FEDERAL RESERVE BANK OF NEW YORK

ECONOMIC POLICY REVIEW

1
Negative Swap Spreads
Nina Boyarchenko, Pooja Gupta, Nick Steele, and Jacqueline Yen

15
Trends in Credit Basis Spreads
Nina Boyarchenko, Pooja Gupta, Nick Steele, and Jacqueline Yen

38
The Pre-Crisis Monetary Policy Implementation Framework
Alexander Kroeger, John McGowan, and Asani Sarkar

71
Review of New York Fed Studies on the Effects of Post-Crisis Banking Reforms
Richard K. Crump and João A. C. Santos

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Contents

1 **Negative Swap Spreads**
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Market participants have been surprised by the decline of U.S. interest rate swap rates relative to Treasury yields of equal maturity over the past two years, with interest rate swap spreads becoming negative for many maturities. This movement of swap spreads into negative territory has been attributed anecdotally to idiosyncratic factors such as changes in foreign reserve balances and liability duration management by corporations. However, we argue in this article that regulatory changes affected the willingness of supervised institutions to absorb shocks. In particular, we find that increases in the required leverage ratio may have changed the breakeven level of the swap spread at which market participants are willing to enter into spread trades. We present a stylized example of these economics, illustrating how a higher leverage ratio can help explain these historic movements in swap spreads.

15 **Trends in Credit Basis Spreads**
Nina Boyarchenko, Pooja Gupta, Nick Steele, and Jacqueline Yen

Market participants and policymakers were surprised by the large, prolonged dislocations in credit market basis trades during the second half of 2015 and the first quarter of 2016. In this article, we examine three explanations proposed by market participants: increased idiosyncratic risks, strategic positioning by asset managers,

and regulatory changes. We find some evidence of increased idiosyncratic risk during the relevant period, but limited evidence of asset managers changing their positioning in derivative products. Although we cannot quantify the contribution of these two channels to the overall level of spreads, the relative changes in idiosyncratic risk levels and in asset manager derivative positions appear small compared with the observed spreads. We present the mechanics of the CDS-bond arbitrage trade, tracing its impact on a stylized dealer balance sheet and the return on equity (ROE) calculation. We find that, given current levels of regulatory leverage, the CDS-bond basis needs to be significantly more negative than pre-crisis levels to achieve the same ROE target.

38 The Pre-Crisis Monetary Policy Implementation Framework

Alexander Kroeger, John McGowan, and Asani Sarkar

This article describes the Federal Reserve's operating framework for monetary policy prior to the expansion of the Fed's balance sheet during the financial crisis. To implement the Fed's mandate of promoting price stability consistent with full employment, the Federal Open Market Committee (FOMC) sets a target for the overnight rate in the federal funds market, where banks trade reserve balances. In the pre-crisis framework, aggregate reserves were scarce, so relatively small changes in the level of reserves would affect rates in the fed funds market. The Federal Reserve Bank of New York's Open Market Trading Desk ("the Desk") forecasted the demand for and supply of reserves on a daily basis, and then conducted repo operations with primary dealers with the objective of supplying enough reserves to maintain the equilibrium rate close to its target. The Desk was successful in achieving this objective, since the fed funds rate generally did remain close to its target, and any deviations were quickly corrected. However, the pre-crisis operating procedures deployed by the Desk were more complex and opaque than alternative operating frameworks, required substantial intraday overdrafts from the Fed to meet banks' short-term payment needs, and had to be abandoned once the Fed's balance sheet expanded in response to the financial crisis. Since the crisis, the Desk has successfully controlled the policy rate using a new framework, suggesting that effective monetary control may be achieved through different frameworks.

71 Review of New York Fed Studies on the Effects of Post-Crisis Banking Reforms

Richard K. Crump and João A. C. Santos

In 2017, the Federal Reserve Bank of New York initiated a project to examine the effects of post-crisis reforms on bank performance and vulnerability. The project, which was completed in June 2018, consisted of twelve studies evaluating a wide set of regulatory changes. The primary focus was how these regulatory changes affected the risk taking, funding costs, and profitability of banks, as well as their impact on liquidity. In this article, the authors survey the twelve papers that make up the project and place the principal findings in the context of the current academic and policymaking debate on the effects of post-crisis changes to financial regulation.

Negative Swap Spreads

Nina Boyarchenko, Pooja Gupta, Nick Steele, and Jacqueline Yen

OVERVIEW

- Market participants have been surprised by the decline of U. S. interest rate swap rates relative to Treasury yields of equal maturity over the past two years, with interest rate swap spreads becoming negative for many maturities.
- Although many factors have narrowed interest rate swap spreads, the authors focus primarily on the impact of regulatory increases in required leverage ratios.
- The authors argue that when exogenous factors narrowed spreads, the leverage requirements reduced incentives for market participants to enter into trades that would have counteracted the effects of exogenous shocks.
- The analysis suggests that, given balance sheet costs, spreads must reach more negative levels to generate an adequate return on equity for dealers—suggesting there may be a "new normal" level at which dealers are incentivized to trade.

An interest rate swap enables two counterparties to swap interest rates for a specific period, typically with one rate fixed and the other an agreed-upon floating rate, such as the three-month Libor (London interbank offered rate). At $288 trillion outstanding in notional value,[1] the interest rate swap market is the largest over-the-counter derivatives market in the world, representing an important source of duration for both interest-rate risk management and investment.[2] Corporations use these swaps to transform their interest rate obligations between fixed and floating rates without having to change the mix of bonds they issue. The use of swaps enables issuers to hedge interest rate risk that could affect investment decisions.

Interest rate swap spreads are the difference between the fixed rate in a swap and the yield of a Treasury security of the same maturity. Historically, most swap spreads have been positive (Chart 1). A market participant may be able to narrow a positive spread by paying the floating rate Libor on an interest rate swap, receiving the fixed rate, and selling short a Treasury bond of the same maturity by lending cash against it in a reverse repurchase agreement (reverse repo).

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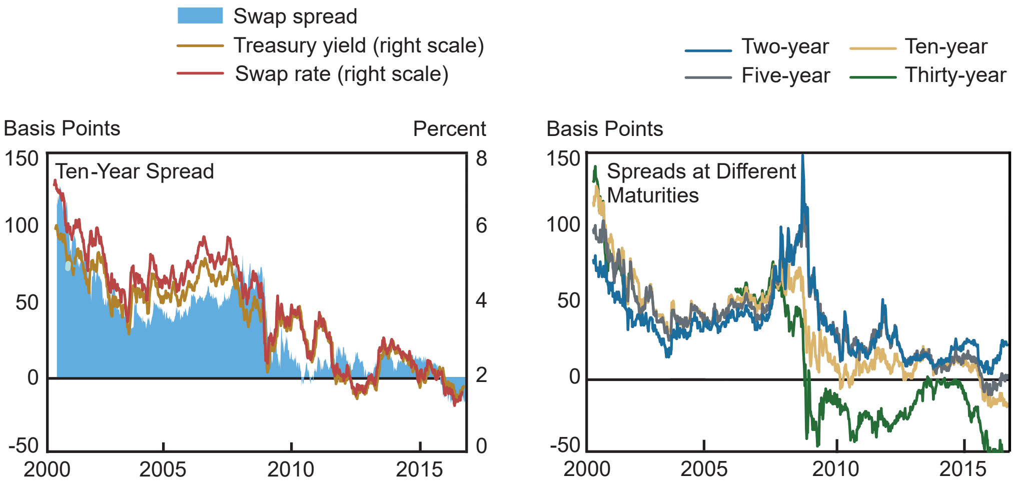
The views expressed in this article are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of New York or of the Federal Reserve System. To view the authors' disclosure statements, visit https://www.newyorkfed.org/research/epr/2018/epr_2018_negative-swap-spreads_boyarchenko.html.

CHART 1
Historical Evolution of Swap Rate, Treasury Yield, and Swap Spread



Source: Federal Reserve Board, H.15 release.

However, Libor generally exceeds the interest rate earned in the reverse repo transaction, making the overall trade uneconomical.[3] Thus, what makes negative swap spreads puzzling is that, when the swap spread is negative, a pure "carry" yield can be earned by paying the fixed rate on the interest rate swap, receiving the floating rate on the swap and holding long a Treasury bond of the same maturity. If interest rates were the only risk factors in this trade, holding to maturity would represent an arbitrage opportunity.

The deviations of swap spreads away from zero suggest the presence of other risk factors—such as counterparty risk for the execution of the swap leg of the trade, ancillary costs to the trade, and limits to arbitrage—which may make holding the trade to maturity infeasible. Market innovations, such as the introduction of mandatory central clearing for U.S.-dollar-denominated interest rate swaps, have reduced the counterparty risk priced into interest rate swaps. However, even the complete removal of counterparty risk premia priced into swaps could only push the Treasury-swap spread to zero, not into negative territory.

In this article, we suggest that regulatory changes help explain negative swap spreads. Although many factors have narrowed interest rate swap spreads[4] since the fall of 2015, we focus primarily on the impact of regulatory increases in required leverage ratios. We show the true cost of entering into a trade to widen interest rate swap spreads—paying a fixed swap rate and buying a Treasury with matched maturity—depends on the capital regulations faced by the firm. We also examine how higher regulatory leverage requirements have lowered the spread at which a market participant can earn the required return on equity (ROE).[5] To find the level at which an arbitrage yield is available, the cost to finance both the interest rate swap and the Treasury security must be considered. Likewise, the amount of equity that must be held for the trade also determines whether the ROE is high enough for market participants to enter into the trade.

We do not argue that it is the higher leverage ratios themselves that have narrowed spreads. Instead, when exogenous factors narrowed spreads, the leverage requirements reduced incentives for market participants to enter into trades that would have counteracted the effects of exogenous shocks. The exogenous factors that market participants have identified as narrowing spreads since fall 2015 include notable selling of foreign reserves by foreign central banks, particularly China; increased swapping of fixed-rate into floating-rate debt; and increased demand by insurance and pension funds to match the extending durations of their liabilities as longer-term government yields declined. These factors put downward pressure on fixed interest-rate swap rates, narrowing their spread to U.S. Treasury bonds. This narrowing revealed the changed economics of spread-widening positions, which will be examined in more detail below.

Our empirical contributions are closely related to the theoretical work on swap spreads by Jermann (2016). Jermann models swap spreads in an environment in which banks face an additional cost for holding Treasury securities. This additional cost creates limits to arbitrage by introducing a wedge between the net benefit of holding a Treasury security long and the benefit of entering into a pay-fixed swap. That model is motivated by the introduction of similar capital regulations to the ones we examine.

The only other article we are aware of that studies negative swap spreads presents a demand-based explanation. Klingler and Sundaresan (2016) find evidence that demand by underfunded pension funds for interest rate swaps is associated with negative thirty-year swap spreads. However, the authors acknowledge that this driver is specific to the thirty-year swap spread. In contrast, regulatory drivers affect the pricing of swap spreads of all maturities.[6]

The rest of this article is organized as follows. Section 1 reviews theoretical arbitrage trades and the recent performance of those trades. Section 2 explains the mechanics of the Treasury-swap trade in detail and examines how post-crisis regulation affects the incentives to engage in this trade. We draw policy conclusions in Section 3.

1. Recent Trends

The negative Treasury-swap spread trade provides a potential trading opportunity for market participants. In particular, if a market participant anticipates that swap spreads will move closer to historical levels, they could enter into a pay-fixed swap while simultaneously holding a long Treasury position of matched maturity. The pay-fixed swap insures the participant against potential future interest rate fluctuations. If the Treasury and the swap have equal risk profiles along all other dimensions, such as counterparty and liquidity risk, this trade represents an arbitrage opportunity in which the market participant earns the Treasury coupon and the three-month Libor from the floating leg of the swap and pays the fixed swap rate and the general collateral (GC) repo cost to finance the Treasury holding. If swap spreads move toward positive territory or stay the same until the unwinding or maturity of the trade, the trade is profitable net the difference between the three-month Libor rate and the GC-repo cost. As the spread between the three-month Libor and the GC repo narrows, the trade becomes less attractive.

Chart 1 (page 2) shows that, historically, the ten-year interest rate swap spread has been positive except for brief episodes. As discussed in the introduction to this article, counterparty risk premia is one of the proposed explanations for positive swap spreads historically. Although the introduction of mandatory interest rate swap clearing on March 11, 2013, ameliorated the counterparty risk that market participants face, spreads to U.S. Treasuries remained positive for intermediate maturities until the second half of 2015. This suggests that the reduction in counterparty risk is not the main driver of negative swap spreads.

Furthermore, the floating rate of the interest rate swap is anchored to the three-month Libor rate, which reflects the credit risk of large financial institutions. In contrast, the Treasury position is funded using GC rates and the Treasury yield reflects only the credit risk of the U.S. government. The right panel of Chart 1 shows that the thirty-year swap spread became negative toward the end of 2008 and has remained negative since. At the same time, the swap spread on the two-year maturity swap has remained positive since 2000.

These moves in swap spreads were abnormal relative to historical experience. Before becoming negative in October 2015, the ten-year swap spread on average was 38 basis points, but has averaged -11 basis points since. Similarly, the thirty-year swap spread on average was 63 basis points before November 2008, but since has averaged -23 basis points.

2. Treasury-Swap Spread Trade in Practice

In this section, we discuss how the Treasury-swap spread trade is implemented in practice, including the capital charges associated with each leg of the trade and the cost of funding both legs of the trade. We propose an explanation for the negative swap spreads that draws on two recent strands of the academic literature on asset pricing: intermediary asset pricing and the margin capital asset pricing model (CAPM). In intermediary asset pricing theory (He and Krishnamurthy 2013; Brunnermeier and Sannikov 2014; Adrian and Boyarchenko 2012), binding capital and liquidity regulations reduce the ability of market intermediaries to absorb shocks affecting either the buy or the sell side of the market. This increases the effective risk aversion of marginal investors in spread trades, potentially leading to prolonged deviations from parity in linked markets. At the same time, since the interest rate swap leg of the Treasury-swap spread trade requires posted margin, the margin CAPM of Garleanu and Pedersen (2011) applies, with deviations from the law of one price larger whenever the marginal cost of financing the margin requirement is higher.

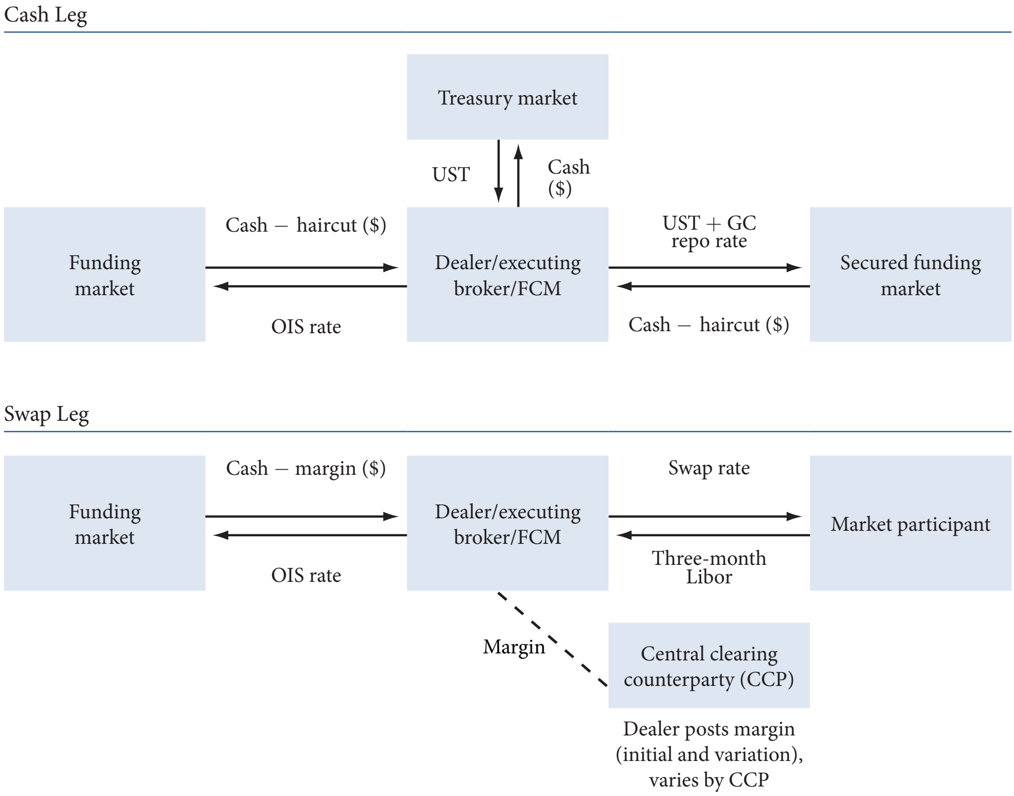
It is important to note that in these theories, as in practice, regulatory constraints and margin requirements are not the source of the divergence in prices between linked markets. Rather, these constraints make market participants less willing to enter into spread trades once a shock occurs in one of the linked markets and thus prolong the dislocation.

2.1 Mechanics of the Trade

The schematic of a typical Treasury-swap spread trade from the perspective of a dealer engaging in the trade on its own behalf is presented in Exhibit 1 below. A key assumption in this example, which we also make when we discuss the balance sheet impact of the trade, is that the dealer uses repo financing to purchase the cash instrument (Exhibit 1, upper panel).

Exhibit 1

Mechanics of the Treasury-Swap Trade



Notes: UST is U.S. Treasury, GC is general collateral, and FCM is futures commission merchant.

The dealer buys a Treasury security and uses it as collateral to borrow in the GC finance repo market. The repo position requires a haircut, which we assume to be 2.8 percent in the balance sheet example below, and the dealer pays the GC repo interest rate, which we assume to be 0.3 percent in annualized terms, each day that its GC position is open.[7] The haircut on the repo is borrowed in short-term unsecured funding markets, with a 0.5 percent interest rate and one-year maturity.[8]

The swap side of the Treasury-swap spread trade is illustrated in the lower panel of Exhibit 1. The dealer enters into a pay-fixed swap with a maturity matched to the Treasury position with the appropriate central clearing counterparty (CCP). In a pay-fixed swap, the dealer pays the fixed interest rate on the swap to the CCP and receives the three-month Libor in return. The CCP requires both an initial margin, assumed to be 3.9 percent for a ten-year maturity, and a variation margin to be posted for the interest rate swap position, which the dealer again borrows in short-term funding markets at approximately the overnight indexed swap (OIS) rate.

In summary, even when the dealer engages in the Treasury-swap trade on its own behalf, four counterparties participate in the transaction: a Treasury market dealer, the counterparty in the GC repo, the lender in the unsecured funding market, and the interest rate swap CCP. The mechanics are similar when the dealer engages in the trade on behalf of a customer, with an extra leg added for the transaction between the dealer and the client. We turn next to the balance sheet impact and equity costs of this trade.

2.2 Balance Sheet Impact of the Trade

The following discussion considers the balance sheet impact of entering a swap spread trade from the perspective of a dealer, focusing on calculating the dealer's supplementary leverage ratio (SLR). Under the SLR guidelines, derivatives affect this balance sheet calculation. The example here is illustrative and numbers may vary for an individual dealer and specific trade.

Consider first the balance sheet impact of the long-Treasury leg of the Treasury-interest rate swap trade, illustrated in Panel A of Table 1. Assume that the trade size is $10 million and the dealer faces a 2.8 percent haircut when buying the Treasury using a three-month GC repo. The trade increases the Treasury position on the asset side of the balance sheet by $10 million. Since the purchase is repo funded, the value of securities sold under agreements to repurchase on the liabilities side of the balance sheet increases by $10 million, less the haircut. In addition, the dealer borrows the $280,000 haircut on the repurchase agreement in short-term funding markets at a 0.5 percent interest rate, increasing its short-term debt.

The balance sheet impact of the interest rate swap, in which the dealer pays the fixed rate and receives the floating rate, is also illustrated in Panel A of Table 1. At the trade's inception, the fixed rate is set such that the fair value of the swap is $0. As the three-month Libor reference rate fluctuates, the market-clearing fixed rate fluctuates as well. Thus, the fair value of the dealer's interest rate swap changes, which translates into either an increase in the "Derivatives with a positive fair value" line on the asset side or the "Derivatives with a negative fair value" line on the liabilities side.

In this example, the swap requires an initial margin of 3.9 percent. Since the dealer will be rebated the margin at trade termination, the margin is reflected as an increase in receivables on the asset side of the balance sheet. At the same time, since the dealer in this example borrows the initial margin in short-term funding markets at a 0.5 percent interest rate, its total short-term debt obligation also increases. In addition, the dealer computes its derivatives exposure, or potential future exposure (PFE),[9] for the centrally cleared interest rate swap, increasing its off-balance-sheet exposure.[10]

The cash flows and "carry" earned on a $10 million ten-year swap spread trade with a holding period of one year, based on dealer estimates, is shown in Panel B of Table 1. In the trade, the dealer enters into a pay-fixed swap with a CCP, which requires it to post an initial margin (IM) of $390,000. The dealer is assumed to borrow the initial margin from short-term funding markets, paying a 50 basis points interest rate ($1,950). In addition to the swap, the dealer purchases the Treasury security, which is funded via repo financing markets. Thus the dealer borrows $10 million to purchase the Treasury, which it posts as collateral for the repo. The repo rate for a ten-year Treasury is assumed to be approximately 30 basis points and represents a financing cost for the dealer. Furthermore, there is an assumed 2.8 percent haircut on the Treasury repo collateral, which means the dealer must borrow this additional amount on short-term funding markets at a 50 basis points interest rate to post to the repo lender.

