every trade in many OTC markets, especially those for swaps and corporate bonds. Further improvements in competition could be achieved through greater use of all-to-all trade.[10]

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[10]I have a potential conflict of interest on this topic, having served as an expert in private litigation involving allegations that large dealers conspired to suppress all-to-all trade in swap markets.

1.11 The efficient stability-liquidity frontier

There is a clear opportunity to make adjustments to the leverage rule that would achieve more financial stability for the same level of market efficiency, or, alternatively, more market efficiency for the same level of financial stability. Relaxing the leverage-ratio rule for extremely safe and economically important intermediation activities, such as conservatively managed matched-book dealing in treasury repos, would have essentially no impact on the stability of large bank-affiliated dealers and would alleviate an important distortion in this critical market. As emphasized in Duffie and Krishnamurthy (2016), the leverage rule impinges on the liquidity of the U.S. Treasury repo market, and therefore on the pass-through efficiency of U.S. monetary policy. The leverage ratio rule also degrades the liquidity of spot treasuries markets, because the treasury repo market anchors the financing and hedging needs of investors in U.S. Treasury securities.

The Bank of England recently noted the unintended adverse consequences for market efficiency caused by applying the leverage-ratio rule to central bank deposits, another very safe asset. The Bank of England responded appropriately by making an exemption. In order to maintain total bank capitalization after this change, the minimum capital required under the leverage rule for the remainder of bank assets was correspondingly raised.

An alternative route toward the efficient regulatory frontier would be via an increase in the risk-weighted-asset (RWA) capital requirements of large banks, enough that the leverage-ratio

rule has no significant likelihood of becoming a binding constraint on a dealer bank's capital, even under regulatory stress tests. (Judging from Figure 2.1.1 of Chapter 2, however, this would require a large increase in RWA capital requirements.) While imperfect and subject to incentive concerns, RWA capital requirements are less distortionary than the leverage-ratio rule, and are at least as effective in promoting financial stability if set conservatively.

Suppose there remains a concern among regulators that even best efforts at RWA-based capital requirements may fail to properly account for risk and may leave the banking system under-capitalized. Suppose further that regulators prefer to have an average level of capitalization among large banks that is based on a gross leverage ratio that does not attempt to adjust for risk. This outcome can be achieved without the market-making distortions associated with the leverage-ratio rule that I have described, as follows. First, compute the aggregate amount A of assets held by the identified set of large banks, without adjusting for their risks. Next, multiply A by a given minimum leverage-based fraction k of capital, implying that the total amount of capital of these banks under the leverage-ratio rule would be $C = kA$. One can now determine the minimum RWA capital ratio $r(C)$ with the property that the total capitalization of these banks is at least C. That is, $r(C) = C/A_W$, where A_W is the aggregate risk-weighted assets of these banks.

By imposing on each bank the RWA requirement based on

this ratio $r(C)$, and by not imposing the leverage-ratio rule, each individual bank will not internalize the distortions to its market making activities that are caused by the leverage-ratio rule.[11] At the same time, average bank capitalization will meet the desired minimum leverage ratio k.

Under this approach, some banks could fail to meet a leverage-ratio rule at the stipulated ratio k, implying that other banks must have a corresponding excess level of capital under the same leverage-ratio rule. That is, this approach to the leverage-ratio rule can be viewed as "macro-prudential," ensuring that the system as a whole meets the leverage criterion, whereas the associated risk-weighted capital requirements are micro-prudential. In practice, one could impose a risk-weighted capital requirement on each bank that is based on the minimum of $r(C)$ and a conventional minimum RWA capital ratio.

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[11]An extremely large bank might internalize the extent to which an increase in its own total assets, unadjusted for risk, increase the system-wide aggregate assets A, and through that, its own share of the system-wide aggregate minimum capital. The resulting market-making distortion, while non-zero, is much more muted than the effect of a bank-by-bank leverage-ratio rule.

2

Leverage Rule Distortions

The market distortions caused by debt overhang are exacerbated by the leverage ratio rule, especially in markets for safe assets. When a bank issues equity in order to meet a high regulatory capital requirement for a low-risk position, bank creditors are more likely to benefit from a transfer of value from bank equity. As a case study, this chapter focuses on the implications of the leverage ratio rule for the liquidity of the market for government security repurchase agreements, known as repos.

2.1   Leverage rule distortions

The leverage ratio rule requires that a large bank's capital must exceed a given fraction of the bank's total quantity of assets, irrespective of their riskiness.

This leverage requirement is simpler than the conventional risk-weighted-asset (RWA) capital requirement, which calls for capital levels that depend on the average risk profile of the

bank's asset portfolio. Conventional RWA capital rules had not worked well leading up to the Great Financial Crisis because the risks of some assets were badly understated. In some cases, the bias in risk measures was caused by the moral hazard of asking banks to measure their own risks using "internal" models, or with their own classifications of asset types by risk category. Because of the advantages of leverage to bank shareholders, banks would typically prefer lower capital levels than regulators would judge socially appropriate from the viewpoint of financial stability. Banks thus have a moral hazard to understate risks.

Regulators are normally government agencies, and tend to assign relatively undifferentiated and unrealistically low risk weights to sovereign debt, a different form of moral hazard related to political economy.

Putting aside these incentive problems in setting risk weights, the assessment of balance sheet solvency risks is a difficult and complex exercise. The simplicity of the leverage ratio rule is also an advantage in this respect. Risk weights are simply not needed.

Overall, the leverage ratio rule therefore leaves less scope for moral hazard or computational complexity, relative to RWA-based capital requirements, when determining regulatory minimum levels of capital for a given asset portfolio.

However, treating all assets as though equivalent when setting minimum capital levels leads to obvious market distortions. If banks prefer more risk per unit of capital than regulators would

find socially optimal, then a capital rule that makes no distinctions with respect to the riskiness of assets encourages a bank to tilt its asset portfolio away from low-risk assets to high-risk assets. This need not lead to financial instability — the required leverage ratio rule could be made correspondingly more stringent. The concern is instead that the amount of intermediation provided by banks to low-risk asset markets has become inefficiently low. This is consistent with modeling[1] by Kiema and Jokivuolle (2014).

When the leverage ratio rule was introduced, it was suggested by some regulators that the rule was intended as a back-stop, rather than as the primary restriction on bank capital.[2] In practice, however, the leverage ratio rule is more binding than risk-based capital rules, at least when applied to the largest U.S. dealer banks. For example, Figure 2.1.1 shows the results of the Federal Reserve's 2017 stress tests for the five most active U.S. dealer banks. These stress tests are in two forms, the Dodd-Frank Act Stress Test (DFAST) and the Comprehensive Capital Analysis and Review (CCAR).[3]

For the 2017 DFAST, Figure 2.1.1 shows the excess capital available for each of these five banks in the stressed scenario, assuming that the bank does not pay distributions to shareholders. When plotting the excess capital ratio (actual minus DFAST re-

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[1] Kiema and Jokivuolle (2014) also show that the leverage ratio rule can reduce financial stability by causing more banks to be jointly vulnerable to similar high-risk assets, unless the minimum leverage ratio pushes capital levels much higher.

[2] See, for example, Basel Committee on Banking Supervision (2013), page 1.

[3] See Board of Governors of the Federal Reserve System (2013).
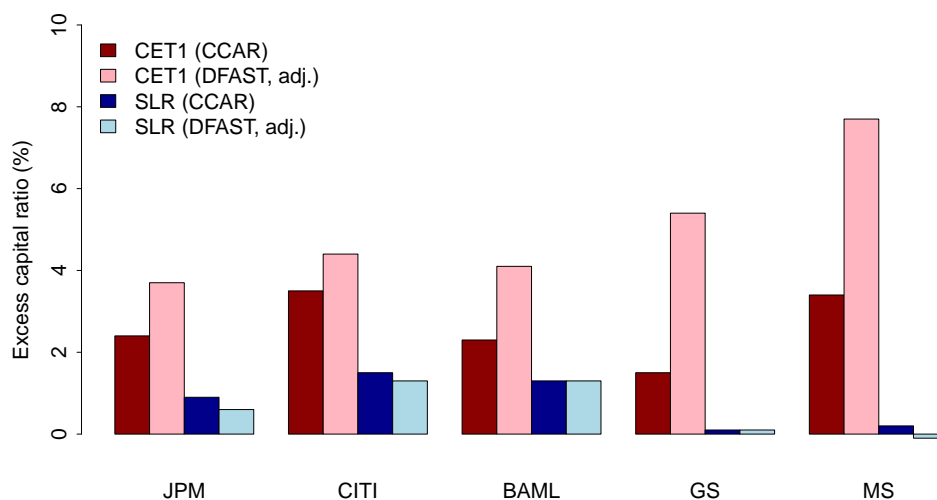
Figure 2.1.1: Results of the Fed's 2017 stress tests for the largest US dealer banks: J.P. Morgan, Citi, Bank of America Merrill Lynch, Goldman Sachs, and Morgan Stanley. CCAR: stressed CET1 after assumed payouts, less 4.5%; stressed SLR less 3.0%. DFAST, adjusted: stressed CET1 (no payouts) less (4.5% + G-SIB surcharge); stressed SLR less the G-SIB minimum of 5%. Data source: Board of Governors of the Federal Reserve, 2017.

quirement) remaining under the stress scenario, I did not assume the minimum post-stress capital ratios actually required by the DFAST. Instead, I used the minimum capital ratios required under Basel III, as applied by the Fed for globally systemically important banks (G-SIBs).[4]

In the case of CCAR, Figure 2.1.1 shows the excess capital available in the stressed scenario, using the standard CCAR assumption that the bank continues to pay distributions to shareholders. On the other hand, CCAR required minimum capital ratios do not include G-SIB surcharges.

For both DFAST and CCAR, the minimum capital require-

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[4]The G-SIB CET1 buffer requirements vary by bank, according to total assets.

ments are of two types, the risk-based measure known as core tier-one equity (CET1) and the measure based on the supplementary leverage ratio (SLR). For the adjusted DFAST calculation, I used the 5% SLR that applies to the dealer divisions of these bank holding companies, rather than the 6% SLR requirement that applies to their commercial banking divisions.

As shown in the figure, the SLR requirement is clearly more binding than the CET1 requirement for all five of the largest U.S. dealer banks, whether under CCAR or under the adjusted DFAST.

Because these stress tests are more binding on the largest banks than are the corresponding ongoing ("unstressed") Basel III capital requirements, one can infer from Figure 2.1.1 that the largest U.S. dealer banks must carefully consider the impact of the leverage ratio rule (SLR) on their minimum capital levels when deciding how much of their balance sheet to allocate to safe asset intermediation. Figure 2.1.1 also shows that the largest banks are not all in the same position with respect to their shadow prices for the SLR constraint.