Table 1

A Dealer's Perspective: Balance Sheet Impact and the Cost to Trade a Treasury-Swap Trade

U.S. Dollars

Panel A: Balance Sheet Impact

Assets		Liabilities	
Cash		Short-term debt	670,000
Treasury securities	10,000,000	Long-term debt	
Securities purchased under agreements to resell		Securities sold under agreements to repurchase	9,720,000
Derivatives with a positive fair value	0	Derivatives with a negative fair value	0
Receivables	390,000	Payables	
Total assets	10,390,000	Total liabilities	10,390,000

Panel B: Costs to Trade

Interest rate swap trade cost	
Initial margin funding ~ one-year OIS	-1,950
Income	
Three-month Libor ~ 0.6 percent	60,000
Subtotal swap income	58,050
Treasury in repo costs	
Treasury repo ~ 0.3 percent	-29,160
Haircut ~ one-year OIS	-1,400
Subtotal Treasury cost	-30,560
Net return from carry	
Swap income	60,000
Swap cost	-1.950
Treasury cost	-30,560
Subtotal before spread	27,490
Swap spread at -0.1 percent	10,000
Total after spread	37,490

Source: Authors' calculations.

Notes: The following assumptions were made: 2.8 percent haircut in the Treasury-collateralized repo trade, with a 0.3 percent interest rate; 0.5 percent interest rate charged in the unsecured funding market; 3.9 percent initial margin on the interest rate swap position; 0.6 percent three-month Libor; $10 million swap notional value; and $10 million Treasury position.

Therefore, the total cost to finance the long Treasury position is the Treasury repo rate plus the haircut financing charge, a total cost of $30,560 in this example.

On the derivative portion of the trade, the dealer pays the fixed ten-year swap rate on the pay-fixed leg of the swap and receives three-month Libor on the floating leg, $60,000. Since the dealer is receiving the Treasury yield and paying the swap rate, on net it is paying the swap spread[11] on the fixed leg of the trade. On the floating leg, the dealer earns three-month Libor while paying the GC repo rate for the Treasury financing and the short-term funding rate for financing the repo haircut and the swap margin. Thus, the net amount the dealer receives on the swap for the first period is the three-month Libor rate earned minus the initial margin funding costs and the Treasury financing cost. The dealer effectively pays the swap spread since it pays the swap rate on the swap and receives the Treasury yield through its long Treasury holding. Combining the amount received by the dealer with the amount paid by the dealer results in the net carry, or profit/income, which in this example is $37,490. Thus, when swap spreads are negative, the dealer earns a positive carry on a long swap spread position since the Treasury yield it receives is greater than the swap rate it pays, net of the spread between Libor and repo rates.

2.3 Profitability of the Swap Spread Trade

The costs associated with swap spread trades have changed since the enactment of mandated clearing of interest rate swaps, which broadly went into effect at the beginning of 2014. Dealer costs have also changed because of implementation of the SLR. These additional costs may be passed on to clients that want to use dealers as their Futures Clearing Merchant (FCM) in order to trade swaps. Market participants note that the higher clearing costs have increased the fees charged by FCM's to clients, with reports that fixed fees can now be as high as $10,000 per month.

Capital Charges

The capital charge, or additional equity required for the arbitrage trade reflects the impact a trade has on the balance sheet. Specifically, the gross notional amount of repo financing, initial margin, repo haircut, and PFE of the derivative instrument require a dealer to hold additional equity under SLR before entering into a trade. In practice, each firm may have its own approach for deciding how much additional equity to hold, which may vary by business unit. The capital charges associated with different leverage ratio assumptions is shown in Table 2. For a swap spread trade, the largest capital charge stems from the cash position since the charge is based on the entire notional amount financed rather than the net repo liability. However, for higher leverage ratios, the equity associated with the derivatives transaction through the initial margin and PFE can also be large.

Anecdotal evidence suggests that dealers increasingly are evaluating trades through a profitability lens based on the ROE for a given trade, which has declined because of higher leverage requirements. Table 2 also shows ROE based on assumed SLRs ranging from 1 to 6 percent. Other key assumptions in this calculation are the spread between swap rates and Treasury yields, and the spread between three-month Libor and repo rates.

Table 2
Components of Regulatory Equity Charges for Treasury-Swap Spread Trade
U.S. Dollars, Except as Noted

	Supplementary Leverage Ratio					
	1%	2%	3%	4%	5%	6%
Treasury	100,000	200,000	300,000	400,000	500,000	600,000
Haircut	2,800	5,600	8,400	11,200	14,000	16,800
Initial margin	3,900	7,800	11,700	15,600	19,500	23,400
Potential future exposure	600	1,200	1,800	2,400	3,000	3,600
Total equity cost	107,300	214,600	321,900	429,200	536,500	643,800
Total profit (return)	37,490	37,490	37,490	37,490	37,490	37,490
Return on equity (percent)	35	17	12	9	7	6

Source: Authors' calculations.

Notes: The following assumptions were made: 2.8 percent haircut in the Treasury-collateralized repo trade, with a 0.3 percent interest rate; 0.5 percent interest rate charged in the unsecured funding market; 3.9 percent initial margin on the interest rate swap position; 0.6 percent three-month Libor; $10 million swap notional; and $10 million Treasury position.

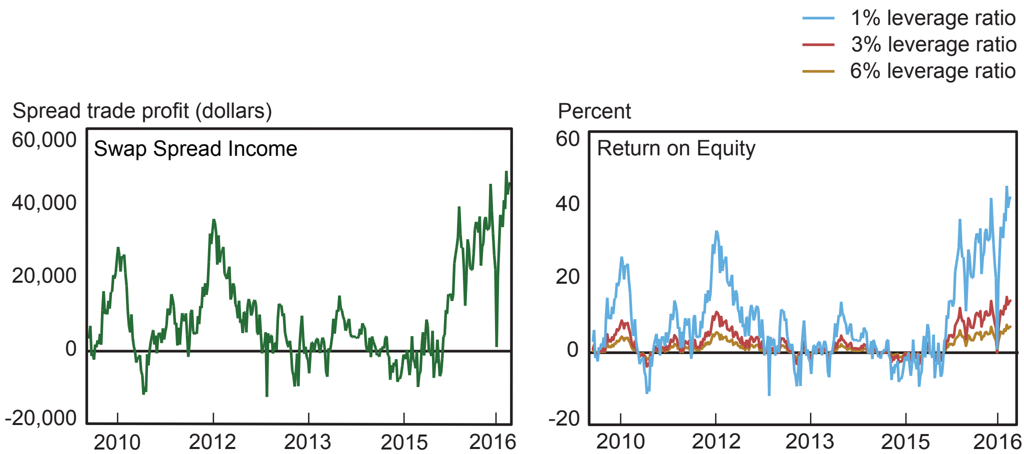
Table 2 suggests that ROE is very sensitive to the capital charge, which in turn is highly sensitive to leverage ratios. An increase or decrease of as little as one percentage point in the leverage ratio can have a big effect. Indeed, the impact on ROE is nonlinear. The ROE declines from 35 percent to 17 percent when the assumed leverage ratio increases from 1 percent to 2 percent, and from 17 percent to 11 percent when the ratio increases from 2 to 3 percent. The SLR for the largest U.S. banks is currently around 6.0 to 6.5 percent.[12] Around this level, ROE for the swap spread trade is at most 6 percent—less than half the 15 percent ROE reportedly targeted by dealers on average.

Compare this to the ROE that would have been earned historically on the Treasury-swap trade. The time series evolution of the profit from the Treasury-swap trade and the total equity cost under different leverage ratio assumptions are presented in Chart 2. As the swap spread and the Libor-OIS spreads fluctuate over time, the income earned on the swap spread trade fluctuates as well (Chart 2, left panel). When the minimum leverage level required by regulation is low, say 1 percent, the implied ROE fluctuates between -10 percent and +40 percent (Chart 2, right panel). However, for higher required leverage levels, the fluctuations are much more modest. With a 6 percent minimum leverage requirement, the implied ROE never reaches above 7.5 percent.

Breakeven Swap Spreads

Although new regulations may have increased the swap spread cost for dealers, there should still be a level at which the difference in pricing between the cash and derivative markets makes dealers willing to enter into an arbitrage trade.

Chart 2
Profitability and Cost of Equity for Treasury-Swap Trade over Time



Sources: Bloomberg L.P.; authors' calculations.

Notes: The following assumptions were made: 2.8 percent haircut in the Treasury-collateralized repo trade, 3.9 percent initial margin on the interest rate swap position, $10 million swap notional, and $10 million Treasury position.

Table 3
Treasury-Swap Spread Required for Return on Equity at Different Dealer Leverage Ratios

Return on Equity (Percent)	Supplementary Leverage Ratio					
	1%	2%	3%	4%	5%	6%
5	21	16	11	5	0	-6
10	16	5	-6	-16	-27	-38
15	11	-6	-22	-38	-54	-70
20	5	-16	-38	-59	-81	-102
25	0	-27	-54	-81	-107	-134
30	-6	-38	-70	-102	-134	-166

Sources: Bloomberg L.P.; authors' calculations.

Notes: Spreads are reported in basis points. The following assumptions were made: 2.8 percent haircut in the Treasury-collateralized repo trade, 3.9 percent initial margin on the interest rate swap position, $10 million swap notional, $10 million Treasury position, and one-year holding period for the swap spread trade.

Table 3 conducts a sensitivity analysis of the breakeven ten-year swap spread needed to achieve a given ROE target at different SLR levels. In the past, when the balance sheet cost was very low because of risk weighting, a dealer could earn a 15 percent ROE at a spread up to 11 basis points simply through carry. At a 5 percent leverage ratio, the spread needs to be -54 basis points to achieve a 15 percent ROE. Although this calculation is subject to many assumptions, it illustrates the costs dealers now face. These higher costs help explain why regulated institutions are less likely to execute swap spread trades unless spreads reach much more negative levels than in the past: A more negative swap spread increases the carry earned, making the trade economical even with the capital charge.

3. Conclusion

Although we cannot precisely measure the costs SLR capital requirements impose, it appears that executing swap spread trades is now more expensive for dealers than in the past largely because of the amount of capital that dealers must hold against these trades. The amount of capital required is driven principally by the cash product position of the trade rather than the derivatives portion. The SLR requires that the entire repo-financed Treasury position be recognized, while the derivatives portion is recognized only up to the margin posted on, and the potential future exposure of the position. As a result, while current negative swap spread levels may have presented attractive trading opportunities in the past—which would have reduced deviations from parity—our analysis suggests that, given the balance sheet costs, these spreads must reach more negative levels to generate an adequate ROE for dealers. This may represent a shift in the spread levels considered attractive for trading, suggesting there may be a "new normal" level at which dealers are incentivized to trade.

At the same time, although Treasury-swap spread trades might be attractive to financial institutions facing fewer regulations, such institutions frequently rely on the regulated financial sector to fund these leveraged positions. Dealers that find spread trades to be unprofitable for their own book are also less likely to provide leverage to their clients pursuing the same trades. Post-crisis regulation may thus also affect the ability of unregulated intermediaries to carry out leveraged trades.

Appendix: Potential Future Exposure

Potential future exposure (PFE) is an estimate of the value of a derivative contract at future points in time, usually within a specified confidence interval such as 95 or 99 percent. It is essentially an estimate of the future replacement cost of the contract via a distribution of potential values rather than a single point estimate.

Although representative of the estimated future distribution, the PFE is defined as the upper bound of the forecasted credit exposures at the given level of confidence over a specified period of time. The PFE is not known with certainty because it estimates the market value in the future. In contrast, the current credit exposure, which is the greater of the present fair value of the contract and zero, is known with certainty since it captures only the current market value.

There are various methodologies used to calculate PFE including simulations of future paths of the inputs used to calculate the replacement value and using a constant exposure method based on a fixed percentage of the effective derivative notional value of the contract. The Basel Accord utilizes the latter methodology, calculating PFE by multiplying the notional value of the derivative contract with a fixed percentage that is based on the PFE Add-on Factor as indicated in the Accord. This factor is based on the asset class and remaining maturity of the derivative contract. Table A1 lists the PFE factor by asset class and maturity.

Table A1

Potential Future Exposure Add-On Factors

Percent

	Interest Rates	FX and Gold	Equities	Precious Metals except Gold	Other Commodities
One year or less	0.0	1.0	6.0	7.0	10.0
More than one year up to five years	0.5	5.0	8.0	7.0	12.0
More than five years	1.5	7.5	10.0	8.0	15.0

Source: Basel III: Finalizing Post-Crisis Reforms, December 2017, https://www.bis.org/bcbs/publ/d424.htm.

Notes

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[1] As of the second half of 2015, BIS semiannual OTC derivatives statistics.

[2] Bretscher, Schmid, and Vedolin (2016) examine a large cross-section of hand-collected data on interest rate hedging by publicly traded firms over the past twenty years. They find that interest rate risk management does indeed help attenuate the impact of interest rate uncertainty on investment. Rampini, Viswanathan, and Vuillemy (2015) use shocks to other parts of bank balance sheets as a source of exogenous variation of institutions' incentives to hedge interest rate risk and find a positive and significant relationship between hedging and net worth, with distressed institutions reducing their hedging intensity.

[3] Since Libor is the interest rate at which banks borrow, it reflects the credit risk of these institutions. The reverse repo rate on U.S. Treasuries lent in general collateral (GC) repo markets, in contrast, is essentially credit risk free.

[4] An interest rate swap spread is termed to "narrow" when it becomes smaller, even when the gap between the swap spread and the yield paid on a matched-duration U.S. Treasury security is negative.

[5] The approach in this article builds on the analysis in Korapaty and Marshall (2015).

[6] Klingler and Sundaresan provide a comprehensive review of the extensive literature on swap rates and Treasury yields, as well as the use of swaps by nonfinancial corporations.

[7] These assumptions are based on interest rates prevailing in the fall of 2015.

[8] The interest rate charged in unsecured funding markets is approximately equal to the interest rate charged in an overnight indexed swap (OIS) with equal maturity. An OIS is an interest rate swap where the periodic floating payment is based on a return calculated from a daily compound interest investment and the reference rate is an overnight rate.

[9] The potential for future exposure (PFE) is a measure of counterparty/credit risk as represented by the maximum exposure under normal market conditions over a future specified period of time. The PFE is included in the denominator of the SLR along with other off-balance-sheet exposures and on-balance-sheet assets. See Appendix for details.

[10] When the dealer executes the trade on behalf of a client instead of itself, the balance sheet impact is similar except for three important differences. First, the initial margin the client posts with the dealer, which the dealer then posts with the CCP, increases the payables on the liabilities side of the dealer's balance sheet, depleting the equity cushion further. Second, if the dealer executes the interest rate swap leg of the trade by buying the swap from their client to face the CCP, the dealer's PFE to the overall trade increases. Finally, if the dealer provides funding to the client, the value of loans on the asset side of the balance sheet increases, expanding the dealer's balance sheet further.

[11] Recall that the swap spread is the difference between the swap rate and the Treasury yield.

[12] Current estimate based on 2015 earnings reports for JPMorgan Chase, Bank of America Merrill Lynch, and Morgan Stanley.

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Trends in Credit Basis Spreads

Nina Boyarchenko, Pooja Gupta, Nick Steele, and Jacqueline Yen

OVERVIEW

• The second half of 2015 and the first quarter of 2016 saw a large, prolonged widening of spreads in credit market basis trades—between the cash bond and CDS markets and between segments of the CDS market.

• This article examines three potential sources of the persistent dislocation: (1) increased idiosyncratic risk, (2) strategic positioning in CDS products by institutional investors, and (3) post-crisis regulatory changes.

• The authors argue that, though post-crisis regulatory changes themselves are not the cause of credit basis widening, increased funding costs associated with tighter balance sheet constraints reduce the willingness of regulated institutions to enter spread-narrowing trades.

• Although some of the underlying factors driving deviations in credit spreads may be transitory, increased funding costs are likely to be more persistent and may point to potentially "new normal" levels for both the CDS-bond and the CDX-CDS bases.

Corporate bonds represent an important source of funding for public corporations in the United States. When these bonds cannot be easily traded in secondary markets or when investors cannot easily hedge their bond positions in derivatives markets, corporate issuance costs increase, leading to higher overall funding costs. In this article, we examine two credit market basis trades: the cash bond-credit default swap (CDS) basis and the single-name CDS-index CDS (CDX) basis, evaluating potential explanations proposed for the widening in both bases that occurred in the second half of 2015 and first quarter of 2016.

The prolonged dislocation between the cash bond and CDS markets, and between segments of the CDS market, surprised market participants. In the past, participants executed basis trades anticipating that the spreads between the cash and derivative markets would retrace to more normal levels. This type of trading activity serves to link valuations in the two markets and helps correct price differences associated with transient or technical factors. However, the persistence and magnitude of dislocations during the first quarter of 2016 suggest that limits to arbitrage in these markets have become more significant than in the past.

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We examine three potential sources of the persistent dislocation: (1) increased idiosyncratic risk, which makes the CDX-CDS spread trade less attractive; (2) strategic positioning in CDS products by institutional investors, which makes the CDS market more liquid than the cash market; and (3) post-crisis regulatory changes. We do not attempt to quantify the contribution of each of these channels to the widening in the CDS-bond and the CDX-single-name spread, but instead consider whether measures of these channels are qualitatively consistent with the limits-to-arbitrage mechanism.

Finally, we review the trade mechanics of the CDS-bond basis trade and set up a stylized balance sheet framework that can be used to assess the impact that capital regulation may be having on incentives to enter into these trades. We lay out trade mechanisms in some detail and create a stylized example, which enables us to quantify the impact that capital and derivatives trading regulation has on incentives to engage in arbitrage trades. The numbers and exact version of the trade laid out in this article are illustrative because there is no standardized arbitrage trade. The exact terms vary depending on the dealer, investor, and cash securities used.

Many market participants, including dealer strategists and buy-side investors, cite balance sheet constraints as an underlying factor contributing to the unusual price dislocations. In particular, market participants believe that balance sheet constraints affect prices through multiple channels, such as liquidity in the cash markets and willingness to facilitate arbitrage trades between the cash and derivatives markets in ways that narrow the pricing gap. We extend the balance sheet example to evaluate the profitability of these trades under various assumptions within a cost-of-capital framework. In this stylized framework, profitability is defined as the return per additional dollar of equity required by the trade. We vary assumptions regarding the targeted leverage ratio and target return on equity (ROE). Before the crisis, capital regulation implied that bank holding companies targeted leverage ratios of around 2 to 3 percent, while current leverage targets are 5 to 6 percent. In our stylized examples, this can result in ROEs that are two to three times lower, making previously attractive trades significantly less economical.

The rest of this article is organized as follows. Section 1 reviews the theoretical basis trades and the recent performance of these trades. We turn toward potential explanations for basis dislocations in Section 2. Section 3 explains the mechanics of the CDS-bond trade in detail and examines how post-crisis regulation affects incentives to engage in this trade. We draw policy conclusions in Section 4.

1. Recent Trends

We focus on two particular credit basis trades: the CDS-cash bond basis trade and the index CDS-single-name CDS (CDX-CDS) basis trade. We begin with a brief description of the current structure of CDS and CDX contracts, and then discuss each of the basis trades in turn.

1.1 CDS Contracts

A credit default swap is a bilateral over-the-counter contract in which the buyer of protection agrees to pay a fixed spread to the seller of protection until the contract expires or the reference obligation underlying the contract experiences a credit event before contract expiration. A single-name CDS contract insures the buyer of protection against credit events experienced by either a single corporation, a sovereign, or a municipality. A CDS index (called CDX for North American reference entities) is a portfolio of single-name CDS and thus insures the protection buyer against credit events experienced by a basket of corporations or sovereign entities. The composition of the basket is determined when the index is rolled to the market. Once index composition is determined, the constituents of the series remain unchanged throughout the lifetime of the contract unless a credit event occurs for a constituent, in which case the defaulting constituent is removed without replacement and settled separately. In this case, a new version of the index series is published, which assigns zero weight to the defaulted constituent and has a reduced notional amount. A new (on-the-run) index series is introduced twice each year in March and September, with renewed maturity and an updated constituent list. Entities no longer qualifying for inclusion in the index based on either credit rating or liquidity are removed and new entities are added to keep the number of reference entities in the index constant, but the majority of the constituents remain unchanged.[1] Trading in previous (off-the-run) series continues after index rolls, though the liquidity in these series is diminished relative to the on-the-run series.

Since April 2009, both single-name and index CDS have been traded with a standardized fixed coupon (100 or 500 basis points for North American reference entities) and an upfront payment from the buyer to the seller, or vice versa. The upfront payment makes the expected present value of the protection bought equal to the expected present value of protection sold, conditional on the fixed spread chosen and common assumptions of the recovery rate in case of a credit event.[2] For both single-name and index CDS, the fixed coupon payments from the protection buyer to the protection seller are made on a quarterly basis, using 360 days per year as the convention.[3] (Boyarchenko et al. [2016] provides more details on the current structure and historical evolution of the CDS market.)

Example: Upfront and the Running CDS Spread

Consider a CDS contract with T years to maturity and fixed spread s. To compute the required upfront payment F, denote by $h(t)$ the (risk-neutral) default intensity—the probability of the reference entity defaulting in the next instant conditional on surviving to date t—and by $D(t)$, the risk-free discount factor applied to cash flows earned in t periods. Then the expected present value of protection bought is

$$V_{\text{float}} = \int_0^T \left[1 - \left(1 + A(t)\right)R\right] h(t) e^{-\int_0^t h(\tau)d\tau} D(t)dt,$$

where $A(t)$ is the accrued interest on the insured bond and R is the expected recovery rate on the bond in case of default. The expected present value of payments made by the buyer of protection is given by

$$V_{\text{fixed}} = s \sum_{i=1}^{N} e^{-\int_0^{t_i} h(\tau)d\tau} D(t_i) + F,$$

where $\{t_i\}$ are the N quarterly payment dates. Thus, given a fixed spread s, and assumptions about the discount rate, default rate, and recovery rate, the upfront payment is calculated as

$$F = \int_0^T [1 - (1 + A(t))R] h(t) e^{-\int_0^t h(\tau)d\tau} D(t)dt - s \sum_{i=1}^N e^{-\int_0^{t_i} h(\tau)d\tau} D(t_i).$$

The equivalent running CDS spread is the spread $\hat{s}$ that equates the value of the fixed leg with the value of the floating leg of the swap for 0 upfront, so that

$$\hat{s} = \frac{\int_0^T [1 - (1 + A(t))R] h(t) e^{-\int_0^t h(\tau)d\tau} D(t)dt}{\sum_{i=1}^N e^{-\int_0^{t_i} h(\tau)d\tau} D(t_i)}.$$

1.2 CDS-Cash Bond Basis Trade

The first basis trade we consider, and the main focus of this article, is the CDS-cash bond basis trade. In the CDS-bond trade, an investor buys (sells) a corporate bond and simultaneously buys (sells) protection on the same reference entity in the CDS market. The CDS bond-basis is then computed as the difference between the running spread ($\hat{s}$ above) on the CDS and the theoretical (par-equivalent) CDS spread implied by the yield on the cash bond. When this basis is negative, the return on the trade is earned by purchasing the cash bond and purchasing protection in the CDS market.[4] Ignoring the funding costs of this trade, a market participant receives the bond coupons, makes or receives the one-time upfront payment, and pays the CDS fixed spread.

Example: Par-equivalent CDS Spread

We now extend the above example to compute the bond-yield-implied par-equivalent CDS spread. Let P_{bond} be the price of a bond written on the same reference entity that pays quarterly coupon payments c and has T years until maturity. The market price P_{bond} implies a default hazard rate curve $\hat{h}(\tau)$ that correctly prices the cash bond, given the risk-free discount curve $D(t)$ and an expected recovery rate R. In particular, $\hat{h}(\tau)$ solves

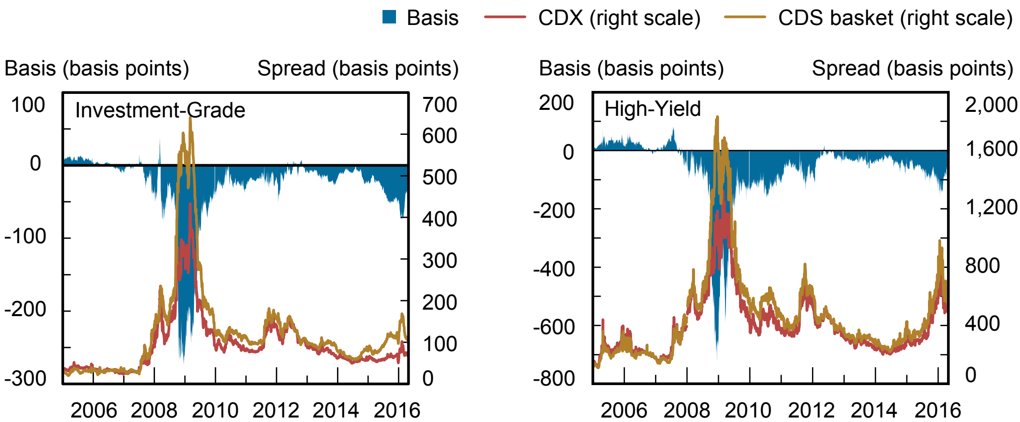
$$P_{\text{bond}} = c \sum_{i=1}^{N} e^{-\int_0^{t_i} \hat{h}(\tau)d\tau} D(t_i) + 100 e^{-\int_0^T \hat{h}(\tau)d\tau} D(T) + R \int_0^T \hat{h}(t) e^{-\int_0^t \hat{h}(\tau)d\tau} D(t)\, dt.$$

The par-equivalent CDS spread, s_{bond} , is then the running spread computed using h as the default intensity

$$s_{\text{bond}} = \frac{\int_0^T [1 - (1 + A(t))R] \hat{h}(t) e^{-\int_0^t \hat{h}(\tau)d\tau} D(t)dt}{\sum_{i=1}^N e^{-\int_0^{t_i} \hat{h}(\tau)d\tau} D(\mathrm{t}_i)}.$$

The CDS-bond basis is then given by the difference between the running spread $\hat{s}$ and the par-equivalent CDS spread s_{bond}.

Chart 1
Historical Evolution of the CDS-Bond Basis



Source: JPMorgan Chase.

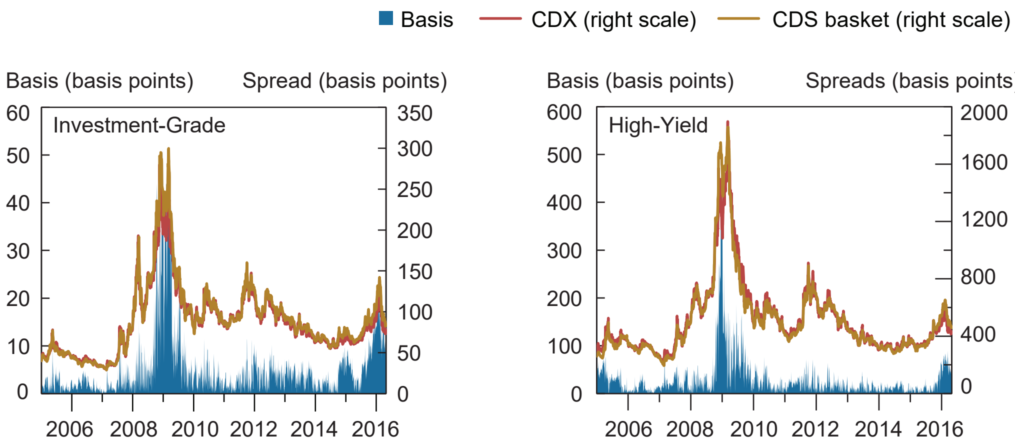
Notes: The chart shows the time series of the CDS-bond spread, the CDS spread, and the bond-implied CDS spread.

In practice, the CDS-bond basis has historically deviated from zero and has varied over time (see Chart 1). One interpretation of the negative basis is that it measures deteriorating liquidity in the cash bond market relative to the CDS market: a more negative CDS-bond basis suggests that the CDS market is more liquid than the cash market. Thus, to transact in the more-liquid market, investors are willing to accept a lower spread.

Although there is no consensus about a single driver that explains the disparity between the market CDS spread and the bond-implied CDS spread, a number of authors have found that funding risk and limited intermediary capital contribute to the negative CDS basis. Bai and Collin-Dufresne (2013) find that funding risk, counterparty risk, collateral quality, and liquidity risk are all potential explanations for the extreme negative basis during the financial crisis. Trapp (2009) has similar findings and also concludes that credit basis trade profitability is affected by the dealer's risk of exiting the CDS position before default or maturity. Choi and Shachar (2014) use data on corporate bond and CDS holdings of individual institutions during the financial crisis. They find that basis widening was precipitated by the unwinding of pre-crisis basis trades by hedge funds. At the same time, limited capital prevented dealers from taking the opposite side of the unwind trade, prolonging the duration of the dislocation. Similarly, Oehmke and Zawadowski (2016) show that, when the CDS-bond basis is more negative, the total net notional value in the corresponding CDS is higher. More generally, Mitchell and Pulvino (2012) find that limited risk-bearing capital at prime brokers during the financial crisis limited the amount of leverage available to hedge funds, severely restricting their ability to maintain similar prices of similar assets.

Nonetheless, market participants were still surprised by how large and persistent the gap between CDS and cash bond spreads had been because, during normal times when the CDS-bond basis became more negative, market participants—such as dealers, hedge funds,

Chart 2
Historical Evolution of the CDX-CDS Basis



Source: Markit.

Notes: The chart shows the time series of the CDX spread, the individual CDS-implied spread (CDS basket), and the CDX-CDS spread.

sophisticated asset managers, and pension funds—executed CDS-cash bond trades that helped reduce dislocation. Chart 1 plots the evolution of the CDS-bond basis for investment grade (left panel) and high-yield (right panel) bond indexes since January 2005. The CDS-bond basis has been increasing since January 2015 for investment grade bonds and the middle of 2015 for high-yield bonds.

1.3 CDX-CDS Basis Trade

For the CDX-CDS basis trade, on the other hand, an investor buys (sells) protection on a CDX index and sells (buys) protection on a portfolio of single-name CDS contracts that replicates the index. Similar to the CDS-bond basis trade, this trade is considered to be free of default risk because the portfolio of single-name contracts perfectly replicates the payoffs from the index contract. The CDX-CDS basis is constructed as the absolute value of the difference between the spread on the CDX index and the spread implied by the spreads paid on the replicating portfolio of single-name CDS contracts. Junge and Trolle (2014) argue that the CDX-CDS basis measures the overall liquidity of the CDS market, with changes to the basis accounting for 30 percent of CDS returns on average. In this trade, ignoring funding costs, the arbitrageur receives the difference between the index spread and the equal-weighted spreads on the underlying single-name CDS.

Chart 2 plots the time series evolution of the quoted spread, the single-name implied spread, and the CDX-CDS basis for the North American investment grade (left panel) and North American high-yield (right panel) on-the-run CDX indexes. Similarly to the CDS-bond basis, the CDX-CDS basis has been increasing since the beginning of 2015, suggesting that, while liquidity

Table 1
Historical Credit Basis Changes

A. CDS-Bond Basis

	One-Month Change (Basis Points)	Percentile	Six-Month Change (Basis Points)	Percentile
Investment-grade	-13.181	10	-24.301	15
High-yield	-19.2	15	-46.859	15

B. CDX-CDS Basis

	One-Month Change (Basis Points)	Percentile	Six-Month Change (Basis Points)	Percentile
Investment-grade	3.357	95	12.312	95
High-Yield	13.756	90	50.271	95

Sources: JPMorgan Chase; Markit; authors' calculations.

Note: The table presents changes up to January 28, 2016, and the percentile of the historical distribution represented by the changes.

of the CDS market has been improving relative to the cash bond market, the liquidity of the CDS market has been deteriorating relative to the CDX market. In February 2016, the CDX-CDS basis reached levels not seen since the financial crisis, rising to a third of the crisis peak.

1.4 Historical Context

These credit bases moves were abnormal relative to historical experience. Table 1 shows that both the one-month and six-month changes in the CDS-bond basis are in the bottom (most negative) 10-15th percentile of historical changes for the investment grade and high-yield indexes. For the CDX-CDS basis, both the one-month and the six-month changes are in the highest (largest) 5th percentile of the historical distribution of changes for both the investment grade and high-yield indexes.

Turning to the relationship between basis and investor transactions, we estimate the relationship between changes in the CDS-bond basis and the unfilled open interest in single-name CDS contracts

$$\Delta \text{CDS} - \text{bond basis}_{it} = \alpha_i + \beta_i \Delta SN \text{ Unfilled Interest}_{it} + \varepsilon_{it},$$

where ΔSN Unfilled Interest_{it} is the growth rate in the difference between the open interest and transaction volume cleared through the Intercontinental Exchange (ICE) for the single-name

Table 2
Basis and Unfilled Interest

	CDS-Bond, Investment-Grade	CDS-Bond, High-Yield	CDX-CDS, Investment-Grade	CDX-CDS, High-Yield
Constant	-0.023	0.320	-0.027	0.163
	(0.309)	(0.699)	(0.101)	(0.410)
Single-name unfilled interest	-0.451***	-0.096***	0.163***	0.004
	(0.061)	(0.005)	(0.015)	(0.005)
Index unfilled interest			-0.209	-2.018***
			(0.289)	(0.691)
Observations	148.0	148.0	148.0	148.0
R-squared	0.03	0.01	0.01	0.02
Adjusted R-squared	0.02	0.01	0.00	0.00

Sources: JPMorgan Chase; Markit; ICE; authors' calculations.

Notes: The table shows the relationship of changes in the CDS-bond basis and the absolute CDX-CDS basis with the growth rate of unfilled interest in index and single-name contracts. Unfilled interest means the difference between the open interest and transaction volume cleared through ICE for the on-the-run index with the five-year tenor (index unfilled interest) and the single-name constituents of the on-the-run five-year index (single-name unfilled interest). Standard errors in parentheses are calculated over time using Newey-West (five lags).

* Significant at the 10 percent level.
** Significant at the 5 percent level.
*** Significant at the 1 percent level.

constituents of the on-the-run CDX index with five-year tenor, and the relationship between the absolute value of the CDX-CDS index and the unfilled open interest in single-name and index CDS contracts

$$\Delta|\text{CDX} - \text{CDS basis}|_{it} = \alpha_i + \beta_{i,1}\Delta SN\text{ Unfilled Interest}_{it} + \beta_{i,2}\Delta\text{CDX Unfilled Interest} + \varepsilon_{it}.$$

Table 2 reports the estimated coefficients and standard errors for these regressions. ICE reports open interest and transaction volume from the standpoint of net buyers in the market. When there is more unfilled interest in the single-name CDS market, the CDS-bond basis becomes less negative, consistent with investors taking more aggressive buy positions in the single-name CDS market that close the CDS-bond basis. Similarly, the CDX-CDS basis decreases when investors take more aggressive sell positions in the index contract and increases when investors take more aggressive buy positions in the single-name replicating basket.

Table 3
Measures of Idiosyncratic Risk as of the Fourth Quarter of 2015

	Upgrades/ Downgrades	Percentile	Percent Changed Every Roll	Percentile	Idiosyncratic Equity Volatility (Percent)	Percentile
Investment-grade	1.04	45	2.4	10	6.75	40
High-yield	0.53	30	15.0	100	11.43	45

Sources: JPMorgan Chase; Markit; Center for Research in Security Prices; authors' calculations.

Notes: The ratio of upgrades relative to downgrades is reported as a fraction—1 corresponds to an equal number of firms downgraded as upgraded and numbers less than 1 correspond to a larger number of downgraded than upgraded firms.

2. Potential Explanations

The explanations offered by market participant for these changes in early 2016 can be grouped into three categories: (1) greater idiosyncratic risk, which makes the CDX index a less attractive instrument for hedging individual exposures; (2) strategic positioning by asset managers; and (3) regulatory constraints, which reduce the attractiveness of basis trades. In this section, we describe the first two explanations. In Section 3, we examine the impact of regulatory constraints.

2.1 Idiosyncratic Risk

Table 3 shows three measures of idiosyncratic risk for investment grade and high-yield firms as of the fourth quarter of 2015, the fraction of names changed every CDX index roll,[5] the number of upgraded firms relative to the number of downgraded firms, and the idiosyncratic equity return volatility. The fraction of names changed every CDX index roll is high when a large fraction of index constituents fails to satisfy either the credit rating or the liquidity requirement for inclusion in the index, implying higher idiosyncratic credit or liquidity risk. The number of firms within each broad rating category that get downgraded relative to the number that get upgraded illustrates changes in the downside rating risk of firms in each rating category. When this fraction is large, firms are more likely to be downgraded than upgraded. We follow Goyal and Santa-Clara (2003) in constructing the idiosyncratic equity return volatility, but we average stock variance within a month credit rating category,[6] rather than within a month, to obtain an estimate of idiosyncratic volatility at the level of credit rating.

The credit-market-based measures, that is, the fraction of names changed every index roll and the number of upgraded relative to downgraded firms, suggest that idiosyncratic risk in the high-yield index was relatively high in the fourth quarter of 2015. By contrast, the idiosyncratic risk in the investment-grade index was in line with historical averages. This suggests that idiosyncratic risk may have contributed to the basis widening for lower-quality firms, but the basis for investment grade firms widened for other reasons. Finally, Table 3 shows that idiosyncratic equity return volatility for both investment grade and high-yield firms was slightly below the median in the second half of 2015, lending credence to the idea that idiosyncratic risk was not a main driver of basis widening.

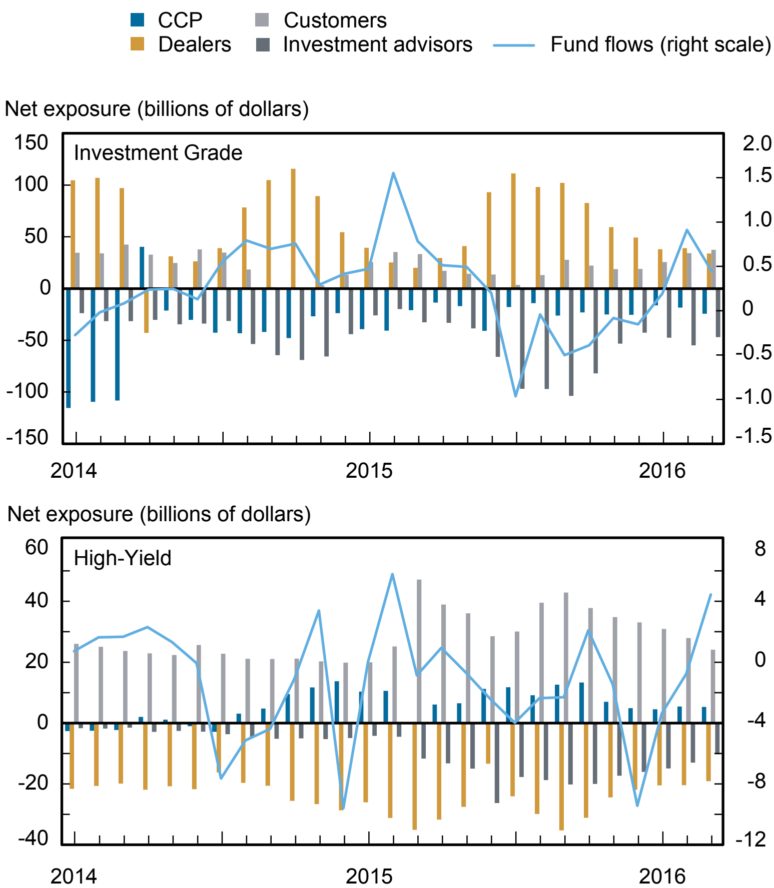
2.2 Strategic Positioning

Some market participants have suggested that, in the second half of 2015, mutual funds specializing in credit strategies may have taken on corporate credit risk by selling protection in the CDS market rather than buying corporate bonds. This strategy has the dual advantage of keeping fund asset allocations in more liquid instruments while allowing mutual funds to retain cash that would have otherwise been used to buy corporate bonds. Thus, using single-name CDS or index contracts instead of bonds to take on exposure to corporate credit risk may provide mutual funds an efficient tool for managing asset liquidity in anticipation of potential outflows.

We use position snapshot data provided by the Depository Trust and Clearing Corporation (DTCC) to the Federal Reserve Board (FRB) to construct net positions in the relevant derivative products, that is, the net position between CDX indexes and the constituent single-name CDS for a given index. DTCC provides weekly snapshots of positions and transactions for contracts that involve either an institution supervised by the FRB as one of the counterparties to the trade or that reference a supervised institution. In particular, the largest dealer banks in the United States (Bank of America, Citibank, Goldman Sachs, JPMorgan Chase, and Morgan Stanley) are supervised by the FRB. Boyarchenko et al. (2016) show that this positions data covers 75 percent of trades reported to DTCC's Trade Information Warehouse in a median week.[7]

Using the weekly position snapshots, we construct net positions for each CDS market participant and aggregate by institution type, including central clearing counterparty (CCP), DTCC dealer, noninvestment advisor DTCC client, and investment advisor. We identify investment advisors by matching participant names to Compustat firms and using the assigned two-digit SIC. Chart 3 shows the net positions in the CDX-CDS basis trade in the investment grade (left panel) and high-yield (right panel) index by type of institution together with monthly net inflows into bond asset managers specializing in investment grade and high-yield bonds, respectively. As suggested by market participants, investment advisors have been increasing their long positions, that is, selling more protection, in the CDX indexes over the past year. Although this increase is unusual for the high-yield index, investment managers typically have a large sell exposure to the investment-grade index. One potential explanation for this increase of sell exposures is strategic positioning. In anticipation of fund outflows, investment advisors seeking credit risk exposure may choose to sell more liquid CDS, taking on negative net exposure in the CDX-CDS trade, rather than buying relatively less liquid corporate bonds. Indeed, increased use of derivative products does seem to precede the increased outflows from both investment grade and high-yield funds. This further decreases the liquidity in the bond market relative to the CDS market and thereby contributes to the widening of the CDS-bond basis. Increased investment advisor CDX index exposure also leads to increased liquidity concentration, along with less frequent CDS rolls every six months,[8] making basis trades costlier to enter and exit because it is harder to match CDS and bond maturities.

Chart 3
Net Exposure to CDX Indexes by Institution Type



Sources: Depository Trust and Clearing Corporation; authors' calculations; Morningstar.