2.2 Repo intermediation under the SLR

As an illustrative case study, I will now focus on the debt-overhang impact of the leverage rule on the incentive of a bank to conduct safe-asset repo intermediation, as depicted in Figure 2.2.1. Here, I closely follow the exposition found in Duffie and Krishnamurthy (2016).
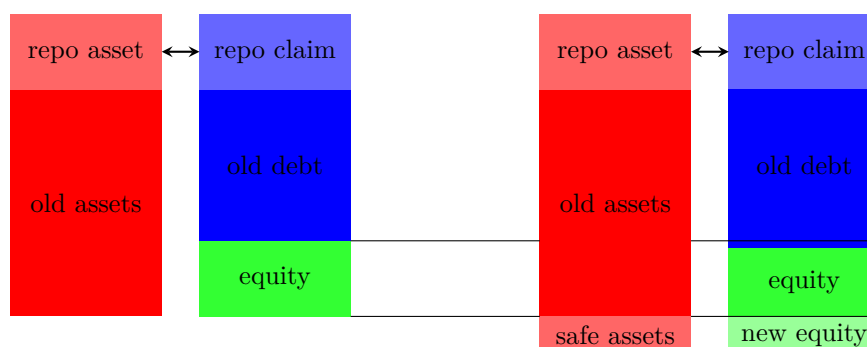
Figure 2.2.1: The impact on shareholder value associated with adding equity capital and adding a low-risk repo to the balance sheet of the bank. The repo has essentially no impact on the safety of the legacy debt, because the repo claims are collateralized and in any case are exempt from bankruptcy law. Adding equity, as would be required for repos under the leverage ratio rule, therefore makes the legacy debt unambiguously safer. Legacy shareholders are thus transferring value to creditors, a form of debt overhang. Shareholders would therefore prefer not to conduct the repo unless the intermediation bid-ask spread on repo is large enough to overcome their debt-overhand costs.

Consider a dealer bank bound by the leverage-ratio rule. The bank must therefore have at least C in additional capital for each additional unit of measured assets, regardless of the asset risk. On a candidate repo trade, the bank would initially receive from its counterparty treasury securities with a market value of $1+H$, in exchange for 1 in cash, where H is a haircut designed to protect the bank from counterparty failure. (A typical current haircut for U.S. treasuries is about 2%.)

At the maturity of the repo in one day, the bank will return the treasuries to the counterparty in exchange for $1 + R$, where R is the repo rate, measured for simplicity on a per-day (rather than annualized basis). The repo rate R exceeds the bank's cost of funding by some spread G. We will assume that the bank is intermediating treasury repos, a "matched-book" activity, so

that the bank can obtain funding in the repo market by using the same treasuries as collateral. In practice, there can be small but non-zero net funding requirements associated with differences in timing between repos and reverse repos.

Repos are exempt from stays at counterparty failure, so the bank could suffer an unexpected default loss on this trade only if, within a day, both of two unusual events happen: (a) the counterparty defaults and (b) the value of the treasuries drops by more than the haircut H. In practice, this combined outcome is so unlikely that an event of this type has not been reported since the 1982 failure of Drysdale Government Securities, when counterparties had simply mistaken[5] their haircut assignments.

So, in the absence of capital requirements, because this intermediation trade involves almost no counterparty risk or funding requirements, it has essentially no impact on the market values of the bank's debt and equity, other than the intermediation gain of G, which we can assume for simplicity is paid to equity as a distribution. Because the leverage rule is binding, however, the bank must have approximately C in additional equity in order to conduct this trade. A simple way for the bank to arrange this additional equity is to retire approximately C worth of unsecured debt, funded by an equity issuance of the same amount. In practice, the bank would not conduct an equity issuance for each repo trade. Instead, it would have a policy for how much repo it wishes to conduct on a normal on-going basis, and adjust its capital structure so as to meet its capital requirements, with

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[5]For details, see Garbade (2006).

some buffer designed to conservatively avoid compliance problems. Either way, whether setting aside C in excess capital in advance of the trade, or raising C at the time of the trade, there is a debt-overhang impact on shareholders.

In our simple example, the remaining legacy unsecured creditors benefit to the extent that the unsecured debt that is retired to conduct this trade no longer claims a share of the recovery value of the bank's assets in the event that the bank defaults. This default-contingent recovery claim is transferred to the remaining unsecured creditors. The market value of this additional default-contingent debt recovery claim, per unit of retired debt, is the difference D between the market value of a default-free debt claim and the market value of an unsecured debt claim on the bank. This difference D is therefore equal to the credit spread S of the bank's unsecured debt. Because C units of debt were retired, the net gain in value to the legacy debt is therefore CS. Given that the balance sheet of the bank is otherwise unchanged, the shareholders' net gain is the funding spread G on the repo trade, less the wealth transfer of CS to legacy unsecured creditors. Thus, the incremental impact of the capital requirement on the bank's incentive to conduct the repo is equal to CS.

For illustration, consider an SLR of 5% (the current minimum regulatory leverage ratio for the largest US dealer banks) and an annualized unsecured bank credit spread of $S = 100$ basis points. (In the absence of a model of the bank's funding strategy

with respect to maturity, I take this spread S to be an average across the entire stack of unsecured debt issued by the bank, assuming that the increase in equity mandated in SLR leads, in steady-state, to a proportionate decrease in unsecured funding debt at all maturities.) The bank must therefore lower its bid and raise its offer for the repo intermediation by $CS = 5$ basis points each in order to compensate shareholders for the effect of leverage ratio, for a total impact on the bid-offer spread for repo intermediation of 10 basis points.

This illustrative impact of the SLR on repo intermediation costs is much bigger than the entire bid-ask spread that applied before the introduction of the SLR, as depicted in Figure 2.2.2. The bid-ask spread is estimated here as the difference between the financing rates paid by non-bank-affiliated dealers in the GCF repo market, relative to the financing rates paid by bank-affiliated dealers (among others) in the tri-party repo market. Since the introduction of SLR, Figure 2.2.2 shows a dramatic increase in bid-ask spreads for repo intermediation by the largest dealer banks. As of early 2018, this bid-ask was roughly similar in magnitude to that suggested by this illustrative theoretical calculation.

The moderate decline in repo bid-ask spreads in late 2016 that is depicted in Figure 2.2.2 reflects the impact of the reform of U.S. money market funds on the amount of repo intermediation done by the large dealer banks. By October 2016, roughly $1 trillion in prime money funds was moved into government
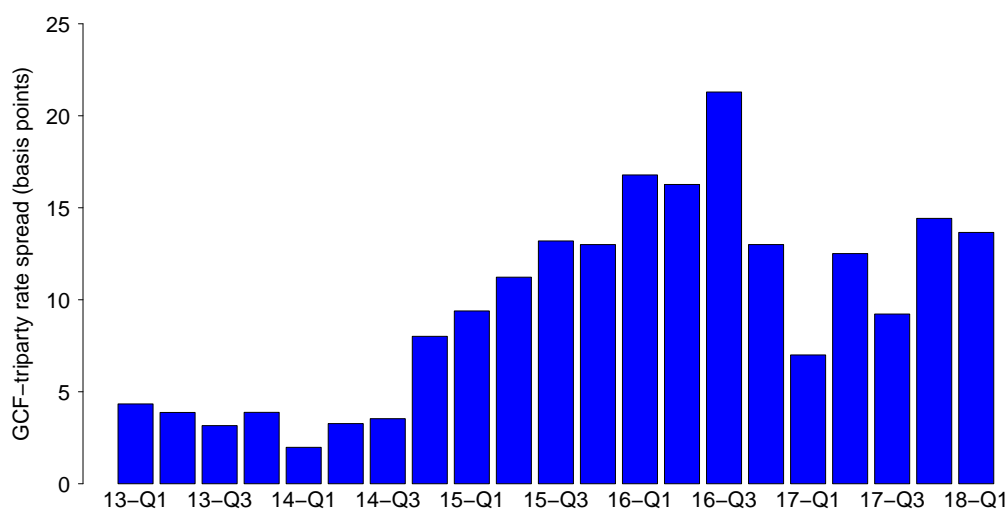
Figure 2.2.2: Average within-quarter difference between overnight GCF and Tri-party repo rates. Data sources: Bloomberg and BNY-Mellon.

money market funds. This caused money market funds to enter U.S. Treasury repos with a much larger set of dealers, including dealers not affiliated with banks that had previously obtained their repo funding from large dealer banks.[6]

The ICMA European Repo Council (2015) states that the leverage ratio rule is a major friction in the provision of repo intermediation by European banks. In terms of the impact of the leverage ratio rule on repo market liquidity, however, Europe has the advantages over the United States of (a) a lower SLR, (b) a more active direct-repo electronic platform trading market, and (c) a much larger degree of broad-market central clearing of repos.

ICMA European Repo Council (2015) also repeats a common

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[6]I am grateful to Lou Crandall for explaining this point to me.

suggestion of bank analysts that the impact of the leverage ratio rule on break-even intermediation bid-ask spreads is the product of the minimum capital C per unit of assets and the rate of return R_E that banks "require" on their equity capital. For this calculation, a common estimate of R_E is 10%. This rule of thumb, if it were correct, would imply that banks must earn CR_E on repo intermediation trades in order for these trades to benefit their shareholders. This is not conceptually correct, and moreover implies an intermediation spread that is unrealistically large. For U.S. dealer banks, $C = 5\%$, so this ad-hoc rule suggests a minimum intermediation return of 50 basis points. Clearly, as shown in Figure 2.2.2, banks are earning intermediation spreads that are far lower than 50 basis points.

The idea that banks must earn their average expected expected rate of return on equity on every use of capital is false. The return on a trade that is necessary to profit shareholders depends on the risk profile of the trade, and on how the trade is funded. Shareholders can benefit from safe asset trades such as repo that earn a much smaller return than R_E, as I showed in my calculations above. Conversely, the market value of a bank's equity could be reduced by certain kinds of risky trades that earn a much higher expected rate of return than R_E. Nevertheless, this $C \times R_E$ rule of thumb seems to have crept into common discussion as though it has self-evident merit, despite the absence of a coherent argument for the rule.

As far as the actual total quantity of repos conducted in Eu-

rope (whether by EU or non-EU banks), the latest survey of
the EU repo market by the International Capital Market Asso-
ciation (2017) shows little change in volume over the five-year
period ending December 2016. Bucalossi and Scalia (2016) esti-
mate little adverse impact of the leverage-ratio rule on European
repo market activity.

Direct-repo market accounts for over half of all European repo
trade. In any case, most European repo intermediation, even on
direct-repo platforms, is done by banks. European and U.S.
markets may evolve toward much more significant direct repo
intermediation, thus returning some liquidity to the market.

European repo market liquidity is also advantaged relative to
the U.S. market by the significant use of repo central counterpar-
ties. This advantage allows some European banks to net some
of their long and short positions so as to reduce their measured
repo assets. That is, a bank doing matched-book repo interme-
diation with counterparties on both sides that clear through the
same CCP can reduce its asset position by netting its long and
short positions at the CCP, thus reduce its regulatory capital
requirement for conducting repo intermediation, and therefore
narrow its required bid-offer spread. Chapter 4 provides a more
detailed discussion of this benefit of central clearing.

Based on data presented by Martin (2016), and shown in
Figure 2.2.3, GCF repo volumes declined by about 30% be-
tween 2012 and 2016, the period over which the SLR was im-
posed on U.S. dealer banks. The amount of cash financing ob-
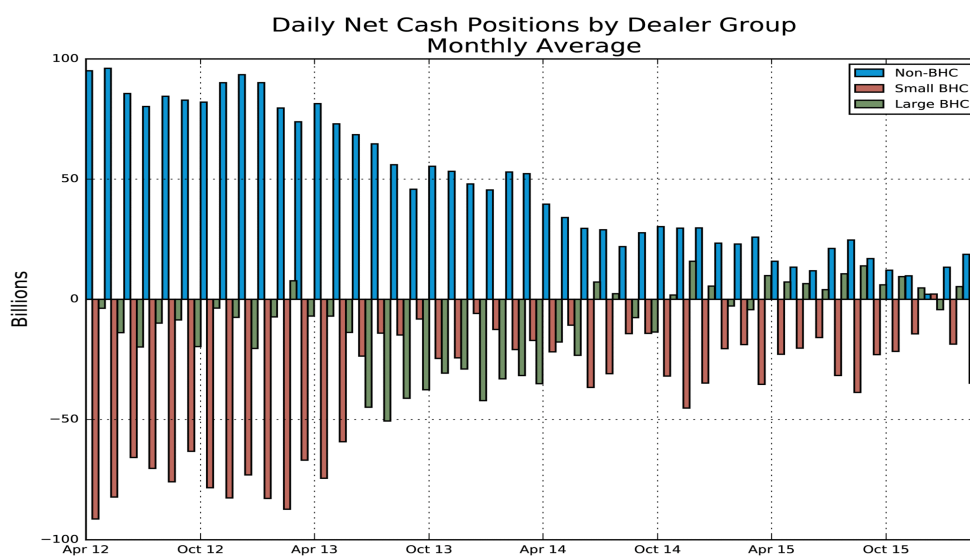
Figure 2.2.3: Figure source: Antoine Martin, Federal Reserve Bank of New York (2016).

tained from bank-affiliated dealers by non-bank-affiliated dealers in this market declined by about 80% from 2013 to the end of 2015. In that two-year period, a proxy measure of the effective bid-ask spread for U.S. government securities repo intermediation increased from under 4 basis points to about 16 basis points, as shown in Figure 2.2.2. In the last quarter of 2015, the three-month treasury-secured repo rates paid by non-bank dealers were higher even than the three-month *unsecured* borrowing rates paid by banks (LIBOR), a clear and significant market distortion.

Chapter 4 discusses potential improvements in market infrastructure that would reduce the amount of dealer balance sheet space necessary to intermediate the repo market, thus mitigating passthrough inefficiencies associated with the SLR. An ex-

ample is a more broadly accessible central counterparty (CCP) for repos. The DTCC has been attempting to broaden access to the Fixed Income Clearing Corporation, a CCP that has been almost entirely limited to inter-dealer trades.

Another option would be a change in the application of the SLR to U.S. government securities repo intermediation. For example, the measured amount of assets represented by government securities repo intermediation could be modified so as recognize the effect of netting, whenever achieved safely within the same asset class. (The SLR rule already permits some netting of repo positions with the same counterparty, but not across counterparties.) An alternative would be to increase conventional risk-weighted capital requirements to the point that the SLR is not close to binding.

2.3   SLR degrades monetary-policy passthrough

Duffie and Krishnamurthy (2016) show how the SLR also induces a pronounced increase in money-market rate dispersion at the end of each calendar quarter.[7] Table 2.1 provides statistics bearing on the end-of-quarter effects on money-market rates, based on a sample from January 1, 2015 to June 30, 2016. The table shows the mean value of each reported variable, excluding the end-of-quarter, as well as the change at the end-of-quarter, and the 95% confidence interval around this change.

Table 2.1 shows that, during the sample period, take-up at

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[7]This section is based largely on content from Duffie and Krishnamurthy (2016).

Table 2.1: End-of-quarter effects on selected money-market rates, for the period January 1, 2015 to June 30, 2016. Source: Duffie and Krishnamurthy (2016)

Variable	Mean, excluding quarter-end	Quarter-end change	95% confidence interval
Fed private-sector RRP volume	$94.2 bn	$206.1 bn	[170.6, 241.5]
1-week T-bill rate − IOER	−26.3 bps	−6.7 bps	[−10.9, −2.5]
O/N TPR TSY repo − IOER	−19.4 bps	0.0 bps	[−1.5, 2.2]
O/N GCF TSY repo − IOER	−6.4 bps	26.4 bps	[21.0, 31.7]
O/N Non-Fin CP − IOER	−17.0 bps	−5.0 bps	[−7.0, −3.1]

the Fed's RRP facility rose by an average of $206.1 billion at the ends of quarters. We also see that the 1-week T-bill rate and the overnight non-financial commercial paper rate fell at quarter ends by between 5 and 7 basis points.[8] The movements in the 1-week T-bill rate imply that the overnight return on T-bills fell by 47 basis points. That is, had we measured a rate on overnight T-bills we would have seen a very large decline in their rates. The data also show that the GCF treasury repo rate rose on quarter ends by an average of 26 basis points, whereas the tri-party repo rate was nearly unchanged. Finally, the table shows that all of these rates were on average below the interest rate offered to banks on their excess reserves (IOER), with the T-bill rate and the tri-party repo rate the lowest, and the GCF repo rate the highest. In mid-2016, the GCF repo rate went well above IOER on quarter ends.

These effects are consistent with the heavy impact shown in Figure 2.3.1 of the leverage ratio rule on foreign-headquarted banks at the ends of calendar quarters. When banks scale back

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[8]When interpreting the fall in the 1-week T-bill rate, one should keep in mind that the T-bill rate reverses and rises back to the average value the day after quarter-end.

their balance sheets, they offer less repos because of the leverage ratio rule. For example, they borrow less in the tri-party repo market and lend less in the GCF repo market. The resulting contraction in lending in the GCF repo market drives up the GCF repo rate. At the same time, because banks scale back borrowing at quarter ends, cash investors that normally invest in bank deposits seek alternative cash investments. This explains the fall in the 1-week T-bill rate and the overnight non-financial commercial paper rate, as well as the fact the tri-party repo rate does not rise. Additionally, this quarter-end effect also induces cash investors to place additional funds at the Fed's RRP facility. Ruane (2015) shows that the amount of quarter-end movement of funds into the Fed's RRP facility essentially offsets the amount of funds coming out of G-SIB tri-party repo funding.[9]

Munyan (2017) shows that the quarter-end reductions in bank balance sheets are most pronounced for foreign banks. Unlike US banks, foreign bank compliance with SLR is monitored at the ends of quarters based on the intra-quarter month-end snap shots.[10] U.S. banks, however comply quarterly under the "eSLR" rule, based on daily averaging within each quarter for on-balance-sheet items and averaging off-balance-sheet items at month-ends within the quarter. Indeed, in addition to large quarter-end rate effects, Munyan (2017) shows smaller but distinguishable end-of-month effects. Figure 2.3.1 shows clear ev-

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[9]See the figure at the bottom of page 22 of Ruane (2015).

[10]See, for example, Ruane (2015).
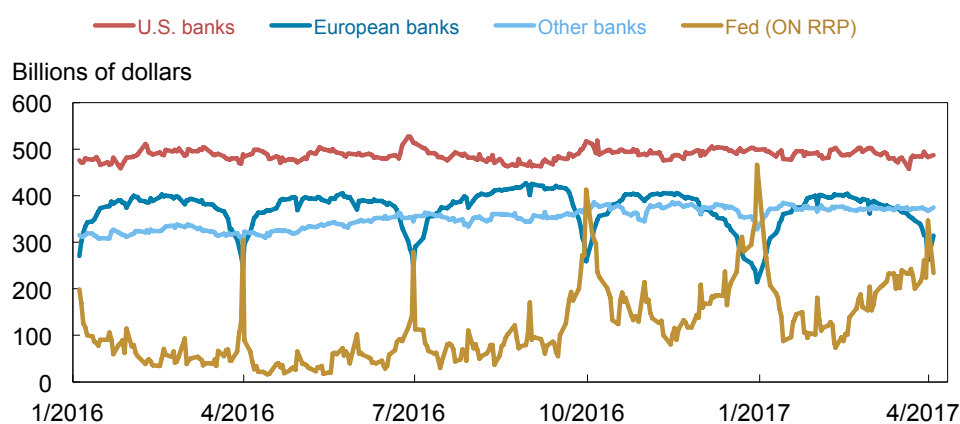
Figure 2.3.1: "European Banks Delever as Reporting Days Approach." Daily collateral outstanding in the tri-party repo market and the Federal Reserve's overnight reverse repo (ON RRP) facility. Figure Source: Egelhov, Martin, and Zinsmeister, "Regulatory Incentives and Quarter-End Dynamics in the Repo Market," Liberty Street Economics, Federal Reserve Bank of New York, August 7, 2017. Notes: Banks headquartered in the euro area and Switzerland report leverage ratios as a snapshot of their value on the last day of each quarter, while their U.S. counterparts report quarterly averages. Totals only include trades backed by Fedwire-eligible securities – that is, U.S. Treasury and agency securities.

idence of this effect. The total amount of tri-party repos outstanding for U.S. banks does not decline significantly at quarter ends. The total of tri-party repos for European banks declines markedly at quarter ends. The quarter-end gaps in the supply of repos from European banks was filled by additional use of the Federal Reserve's reverse repurchase facility (RRP).

3

Dealer Funding Costs

This chapter discusses the impact of dealer funding costs on market liquidity. Again, debt overhang is the driver. The impact on market liquidity can be large even in the absence of regulatory capital requirements. Indeed, we will see that funding-cost frictions are *much larger* than regulatory-capital frictions for safe assets whose intermediation requires significant unsecured funding (whether debt or equity).