Notes: The chart shows the Net exposure (CDX position net of the position in the replicating portfolio of single name CDS) for investment-grade North American CDX indexes, together with monthly net flows into mutual funds specializing in investment-grade bonds (upper panel) and in high-yield bonds (lower panel). CCP is central clearing counterparty.

3. CDS-Bond Trade in Practice

In this section, we discuss how basis trades are implemented in practice, including capital charges and funding cost for both legs of the trade. In particular, this section approaches basis deviations from the viewpoint of a confluence of intermediary asset pricing and margin asset pricing. In intermediary asset pricing theory (see, for example, He and Krishnamurthy [2013]; Brunnermeier and Sannikov [2014]; and Adrian and Boyarchenko [2012]), binding capital and liquidity regulation increases the effective risk aversion of intermediaries, which are the marginal investors in these markets. Higher effective risk aversion leads to higher risk premia, including higher liquidity risk premia, and can thus prevent basis trades from being executed. At the same time, since the CDS leg of the CDS-bond basis trade requires posted margin, the margin capital asset pricing model of Garleanu and Pedersen (2011) applies, with deviations from the law of one price larger whenever the marginal cost of financing the margin requirement is higher.

3.1 Mechanics of the Trade

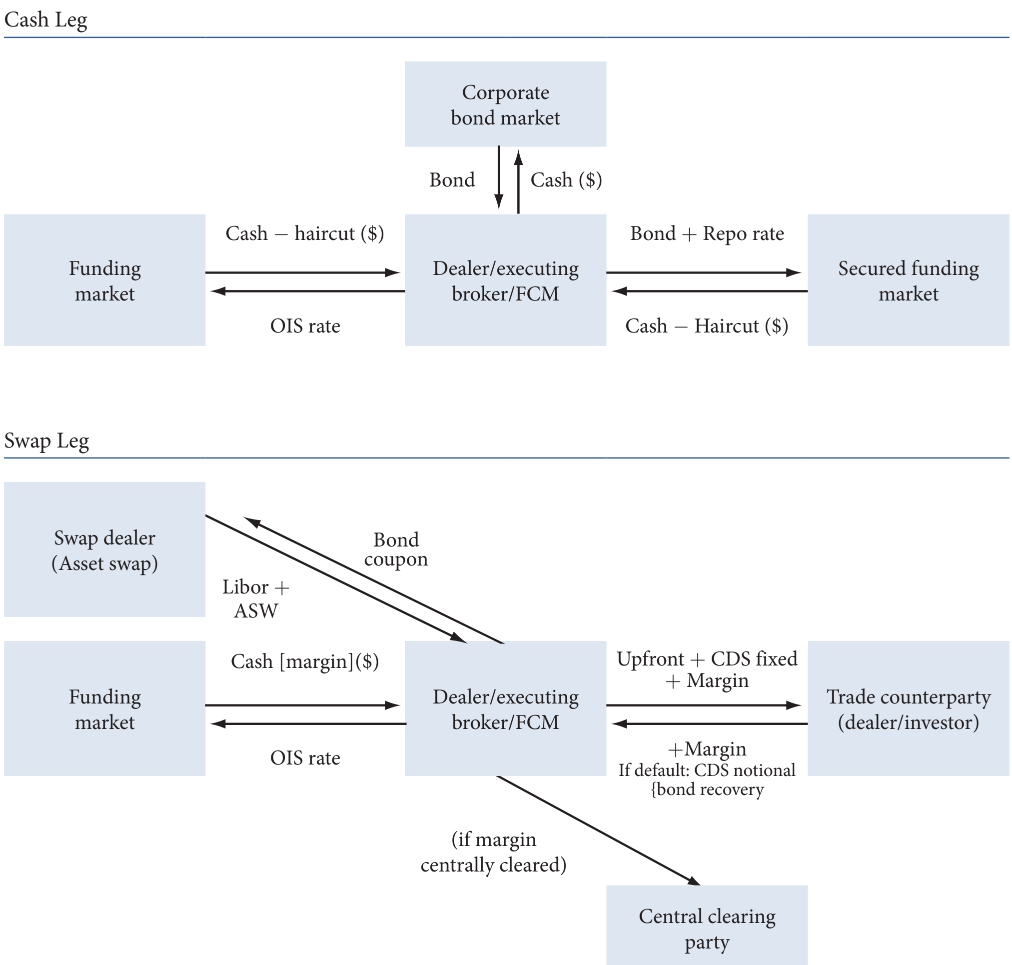
Exhibit 1, page 27, illustrates the different transactions required to complete the CDS-bond trade from the perspective of a dealer executing it for its own book. A key assumption in this example, which we also make when we discuss the balance sheet impact of the trade, is that the dealer uses repo financing to purchase the cash instrument (Exhibit 1, upper panel). The dealer buys a corporate bond and uses the cash bond as collateral to borrow in the tri-party repo market. The dealer pays the repo interest rate for each day that secured funding is used (which we assume to be 0.48 percent in the balance sheet example in Section 3.2) and receives the market value of the corporate bond used as collateral less the haircut on the bond (assumed to be 5 percent). The remainder of the purchase value of the corporate bond is financed in short-term unsecured funding markets with 0.5 percent interest rate and one-year maturity.[9]

The lower panel of Exhibit 1 illustrates the derivative leg of the trade. The dealer buys a CDS that provides protection from default on the corporate bond.[10] Since single-name CDS do not have mandatory clearing requirements, but may be accepted for central clearing on a CCP, the dealer can face either a CCP if a contract is cleared on a voluntary basis, another dealer, or a nondealer customer when entering into a CDS contract. For U.S. reference entities, the dealer pays the standard fixed rate of 100 or 500 basis points per period based on the notional value of the CDS and may receive or pay an upfront amount. That payment reflects the fact that the fair value of the CDS contract may not be zero at inception given that the standard fixed-rate payments on the contract may be higher or lower than the actual market spread for the CDS. The CDS transaction requires posting initial margin to the CCP or market participant if the CDS is not centrally cleared. To fund this initial margin, the dealer borrows from the funding market, paying the interest rate of the one-year overnight indexed swap (OIS). If the values of the swap and/or CDS change over time, the dealer must post variation margin. When the dealer purchases the CDS from a participant other than the CCP, the dealer also requires its counterparty to post initial and variation margin to protect itself from the risk of counterparty default before a default of the reference entity.

3.2 Balance Sheet Impact

Table 4, page 28, illustrates how a credit basis trade affects a dealer's balance sheet. The key assumptions in this example are the haircut charged on financing the corporate bond purchase in the repo market, the initial margin required on the single-name CDS position, and whether the CDS is centrally cleared, which determines the potential future exposure (PFE) cost.

Exhibit 1
Mechanics of the Bond-CDS Trade



Notes: ASW is asset-swap spread, GC is general collateral, and FCM is futures commission merchant.

Consider first the balance sheet impact of the long corporate bond leg of the negative basis trade, illustrated in Panel A of Table 4. Assume a $10 million trade in which the dealer faces a 5 percent haircut when buying the corporate bond using repo funding. The trade increases the corporate bond position on the asset side of the balance sheet by $10 million. Since the purchase is repo funded, the value of securities sold under agreements to repurchase on the liabilities side of the balance sheet increases by $10 million less the $500,000 haircut. In addition, the dealer borrows the $500,000 haircut on the repurchase agreement in short-term unsecured funding markets at a 0.5 percent interest rate, increasing its short-term debt.

Panel B of Table 4 illustrates the balance sheet impact when the dealer buys CDS protection, paying a standard fixed rate of 100 or 500 basis points. At inception of the trade, if the market rate

Table 4
Balance Sheet Impact and Cost to Trade of a CDS-Bond Trade
U.S. Dollars

Panel A

Assets		Liabilities	
Cash		Short-term debt	500,000
Corporate bonds	10,000,000	Long-term debt	
Securities purchased under agreements to resell		Securities sold under agreements to repurchase	9,500,000
Derivatives with a positive fair value		Derivatives with a negative fair value	
Receivables		Payables	
Total assets	10,000,000	Total liabilities	10,000,000

Panel B

Assets		Liabilities	
Cash		Short-term debt	700,000
Corporate bonds	10,000,000	Long-term debt	
Securities purchased under agreements to resell		Securities sold under agreements to repurchase	9,500,000
Derivatives with a positive fair value	166,385	Derivatives with a negative fair value	
Receivables	200,000	Payables	166,385
Total assets	10,366,385	Total liabilities	10,366,385

(continued)

Table 4 (continued)

Balance Sheet Impact and Cost to Trade of a CDS-Bond Trade

U.S. Dollars

Panel C

Single-name CDS trade	
Trade size	
Notional	10,000,000
Initial margin received (payable)	400,000
Initial margin posted (receivable)	(200,000)
Upfront for fixed premium (with accrual)	166,385
CDS costs	
Initial margin funding cost ~ one-year OIS	(1,000)
CDS running premium	
CDS trade spread (effective)	(65,500)
CDS fixed premium (actual with upfront)	(100,000)
Subtotal CDS payment	(66,500)
Corporate bond in repo	
Trade size	
Corporate bond	10,000,000
Haircut ~ 5 percent	500,000
Costs	
Corporate bond repo ~ 0.48 percent	(45,600)
Haircut ~ one-year OIS	(2,500)
Subtotal corporate cash bond cost	(48,100)
Net return from carry	
CDS payment	(65,500)
CDS cost	(1,000)
Corporate bond cost	(48,100)
Total before spread	(114,600)
(CDS-cash basis) * bond notional	134,000
Total after spread	19,400

Source: Authors' calculations.

Notes: This table presents a stylized example of the balance sheet impact and the cost-to-trade a five-year CDS-cash basis trade on Time Warner Cable February 2021, from a dealer's perspective. The following assumptions were made: 5 percent haircut in the cash bond-collateralized repo trade, with a 0.48 percent interest rate; 0.5 percent interest rate charged in the overnight interest rate swap market; 4 percent initial margin from the seller of the CDS; 2 percent initial margin from the buyer of the CDS; and 1 percent fixed spread on the CDS.

of the CDS contract differs from the standard rate paid, the fair value of the CDS will not be zero as with an interest rate swap. If the CDS market rate, that is, the implied fixed rate on the contract that would result in an initial fair value of zero, is higher than the fixed rate actually paid, the dealer will pay an upfront premium in addition to the standard fixed rate and vice versa. However, in the example in Table 4, the market rate is lower than the fixed rate paid, so the dealer receives an upfront payment of $166,385, which represents the present value of the difference between the actual fixed rate paid (100 basis points) and the market rate (65 basis points) over the life of the contract.[11]

As the market rate of the CDS fluctuates, its fair value will change, translating into either an increase in the "derivatives with a positive fair value" line on the asset side of the balance sheet or an increase in the "derivatives with a negative fair value" line on the liabilities side. Purchasing the CDS requires an initial 2 percent margin,[12] reflected as an increase in receivables. The dealer borrows the initial margin in short-term funding markets at a 0.5 percent interest rate, increasing its short-term debt issuance. In addition, the dealer computes its potential future exposure (PFE) for the CDS, which increases its off-balance-sheet assets. PFE is calculated as the product of the effective notional principal of the CDS contract and the corresponding conversion factor provided by the Basel Committee's Basel III leverage ratio framework.[13] In this example, for a five-year investment grade non-cleared CDS, the applicable conversion factor in the PFE calculation is 5 percent.

When the dealer carries out the trade on behalf of a client instead of itself, the balance sheet impact is similar except for three important differences. First, the initial margin the client posts with the dealer, which the dealer then posts with the CCP, increases the payables on the liabilities side of the dealer's balance sheet, depleting the equity cushion further. In addition, if the dealer executes the CDS leg of the trade by buying CDS protection from its client to face the CCP, the dealer's PFE to the overall trade increases. Finally, if the dealer provides funding to its client, the value of loans on the asset side of the balance sheet increases, further expanding the dealer's balance sheet.

Table 4, Panel C illustrates the cash flows received by a dealer holding a $10 million position in the CDS-bond basis trade for one year. The trade requires the dealer to buy a CDS from another market participant, for example, another dealer, which requires the CDS buyer to post an initial margin for the trade ($200,000). The dealer also requires the CDS seller to post an initial margin ($400,000) to ensure the dealer from seller counterparty risk. The dealer borrows this initial margin from short-term funding markets, paying a rate based on the overnight indexed swap on the loan ($1,000 per year). In addition, if the 100-basis-points fixed spread on the contract does not equalize the value of the protection bought to the present discounted value of the fixed payments, the dealer receives an upfront payment ($166,385) from the seller of protection.

In addition to the swap, the dealer holds a cash position in a bond deliverable into the CDS contract in case a credit event occurs. Purchase of this bond is financed through repo markets. The dealer borrows $10 million to purchase the bond, which it then posts as collateral for the secured loan. The repo rate for the bond is assumed to be 48 basis points and represents a funding cost to the dealer. In addition, the repurchase agreement requires a 5 percent haircut, which the dealer also borrows in the short-term funding markets, similar to the initial margin, increasing the overall funding cost of the bond position. Thus, the total cost of funding the long bond position is the corporate bond repo interest ($45,600) plus the haircut financing charge ($2,500), totaling $48,100 for the $10 million position.

Table 5
Equity Charges for Bond-CDS Trade
U.S. Dollars, except as noted

	Supplementary Leverage Ratio					
	1%	2%	3%	4%	5%	6%
Corporate bond	100,000	200,000	300,000	400,000	500,000	600,000
Derivative fair value: max(F-V; 0)	0	0	0	0	0	0
Haircut	5,000	10,000	15,000	20,000	25,000	30,000
Net initial margin	2,000	4,000	6,000	8,000	10,000	12,000
Potential future exposure	5,000	10,000	15,000	20,000	25,000	30,000
Total equity cost	112,000	224,000	336,000	448,000	560,000	672,000
Total profit (Return)	19,400	19,400	19,400	19,400	19,400	19,400
Return on Equity (percent)	17	9	6	4	3	3

Source: Authors' calculations.

Note: The table shows the components of regulatory equity charges for the corporate bond-CDS trade for different levels of the leverage ratio, together with the implied return on equity.

On the derivative side of the trade, the dealer pays the fixed spread and receives the upfront, which we convert to the equivalent running spread ($65,500). Since the dealer receives the bond yield and pays the CDS effective spread, it receives the CDS-cash basis. Combining the amount received by the dealer (the basis) with the total cost of the position (cost of funding of initial margins and cost of repo financing of the bond position) gives the net carry (profit or income) on the trade, which equals $19,400 in this example. Thus, when the CDS becomes cheap relative to the value of the bond, the dealer earns positive carry.

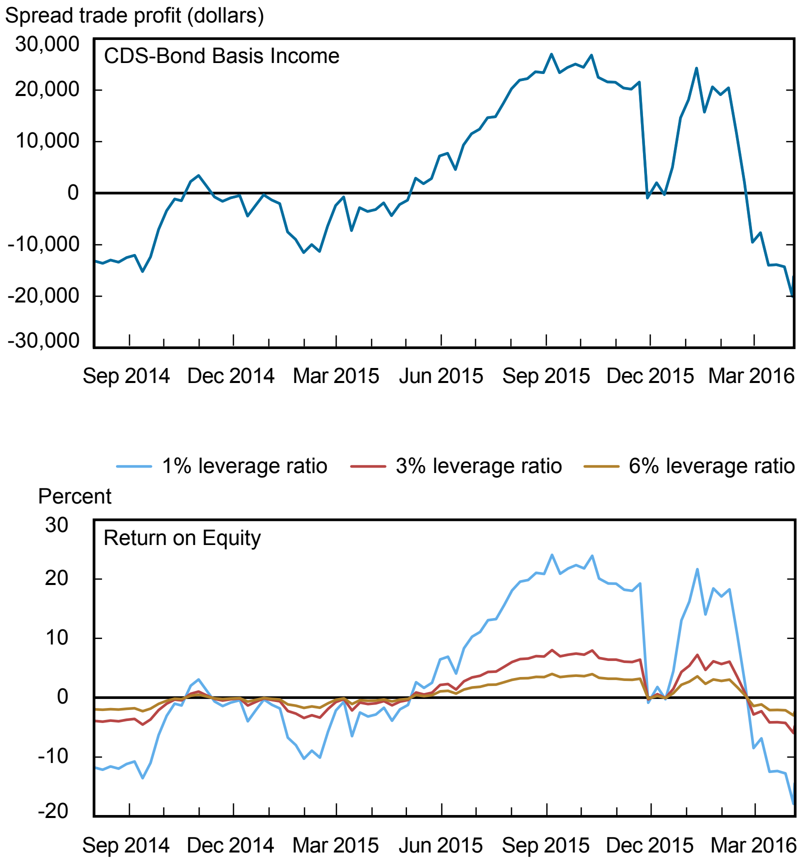
3.3 Profitability of the Trade

The costs of CDS positions have changed since enactment of mandatory clearing rules for index trades in 2013 and voluntary clearing of some single-name trades. From the dealers' perspective, new capital regulation, in particular the Supplemental Leverage Ratio (SLR) rule finalized in September 2014, has increased basis-trade costs. These additional costs may be passed on to non-dealer clients that use dealers as their futures clearing merchant in the swap trade.

Capital Charges

The balance sheet changes described above lead to a capital charge for the dealer in the form of additional equity required. Specifically, to satisfy the SLR, the gross notional amount of repo financing, initial margin, repo haircut, and PFE of the derivative instrument all require the dealer to hold additional equity before entering into the trade. While each firm and each business unit

Chart 4
Profitability and Equity Cost of Investment Grade Bond-CDS Trade over Time



Sources: Bloomberg L.P.; authors' calculations.

Notes: The following assumptions were made: 5 percent haircut in the cash bond-collateralized repo trade, 4 percent initial margin from the seller of the CDS, and 2 percent initial margin from the buyer of the CDS.

within the firm may have its own approach for appraising how much additional equity should be raised, Table 5 computes representative capital charges associated with different levels of the target leverage ratio. As the table shows, the largest capital charge stems from the cash bond leg of the trade, since the capital charged is based on the entire notional amount financed rather than net repo liability. However, for higher leverage ratios, the equity associated with the derivative leg of the trade can also be large, through the capital charge for the initial margin and the PFE.

Anecdotal evidence suggests that dealers have increasingly been viewing their activity through the lens of the return on equity (ROE) generated by a given trade, which has declined across the board because of higher leverage (that is, stricter capital) requirements. Table 5 also reports the ROE on the CDS-bond trade based on assumed leverage ratios ranging from 1 to 6 percent. The ROE is very sensitive to leverage ratios. Indeed, the ROE declines from 17 percent to 9 percent when the

Table 6

Bond-CDS Spread Required for Return on Equity at Different Dealer Leverage Ratios

Return on Equity (Percent)	Supplementary Leverage Ratio					
	1%	2%	3%	4%	5%	6%
5	-123	-128	-134	-139	-145	-151
10	-128	-139	-151	-162	-173	-184
15	-134	-151	-167	-184	-201	-218
20	-139	-162	-184	-207	-229	-251
25	-145	-173	-201	-229	-257	-285
30	-151	-184	-218	-251	-285	-319

Source: Authors' calculations.

Notes: Spreads are reported in basis points. The table shows the maximum bond-CDS spread that generates different ROE levels for disparate assumptions on the leverage ratio of the dealer.

assumed leverage ratio increases from 1 percent to 2 percent, and then declines a further 3 percentage points when the leverage ratio increases from 2 percent to 3 percent. At around a 6 percent leverage ratio, corresponding to the SLR for the largest U.S. banks in 2015, the ROE for the CDS-bond trade is 3 percent at most, well below the 15 percent ROE reportedly targeted by dealers.

Compare this with the ROE that would have been earned historically on the investment grade bond-CDS trade. Chart 4 plots the time series evolution of the profit from the bond-CDS trade and the total equity cost under different leverage ratio assumptions. As the CDS-bond basis and the OIS spread fluctuate over time, the income earned on the swap spread trade fluctuates as well (Chart 4, top panel). When the regulatory minimum leverage level is low, say 1 percent, this translates into the implied ROE fluctuating between -10 percent and +20 percent (Chart 4, lower panel). However, for higher required leverage levels, the fluctuations are much more modest, with the implied ROE never reaching above 5 percent for the 6 percent minimum leverage requirement.

Breakeven Basis

While new regulations may have increased dealer CDS-bond trade costs, there should still be a CDS-bond basis level at which the trade generates an attractive ROE. Table 6 conducts a sensitivity analysis of the breakeven CDS-bond basis needed to achieve a given ROE target for different leverage ratio levels. In the past, at low regulatory leverage levels, a dealer could have earned a 15 percent ROE when the CDS-bond basis was below negative 134 basis points simply through carry. Now, at a 6 percent leverage ratio, the basis needs to be negative 218 basis points to achieve the same ROE target. While this calculation is subject to many assumptions, it illustrates the costs faced by dealers and helps explain their possible reluctance to enter into basis trades.

3.4 Considerations for the CDX-CDS Basis Trade

For the CDX-CDS basis trade, many of the considerations discussed above still apply. The major difference is that the CDX-CDS basis trade does not have a cash product that must be financed via leverage. At the same time, each individual CDS contract requires a margin to be posted with the counterparty to the contract. The CDX-CDS basis trade is further complicated by differences in the clearing requirements for single-name and index contracts. In particular, under current regulation, index CDS contracts are required to be centrally cleared. Single-name CDS, on the other hand, are not required to be centrally cleared. Thus, the margin requirements for the long and the short sides of the CDX-CDS trades cannot be offset against each other. For example, to put on the CDX-CDS basis trade for the investment grade index (CDX.NA.IG), a market participant must post margin with the CCP clearing the index (ICE) and with the CCPs clearing the eligible single-name contracts (ICE, CME, LCH). In addition, since all the CDS contracts trade on a standardized basis, all contracts necessary for this trade will have non-zero upfront payments, further increasing the cost of entering into the trade.