3.1   An illustrative example: T-bill investment

The following simple example from Andersen, Duffie and Song (2018) illustrates the meaning of funding costs. A dealer purchases $100 face value of one-year T-Bills, and commits to hold them to maturity. Risk-free interest rates are, for simplicity of illustration, assumed to be zero. The dealer purchases the T-bills at their mid-market value, $100. The purchase is funded by issuing unsecured debt. This could be motivated by a desire to
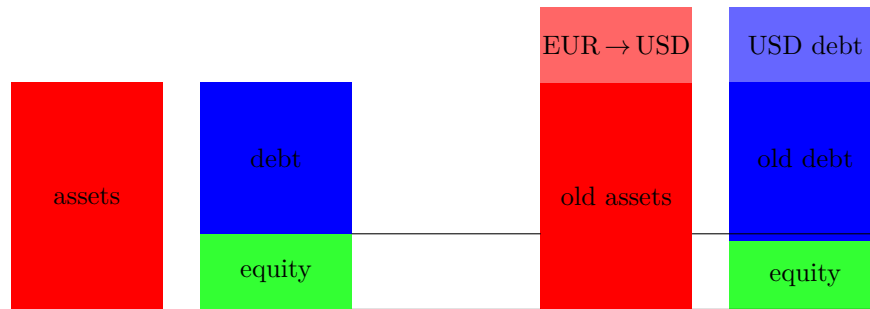
Figure 3.1.1: A bank funds synthetic dollar assets with dollar debt. The bank issues USD commercial paper to fund the purchase of euro commercial paper of equal market value, whose payoff is swapped to USD using forward foreign exchange contracts.

increase the dealer's regulatory measure of High Quality Liquid Assets (HQLA). The dealer has an unsecured one-year credit spread of 50 basis points. At the end of the year, the T-bills will pay $100 and the dealer will repay $100.50 on its financing. The dealer's shareholders will therefore suffer a net loss in one year, after financing costs, of $0.50. This loss will be borne by the dealer's shareholders only if the dealer survives. Assuming the dealer's one-year risk-neutral survival probability p^* is 0.99, the shareholder equity value is thus reduced by $p^* \times 0.50 = 0.495$. As depicted in Figure 3.1.1, this funding cost to shareholders is a transfer in value to legacy creditors, who now have access to an additional safe asset in the event of default.

Were it not for the HQLA requirement in this example, the dealer would not conduct this trade at the given pricing terms. The dealer's shareholders benefit from this trade only if the T-bills can be purchased at a price below $99.505.

3.2 Post-crisis increases in dealer funding costs

While funding costs have long been informally considered an input to dealer trading decisions, they increased dramatically with the widening of bank credit spreads during the Great Financial Crisis. As discussed in Chapter 1 and as shown Figures 1.2.3 and 1.2.4, bank credit spreads have remained wide relatively to their pre-crisis levels, despite significantly increased capital levels.[1] Beginning in 2011, major dealer banks started to formally account for their funding costs in the form of funding value adjustments (FVAs).[2] This new practice is described by Cameron (2014), Becker (2015), and Andersen, Duffie and Song (2018). Some examples of disclosed FVAs are shown in Table 3.1.

As another example of the impact of increased funding costs, Wang, Wu, Yan and Zhong (2016) show that the "big-bang" in the credit default swap (CDS) market in 2009 caused dealers to increase their bid-ask spreads on CDS. This was apparently caused by the increased funding costs associated with the introduction of upfront payments. Wang, Wu, Yan and Zhong (2016) write: "Intuitively, the upfront payment is an impediment to trading, and so reduces the market liquidity, leading to higher bid-ask spreads." They found that "for a CDS contract with a spread level of 300 basis points, at the average level of

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[1]Berndt and Duffie (2018) provide empirical evidence.

[2]As noted by Andersen, Duffie and Song (2018), dealers have been inappropriately treating FVAs as reductions in the market values of their swap books rather than as transfers from equity values to debt values. Although financial accounting standards do not support FVA practice, large accounting firms have accepted FVA disclosures in dealers' financial statements. See, for example, Ernst and Young (2012) and KPMG (2013).

Table 3.1:   Funding value adjustments of major dealers (millions). Source: supplementary notes of quarterly or annual financial disclosures. The $1.5 billion 2013 FVA of JP Morgan includes an FVA of about $1.1 billion for derivatives and about $400 million for structured notes. Source: Andersen, Duffie and Song (2018).

	Amount	Date Disclosed
Bank of America Merrill Lynch	$497	Q4 2014
Morgan Stanley	$468	Q4 2014
Citi	$474	Q4 2014
HSBC	$263	Q4 2014
Royal Bank of Canada	C$105	Q4 2014
UBS	Fr267	Q3 2014
Crédit Suisse	Fr279	Q3 2014
BNP Paribas	€166	Q2 2014
Crédit Agricole	€167	Q2 2014
J.P. Morgan Chase	$1,500	Q4 2013
Nomura	$98	Q1 2014
ANZ	AUD61	Q4 2013
Bank of Ireland	€36	Q4 2013
Deutsche Bank	€364	Q4 2012
Royal Bank of Scotland	$475	Q4 2012
Barclays	£101	Q4 2012
Lloyds Banking Group	€143	Q4 2012
Goldman Sachs	Unknown	Q4 2011

the Libor-OIS spread in our sample, 32 basis points, the upfront payment introduced by the CDS Big Bang increases the bid-ask spread by 1.5 basis points. This is a sizeable effect as the bid-ask spread in our sample has a mean of 9.6 basis points and median of 5.3 basis points."

In the next section of this Chapter, I review a model of the debt-overhang impact of funding costs on bank equity values, and the resulting incentives for reduced market making. Then, in the remainder of the chapter, I focus on the effect of increased dealer funding costs on the post-crisis violations of covered interest parity (CIP) documented by Du, Tepper and Verdelan (2018) and Rime, Schrimpf and Syrstad (2017). For a dealer to benefit its shareholders by arbitraging a CIP violation, our FVA

calculations imply that the CIP basis must roughly exceed the dealer's credit spread.

3.3 A model of dealer funding costs

Here, I summarize a simplified version of the model of shareholder funding costs of Andersen, Duffie and Song (2018). There is a finite number of states of the world. The one-period risk-free discount is $\delta = 1/R$, where R is the gross risk-free rate of return.

The market value of any available payoff Z is assumed to be $\delta E^*(Z)$, where E^* denotes expectation with respect to risk-neutral probabilities.[3] This formulation does not assume the absence of arbitrage. Indeed, it is critical for the viability of dealers that they can overcome debt overhang costs to their shareholders by violating the law of one price, buying assets at prices lower than those at which they sell them.

At time 1, the dealer's assets pay some random amout A, and its liabilities claim L, a positive constant. To avoid singularities, I assume that $P(A = L) = 0$ and that the probability of the default event $D = \{A < L\}$ is not zero.

The dealer may enter a new trade with time-1 per-unit payoff of $Y \geq 0$. The per-unit marginal funding required to buy the asset is u. Our base case is that the dealer funds the trade with

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[3]For the existence of risk-neutral probabilities, we assume that market valuation functional is linear, in that $V(\alpha X + \beta Y) = \alpha V(X) + \beta V(Y)$ and increasing, in that for $X \geq Y$ and $X \neq Y$, we have $V(X) > V(Y)$. Unless markets are complete, the risk-neutral probabilities are not uniquely determined.

new unsecured debt. In later sections, I extend to handle the case of equity funding, whether or not required by regulation.

After financing a position of size q by issuing new debt, the dealer's total assets are

$$\mathcal{A}(q) = A + qY$$

and its total liabilities are

$$\mathcal{L}(q) = L + u(R + s(q)),$$

where $s(q)$ denotes the credit spread on the new debt. The limit credit spread $\lim_{q\downarrow 0} s(q)$ on the newly issued debt is equal to the credit spread S on the dealer's legacy debt.[4]

The marginal increase in the value of the firm's equity, per unit investment, is defined by

$$G = \left.\frac{\partial \delta E^*[(A + qY - L - u(R + s(q)))^+]}{\partial q}\right|_{q=0}.$$

Andersen, Duffie and Song (2018) calculate that the marginal increase in equity value is

$$G = p^*\pi - \delta \operatorname{cov}^*(1_D, Y) - \text{FVA}, \qquad (3.3.1)$$

where

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[4]This fact is shown by Andersen, Duffie and Song (2018), who provide the explicit calculation $S = E^*(\phi)R/(1 - E^*(\phi))$, for a fractional default loss to creditors in $\phi = 1_D(L - \kappa A)/L$, where $\kappa \in [0, 1)$ is the recovery fraction of assets in the event of default. The remaining fraction $1 - \kappa$ is a frictional default distress costs, which is permitted be zero.

$p^* = 1 - P^*(D)$ is the risk-neutral survival probability.

$\pi = \delta E^*(Y) - u$ is the marginal profit on the trade.

$\text{FVA} = p^* \delta u S$ is the funding value adjustment.

The second term, $\delta \operatorname{cov}^*(1_D, Y)$, reflects the potential for asset substitution, as described in Chapter 1. Purchase of a risky asset that is negatively correlated with the dealer's default benefits the dealer's shareholders because they can "walk away" from losses at default and keep gains when surviving. Andersen, Duffie and Song (2018) calculate the second-order term in the Taylor series expansion of the shareholder gain in value, which also includes a natural and explicit asset-substitution effect.

For the low interest rates and high dealer survival probabilities typical of current developed-market economies, we have $p^* \delta \simeq 1$, so the FVA per unit of funding, $p^* \delta S$, is approximately equal to the dealer's one-period credit spread S. Suppose the asset is safe, implying that $\operatorname{cov}^*(1_D, Y) = 0$. In order to benefit shareholders, the dealer must then purchase the asset at a price sufficiently below its market value to achieve an excess rate of return on the purchase that is at least as large as the dealer's credit spread S. If the asset is risky, but has a payoff that is positively correlated with the dealer's default, in that $\operatorname{cov}^*(1_D, Y) > 0$, then the required profit on the trade must be even larger, because of the "negative" asset substitution effect.

Andersen, Duffie and Song (2018) consider a multi-period extension of the funding costs to shareholders. They do not,

however, model the opportunity to re-use the funding that is released, if the asset is sold before it matures, for subsequent asset purchases. This benefit is bigger for higher-turnover dealing businesses. For example, suppose the required funding u is released and re-used for an otherwise identical trade, k times per period. Then, very roughly speaking, the excess intermediation return that must be achieved on each purchase in order to overcome funding costs is reduced by a factor of k.

Consider for example the case of a safe asset, which we showed must be purchased so as to produce an excess return of approximately S in a one-period model. With a dealer turnover rate of k per period, the required excess intermediation return is reduced to S/k. This remains to be formalized with a proper multi-period model.[5]

3.4 CIP arbitrage could harm shareholders

I will now summarize from Andersen, Duffie and Song (2018) an illustrative case study of the implications of funding value adjustments for the incentives of a dealer-bank to "arbitrage" violations of covered interest parity.

Du, Tepper and Verdelan (2018) and Rime, Schrimpf and Syrstad (2017) have shown that the interest rates at which some big banks borrow US dollars outright in wholesale funding markets have been significantly below the rates for synthetic US dollar borrowing that could be obtained via foreign exchange

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[5]This is a subject of ongoing research collaboration with Yao Zeng.

(FX) markets. The synthetic method is to borrow a foreign currency, euros for example, and to exchange the euros for dollars (at spot, and back again at maturity) using FX forwards or cross-currency swaps. If the credit qualities of the two dollar positions, direct and synthetic, are the same, then the associated interest rates "should" be the same absent trade frictions, a point first noted by Keynes (1923) and now known as covered interest parity (CIP). Any difference in these two rates, actual minus synthetic, is called the CIP basis. Among practitioners, the CIP basis is more commonly known as the cross-currency basis.

Between 2010 and 2016, on average over major currencies, Du, Tepper and Verdelan (2018) estimate a CIP basis of about minus 24 basis points at 3 months and about minus 27 basis points at 5 years. Figure 3.4.1 shows violations of covered interest parity for G10 currencies at a maturity of five years.

Violations of CIP in the Yen have been much wider, especially at quarter ends, as shown in Figure 3.5.1.

Rime, Schrimpf and Syrstad (2017) show that, once accounting for actual available transactions prices, profitable arbitrage of the CIP basis is possible for only a subset of highly capitalized banks. Neither of these studies, however, consider whether CIP arbitrage is beneficial to bank shareholders, that is, after considering the adverse impact of FVAs, among other potential frictions.

We will review an illustrative numerical example. Suppose

the one-year USD risk-free rate is zero. A bank considering a CIP arbitrage trade has a one-year credit spread of 35 basis points. The bank can thus borrow $100 with one-year USD commercial paper that promises investors $100.35. The bank could then invest $100 in one-year euro CP, and swap the proceeds to dollars with a forward FX contract. In order to allow for an easy analysis of the attractiveness of this trading opportunity, we suppose that the resulting synthetic dollar asset has the same all-in credit quality as that of the bank's own commercial paper issuance, and that the two payoffs are risk-neutrally uncorrelated. But we will suppose that the synthetic dollar position promises $100.60, for a CIP basis of -25bps.

The bank thus has a new liability with a market value of $100 and a new asset with a market value of $100.65/1.0035 \simeq$ $100.25, for a trade profit of approximately $0.25.

However, the marginal value of the trade to the bank's shareholders is negative, because, *conditional on the bank's survival,* the expected incremental payoff to equity is $100.25 $-$ $100.35 $= -$ $0.10. Conditional on default, the bank's equity gets nothing.

In order for a trade like this to benefit shareholders, the CIP basis would need to exceed the proportional funding cost of approximately 35 basis points.[6]

Most or all of the effective CIP violations documented by

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[6]The value of this trade to dealer shareholders can also be computed directly, in this simple example, as the product of the risk-neutral survival probability and the expected trade net profit allocated to shareholders, after financing costs, conditional on the event of survival, which is $0.993 \times \big($100.60\big(0.993 + 0.0035\big) - $100.35\big) \simeq -$0.10$.
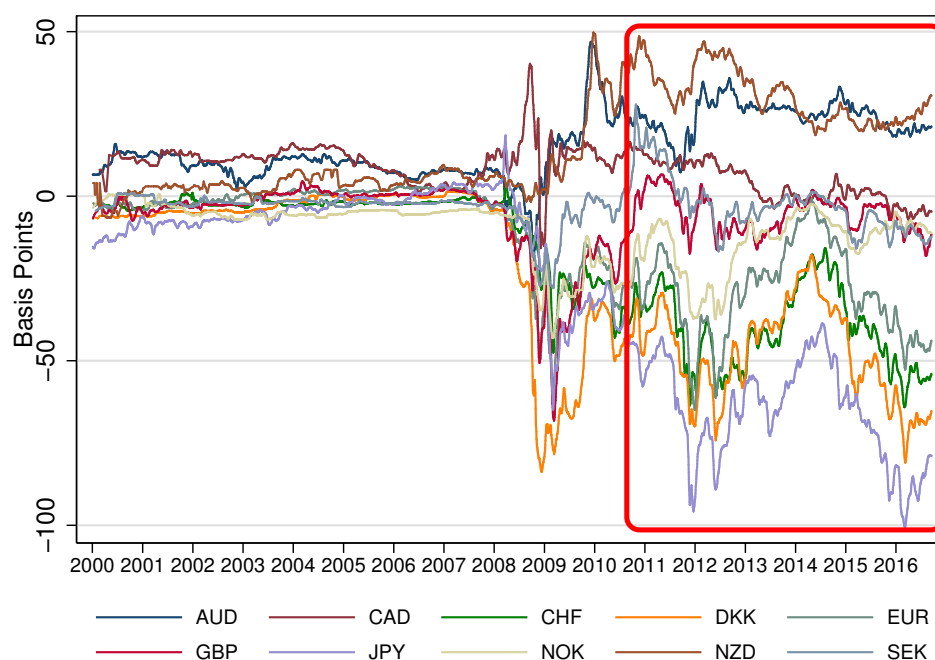
Figure 3.4.1: Ten-day moving averages of the five-year Libor cross-currency basis, in basis points, for G10 currencies relative to the U.S. dollar. Source: Du, Tepper, and Verdelhan (2018).

Rime, Schrimpf and Syrstad (2017) are below the associated proportional FVAs of global banks, based on current credit spreads.

As noted by Du, Tepper and Verdelan (2018), CIP violations were extremely small before the financial crisis of 2007-2009. Consistent with this, major dealer-bank credit spreads (thus FVAs) were also extremely small before the financial crisis.

3.5 Regulatory capital and the CIP basis

Regulatory capital requirements pose an additional friction on CIP arbitrage that can be analyzed within the modeling framework of Andersen, Duffie and Song (2018). Under the leverage-
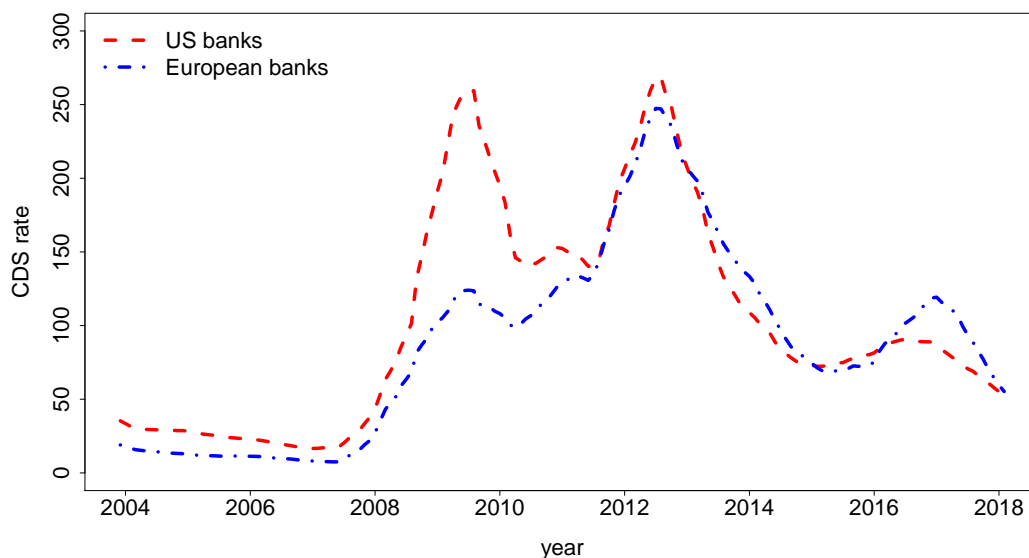
Figure 3.4.2: Five-year CDS rates of major dealers. Averages of the 5-year CDS rates of five large U.S. banks (JPM, Citi, BAML, MS, GS) and of five large European banks (Deutsche Bank, BNP, SocGen, Barclays, RBS). Data source: Bloomberg.

ratio rule, a bank may be required to finance a fraction C of an investment with new equity, and only $1 - C$ with debt. In that case, based on the marginal value to shareholders of equity financing that is computed by Andersen, Duffie and Song (2018), the marginal cost of an asset to bank shareholders, per unit of funding, above that for all-debt financing, is

$$C(1 - p^* - \text{FVA}). \qquad (3.5.1)$$

For the largest U.S. bank dealers, the supplementary leverage ratio rule implies that $C = 6\%$. From (3.5.1), the additional cost to the shareholders for the CIP basis trade described in the above example is 2.1 basis points, for a total proportional

funding cost to shareholders of approximately $35 + 2 = 37$ basis points.

This illustrative calculation, however, ignores the additional funding costs for the FX derivative that swaps the euro cash flows back into dollars. The regulatory capital charge for the FX derivative could be roughly as large as that for the euro commercial paper. Moreover, the margin required for the FX derivative would also have a funding cost.

In practice, a bank would not obtain equity funding on a trade-by-trade basis. The bank would instead arrange in advance for enough excess regulatory equity capital to accommodate its likely potential trades. We do not model the more complicated role of anticipatory funding.

The extra marginal cost (3.5.1) annualizes to roughly CS (assuming a loss given default of 0.5). Thus, for the purchase of safe assets, the shareholder breakeven excess intermediation return is the total annualized funding cost to shareholders of roughly $(1 + C)S$. Notably, only a small fraction of this total funding cost is caused by the regulatory capital requirement. Most of the cost is debt financing costs to shareholders. Debt financing costs are significantly higher in the post-crisis period, not because of capital requirements, but because of new failure-resolution regulations, under the Dodd-Frank Act in the U.S. and under Europe's Bank Resolution and Recovery Directive (BRRD).

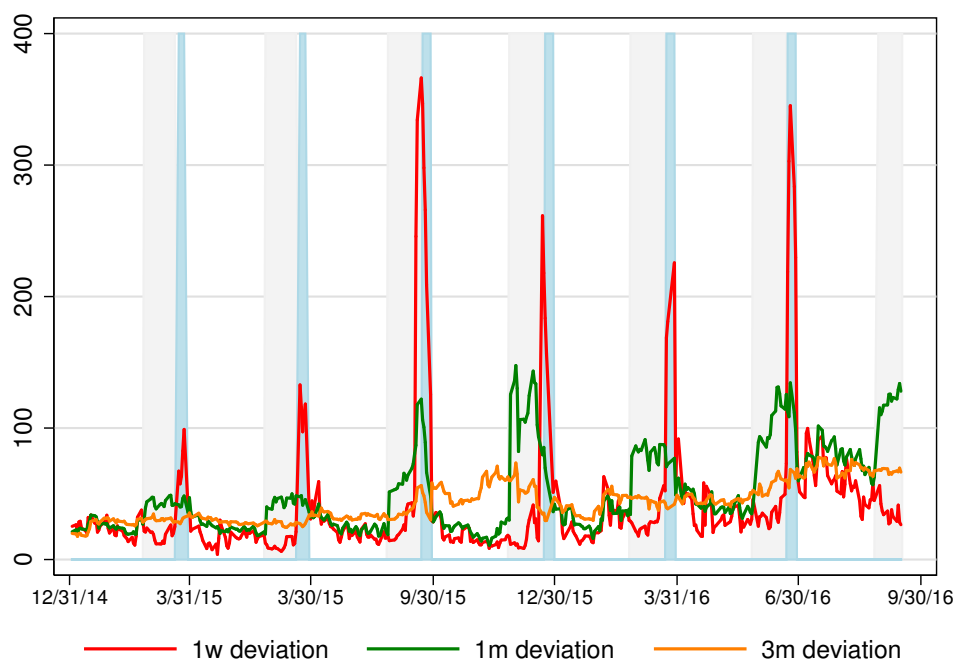Figure 3.5.1 from Du, Tepper and Verdelan (2018) shows that

Figure 3.5.1: The absolute values of the one-week (red), one-month (green), and three-month (orange) Libor CIP basis for the Japanese Yen, relative to the U.S. dollar. The blue and gray shaded regions correspond to periods during which the settlement and maturity of one-week contracts and one-month contracts, respectively, span the end of a quarterly reporting period. Source: Du, Tepper, and Verdelhan (2018).

violations of covered interest parity for Japanese Yen spike dramatically at quarter ends, when regulatory capital is measured. This is consistent with an extremely rigid capital structure, that is, a high frictional cost to shareholders for raising capital in order to exploit CIP arbitrage at quarter ends.