4. Conclusion

Overall, we find that the widening in the credit basis can be broadly explained by changes to liquidity preference and liquidity concentration, increased idiosyncratic risk of the constituents of the high-yield index, and increased funding costs tied to balance sheet constraints. Although some of these factors may be transitory—for example, as the outlook for energy companies stabilized, idiosyncratic risk of high-yield companies decreased—others are more persistent and may point to potentially "new normal" levels for both the CDS-bond and CDX-CDS bases.

While we cannot precisely measure the costs incurred from mandated central clearing and SLR capital requirements, it appears that executing credit-basis trades is now costlier for dealers than in prior years, largely due to the amount of capital that dealers must hold against these trades. Of note, the amount of capital required is largely driven by the cash position of the trade, rather than the derivatives portion. As a result, while current CDS-cash basis levels may have been attractive to trade in the past, which would have lessened the dislocations, our analyses suggest that these spreads must still reach more negative levels to produce adequate returns on equity for dealers, given the balance sheet costs. Although this may represent a shift in the levels considered attractive to trade, it suggests there may be a "new normal" level at which dealers may be incentivized to enter into these spread and basis trades, which eventually should narrow the dislocations. Indeed, the CDS-cash basis became less negative in the spring of 2016, though this appears to have resulted from an increase in demand for corporate bond products following alleviation of macro risks, not from dealer arbitrage activity.

Appendix: Potential Future Exposure

Potential future exposure (PFE) is an estimate of the value of a derivative contract at future points in time, usually within a specified confidence interval such as 95 or 99 percent. It is essentially an estimate of the future replacement cost of the contract via a distribution of potential values rather than a single point estimate.

Although representative of the estimated future distribution, the PFE is defined as the upper bound of the forecasted credit exposures at the given level of confidence over a specified period of time. The PFE is not known with certainty because it estimates the market value in the future. In contrast, the current credit exposure, which is the greater of the present fair value of the contract and zero, is known with certainty since it captures only the current market value.

There are various methodologies used to calculate PFE including simulations of future paths of the inputs used to calculate the replacement value and using a constant exposure method based on a fixed percentage of the effective derivative notional value of the contract. The Basel Accord utilizes the latter methodology, calculating PFE by multiplying the notional value of the derivative contract with a fixed percentage that is based on the PFE Add-on Factor as indicated in the Accord. This factor is based on the asset class and remaining maturity of the derivative contract. Table A1 lists the PFE factor by asset class and maturity.

Table A1

Potential Future Exposure Add-On Factors

Percent

	Interest Rates	FX and Gold	Equities	Precious Metals Except Gold	Other Commodities
One year or less	0.0	1.0	6.0	7.0	10.0
More than one year up to five years	0.5	5.0	8.0	7.0	12.0
More than five years	1.5	7.5	10.0	8.0	15.0

Source: Basel III: Finalizing Post-Crisis Reforms, December 2017, https://www.bis.org/bcbs/publ/d424.htm.

Notes

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[1] The North American Corporate Investment Grade (CDX.NA.IG) has 125 constituents and the North American Corporate High Yield Index (CDX.NA.HY) has 100 constituents.

[2] The rapid growth of the CDS market in the early 2000s was reflected not only in enormous levels of gross notional amount outstanding, but also in operational backlog. Therefore, the CDS contract and its trading conventions were changed on April 2009 as part of the Big Bang Protocol to create a more standardized contract intended to eliminate offsetting trades and facilitate centralized clearing.

[3] CDX.EM, the emerging market CDS index, is an exception with semiannual payments.

[4] This trade, while free of default risk, is exposed to interest rate risk. Some market participants enter into an asset swap, which converts the fixed coupons paid on the bond to a floating rate equal to the asset swap spread plus Libor. In this case, the CDS-bond basis is defined as the difference between the asset swap spread and the CDS par-equivalent spread.

[5] Changes to the inclusion methodology for the CDX HY index went into effect starting with the September 2015 roll in an effort to better align the derivative index with HY cash indexes. These changes did not affect the inclusion criteria for the investment grade index.

[6] That is, each month, we average the stock variance of all firms with an investment-grade credit rating to create the idiosyncratic equity volatility for investment grade firms; similarly, we average the stock variance of all firms with a high-yield credit rating to create the idiosyncratic equity volatility for high-yield firms.

[7] See Boyarchenko et al. (2016) for a more detailed description of the supervisory DTCC data, as well as a more detailed comparison between the supervisory sample and the Trade Information Warehouse universe of transactions.

[8] Prior to the crisis, CDS were rolled on a quarterly basis.

[9] These assumptions are based on interest rates prevailing in fall 2015. The interest rate charged in unsecured funding markets is approximately equal to the interest rate charged in an overnight indexed swap (OIS) with equal maturity. An OIS is an interest rate swap in which the periodic floating payment is based on a return calculated from a daily compound interest investment and the reference rate is an overnight rate.

[10] Market participants may also execute a third leg, which is an asset swap that hedges the corporate bond's interest rate risk. In the asset swap, the dealer pays a fixed rate based on the bond's coupon and receives the equivalent floating rate based on LIBOR plus the swap spread.

[11] The upfront premium also includes accrued interest from the last semiannual CDS coupon date.

[12] If the CDS is cleared, the investor purchasing it posts half the initial margin required by the clearing member for selling CDS protection. In this example, the clearing member requires 4 percent initial margin from a counterparty selling CDS, and 50 percent times 4 percent equals a 2 percent initial margin for a counterparty buying CDS protection.

[13] Our example assumes that the single-name CDS is not cleared and that bilateral netting is not applicable. If netting were applicable, it could be used to offset up to 60 percent of the effective notional value.

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The Pre-Crisis Monetary Policy Implementation Framework

Alexander Kroeger, John McGowan, and Asani Sarkar

OVERVIEW

• Before the 2007-09 financial crisis, the Fed's operating framework for monetary policy reflected a banking system in which the scarcity of reserves meant that small changes in reserves would affect fed funds rates.

• The authors assess the framework and find that it met the Fed's monetary policy objectives by keeping rates close to target but had certain negative effects on financial market functioning and employed operating procedures that were rather opaque and inefficient.

• During the crisis, the Fed boosted reserves in a bid to foster economic recovery, and this increase necessitated changes in how the Fed conducts monetary policy. The new approach has also controlled rates well since the crisis, suggesting that alternate frameworks can be effective.

The Federal Reserve's (the Fed's) operating framework for monetary policy changed during the financial crisis of 2007-09. This change occurred because the Fed implemented an accommodative monetary policy to facilitate economic recovery from the crisis by substantially increasing the amount of reserves in the banking system and by reducing interest rates to close to zero (Bech and Klee 2011). By comparison, in the pre-crisis period the supply of reserves was relatively scarce. The aim of this article is to assess the Fed's monetary policy framework prior to the crisis in order to better understand the changes in the implementation of monetary policy since the crisis.

A monetary policy framework is a means of implementing a central bank's monetary policy (Bindseil 2004). Such a framework consists of an operational target and an operating framework for achieving the target. The Fed's statutory mandate in conducting monetary policy is to promote price stability consistent with full employment.[1] To implement this mandate, the Federal Open Market Committee (FOMC) sets a target for the overnight rate in the federal funds market, where banks trade reserve balances ("reserves"), which are deposits held by banks at the Fed.[2] Changes in the federal

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The views expressed in this article are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of New York or the Federal Reserve System.
To view the authors' disclosure statements, visit https://www.newyorkfed.org/research/epr/2018/epr_2018_pre-crisis-framework_sarkar.

funds rate are, in turn, expected to be transmitted to other interest rates and, ultimately, to the real economy. The pre-crisis operational framework consisted of monetary policy instruments (mainly the conduct of open market operations, or OMOs) and procedures for using these instruments to encourage banks to trade fed funds near the stated target rate. The New York Fed's Open Market Trading Desk ("the Desk") carried out OMOs on a daily basis to keep the overnight fed funds rate close to its target.

The fed funds market represents the market for bank reserves. Fluctuations in the fed funds rate reflect changes in the demand for and supply of reserves. Prior to the crisis, the demand for reserves arose mainly from banks' need to meet uncertain intraday payment flows, after satisfying minimum reserve requirements. Because no interest was paid on reserves, banks wished to minimize their reserve holdings. The aggregate demand for reserves was sensitive to interest rates since reserves were scarce—the Fed supplied only a small amount of reserves in excess of what banks were required to hold in the aggregate. The daily variation in the supply of reserves was mainly determined by so-called autonomous factors (such as currency in circulation) outside the direct control of the Fed. Therefore, the Desk's job was to forecast the evolution of the autonomous factors and the demand for reserves and, on an ex ante basis, supply enough reserves to keep the market for reserve balances in equilibrium. The aggregate amount of reserves was distributed to individual banks through the fed funds market.

In this article, we show that during the pre-crisis period the Desk was generally successful in achieving its primary objective of meeting the fed funds target. Overnight rates were generally close to the target fed funds rate, even during periods of relatively high liquidity demand. Further, when the fed funds rate, on occasion, deviated from its target (such as at the end of quarters), it reverted to the target within a day or two. Finally, changes in the fed funds rate were quickly transmitted to other overnight money market rates.

In addition to the primary objective of controlling its operational target, a central bank might consider other criteria to evaluate the effectiveness of its operational framework: efficiency (that is, meeting objectives with as few resources as possible), transparency (that is, operating in a manner well understood by market participants), universality (that is, being able to implement monetary policy under a range of economic conditions), and the promotion of financial stability (that is, ensuring that the operational framework does not impair market functioning).[3]

While the pre-crisis monetary policy framework was successful in meeting its monetary objectives, the associated operational procedures were complex and opaque. The operational framework relied on a discretionary and interventionist approach (Logan 2017) based on daily management of the supply of reserves that required detailed market intelligence and expert judgment (Bernanke 2005). The Desk had to provide daily forecasts of reserve demand and supply over multiple days, and to conduct repurchase ("repo") or reverse repo operations almost daily. Reserve demand was difficult to forecast daily, and even predictable changes required OMOs on most days (Logan 2017). Forecasting the autonomous factors that caused daily variations in the supply of reserves was also challenging. Liquidity management in such a framework appears more complex than in a "symmetric corridor system" with standing deposit and lending facilities, as operated by some other central banks.[4] The system also lacked transparency, since the Fed, unlike other central banks, did not publish its forecast of autonomous factors (Hilton 2008). Regarding universality, the pre-crisis operational framework faced difficulties in the post-crisis environment when demand for reserves became highly volatile (Hilton 2008). Also, supplying reserves to meet forecasted demand became impractical post-crisis, when the amount of reserves in the banking system exceeded demand for reserves by a wide margin.

Turning to the goal of not impairing financial market functioning, we first focus on the functioning of payment systems. In particular, in the pre-crisis period the Fed routinely extended large amounts of (sometimes unsecured) intraday credit to banks to meet payment system demands, for a fee. Since banks needed these funds for only a few hours a day, they did not find it cost effective to borrow overnight in the fed funds market. While these "daylight overdrafts" were necessary to facilitate payments, they also exposed the Fed to the potential for loss. For the banks, the need to avoid overdrafts and meet reserve requirements, combined with the lack of interest payments on reserves, implied that their cash management system was rather costly (Logan 2017).

The Fed affected financial markets in two other areas prior to the crisis: asset eligibility criteria for OMOs and money market functioning. Assets that were eligible for purchase by the Desk, including repo operations, might benefit from enhanced liquidity and the ability to obtain central bank credit, compared with ineligible assets. Since the Fed accepts only highly liquid assets in its OMOs, including Treasury and agency securities, any distortionary effects on asset prices were likely minimized. Regarding money market functioning, the scarcity of reserve balances prior to the crisis (relative to the required and precautionary demand for reserves) resulted in large trading volumes in the fed funds market because, toward the end of the trading day, banks with surplus reserves had an incentive to trade with banks with too few reserves. While it is unclear whether an active fed funds market should be a goal of a monetary policy framework, the market activity likely facilitated both rate discovery (that is, the determination of an equilibrium rate through trading) and the quick transmission of the target rate to related money markets.

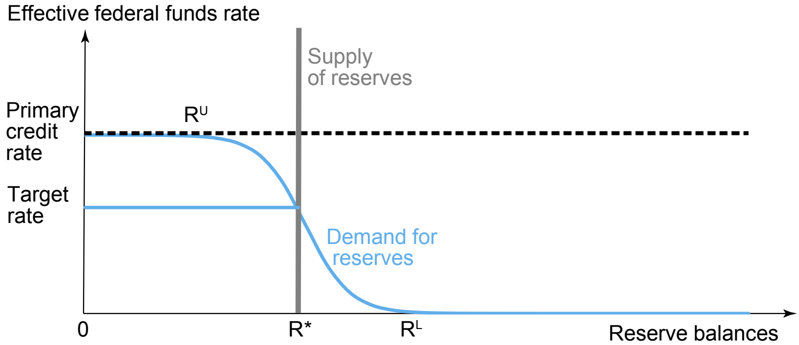
The article is organized as follows. Section 1 discusses the basic economic premise underlying the pre-crisis framework, and then describes how rate determination in actuality deviated substantively from the textbook example. Section 2 details how the framework was implemented in practice, and includes a description of the role of the reserve maintenance period. We discuss the effectiveness of the framework in meeting the primary monetary policy objectives in Section 3 and evaluate how well the framework met the objectives of operational effectiveness and financial stability in Section 4. Section 5 concludes with a brief summary and remarks on some aspects of the pre-crisis framework that have changed since the crisis.

1. The Economics of the Pre-Crisis Monetary Policy Operating Framework

In this section, we discuss the economic foundation of the monetary policy operating framework in terms of the demand for and supply of reserves. We show that the pre-crisis monetary regime can be viewed as managing the supply of reserves so that equilibrium is maintained on the steeper, relatively inelastic portion of the demand curve for reserves. However, we further note how the actual framework deviated significantly from this idealized model.

The aggregate demand for reserves is plotted in Chart 1, with the horizontal axis representing the total reserve balances of banks and the vertical axis representing the effective federal

Chart 1
The Market for Reserves



funds rate (EFFR), calculated as a volume-weighted average rate of each business day's fed funds transactions.[5] A target EFFR was the Fed's primary monetary policy tool prior to the crisis. In the fed funds market, banks traded reserves with each other on an unsecured basis, typically with an overnight tenor. The supply of fed funds was determined exogenously (from the point of view of market participants) by the Federal Reserve, which, through OMOs, targeted a specific amount of reserves, R*, on a daily basis in order to meet the Desk's forecast of reserve demand.

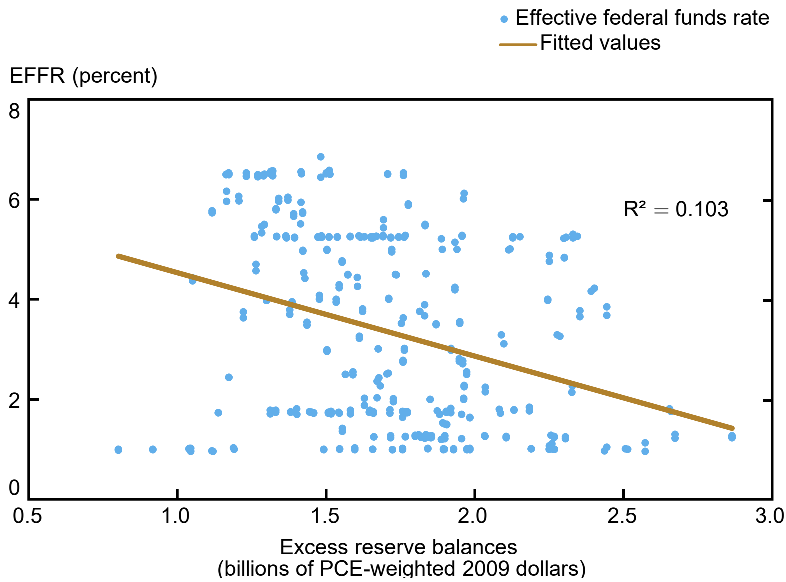
The demand for reserves is downward sloping, reflecting the opportunity cost of holding reserves, except at the ceiling, R^U, and the floor, R^L, of the EFFR, where it is flat (Keister, Martin, and McAndrews 2008). Reserve requirements necessitated that banks hold minimum reserve balances on average (as a percentage of their net transaction accounts) in their accounts with Federal Reserve Banks. However, because of the uncertainty of payment flows, banks could not meet their requirements exactly. In deciding how much additional reserves to hold, banks had to balance the income forgone from holding excess reserves against the cost of borrowing fed funds at the EFFR. Higher levels of the EFFR increase the opportunity costs of holding reserves and reduce the demand for reserves.

The demand for reserves is flat at the lower and upper bounds of the EFFR. The lower bound for the EFFR was zero because banks had no incentive to lend reserves at a negative rate, since they could earn zero interest by simply keeping reserves in their Fed account. At R^L, where the demand curve intersects the horizontal axis, banks hold sufficient reserves to meet all possible payment needs. Thus, banks are indifferent to holding any reserves to the right of R^L because the opportunity cost of holding reserves is zero. Since the discount window's primary credit facility is an alternative to the fed funds market as a source of reserves for financially sound banks with adequate collateral,[6] the primary credit rate (which exceeds the target rate) acts as the upper bound above which banks would not borrow in the fed funds market.[7] When the EFFR equals the primary credit rate, banks are indifferent between holding reserves and borrowing at the discount window, and so the demand curve is flat to the left of R^U.

Before the crisis, the Federal Reserve carried out monetary policy by operating in the downward sloping region of the demand curve for reserves. This implies that the Fed raised rates by draining reserves (decreasing supply) and lowered rates by adding reserves (increasing supply) to the system. Empirically, in a simple plot of the effective federal funds rate against excess

Chart 2

The Empirical Relationship between Excess Reserve Balances and the EFFR: 2000-07



Sources: Federal Reserve Bank of St. Louis; authors' calculations.

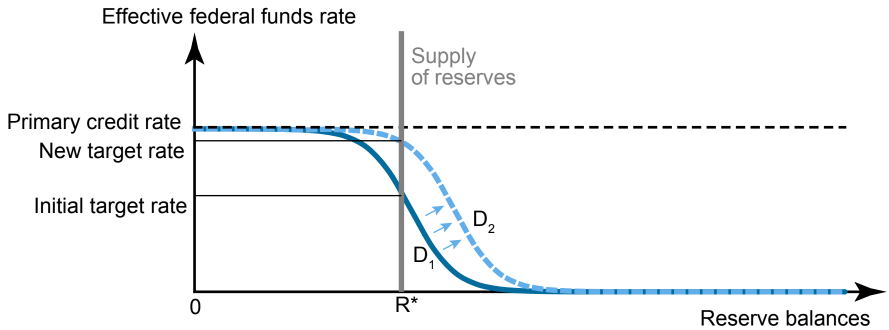
Notes: The chart shows maintenance period averages from January 1, 2000, through July 1, 2007. Periods with exceptionally high reserve balances, such as around September 11, 2001, have been excluded. PCE is personal consumption expenditures.

reserves (with both averaged over maintenance periods, a two-week time period over which reserve requirements are applied), the fitted relationship is negative and statistically significant (see Chart 2).

However, as Chart 2 notes, excess reserve balances explain only 10 percent ($R^2 = 0.10$) of the variation in the fed funds rate. The high level of noise in the relationship between rates and reserves in the data indicates that, in practice, the relationship between reserve balances and the fed funds rate is more complicated than the stylized theory illustrated in Chart 1 (as also noted by Judson and Klee [2010]). One complication is that the distribution of reserves across banks matters. Since larger institutions traded excess reserve balances more actively than smaller institutions, a temporary concentration of reserves in large institutions could have entailed lower rates. Therefore, the aggregate amount of reserves was not the only variable that mattered. Nevertheless, Ennis and Keister (2008) show how the basic conclusions from the simple analysis do not change, even after accounting for bank heterogeneity.

An additional complication is that the demand for reserves likely shifts over time because of both long-term changes in the need for liquidity (for example, as a result of technological and regulatory changes) and short-term fluctuations in liquidity needs and expectations of rate changes throughout the maintenance period. For instance, Carpenter and Demiralp (2006a) present evidence of increases in demand for bank reserves in expectation of an FOMC rate increase, illustrated as the shift from D_1 to D_2 in Chart 3. These demand movements

Chart 3
Shifts in the Demand for Reserves



complicate the relationship between the Desk's actions and changes in the fed funds rate, since the EFFR can move in the absence of any intervention by the Desk. Several researchers have identified the demand curve more precisely by estimating unexpected shocks to the supply of reserves (see Hamilton [1997], Carpenter and Demiralp [2006b], Judson and Klee [2010], and Ihrig, Meade, and Weinbach [2015]).