4

Market Design Implications

This chapter[1] discusses how some of the market frictions caused by dealer debt overhang and low competition in OTC markets can be mitigated by improvements in market design.

Dealer intermediation practices have adapted to the higher shadow price for access to their balance sheets. For example, as explained in Chapter 1, dealers are now more likely than before to act as agents that match buyers and sellers, rather as principals that buy or sell on their own accounts. Dealers have also made much heavier use of financial market infrastructure, such "compression" services, described later in this chapter, that eliminate redundant swap positions.

Under the Dodd-Frank Act and the European Union's Markets in Financial Instruments Directive II (MiFID II), regulators have mandated the use of trade platforms for standard financial products. All-to-all trade, however, has been elusive, even for some heavily traded products. Despite the increased cost of

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[1]Some portions of this chapter are based on Duffie (2016).

access to dealer balance sheets, neither regulations nor market forces have had much success in increasing the opportunities for ultimate buy-side firms to trade directly with each other. Some OTC markets could become more efficient once dealer intermediation is supplanted with more all-to-all anonymous trade competition.[2] Here, the biggest deficiencies are related to a lack of price transparency and a weak degree of competitive bidding for trades. Policy objectives should include deeper and more liquid markets, lower execution costs, and better allocative efficiency.

4.1   Opaque bilateral trade is inefficient

In an opaque bilateral over-the-counter (OTC) market, two buy-side firms are rarely if ever be able to identify each other as sources of direct trading benefits. In OTC markets, a buy-side firm often has no reasonable option but to trade with a dealer. In order to conduct a trade in the bilateral OTC market, a representative of a buy-side firm would typically contact a dealer's trading desk and ask for price quotes.

Bilateral (one-on-one) trade negotiation places a buy-side firm at a substantial bargaining disadvantage to a dealer. A buy-side firm rarely has as much information as the dealer concerning the going price for the specific product. Thus, when offered given price terms by a dealer, a buy-side firm cannot be confident whether the dealer's quotes are near the best avail-

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[2]I have a potential conflict on interest on this subject, having served as an expert in litigation in which dealers are alleged to have limited competition in OTC markets.

able quotes in the market. The buy-side firm does not know, moreover, which dealers are likely to provide the best quotes for the trade in question. Moreover, a buy-side firm cannot force two or more dealers to compete effectively against each other for the trade because of the bilateral nature of the bargaining encounter. This situation is modeled by Duffie, Dworczak and Zhu (2017). I will now elaborate on this point.

A buy-side firm has the option to reject the price terms quoted by the dealer with whom it is negotiating, and then search for better terms from another dealer. In many cases, however, the buy-side firm must negotiate with dealers sequentially, that is, one at a time. The buy-side firm cannot choose the best from among various different dealers' simultaneously executable quotes. The mere fact that a buy-side investor can eventually request quotes from different dealers does not in itself cause dealers to compete aggressively with each other in order to win the investor's trade. This situation is modeled by Zhu (2012).

In this setting of one-on-one negotiation, a buy-side market participant has no ability to force dealers to compete directly with each other. When facing a buy-side customer, each dealer holds a degree of monopoly power over its buy-side customer because the customer has no ability to pick the best of many simultaneously executable price quotes. The exercise of this market power reduces the volume of beneficial trade, and can also raise search costs and reduce matching efficiency, as found
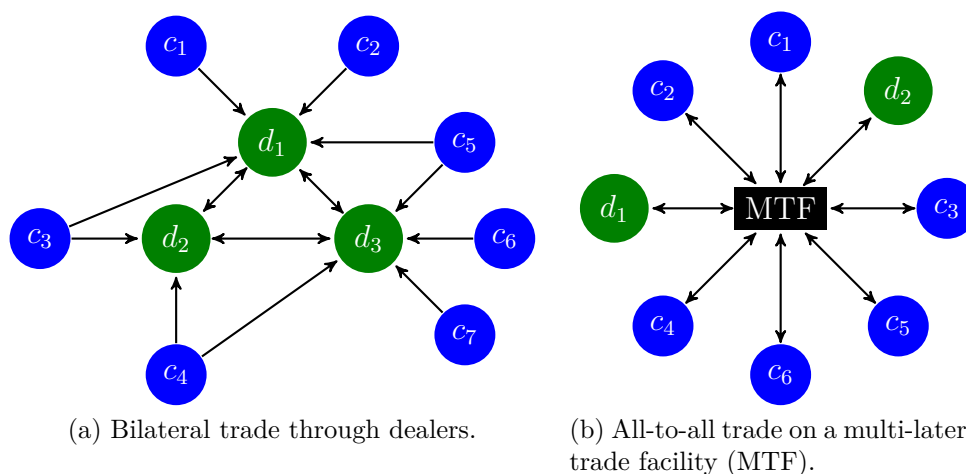
(a) Bilateral trade through dealers.   (b) All-to-all trade on a multi-lateral trade facility (MTF).

Figure 4.1.1: Schematics of markets based on (a) bilateral dealer-intermediated trade and (b) all-to-all trade on a multilateral trading facilty (MTF) such as a central limit order book (CLOB).

in some settings analyzed by Duffie, Dworczak and Zhu (2017).

4.2 Multilateral trade

The distinction between bilateral customer-to-dealer trade and all-to-all trade on a multilateral trade facility is illustrated in Figure 4.1.1. A multilateral trading method used in equity markets is an exchange-based standing central limit order book (CLOB), onto which market participants can at any time (during exchange hours) post limit orders (again, price-quantity pairs) or market orders. Market orders are for immediate execution against the best available limit orders. Limit orders remain on the order book until cancelled or until executed against a market order or a new crossing limit order. Many variant types of orders are permitted.

Multilateral trade can be based on other trade protocols. For example, a request-for-quote (RFQ) protocol allows firms to launch a request to buy, or to sell, often for a stated quantity of the financial instrument. Participants on an RFQ platform respond to requests with price quotes. The requester picks a quote. This is essentially an auction. Vogel (2017) models the potential improvements associated with the introduction of multilateral trade platforms into an otherwise purely bilateral market.

On an all-to-all central limit order book (CLOB), the best price quotes on the limit order book are transparent to all market participants and are simultaneously executable. For example, a buyer can choose the lowest of all of the simultaneously available quoted prices. This is the essence of effective pre-trade price transparency. Moreover, on an all-to-all CLOB, a buy-side firm has the option supply quotes to other market participants, thus offsetting some of its execution costs with the ability to both make and take quotes. Setting up CLOB venues is justified when trading activity is sufficiently broad spread and frequent to generate attention to trading opportunities by liquidity providers and to provide sufficient fee income to the venue operator.

Given their set-up costs, exchanges are not appropriate for every type of financial instrument. Exchanges are more likely to be efficient when there is sufficiently widespread and frequent trading interests.

An alternative all-to-all platform design involves scheduled double-auction trading sessions at which multiple bidders post price-quantity pairs for purchase or sale. Each participant can post multiple bids. Demand and supply schedules constructed from the bids and offers, respectively, then determine a clearing price at which orders to buy at higher prices are filled and orders to sell at lower prices are filled. (Orders at the clearing price may be rationed.)

4.3   Size discovery

Size-discovery trade protocols, such as workup and dark pools, are also popular. In this case, the trade price is fixed in advance of quantity submissions to buy and to sell at the fixed price. Because of this, the market will not generally clear — there will either be an excess of buy orders or an excess of sell orders. The "heavy side" is rationed.

Some size-discovery trade is designed to shield uninformed market participants from adverse selection by informed market participants and to limit front running.[3] Another justification is the ability to cross large and buy and sell orders without price impact, as modeled by Duffie and Zhu (2017).

For example, Figure 4.3.1 illustrates the effect of introducing a workup trading session before trading begins on an exchange market. Without workup, unwanted inventory positions, whether long or short, decline slowly toward efficient levels, be-

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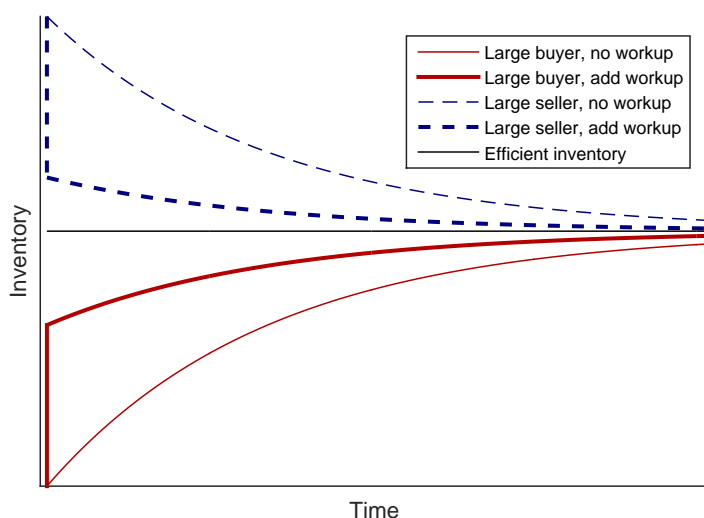
[3]See Zhu (2013) and Pancs (2014).

Figure 4.3.1: Inventory paths with and without a workup. The thin-line plots are the equilibrium inventory paths of a buyer and a seller in sequential-double-auction market. Plotted in bold are the equilibrium inventory paths of the same buyer and seller in a market with a workup followed by the same sequential-double-auction market. Figure source: Duffie and Zhu (2017).

cause investors trade gradually in order to mitigate price impact. With an initializing workup session, however, there is an opportunity for a large buyer and a large seller to instantly cross large orders at a price that is frozen in advance of the expression of order sizes, thus insensitive to order sizes.

Antill and Duffie (2018), however, show that the anticipation of future size-discovery sessions dilutes the incentive to trade on price-discovery platforms, such as the central limit order books of exchanges. Investors reduce their exchange price impacts by waiting for size-discovery sessions to unload large positions. As a result, exchange market depth declines. This decline in exchange market depth has the negative feedback effect of further discour-

aging the placement of orders on price-discovery exchanges, further reducing market depth, and so on. Antill and Duffie (2018) show that the net effect of size-discovery trading can actually be a decline in the overall allocative efficiency of financial markets.

Degryse et al. (2015) find that a one-standard-deviation increase in dark trading (including dark pools) for a particular stock is associated with a reduction in exchange market depth for that stock by 5.5%. Nimalendran and Ray (2014) also find dark trading is associated with greater price impact in lit markets.