2. Conduct of Monetary Operations in the Pre-Crisis Era

Just as actual shifts in the demand for reserves occurred for reasons absent in the stylized model, the day-to-day implementation of monetary policy also involved complications beyond those discussed earlier. For example, in managing daily liquidity, the Desk had to account for variations within a reserve maintenance period.[8] Depository institutions only needed to maintain the required reserve balance *on average* over the reserve maintenance period. The task of the Desk was to accurately forecast the supply and demand for reserve balances for each day of the two-week maintenance period, adjusting it daily based on market conditions and the distribution of reserves among banks. In the remainder of this section, we describe the maintenance period structure and the Desk's forecasting exercise.

2.1 The Reserve Maintenance Period

Reserve maintenance periods begin on a Thursday and end on the second Wednesday thereafter. Some smaller depository institutions have a weekly maintenance period. Reserve requirements and the portion that is satisfied with cash holdings (vault cash) are calculated before the start of each reserve maintenance period (known as "lagged reserve accounting"). In order to allow depository institutions greater flexibility in maintaining account balances, the Desk averaged banks' holdings of reserve balances over these two weeks when determining whether banks' reserve holdings met requirements.[9] Averaging allowed banks to effectively manage unexpected payment shocks that would cause them to hold too few or too many reserves relative to requirements on any given day in a maintenance period. Since the flexibility offered by averaging diminishes as the number of days remaining in a maintenance period declines (until they have no flexibility on the maintenance period settlement day), banks generally tended to hold relatively few balances early in a maintenance period in order to maximize their flexibility in absorbing payment shocks later in the period. Another feature of the reserve maintenance period that helped smooth the volatility of the EFFR toward the end of the period was depository institutions' ability to carry over (subject to restrictions) excess balances from one maintenance period to the next. This ability reduced distortions that could have resulted from the incentive to offload excess reserves in the last few hours of the maintenance period.

2.2 The Desk's Forecasts and Operations

In order to ensure that rates remained responsive to changes in reserves, the Desk typically left a "structural deficit" in the banking system. In other words, the Desk left the total amount of reserves backed by outright Treasury purchases (that is, purchases of Treasury securities in the secondary trading markets) just below the level of aggregate reserves required by the banking system. Maintaining a structural deficit helped the Desk interact efficiently with its primary dealer counterparties. Since primary dealers are the Desk's traditional counterparties, and dealers are natural seekers of funding and providers of collateral, maintaining a repo book of variable size with the dealers was more effective than maintaining a reverse repo book, because dealers typically had limited capacity to invest funds or receive collateral.

An implication of the "structural deficit" was that the Desk effectively faced a downward-sloping demand for reserves (Chart 1). Further, the practice of not paying interest on reserves meant that banks were highly sensitive to the opportunity cost of holding reserves—in other words, the slope of the demand curve was relatively steep. Given its forecasts of the demand for reserves and of changes in the supply of reserves, the Desk would fine-tune the level of reserves by conducting daily repo operations, thereby adding reserves to or subtracting reserves from the system. This procedure, when successfully carried out, ensured that the EFFR remained close to the target rate on a daily basis. The aggregate reserves were then redistributed within the banking system as reserve-deficit banks traded with reserve-surplus banks in the fed funds market.

The demand for reserves had three components: required reserves, contractual clearing balances, and "excess" reserves to meet intraday payment flows (Exhibit 1). For example, in 2004, required reserves averaged $11 billion, contractual clearing balances averaged $10.4 billion, and excess reserves averaged $1.6 billion (Board of Governors 2005). Banks are required to hold reserves against transaction deposits, which are checking accounts and other interest-bearing accounts offering unlimited checking privileges. In practice, changes in required reserves reflected changes in transaction deposits, since the Federal Reserve rarely changed the required reserves ratio (Board of Governors 2005).

Some banks voluntarily held significant levels of contractual clearing balances at their Reserve Banks, in addition to their required reserve balances. Clearing balances provided banks with increased flexibility in holding reserves across the maintenance period. Banks were compensated on their clearing balances based on three-month Treasury bill rates. However, the income credits could only be used to defray the cost of Federal Reserve services, such as

Exhibit 1
The Market for Balances at the Federal Reserve before 2007

Required Reserve Balances	SOMA Securities Portfolio
• Held to satisfy reserve requirements • Do not earn interest	• Holdings of U.S. Treasury and agency mortgage-backed securities (MBS) and repurchase agreements
Contractual Clearing Balances	**Discount Window Loans**
• Held based on contractually agreed-upon amounts • Generate earnings credits that defray the cost of Federal Reserve priced services	• Credit extended to depository institutions through the discount window
Excess Reserves	**Autonomous Factors**
• Held to provide additional protection against overnight overdrafts and reserve or clearing balance deficiencies	• Other items on the Federal Reserve's balance sheet such as Federal Reserve notes, Treasury's balance at the Federal Reserve, and Federal Reserve float

check clearing and Fedwire services, thus limiting their value (Hilton 2008). Penalties applied if a bank had not accumulated sufficient balances over a two-week maintenance period to meet its reserve requirements and clearing balance obligations, or if it ended any day overdrawn on its Fed account (Hilton 2008). Therefore, the sum of reserve requirements and contractual balances created a predictable level of demand for reserves.

"Excess reserves" were the amount of reserves that a bank held in excess of required reserves and contractual balances to meet unexpected intraday payment needs that might otherwise have created an intraday or overnight overdraft on its account. The daily demand for excess reserves was the least predictable element of the demand for reserves, since it depended on the volume and volatility of daily payment flows (Board of Governors 2005). Average reserve balances in 2006 were about $17.5 billion, of which excess reserves were $2.0 billion. The total level of reserves was much smaller than daily payment flows, a disparity that had significant implications for banks' ability to meet payment needs during the day, as we describe in Section 4 and in Box 6.

Using reserve requirements along with the anticipated demand for liquidity, the Desk forecasted the average excess reserves over a maintenance period based on the expectation that different types of banks typically hold different levels of reserve balances. In particular, small banks with limited access to funding markets demanded some level of excess reserves each day—typically between $1.5 billion and $2 billion—as a cushion against liquidity shocks (Hilton 2008). The Desk had to take this component of reserve demand into account in its daily calculations of the reserve supply needed to maintain equilibrium in the fed funds market.

The Desk estimated total demand for reserves for the entire fourteen-day maintenance period. For example, if the Desk observed that a bank already held more reserves than it needed to meet its requirement for the entire maintenance period—a situation known as a "lock-in"— then the Desk would increase its estimate for excess reserve demand for that specific maintenance period (since the "locked-in" reserves are not available to be lent to banks with a reserve deficit). In addition, for each day of the maintenance period, the Desk estimated the demand for reserves based, in part, on the maintenance-period-to-date distribution of reserve holdings.

The supply of Federal Reserve balances to banks comes from three sources: the Fed's portfolio of securities and repurchase agreements; loans through the Fed's discount window facility; and liabilities on the Fed's balance sheet that are outside the Desk's control, known as autonomous factors (Exhibit 1). The securities portfolio, which consisted of outright purchases of securities and repurchase agreement operations, was the most important source of reserve supply. Discount window lending was the least important, since banks rarely borrowed from the facility. For example, no discount window loan was outstanding on the Fed's balance sheet on August 8, 2007, the start of the financial crisis (Hilton 2008). Autonomous factors caused large daily variations in the supply of reserves. The major categories of autonomous factors are currency in circulation, the Treasury's balance at the Fed, foreign central bank investments in a "repo pool," and Federal Reserve "float" (see Box 1 for further discussion of the foreign repo pool and other autonomous factors).

The Desk had to forecast changes in autonomous factors extending several weeks into the future (Board of Governors 2005) as well as the resulting impact of these changes on reserves so that these effects could be factored into the desired size of daily OMOs. For example, if changes in autonomous factors were forecasted to increase (reduce) reserves by, say, $1.0 billion, then the Desk might reduce (increase) the size of its outstanding repo operations by the same amount, all else equal. Federal Reserve notes represent the largest autonomous factor. When the Fed issues currency to a bank, it debits the bank's account at the Fed, causing reserves to fall. The Treasury's account at the Fed is the next largest contributor to fluctuations in autonomous factors. Since the Treasury is not a bank, changes in its account balance result in corresponding changes in the supply of reserves. Treasury balances, the foreign repo pool, and the float are the autonomous factors most difficult to predict on a daily basis (Hilton 2008).

Each day, the Desk compared forecasts of the supply of reserve balances from autonomous factors with its projections of demand for reserves and determined the need for OMOs.[10] In addition to forecasting daily changes in autonomous factors, the Desk also forecasted longer-term trends, such as seasonal growth in currency in circulation (for example, demand for currency tends to increase around Thanksgiving and Christmas) and the long-term growth rate of currency. If these longer-term projections indicated that the supply of reserves was likely to be low for several weeks, then outright purchases of Treasury securities or long-term repos might be needed.[11] Outright holdings of Treasury securities were preferred both for operational considerations and to limit direct credit extensions to private market participants (Hilton 2008).

In practice, the Desk generally relied on temporary OMOs to achieve the daily changes in reserves required to keep the fed funds rate near its target. These operations typically involved conducting repos and reverse repos (generally of overnight duration) to increase and decrease, respectively, the supply of reserves with primary dealers.[12] For example, in 2004 the Desk conducted 299 repo operations for about $1.9 trillion and purchased outright $50 billion of securities (Board of Governors 2005). Using repos allowed the Desk to easily expand or contract the level of reserves with minimal disruption to the functioning of the market in which the underlying securities were traded. Further, repo transactions reduced the need to make frequent temporary downward adjustments to outright holdings. (Box 2 describes how the Fed conducted repo operations when dealer inventories were low.)

Box 1

What Are Autonomous Factors?

The term "autonomous factors" refers to items on the Federal Reserve's balance sheet that are outside the control of the Open Market Desk of the Federal Reserve Bank of New York. The Desk needs to forecast changes in autonomous factors because these changes affect the level of reserves in the banking system. For example, when the Treasury's account balance at the Fed increases, reserves are effectively drained, since funds are de facto transferred from the private sector into the Treasury's Fed account. Conversely, when the Fed spends money—for example, on employee salaries or remittances to the Treasury—the level of reserves in the system increases. Most daily changes on the Fed's balance sheet are too small to make a difference in monetary policy implementation. However, changes in some balance-sheet categories were routinely large enough to matter; that is, these types of balance-sheet changes routinely had a significant impact on the overall level of reserves and needed to be considered as the Desk developed its plans for the appropriate size of OMOs. We discuss the Desk's routine forecasts of these balance-sheet categories, or autonomous factors, below.

Currency in Circulation

Currency in circulation is typically the largest and most important autonomous factor to forecast. When a bank places an order for currency with a Federal Reserve Bank, the latter fills the order and debits the bank's account at the Fed and total reserve balances decline. Currency is fungible with reserves; a bank's actions to withdraw (deposit) currency from its Fed account increases (reduces) currency in circulation, thus reducing (increasing) reserves. The outstanding level of currency in circulation varies with both seasonal and longer-term trends. Longer-term trends include transactional demand for currency as well as foreign demand to hold U.S. dollars as a store of value. As the demand for currency grows with the economy, reserves would decline and the fed funds rate would rise if the Fed did not offset diminishing reserves by conducting repo operations or by purchasing securities. The expansion of Federal Reserve notes in circulation is the primary reason that the Fed's holdings of securities grew over time during the pre-crisis period.

Float

Federal Reserve float is created when credit to the account of the bank presenting a check for payment occurs on a different day than debit to the account of the bank on which the check is drawn. Float temporarily adds reserve balances when there is a delay in debiting the paying institution's account; conversely, float temporarily drains balances when the payer's account is debited before the payee receives credit. Float tended to be quite high and variable whenever the normal check-delivery process was disrupted, such as during bad weather when travel delays could slow down the delivery and processing of physical checks. The magnitude of differences in the timing of float has decreased in recent years because more transfers are conducted electronically.

Treasury General Account (TGA) Balance

The Fed serves as fiscal agent for the U.S. Treasury and the TGA functions as the checking account for the U.S. Treasury. The Treasury draws on this account to make payments by check or direct deposit for all types of federal spending. Since the Treasury is not a bank, its payment to the public reduces the TGA balance and increases reserve balances available to banks. Changes in the TGA

(Continued on next page)

Box 1 *(Continued)*

balance tend to be less predictable following corporate and individual tax dates, especially in the weeks following the April 15 deadline for federal income tax payments. Before the crisis of 2007-09, the Treasury could redirect funds from the TGA account to private banks through the Treasury Tax and Loan program (https://www.newyorkfed.org/aboutthefed/fedpoint/fed21.html). Doing so helped moderate the day-to-day volatility of this liability on the Fed's balance sheet, volatility that would complicate reserve forecasting.

Foreign Repo Pool

About 250 central banks and foreign official institutions have accounts with the New York Fed's Central Bank and International Account Services (CBIAS) division, which offers payment, custody, and investment services to these accounts (see https://www.newyorkfed.org/aboutthefed/fedpoint/fed20.html). CBIAS also offers an investment product, known as the foreign repo pool, in which CBIAS accounts can invest overnight funds in a repo arrangement backed by SOMA collateral. Funds that are held in CBIAS accounts at the New York Fed, whether in the foreign repo pool or in transaction accounts, drain reserves from the banking system. (By definition, funds held at the Fed reduce the supply of reserves held by the private sector).

Until the mid-1990s, the Desk sometimes directed CBIAS accounts to conduct repos with private market participants as a means of fine-tuning the level of reserves in the system. The Desk stopped this process in the mid-1990s by moving to a framework in which CBIAS accounts were encouraged to keep consistent, albeit fairly low, balances in their foreign repo pool accounts. CBIAS staff would counsel accounts to encourage stability in their holdings. Since stability was encouraged in these accounts, the Desk would treat typical foreign repo pool balances as a "permanent" reserve drain and the day-to-day fluctuations in the foreign repo pool became a significant autonomous factor.[a]

Before the crisis, balances in the foreign repo pool averaged around $40 billion. As of early 2018, foreign repo balances tend to be around $230 billion to $250 billion. Use of the pool has increased over time as constraints placed on CBIAS customers have been removed (see https://www.newyorkfed.org/newsevents/speeches/2016/pot160222). This new paradigm has increased both the level and the variability of the foreign repo pool, but such variability no longer causes issues with monetary policy implementation, since the Desk no longer actively manages reserve balance levels.

CBIAS balances are published under the heading "Reverse Repurchase Agreements – Foreign Official and International Accounts" in the H.4.1 Federal Reserve Statistical Release, which is published weekly (https://www.federalreserve.gov/releases/h41/current/).

[a] The Desk had another CBIAS investment product that helped control the day-to-day level of reserves. On a voluntary basis, the Desk would sell fed funds as an agent for pooled CBIAS funds. This approach allowed the accounts to earn a return on unexpected end-of-day balances while minimizing disruption to the supply of reserves resulting from unexpected operational issues, such as a failure to receive delivery on the purchase of Treasury securities.

Box 2

How Did the Desk Avoid Conducting Undersubscribed Repo Operations?

As described in this article, the Desk generally conducted daily repo operations in order to change the overall level of reserves in the system to match the Desk's daily forecast of demand for these reserves. The near-daily conduct of these operations, which typically settled on a T+0 basis (that is, on the same day as the trade occurred), raises the question of how the Desk avoided having undersubscribed operations, which would have resulted in supplying less reserves than intended. This risk is not insignificant, because dealers submitting winning propositions in repo operations must pledge unencumbered collateral to the Desk through their designated tri-party clearing agent in order for the transaction to settle and for intended reserves to hit the banking system. What if there isn't much unencumbered collateral on dealers' balance sheets?

In practice, the temporary OMOs were rarely undersubscribed, even though the typical operation time of 9:30 a.m. came after the time when most repo volume occurs on a daily basis. The main reason is that the Desk's typical take-down in short-term repo operations totaled about $7.0 billion a day, much less than the typical overnight repo volumes that are conducted in the private market. In addition, based on experience, the Desk could often anticipate when collateral shortages might develop, and it planned around them accordingly. The following table provides an illustrative example of how the Desk arranged the tenor of repo operations to minimize the risk of conducting undersubscribed operations ahead of the March 2006 quarter-end date.[a]

Open Market Trading Desk Repo Operations, March 2016

Date	Term (Days)	Propositions Received (Billions of U.S. Dollars)	Propositions Accepted (Billions of U.S. Dollars)
Wednesday, March 29, 2006	5 (spanned weekend)	37.9	5.50
Thursday, March 30, 2006	5 (spanned weekend)	22.95	5.00
Thursday, March 30, 2006	1	29.65	3.25
Friday, March 31, 2006	3 (spanned weekend)	11.55	4.25

Source: Federal Reserve Bank of New York.

From the table above, we observe that the Desk conducted two short-term repo operations that not only provided reserves on the days they were conducted (Wednesday, March 29, and Thursday, March 30) but the tenor of these repo operations was such that they provided reserves over the upcoming weekend, which included the quarter-end date of Friday, March 31. In this manner,

(Continued on next page)

[a] The table ignores the conduct of "longer-term repos," which are discussed elsewhere in this article.

Box 2 *(Continued)*

the Desk added $10.5 billion of reserves that were outstanding over the quarter-end date. On the quarter-end date itself, the Desk added another $4.25 billion, such that total short-term repo operations increased reserve levels over the quarter-end date by $14.75 billion. Since the Desk observed that dealers were more likely to be short of collateral over quarter-end dates, this strategy enabled the Desk to successfully avoid an undersubscribed operation. Note that total propositions submitted for the repo operation conducted on March 31, 2006, were only $11.55 billion, suggesting that a straightforward, over-the-weekend operation with a desired target amount of $14.55 billion would have been undersubscribed. The Desk frequently referred to this approach as "layering in reserves."

2.3 Volatility of Rates during the Reserve Maintenance Period

While the reserve maintenance period allowed depository institutions greater flexibility in managing reserve balances, it also posed challenges to forecasting and interest rate control. One concern was that reduced flexibility toward the end of the maintenance period would make the fed funds rate particularly sensitive to shocks, inhibiting the Fed's ability to achieve the target. This challenge is evident in the relatively high intraday standard deviation in the fed funds market toward the end of reserve maintenance periods, consistent with the findings of Bartolini, Bertola, and Prati (2000) (see Chart 4). In the next section, we examine the Desk's ability to manage end-of-maintenance-period volatility.

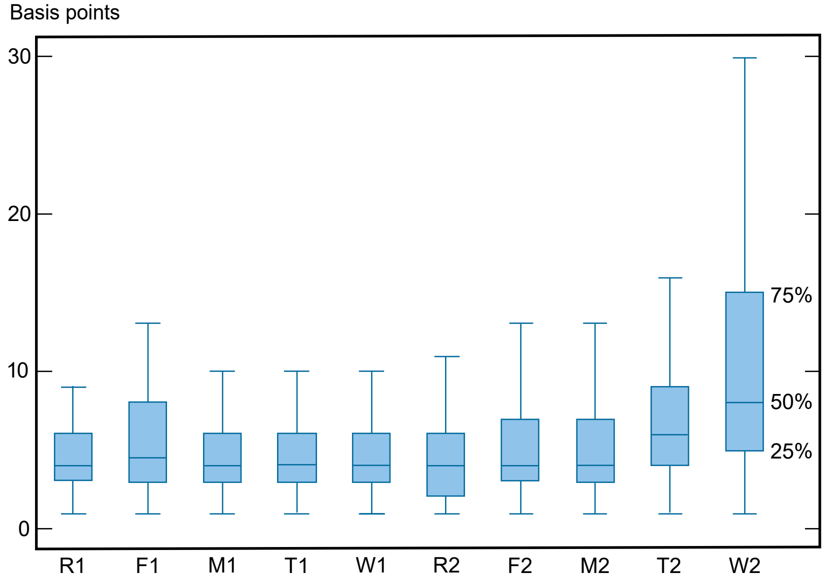
3. Effectiveness in Meeting Primary Monetary Policy Objectives

How effective was the pre-crisis framework in meeting the primary objectives of monetary policy? In this section, we focus on the Desk's control of short-term rates and whether changes in the policy rate were quickly transmitted from the fed funds market to other money markets. First, we show that in spite of increasing intraday dispersion of the fed funds rate toward the end of the maintenance period, the effective rate remained close to target levels. Then, we demonstrate that while the fed funds rate deviated from its target toward the end of quarters (when demand for liquidity was high), it quickly reverted to normal levels within one day. Finally, we document that policy rate changes were rapidly transmitted from the fed funds rate to other money market rates.

3.1 Control of the Policy Rate

Deviations from the target for the federal funds rate rarely exceeded 20 basis points, as the left panel of Chart 5 shows. Moreover, the deviations do not appear to be persistent; instead, larger deviations are generally followed by smaller ones. This was true even toward the end

Chart 4
Intraday Standard Deviation of Effective Federal Funds Rate during Maintenance Period



Sources: Federal Reserve Bank of New York; authors' calculations.