Consistent with these concerns raised in theoretical and empirical research, the Markets in Financial Instruments Regulation (MiFIR - 600/2014/EU) has placed caps on dark trading venues, so that[4] "the percentage of trading in a financial instrument carried out on a trading venue under those waivers shall be limited to 4% of the total volume of trading in that financial instrument on all trading venues across the Union over the previous 12 months," and "overall Union trading in a financial instrument carried out under those waivers shall be limited to 8% of the total volume of trading in that financial instrument on all trading venues across the Union over the previous 12 months."

Despite concerns about the impact of size discovery on allocative efficiency, size discovery trade protocols are extremely popular in some markets. For example, Fleming and Nguyen (2015) find that approximately half of the volume of trade in

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[4]See   http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:
OJ.L_.2014.173.01.0084.01.ENG for the text of Regulation (EU) No 600/2014.

the interdealer treasury market is conducted in workup sessions. Collin-Dufresne, Junge and Trolle (2016) find that well over half of trade in credit default swap indices is conducted by size discovery, in the form of workup and matching sessions.

4.4 Mandating multilateral trade facilities

In the U.S., Europe, and Japan, significant post-crisis regulatory steps have been taken toward improved pre-trade price transparency and competition, especially through mandated use of multilateral trade facilities (MTFs). Until new regulations forced some trading onto MTFs, most customer-to-dealer OTC trade was bilaterally negotiated between a buy-side firm and a dealer. Now, according to ISDA data, more than two thirds of customer-to-dealer trades in standardized interest-rate swap and credit default swap index products in the U.S. is conducted on MTFs, which are called swap execution facilities (SEFs).

As depicted in Figure 4.4.1, buy-side firms typically obtain their positions on a customer-to-dealer MTFs at which more than one dealer responds to the buy-side firm's request for a quote (RFQ). In practice, it is rare for buy-side firms to post their own quotes on an RFQ MTF. This narrowed use of MTFs represents a loss of efficiency, because it reduces the degree of competition among dealers, and lowers the efficiency of matching between buyers and sellers.

Another caused for the reduced efficiency of OTC markets is the fragmentation of trade in the same financial instrument

(a) A trade platform on which dealers d_1, d_2, and d_3 meet the request for a quote by buy-side customer c_1.

(b) Fragmented platform trading, in which customer c_1 requests quotes from dealers d_1 and d_2 on one platform, and requests quotes from dealers d_2 and d_3 on another platform.
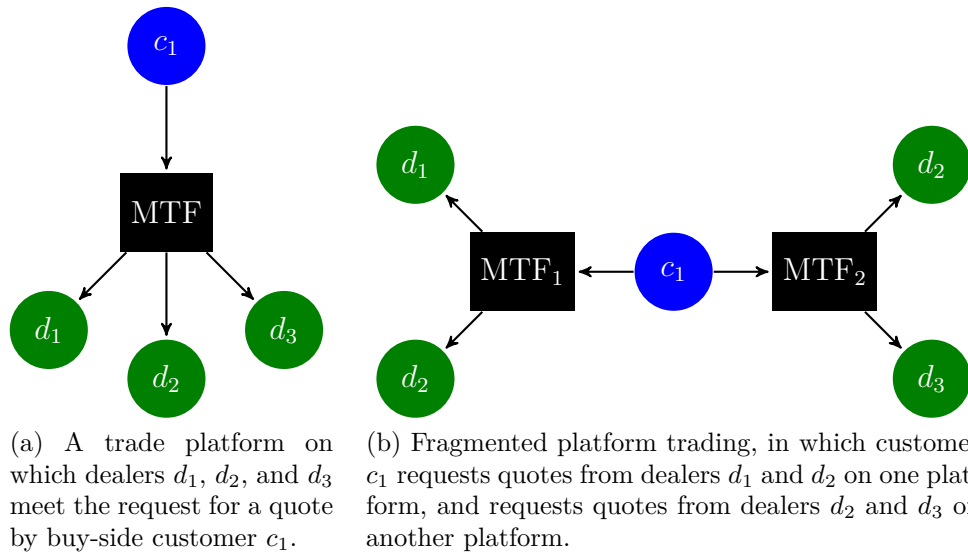
Figure 4.4.1: Fragmentation of trade across platforms is a limit on competition by dealers, and harms market liquidity.

across different MTFs. Fragmentation reduces competition and increases search costs. The social costs of fragmentation of trade across MTFs is analogous, at a higher level, to the costs of dispersed bilateral trade. Colliard and Foucault (2012) model a related cost of fragmentation across platforms.

Well-established economic theory implies that markets are more efficient and investors receive better pricing when more market participants compete for trade at the same venue. Most obviously, from the viewpoint of a quote seeker, the best price from among a small set of bidders is not as attractive as the best price available from an enlarged set of bidders. This is true even if the bids do not depend strategically on the size of the bidding population. For example, for a would-be seller of a financial asset, the highest of the first 5 prices drawn from a given pool of potential bid prices is not as high as the highest

of the first 50 bid prices. Strategic competition among bidders further improves the best price available to the quote seeker. That is, a given bidder will compensate for an increase in the population of competing bidders by bidding more, being aware that a given bid price is less likely to be the highest price as the set of bidders is enlarged.

Figure 4.4.2, from a study of bond trading platforms by Hendershott and Madhavan (2015), supports the theoretically anticipated relationship between the number of dealers providing quotes on Market Axess, a corporate bond MTF, and the expected trading cost to the quote requester, controlling for other factors. Figure 4.4.2 shows that expected trading costs decline rapidly with the number of dealers providing quotes on the same platform.

A significant fraction of inter-dealer trade is conducted on MTFs that use a central limit order book. The result, illustrated in Figure 4.4.3, is sometimes called a two-tiered market. In terms of improving competition and lowering trading costs to buy-side market participants, post-crisis financial reforms fall short in many cases by not bringing all wholesale market participants, including dealers and buy-side firms, together onto common venues based on all-to-all anonymous trade.

4.5 Post-trade price transparency

In any market format, competition is generally improved by fast and comprehensive post-trade transaction reporting. For exam-
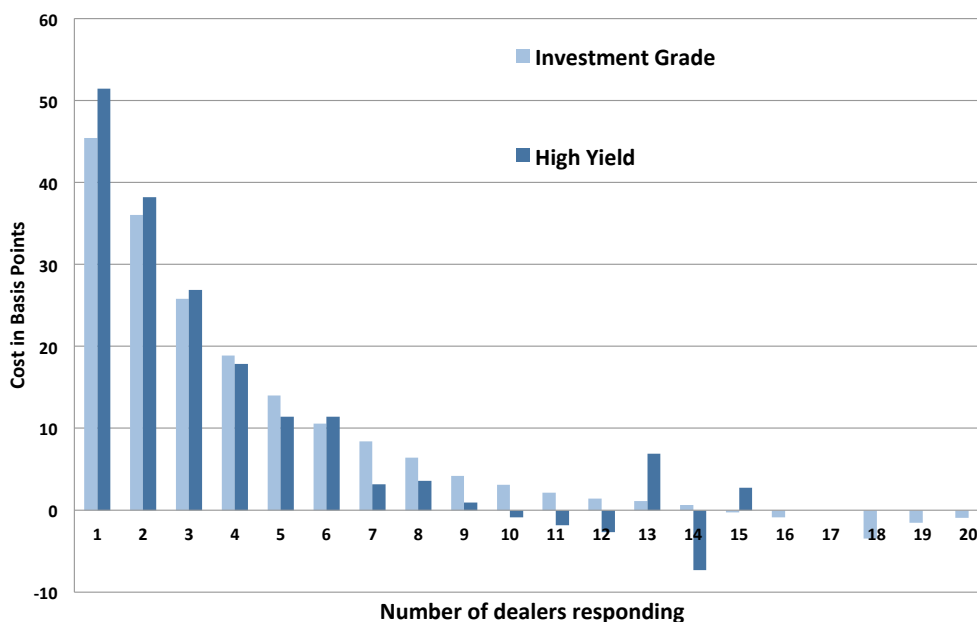
Figure 4.4.2: How transaction costs vary with the number of dealers responding to a request for quotes. Source: Hendershott and Madhavan (2015). The figure shows costs in basis points of notional amount, by the number of dealer responses in all electronic auctions on Market Axess in the sample with at least one response, broken down for investment-grade (IG) and high-yield (HY) bonds. Data are from January 2010 through April 2011, excluding all interdealer trades.

ple, beginning in 2003, the U.S. brought post-trade price transparency into its corporate and municipal bond markets with the Transaction Reporting and Compliance Engine (TRACE). The quick public dissemination of transactions prices gives all market participants an indication of the prices at which trades may be available in the next short interval of time. Knowledge of the going price is a particularly important mitigant of the bargaining disadvantage of buy-side market participants, who generally have much fewer direct observations of trading encounters than do dealers.
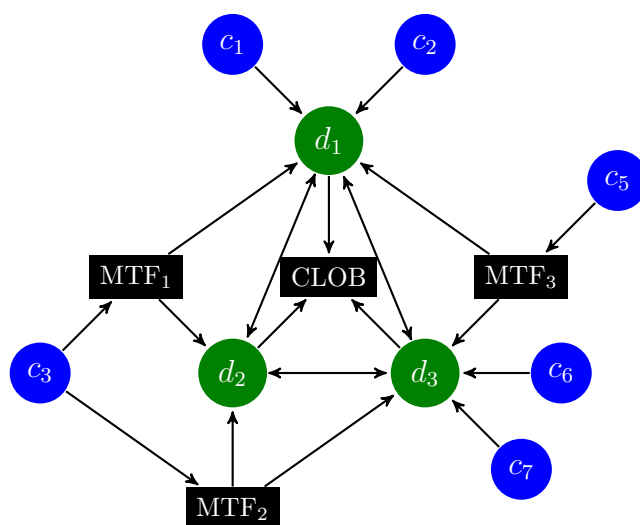
Figure 4.4.3: Now typical fragmented two-tiered OTC markets.

The Dodd-Frank Act aimed at the swap market. With some exceptions, standardized swaps have been designated for immediate and public transactions reporting. Japan has followed a course similar to that of the U.S. Europe's Markets in Financial Instruments Directive (MiFID II) and proposed MIFIR implementing regulations are more ambitious in scope than U.S. trade-competition reforms, but have moved more slowly.

As explained by Duffie, Dworczak and Zhu (2017), financial benchmarks are also a source of post-trade price transparency. The European Union has recognized the social benefits of reliable and transparent benchmarks with supporting legislation and regulation.

In addition to improving the ability of investors to shop for a better price, post-trade transaction reporting allows buy-side investors to monitor and discipline the execution quality of their past trades by comparing the prices that they obtained from a

dealer with the prices that were obtained for other trades conducted elsewhere in the market at around the same time. A dealer, aware of being monitored in this fashion through post-trade price dissemination, and at risk of losing reputation and repeat business over poor execution prices, will provide somewhat better pricing to its customer.