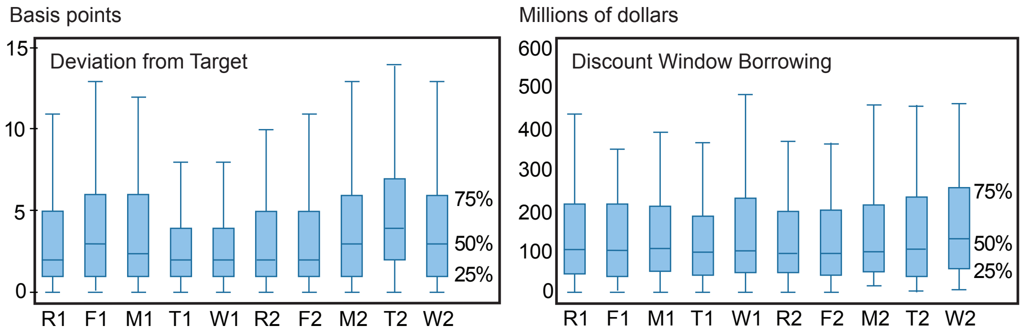
Notes: Using data on the daily standard deviation of the effective federal funds rate (EFFR) (https://apps.newyorkfed.org/markets/autorates/fed%20funds) for the period July 3, 2000, through August 1, 2007, the chart shows the rate's distribution by day in the reserve maintenance period. Fifty percent indicates the median level, and 25 percent and 75 percent indicate the 25th and 75th percentiles of the distribution, respectively. The ends of the whiskers represent observations up to 1.5 times the interquartile range. R1/2 is the first/second Thursday of the maintenance period; F1/2 is the first/second Friday of the maintenance period; M1/2 is the first/second Monday of the maintenance period; T1/2 is the first/second Tuesday of the maintenance period; W1/2 is the first/second Wednesday of the maintenance period; W2 is the settlement date.

of the maintenance period when the rates were more widely dispersed (Chart 4); indeed, the EFFR did not drift significantly farther from the target rate at the end of maintenance period than it did on other days in the maintenance period. This small deviation was not the result of banks borrowing heavily from the discount window to meet their demand for reserves. As the right panel of Chart 5 shows, while depository institutions tended to borrow more from the discount window on the last day of the maintenance period, the amount borrowed was small in comparison with the amount of excess reserves. In other words, the low volatility of fed funds during the end of maintenance periods cannot be attributed to banks smoothing their demand for reserves through discount window borrowings. Rather, the evidence from Chart 5 suggests that the Desk was successful in managing reserves throughout the maintenance period and, in particular, the ends of maintenance periods did not significantly impair the Desk's ability to implement monetary policy.

While the fed funds rate, on average, was close to its target, it could occasionally deviate from that target. Typically, autonomous factors could experience movement that the Desk would forecast imperfectly and the difference would result in small supply-demand

Chart 5

Absolute Deviation of Effective Federal Funds Rate from Target and Discount Window Borrowing by Day of Maintenance Period



Sources: Federal Reserve Bank of New York; authors' calculations.

Notes: The left panel shows the distribution of the absolute deviation of the federal funds rate from the target rate by day during the maintenance period, for the time frame from July 1, 2001, through August 1, 2007. The right panel shows the distribution of discount window borrowings by day during the maintenance period, for the time frame from January 1, 2003, through June 30, 2007. Fifty percent indicates the median level, and 25 percent and 75 percent indicate the 25th and 75th percentiles of the distribution, respectively. Ends of the whiskers represent observations up to 1.5 times the interquartile range. R1/2 is the first/second Thursday of the maintenance period; F1/2 is the first/second Friday of the maintenance period; M1/2 is the first/second Monday of the maintenance period; T1/2 is the first/second Tuesday of the maintenance period; W1/2 is the first/second Wednesday of the maintenance period; W2 is the settlement date.

mismatches. Other deviations were generally predictable (and therefore could be anticipated and partially offset by the Desk) and well understood. For example, large rate movements could occur within a reserve maintenance period ahead of a widely anticipated rate change by the FOMC; rates would typically fall on the first Friday of each maintenance period and typically increase on high payment flow days. More important, rates quickly reverted to the target following such deviations.

To illustrate the resilience of the policy rates during periods of high volatility, we consider the behavior of fed funds rates during quarter-ends (see Box 3 for further details). Heightened volatility around quarter-end dates typically caused the fed funds rate to deviate from the target. This deviation increased by an average of 6 basis points on the last day of the quarter (day 60 in Chart 6, page 55) and by 8 basis points the following day (day 1 in Chart 6, which is the first day of the following quarter). By contrast, on more "typical" days (that is, excluding the quarter-end date plus the two days before and after it), the fed funds rate was within a basis point of the target, on average. The fed funds rate sometimes increased sharply at the end of months, which accounts for the spike on day 20, but volatility on these days was not unusually high.

In order to stabilize fed funds rates around quarter-end dates, the Desk supplied extra reserves to meet the surge in demand (see page 54 of Box 3). Moreover, the Desk planned to leave relatively low levels of reserves on other days in the same reserve maintenance period. Otherwise, the supply of reserves would have exceeded demand over the non-quarter-end days of the

Box 3:

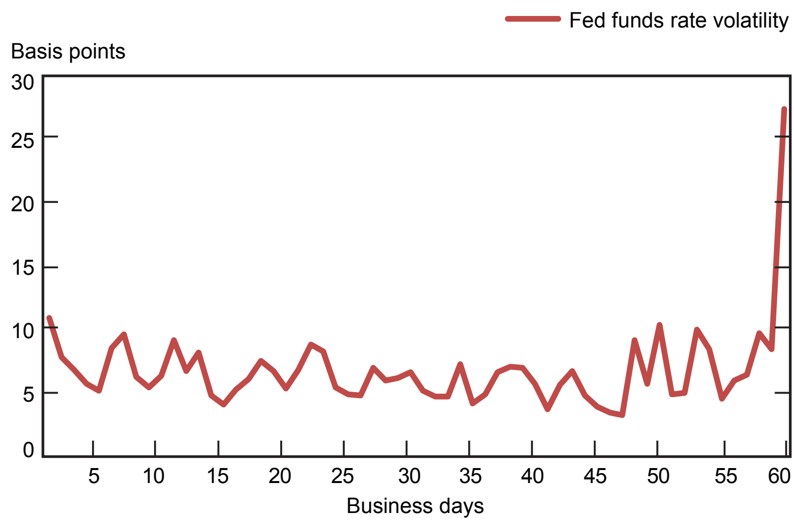
Quarter-End Dynamics of Federal Funds Rates

Volatility of Fed Funds Rates at Quarter-Ends

Quarter-end volatility remained a feature of the fed funds markets in the years before the financial crisis. Chart 3A plots the intraday volatility of the fed funds rate for each day of the quarter, averaged across quarters from the fourth quarter of 2004 to the second quarter of 2007. During this time period, there was a clear trend of elevated intraday volatility on the quarter-end date.

Chart 3A

Volatility of Federal Funds Rate Spikes on the Last Day of the Quarter: 2004:Q4 to 2007:Q2



Source: https://apps.newyorkfed.org/markets/autorates/fed%20funds.

Notes: The chart shows, for each day *t,* the median of the intraday standard deviation of the federal funds rate across quarters. Day 60 is the quarter-end date. Day 1 is the start of the quarter. The quarters are standardized to sixty days by using the first thirty days from quarter-start and the last thirty days from quarter-end, excluding days in the middle for quarters with more than sixty days. Rates are in basis points.

Level of Fed Funds Rates during Quarter-Ends

Heightened volatility around quarter-end dates typically caused the fed funds rate to deviate from the target. This deviation increased by an average of 6 basis points on the last day of the quarter (day 60) and by 8 basis points the following day (day 1), as shown in Chart 6, page 18. By contrast, on more "typical" days (excluding the quarter-end date plus the two days before and after it),

(Continued on next page)

Box 3 *(Continued)*

the fed funds rate was within a basis point of the target, on average. The fed funds rate sometimes increased sharply at the end of months, which accounts for the spike on day 20, but volatility on these days was not unusual (as shown in Chart 3A).

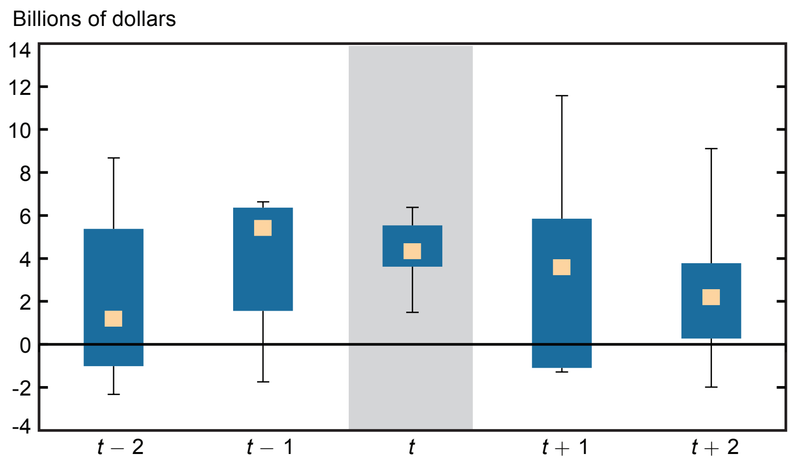
Supply of Reserves during Quarter-Ends

In order to stabilize fed funds rates around quarter-end dates, the Desk supplied extra reserves to meet the surge in demand. Moreover, the Desk planned to leave relatively low levels of reserves on other days in the same reserve maintenance period (that is, the period over which banks' required reserves are calculated). Otherwise, the supply of reserves would have exceeded demand over the non-quarter-end days of the maintenance period, pushing rates below the target once the quarter-end had passed.

The box-whisker plot of the distribution of excess reserves in Chart 3B shows that the Desk left an average of more than $4 billion of excess reserves around quarter-end dates. In contrast, the Desk on average left less than $0.5 billion of excess reserves on non-quarter-end days of the maintenance period. The chart further indicates that the *range* of excess reserves was relatively narrow, between $3 billion and $6 billion on most quarter-end dates, suggesting that the Fed chose not to eliminate reserve demand shocks completely, as was also found by Bartolini, Bertola, and Prati (2002).

Chart 3B

Excess Reserves around Quarter-End: 2004:Q4 to 2007:Q2

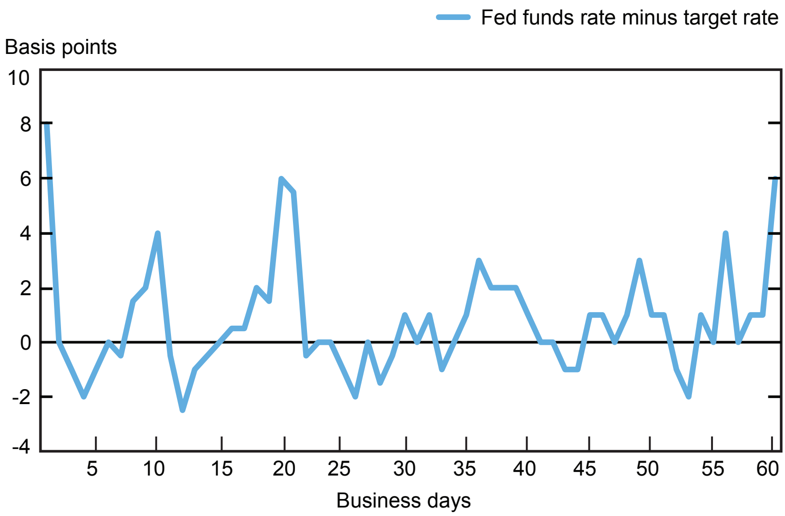


Source: Federal Reserve Bank of New York.

Notes: Day *t* (shaded) is the quarter-end date. The chart plots the distribution of excess reserves for the five quarter-end dates. For each date, the blue box includes values between the 25th and 75th percentiles of the distribution, with the median indicated by the orange box. The "whiskers" indicate outliers beyond this range.

Chart 6

Federal Funds Rate Spikes around the End of Quarters: 2004:Q4 to 2007:Q2



Source: Federal Reserve Bank of New York.

Notes: The chart shows the median of the difference between the federal funds rate and the target rate across quarters for each day. Day 60 is quarter-end. Day 1 is the start of the quarter. The quarters are standardized to sixty days by using the first thirty days from quarter-start and the last thirty days from quarter-end, excluding days in the middle for quarters with more than sixty days.

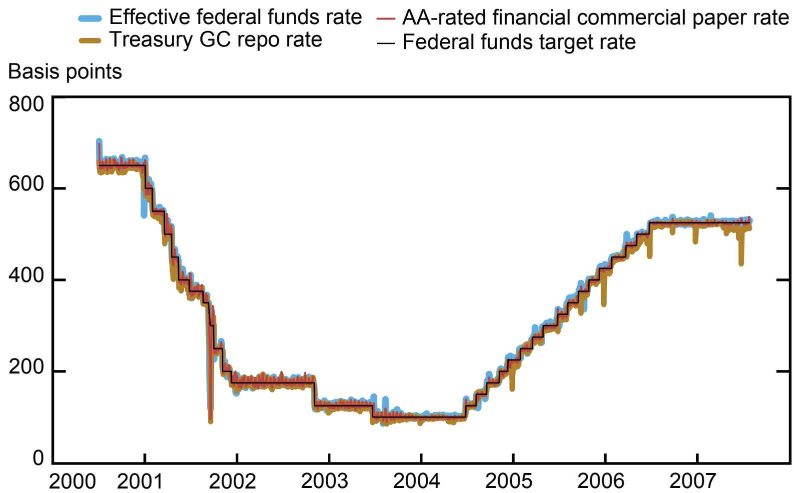
maintenance period, pushing rates below the target once the quarter-end passed. Consequently, the deviation of the fed funds rate from its target was short-lived, generally falling back to the target rate on the second day after quarter-end (Chart 6).

3.2 Transmission of the Policy Rate to Other Money Markets

The FOMC traditionally implements monetary policy by announcing a policy target rate for the EFFR, with the expectation that its decisions will quickly be transmitted to all money market rates. Because the Fed does not directly control market interest rates, it relies on arbitrage forces in money markets to transmit the change in the fed funds rate to other short-term rates.[13] A variety of market participants can be arbitrageurs, including primary dealers that operate in most short-term money markets and hedge funds that seek to profit from price discrepancies in related markets. In this section, we examine the effectiveness of arbitrage before the recent financial crisis.

In the pre-crisis period, because banks active in multiple money markets could earn a profit when money market rates were misaligned, arbitrage kept those rates aligned and thus facilitated the transmission of monetary policy. As shown in Chart 7, the overnight AA financial commercial paper rate, the EFFR, and the overnight Treasury general collateral (GC)[14] repo rate were highly correlated before the crisis, as would be expected with

Chart 7
Overnight Money Market and Target Federal Funds Rates: July 2000–July 2007



Sources: Federal Reserve Bank of New York; Bloomberg L.P.

Notes: All rates are of overnight tenor. GC is general collateral.

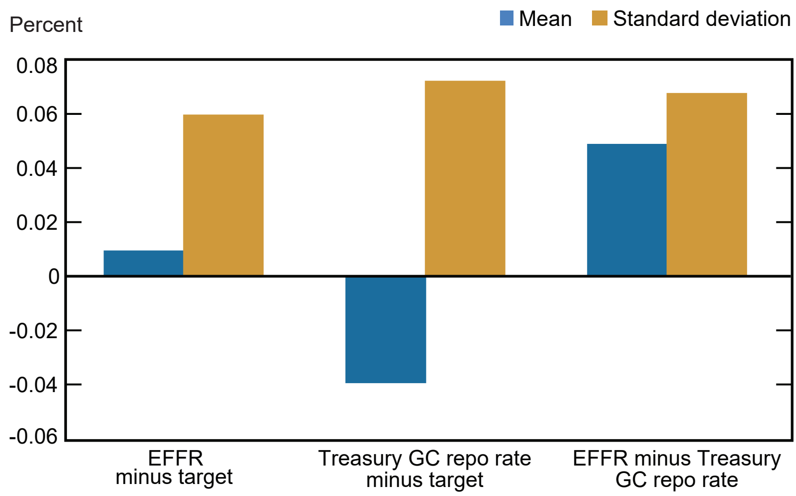
effective arbitrage.[15] Other short-term money market rates, such as Eurodollar rates (not shown in the chart), were also tightly aligned with the EFFR.

On average, the EFFR and the Treasury repo rate generally remained close to the FOMC's target rate (Chart 8). Also, the repo rate was consistently below the fed funds rate, as should be expected since repos are secured and fed funds are not. As a result, the average difference between the EFFR and repo rates (or the spread) was positive. Of note, the standard deviation of both rates is relatively high compared with the respective means, in particular for the EFFR. To the extent that the volatility is fundamental, the relatively high standard deviation may represent price discovery (that is, discovery of the rate equilibrating the demand for and supply of reserves) occurring in the actively traded fed funds market. We return to this issue in Section 4, where we discuss the advantages of active trading in the money markets for monetary policy implementation.

In Box 4, we present a formal test of monetary policy transmission using Granger causality tests and daily data. We show that past values of the EFFR "cause" (or predict) the current repo rate in the pre-crisis period, a pattern one would expect if arbitrageurs operated to keep intermarket rates aligned. In turn, the existence of arbitrage activity likely facilitated the transmission of changes in the target rate to the repo market. The results further show that the repo rate also Granger-causes the EFFR in the pre-crisis period, indicating two-way flows of information between the fed funds and repo markets. This result indicates that neither market is dominant in an informational sense.

In addition to examining the fed funds market, we analyze transmission between the Eurodollar market and the repo market. We find that changes in the Eurodollar rate are also transmitted to the repo rate (as might be expected, since the Eurodollar and the EFFR have historically been tightly connected).

Chart 8
Deviations from the Target Federal Funds Rate: January 2002–December 2006



Notes: The chart shows the means and standard deviations, respectively, of the effective federal funds rate (EFFR) and the repo rate, measured as deviations from the target federal funds rate during the pre-crisis period. Also shown are the mean and standard deviation of the spread (that is, the EFFR minus the repo rate). GC is general collateral.

4. Operational Effectiveness and Financial Market Functioning

While its primary task is controlling the fed funds target, a monetary policy framework can also be evaluated with respect to objectives related to operational effectiveness and financial market functioning. In this section, we evaluate the pre-crisis framework's operational effectiveness by analyzing the efficiency and transparency of the Desk's day-to-day actions and procedures in managing liquidity and by viewing the framework through the lens of universality—whether the framework remains applicable in different states of the economy. We assess the financial objectives by examining the impact of the Fed's collateral policy and by exploring the monetary policy framework's effect on money market and payment system activity (Bindseil 2016).

4.1 Operational Objectives: Efficiency and Transparency of Procedures

Before the crisis, the Desk's procedures for controlling short-term interest rates were complex and resource-intensive, resulting from the need to manage liquidity daily and, consequently, to forecast reserve supply and demand conditions daily, a technically challenging task (Bernanke 2005).[16] In addition, the Federal Reserve did not publish its forecasts, which made the procedures rather opaque to market participants.

Box 4

Testing Monetary Policy Transmission with Granger Causality Tests

To evaluate the strength of monetary policy transmission, we conduct a Granger causality test using daily data. Past values of the effective federal funds rate "caused" (or predicted) the current repo rate in the pre-crisis period (see table), indicating that the Fed's monetary policy decisions were transmitted to the repo market. Also, the results show that the repo rate Granger-caused the EFFR in the pre-crisis period, showing a two-way flow of information between the fed funds and repo markets.

Does the Federal Funds Rate Predict the Repo Rate in the Pre-Crisis Period?

	Result
Does the fed funds rate predict the repo rate?	Yes
Does the repo rate predict the fed funds rate?	Yes

Notes: The table shows results from a Granger causality test for the period January 2002 to December 2006. Rates are measured relative to the target federal funds rate.

One concern with the analysis is that the reporting time of the data is not synchronized: the repo rate is reported as of 9 a.m. EST, whereas the EFFR is an all-day rate. To address this issue, we estimate the Granger causality between the one-day lagged value of the EFFR and the repo rate and, further, between the General Collateral Finance Repo (GCF Repo®) Treasury rate (which is reported at the end of the day) and the EFFR.[a] In both cases, we obtain a similar result: there is bi-directional causality between the EFFR and the repo rate during the pre-crisis period.

We focus on the transmission from the EFFR to the repo rate because of the historical importance of the fed funds market and the availability of a long time-series of data for the EFFR. However, in an unreported analysis, we also find that Eurodollar rate changes are transmitted to the repo rate (as might be expected, since the Eurodollar and fed funds rate have historically been tightly connected).

[a] Another alternative is to use a morning funds rate, such as the Broker's Fed Funds Open. However, these rates represent quotes and not transactions, and, moreover, they are not based on meaningful volumes.

In a multiple-day reserve maintenance system, the daily distribution of reserves may, in theory, be less important, since reserve requirements only have to be met by the end of the period. But because total requirements were low relative to the daily volatility of autonomous factors, the Desk had to evaluate reserve supply and demand conditions closely every morning. Most days, the Desk conducted the following activities:

- forecast numerous autonomous factors over a multiday horizon;
- forecast reserve demand for multiday horizons and for different types of banks; and
- plan and execute the repo or reverse repo operations.

A description of a typical day in the life of the Desk (as is provided in Board of Governors [2005]) gives a sense of the resources required on a daily basis to conduct monetary operations. The day would start with independent projections of the supply of and demand for reserves by two groups of staff members, one at the Federal Reserve Bank of New York and the other at the Board of Governors in Washington. Then a conference call would be held that included the manager of the System Open Market Account (SOMA) in New York, staff at the Board of Governors, and a Federal Reserve Bank president who was at the time a voting member of the FOMC. Participants would discuss the day's forecasts for reserves and financial market developments, especially in the federal funds market. Based on this information, a plan for conducting OMOs would be formulated and a repo operation with primary dealers would typically be executed at this time. Primary dealers would learn of the size of the repo operation only after it was concluded, and the desired level of reserves resulting from the operation was never published. Longer-term repos would be arranged earlier in the morning, usually on a specific day of the week. If an outright operation was also needed, it would be executed later in the morning, after the daily repo operation was completed.