The remainder of this sub-section, which is based on an appendix of Duffie (2016), summarizes the empirical evidence of the impact of TRACE post-trade price transparency on the liquidity and competitiveness of U.S. corporate bond trading.

Bessembinder and Maxwell (2008) reported that "The introduction of transaction price reporting for corporate bond trades through the TRACE system in 2002 comprised a major shock to this previously opaque market. Investors have benefited from the increased transparency through substantial reductions in the bid-ask spreads that they pay to bond dealers to complete trades. Conversely, bond dealers have experienced reductions in employment and compensation, and dealers' trading activities have moved toward alternate securities, including syndicated bank loans and credit default swaps. The primary complaint against TRACE, which is heard both from dealer firms and from their customers (the bond traders at investment houses and insurance companies), is that trading is more difficult as dealers are reluctant to carry inventory and no longer share the results of their research. In essence, the cost of trading corporate bonds decreased, but so did the quality and quantity of

the services formerly provided by bond dealers." Bessembinder, Maxwell and Venkataraman (2006) found that with the introduction of TRACE, trade execution costs fell by about 50% for those bonds whose transactions were covered by TRACE. They also found a spillover effect: Even for bonds not covered at that time by TRACE, transactions costs dropped by 20%. The authors speculate that publishing the prices of TRACE-eligible bonds provided additional information on the fair market values of bonds not eligible for TRACE reporting.

Edwards, Harris and Piwowar (2007) also find that TRACE reduced transactions costs. Goldstein, Hotchkiss and Sirri (2007), however, find that less frequently traded bonds, and very large trades, showed no significant reduction in bid-ask spread with the introduction of public transaction reporting under TRACE. Moreover, Goldstein, Hotchkiss and Sirri (2007) and Asquith, Covert and Pathak (2013) do not find that TRACE increased trading activity. Indeed, Asquith, Covert and Pathak (2013) found that TRACE reduced trading activity significantly for high-yield bonds. A reasonable interpretation is that, with the reduced profitability of market making caused by greater price transparency, dealers had a reduced incentive to make markets, especially in thinly traded bonds.

Bessembinder and Maxwell (2008) note the dramatic increase in corporate bond trading volume on the electronic platform, MarketAxess, that followed the introduction of TRACE, saying, "We believe that TRACE improved the viability of the

electronic market. In the presence of information asymmetries, less-informed traders will often be dissuaded from participating in a limit order market, knowing that their orders will tend to be 'picked off' by better-informed traders if the price is too aggressive, but left to languish if not aggressive enough. TRACE likely increased traders' willingness to submit electronic limit orders by allowing traders to choose limit prices with enhanced knowledge of market conditions."

While bid-ask spread is often a useful measure of trading costs, Asquith, Covert and Pathak (2013) focus on intra-day price dispersion. The relevance of this measure is motivated by the idea that, in an opaque OTC market, the same bond, on the same day, can be traded by dealers at much different prices with some customers than with other customers, even if there has been no significant new fundamental information on the bond's quality during the day. Asquith, Covert and Pathak (2013) showed that the intra-day dispersion of prices for riskier corporate bonds was reduced on average by over 40% with the introduction of TRACE post-trade price transparency for those bonds. This represents a dramatic reduction in effective trading costs for those buy-side investors who, without TRACE transparency, had been paying far higher trading costs than other (presumably more sophisticated and better informed) market participants.

4.6   Market infrastructure

When sufficiently active,[5] central counterparties (CCPs) reduce the need for dealer balance sheet space by netting the long and short positions of large dealers at the CCP. The Dodd-Frank Act and MiFID II now mandate that standard swaps are to be centrally cleared, subject to exemptions. Because of these new regulations, central clearing is now the norm in the swap market. For example, according to ISDA over three quarters of interest rate swaps and index credit default swaps are now centrally cleared.

The U.S. government securities repo market still relies on a narrow inter-dealer repo central counterparty (CCP), the Fixed Income Clearing Corporation (FICC). As illustrated in Figure 4.6.1, a broad-market CCP would include as clearing members a range of buy-side firms, such as money market funds, pension funds, insurers and hedge funds. Various attempts to introduce a broad-market CCP have not yet been successful. A broad-market CCP would allow more scope for long and short positions intermediated by primary dealers to be offset through multilateral netting at the CCP, thus reducing the use of balance sheet space. Again, the Supplementary Leverage Ratio (SLR) Rule discussed in Chapter 2 is especially implicated.

The beneficial effects of multilateral trade platforms and CCPs are related, but are not the same. Multlateral trade platforms allow some disintermediation of dealers, by allowing ultimate

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[5]The netting benefits of central clearing are modeled by Duffie and Zhu (2017).
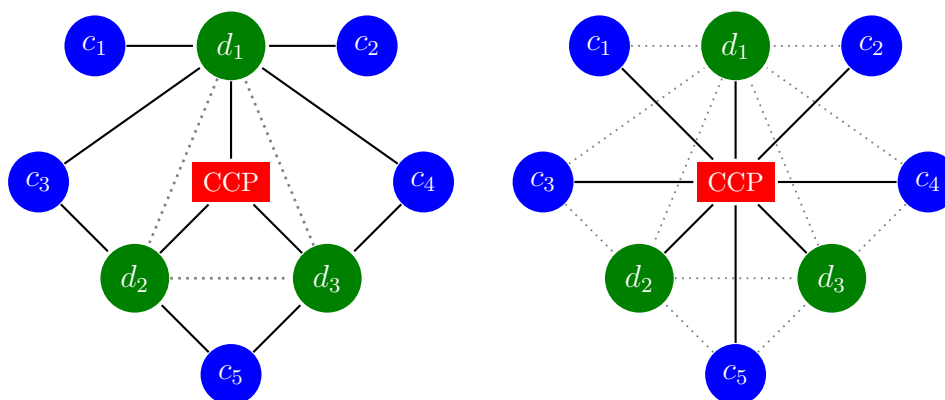
(a) A narrow inter-dealer CCP. Dealers d_1, d_2, and d_3 centrally clear their trades with each other. Positions of dealers with counterparties that are not clearing members, c_1, c_2, c_3, c_4, and c_5, remain on the balance sheets of dealers.

(b) Role of broad-market CCP. For example, the positions of d_1 with c_1, c_2, c_3, and c_4 can also be novated to the CCP, further reducing the balance sheet space of d_1 required to intermediate the repo market.

Figure 4.6.1: Original trades that were subsequently novated to the CCP are shown in dotted lines. Through this novation, known as "central clearing," the CCP becomes the buyer to each original seller, and the seller to each original buyer. With an inter-dealer central counterparty (CCP), as shown in Panel (a), a dealer such as d_1 novates to the CCP its trades with other dealer clearing members, d_2 and d_3, thus reducing its gross outstanding positions and use of balance sheet space, through the effect of netting long against short positions. This is also systemically safer (assuming the CCP is sound). Positions with counterparties that are not clearing members, such as c_1, c_2, c_3, and c_4, remain on the balance sheet of d_1. With a broad-market CCP, as shown in Panel (b), more positions can be novated to the CCP, thus further reducing the use of space on dealers' balance sheets. This mitigates the cost of intermediation to dealers' shareholders for meeting regulatory capital requirements, especially under the Supplementary Leverage Ratio Rule. Figure source: Duffie and Krishnamurthy (2017).

buyers and sellers to trade directly with each other. Broad-market CCPs allow more scope for multilateral netting after trades are executed, thus reducing the amount of balance sheet space that dealers need to intermediate a given amount of trade.

The key impediment to the introduction of a broad-market repo CCP has been the liquidity commitments necessary to safely manage the larger amounts of collateral that would be held by a broad-market CCP, in the event that one or more clear-

ing members fail. In principle, the additional liquidity would need to be committed in advance, in some combination, by the non-dealer clearing members, the CCP operator, the dealer clearing members, or the Federal Reserve (as a lender of last resort). The DTCC has indicated some progress.[6]

4.7 Compression trading

Compression trading, a powerful method for conserving space on the balance sheets of major dealers, eliminates swap positions that are redundant from the viewpoint of their primary purpose of creating or offsetting exposures to market prices, but otherwise expose a dealer to counterparty risk. Along with the unnecessary counterparty risk, if they are not eliminated these redundant swaps involve regulatory capital requirements and force the dealer to post additional collateral, which involves funding costs to dealer shareholders, as explained in Chapter 3.

Redundant long and short positions involving multiple dealers can be discovered via data-sharing arrangements between the dealers and special utilities. These compression utilities, such as TriOptima, then algorithmically initiate a sequence of trades between various pairs of dealers that effectively "tears up" the redundant swap positions, as illustrated in Figure 4.7.1. By February 2018, TriOptima alone had triggered compression trades that eliminated $1,121 trillion notional of swap positions.

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[6]The approach of the DTCC would have some large institutional cash investors such as money funds provide a committed line of collateralized cash lending to a "capped, committed liquidity facility" (CCLF), for a period of up to several days.
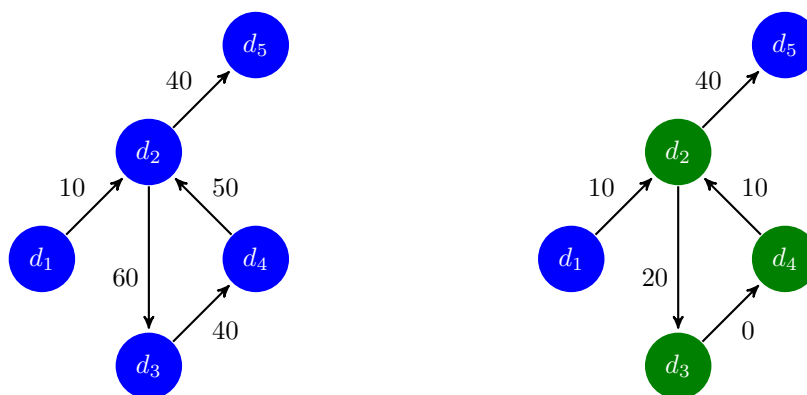
Figure 4.7.1:   A compression trade that eliminates a redundant circle of positions of size 40 (counterclockwise, involving dealers 2, 3, and 4) with a circle of clockwise trades of size 40. Counterparty exposures and initial margin are reduced without changing market exposures. Example service providers: TriOptima (over $1 quadrillion notional eliminated, largely interest-rate swaps).

According to data collected and aggregated by the Bank for International Settlements, the total gross market value of outstanding swap positions, before considering netting and collateral, has been dramatically reduced, with no significant decline in the total annual volume of swap trade.[7] This total gross market value declined from approximately $35 trillion in 2009 to approximately $17 trillion as of June 2017. I surmise that a significant portion of this improvement in the efficiency of balance-sheet usage is due to compression trading. Similarly, gross swap-market credit exposures, which adjust gross market values for legally enforceable bilateral netting agreements, but not for collateral, have fallen to their lowest level since 2007. For example, gross credit exposures declined from $3.3 trillion at the end of 2016 to $2.8 trillion at June, 2017.

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[7]ISDA provides data on trading activity.

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