Unlike at many other central banks, the Desk did not publish its forecasts (Hilton 2008), so market participants sometimes had difficulty interpreting the Desk's actions. For example, market participants would often speculate that day-to-day changes in outstanding repo operations matched the Fed's estimate for daily changes in the demand for reserves. This speculation was inherently flawed, since it ignored the equally important impact of forecasted changes to autonomous factors, into which market participants had limited insight. The Desk did not publish its daily targeted level of reserves on an ex post basis, and the intended sizes of repo operations were not announced concurrent with the operations. Repo market participants often had only a vague idea of what the sizes of the repo operations would be at the time they were announced and then had difficulty interpreting the results after they were released.

Would an alternative framework have achieved the intended monetary policy goals with less operational complexity? In theory, a symmetric corridor system, with the target rate in the middle of the standing deposit and lending rates, might have required less daily intervention by the Desk as long as banks were able and willing to access the central bank's standing facilities. This system ensures that expected rates in the maintenance period are around the target rate, since it is equally likely that banks would be in reserve deficit or surplus over the maintenance period and, further, the costs of both outcomes are symmetric around the policy rate (Hilton 2008; Bindseil 2014). However, the interest rate corridor in the United States was not symmetric, since there was no standing interest-bearing deposit facility. Instead, the effective deposit rate was zero, since no interest was paid on reserves. Because banks' opportunity cost of holding reserves was zero, the cost of having surplus reserves was higher than the cost of being in deficit, resulting in a bias toward rates below the fed funds target (Hilton 2008). Bindseil (2014) examines a number of alternative monetary policy frameworks with symmetric corridors and shows that, during the pre-crisis period, they were all effective in meeting their monetary policy objectives, suggesting that the Fed could have met its monetary policy objectives using a simpler framework.

Why was the Desk able to meet its monetary policy objectives in spite of a complex and opaque operating framework? Hilton (2008) suggests that one factor might have been the Desk's daily fine-tuning of the supply of reserves, whereby, when rates deviated from the target, it responded by adjusting the daily supply of reserves to induce rate movements in the reverse direction. This behavior may have helped to ensure that expected future rates remained anchored around the target rate. Market participants responded appropriately to the Desk's fine-tuning because the Desk had built up a consistent record of success in forecasting reserve demand and supply factors. The Desk's forecasting ability and market confidence were mutually reinforcing elements that anchored market expectations and ensured that the EFFR stayed close to the policy target rate.

4.2 Operational Objectives: Universality

A universal (state-independent) framework is one that remains effective across different financial and macroeconomic conditions. All else equal, a more universal framework is desirable, since it allows the central bank to avoid the fixed costs of designing, testing, and implementing new frameworks as conditions evolve. A more universal framework could also help avoid unexpected shifts in the operating framework if conditions change rapidly (for example, during a crisis). Such sudden alterations to the operating framework could be suboptimal if they are made under time constraints, as during a crisis.

One disadvantage of the pre-crisis framework vis-à-vis universality was that in order to control the fed funds rate, the Desk needed to have control over the size of the Federal Reserve's balance sheet. But if the Federal Reserve needed to change the amount of reserves for a reason other than altering the fed funds rate, the Desk could lose control of the policy rate. This limitation became relevant in 2008 when the provision of large amounts of liquidity undermined control of the interest rate, a topic we explore in the concluding remarks of this article.

A second disadvantage of the pre-crisis framework was that active daily management of reserves, and the attendant forecasts of the conditions for reserve demand and supply, proved to be particularly problematic during crisis periods. For example, during the early stages of the financial crisis (primarily in 2007 and 2008), demand for reserves proved particularly hard to predict, resulting in large intraday swings in the federal funds rate (Hilton 2008).

4.3 Financial Market Functioning Objectives: Asset Eligibility Policy

Central banks affect market functioning through their asset eligibility framework, including collateral eligibility for discount window borrowing. Assets eligible for use as collateral may benefit from increased liquidity and enhanced ability to obtain credit, compared with ineligible assets.[17] Further, to the extent that "haircuts" do not fully reflect risks—for example, if they do not vary by counterparty—the price of eligible assets might be distorted (a "haircut" being the difference between the market value of the asset pledged as collateral and the amount of the loan). These market effects are likely to be higher, the broader the set of collateral assets. For example, if the central bank accepts a wide range of collateral assets, then banks may have an incentive to structure their balance sheets to maximize access to central bank credit (Bindseil 2014).[18]

The Federal Reserve Act limits the types of assets that the Federal Reserve may acquire through open market operations. In practice, the Fed accepts only high-quality assets in its

OMOs—namely, Treasury debt and debt issued or fully guaranteed by U.S. federal agencies, which includes agency mortgage-backed securities. A wider variety of assets, including government and private-sector securities, mortgages, and consumer and commercial loans, are eligible to be pledged against discount window loans. Since discount window borrowings were negligible in normal times, the eligibility criteria for OMOs were the binding constraints. The strictness of the OMO eligibility criteria likely reduced the distortionary effects on asset prices, since the additional liquidity benefits of being granted eligibility are likely small for these types of assets.[19]

An alternative view is that the central bank should actively use its collateral policy to support an important asset market that is currently illiquid. Indeed, in the 1920s and 1930s, the Fed took an active role in enhancing the liquidity of the U.S. Treasury bond markets, in part by including these securities as collateral for its nascent OMOs (Garbade 2012). Later, the U.S. Treasury bond markets developed into some of the most liquid asset markets, and so the Fed no longer needed to actively support these markets through its collateral policy. Under this view, inclusion of a broader range of assets for collateral eligibility, even if that involves including illiquid assets, may be desirable.

4.4 Financial Market Functioning Objectives: Money Market Activity

A framework based on reserve scarcity is likely to encourage higher interbank trading activity than one with reserve abundance. Indeed, the scarcity of reserve balances relative to required and precautionary demand for reserves that was a feature of the pre-crisis framework resulted in large volumes of trading between banks, since banks with more reserves than necessary would have an incentive to trade with banks that had too few reserves. For example, in the fourth quarter of 2006, brokered fed funds activity averaged $95 billion per day. In contrast, under an abundant-reserve regime in the fourth quarter of 2015, the volume of brokered fed funds averaged only $42 billion per day. (See Box 5 for a more detailed discussion of changes in fed funds market activity since the crisis).

As a general matter, it is unclear whether supporting active money markets should be a goal of a monetary policy framework. Active money markets may promote the transmission of changes in policy rates to the broader market by facilitating arbitrage, enabling price discovery, and promoting market discipline. However, alternative markets (such as short-term funding markets) may be available for providing these benefits. The potential signaling benefits from money markets are also hard to quantify. Changes in trading volumes may not be driven by fundamentals but rather by idiosyncratic payment shocks. Further, participants' efforts to monitor the credit quality of counterparties vary considerably, and it may be difficult to value the social good that results from such monitoring, given that contagious credit and liquidity shocks may force lenders to withdraw funding broadly.[20]

In the particular circumstances of the pre-crisis period, however, activity in the fed funds market likely provided some benefits. An active fed funds market probably promoted rate discovery, which facilitated the quick transmission of changes in the EFFR to other money market rates (see Section 3).

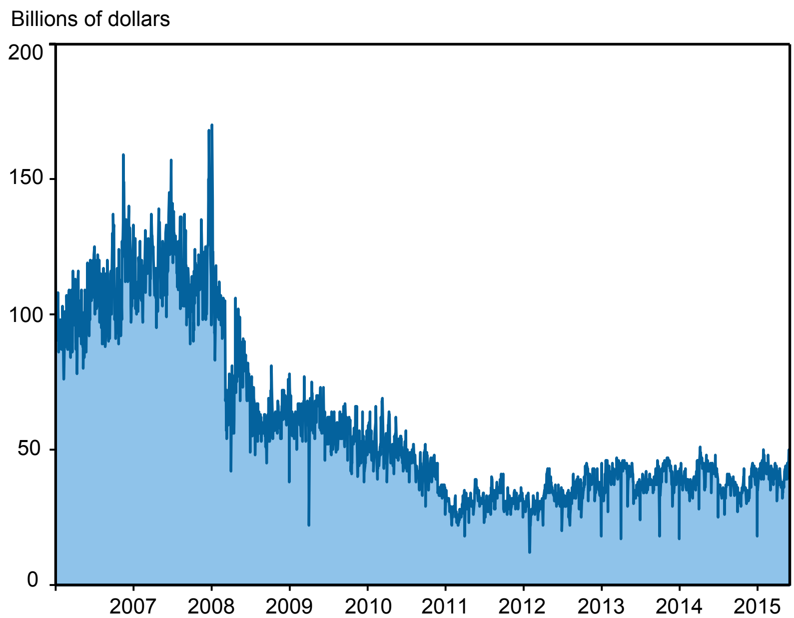
Box 5

Federal Funds Market Activity before and after the Crisis

The pre-crisis period was characterized by significant interbank trading. Banks would trade fed funds for a variety of reasons, including avoiding overnight overdrafts, smoothing daily balances emanating from day-to-day fluctuations in both assets and liabilities, and meeting reserve requirements over the two-week reserve maintenance period. In addition, because the yield curve was typically upward-sloping, some banks established a "structural short" position wherein they would effectively fund longer-term assets through consistent borrowing in the fed funds market.

Along with the shift to abundant reserves following the crisis of 2007-09, fed funds trading volume declined sharply. This decrease is evident in the chart below, which shows a roughly 50 percent drop in the volume of brokered fed funds after the crisis.

Brokered Federal Funds Rate Volume: October 2006–February 2016

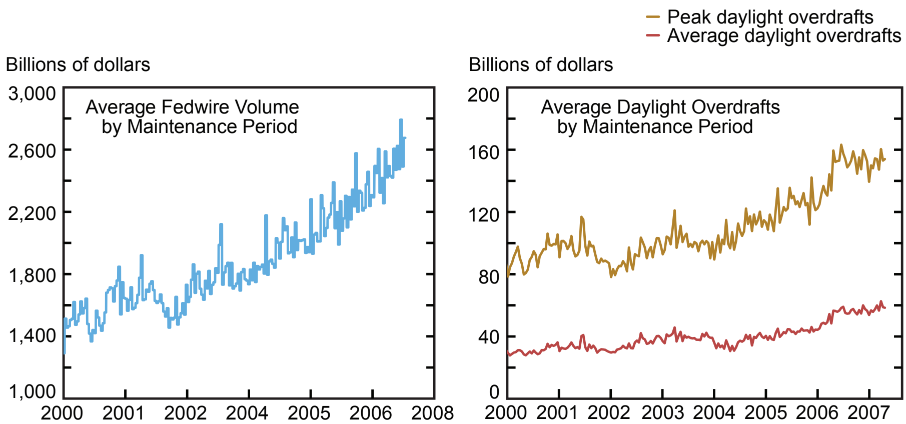


Source: Federal Reserve Bank of New York.

Note: The data are the result of aggregating daily total volumes voluntarily supplied by federal funds brokers.

Activity in the fed funds market is currently dominated by investors that were ineligible to receive interest on excess reserves (IOER) interacting with mostly foreign banking organizations that generally leave the borrowed proceeds at the Fed to earn IOER, in a trade known as IOER arbitrage. As a result, the fed funds market now differs fundamentally from what it was pre-crisis. Most, if not all, of the pre-crisis motivations for borrowing and selling fed funds have changed significantly, and new Basel III regulations discourage banks from funding longer-term assets with short-term liabilities. As a consequence, fed funds trading volumes are now persistently lower than they were pre-crisis.

Chart 9
Time Series of Fedwire Volume and Daylight Overdrafts by Maintenance Period



Sources: Federal Reserve Board; Federal Reserve Bank of New York; authors' calculations.

Note: Both panels reflect data for the period from January 1, 2000, through August 1, 2007.

4.5 Financial Market Functioning Objectives: Payment System Activity

In the pre-crisis period, banks relied on substantial provisions of intraday, or daylight overdraft, credit from the Fed, because the level of reserves was insufficient to cover the clearing needs of the payment system. Since the Fed charged low fees for intraday credit, banks relied on the Fed as a source of intraday funding and did not necessarily borrow in the wholesale funding markets to address shortfalls. With average daily Fedwire volume of $2.28 trillion and average reserve balances of just $9 billion held at Federal Reserve Banks in 2006, large daylight overdrafts were a likely consequence of the low levels of reserves in the system. (Box 6, page 64, discusses to what extent private solutions to the problem of intraday credit existed.)

Peak daylight overdrafts (the largest total amount of credit outstanding at any time) as well as average overdrafts by maintenance period over the pre-crisis period are shown in the right panel of Chart 9 (above). In 2006, the use of intraday overdrafts averaged roughly $51 billion during operating hours, and, on average, $140 billion was outstanding at peak use over a maintenance period (roughly 6 percent of average payment volume over Fedwire). Peak overdraft use steadily increased in the pre-crisis period starting in 2000.

While daylight overdrafts facilitate payments, they also expose the Fed to the potential for loss, should the institutions incurring negative balances fail to replenish their funds. (See Box 6 for more discussion of the evolution of the Fed’s Payment System Risk policy).

Box 6

Changes to the Payment System Risk Policy Regarding Overdrafts

The Federal Reserve's Payment System Risk Policy

The extension of intraday credit by Federal Reserve Banks is governed by the Fed's Payment System Risk (PSR) policy. The policy addresses the risks that payment, clearing, and settlement activities present to the Fed and the financial system as a whole, and it also governs Reserve Banks' provision of intraday credit to accountholders. (For more information, see https://www.federalreserve.gov/paymentsystems/psr_about.htm.)

The policy was first written in 1985 and has been amended multiple times since then. It was modified in 1994 to charge banks fees for their use of intraday credit. In 2001, changes to the PSR policy allowed institutions meeting certain criteria to obtain collateralized overdrafts above their authorized capacity, known as net debit caps. In 2006, the policy was revised to require government-sponsored enterprises (GSEs) and international organizations to pre-fund Fedwire payments of principal and interest due on their outstanding debt, thus precluding the Fed from granting intraday credit to these institutions. In 2008, the policy was once again revised by setting the fee for collateralized overdrafts at zero and raising the fee for uncollateralized overdrafts to 50 basis points. This policy change was intended to improve the efficiency of the payments system while also limiting the credit exposure of Federal Reserve Banks. These changes went into effect in 2011.

Changes in Peak Intraday Overdraft Activity

The chart on page 65 presents peak intraday overdraft activity by quarter since 1986. We observe a temporary slowdown in the growth of intraday credit around the time of the implementation of the GSE restriction. However, it is difficult to attribute causation, since other factors may have been responsible for the slowdown. Peak intraday credit resumed growing later in 2006 and ultimately crested sometime in 2008. (See https://www.federalreserve.gov/paymentsystems/psr_data.htm.)

The most striking feature of the chart is the dramatic decline in the use of intraday overdraft credit once the Fed's balance sheet expanded in the fourth quarter of 2008. Excess reserve balances grew dramatically during this time, first from draws on various liquidity facilities and then from the Fed's large-scale asset purchase programs. As excess reserve levels have remained high, demand from banks to borrow funds from the Fed on an intraday basis has remained low for many banks.

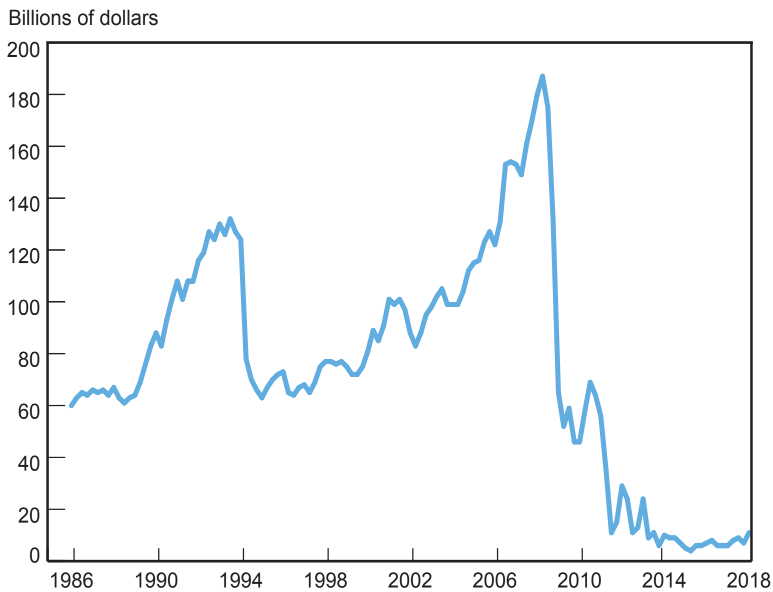
Private Solutions to the Need for Intraday Overdrafts

During the period of high intraday credit use, no private market for providing this specific type of credit materialized. However, there were some informal market-oriented solutions to provide credit on an intraday basis. One solution was for large GSEs to obtain a collateralized intraday credit line from a large money center bank. The other solution for borrowers that were facing large intraday credit needs was to borrow overnight money in the brokered fed funds market on a "fill or kill" basis. With a fill or kill order, the lender agrees to send the funds promptly, say, in a fifteen-minute window, and the borrower returns the funds within a twenty-three-hour window by market convention. The borrower is willing to pay a little more to borrow funds in this manner and thereby receives immediate relief on intraday credit issues by receiving the funds promptly. This solution was widely used by market participants in the pre-crisis period.

(Continued on next page)

Box 6 *(Continued)*

Peak Daylight Overdrafts



Source: Federal Reserve Board.

Note: Amounts are based on a 21.5-hour Fedwire day.

5. Concluding Remarks

Control over the federal funds rate represented the primary policy tool of the Fed's pre-crisis operating framework. In order to exert this control, the Fed relied on a scarcity of reserves to ensure that the fed funds rate would be sensitive to the level of reserves in the system. To adjust the rate, the Desk forecasted the demand for and supply of reserves daily, and then typically increased or decreased the amount of reserves available to banks relative to forecasted demand by changing the size of daily repo operations. The aggregate amount of reserves was distributed among banks by means of trading in the fed funds market. Arbitrageurs aided the framework by transmitting changes in the fed funds rate to other short-term interest rates and to the real economy more broadly. In this article, we discussed the desirability of the pre-crisis framework in the context of meeting monetary policy objectives while conducting monetary operations in an efficient and transparent manner, such that financial market functioning was not impaired.

The pre-crisis framework was effective at meeting monetary policy objectives. First, the Desk successfully maintained the EFFR close to the target rate set by the FOMC, even during periods of significant volatility in banks' demand for reserves. Furthermore, deviations were not persistent—the Desk generally corrected any short-term movements in the fed funds rate. Finally, changes in the target rate were quickly transmitted to other money market rates.

The pre-crisis framework receives mixed reviews in terms of unimpaired financial market functioning. Having a relatively restricted set of collateral eligible for open market operations ensured that the Desk's operations did not significantly affect the relative pricing of risk. The scarcity-of-reserves paradigm also ensured relatively active trading in the interbank market. However, this same paradigm placed strains on the interbank payment system, leading to heavy use of daylight overdraft credit from the Fed.

The pre-crisis operational framework scores less well in terms of meeting monetary objectives efficiently and transparently. Implementing the operating procedures was complex and the procedures were opaque, which meant that market participants generally found them difficult to understand. In addition, the framework lacked universality in that large changes in aggregate reserve balances could undermine the Desk's ability to control the policy rate. This critique became relevant in 2008 when the Federal Reserve implemented emergency lending programs to combat the effects of the financial crisis. These programs expanded the aggregate amount of reserve balances for reasons other than monetary policy, causing the Desk to lose control over the policy rate. Finally, the daily operational procedures did not adapt well to crisis market conditions as reserves demand became difficult to predict, resulting in high intraday volatility.

In order to regain control of the policy rate, the Fed abandoned the pre-crisis framework in favor of a framework that would allow the Desk to continue to carry out FOMC objectives regardless of the amount of reserves in the banking system. Unlike the pre-crisis framework, the current monetary policy framework is one of reserve abundance, whereby, through the use of administered rates (those rates set by the Fed and not determined in the markets), the fed funds rate is kept within a range set by the FOMC. Using this new framework, the Desk has continued to maintain the policy rate within the target range set by the FOMC. This success demonstrates that while the pre-crisis framework offered effective monetary control, this control was not unique to that paradigm.

The abundant-reserves framework has resulted in changes to other aspects of the pre-crisis framework. With the abandonment of the scarcity-of-reserves approach, banks no longer rely heavily on overdraft credit from the Federal Reserve. As a further by-product, the abundant-reserves framework has diminished banks' need to transact in the fed funds market, causing a reduction in volume (see Box 5). However, the benefits of active money markets are debatable and must be weighed against reduced volatility of the EFFR (Potter 2016).

While the current framework will likely evolve as the FOMC considers its appropriateness in meeting future monetary policy challenges, a return to the pre-crisis framework is not necessarily desirable. As we have shown in this article, the pre-crisis framework had several shortcomings that can probably be addressed.

Notes

[1] In addition, the mandate requires the Fed to maintain moderate levels of the long-term interest rate (Board of Governors of the Federal Reserve System 1994).

[2] In this article, we use "bank" to mean "depository institution." Technically, they are not equivalent, since some nonbank intermediaries, such as credit unions or savings and loan associations, can also take deposits.

[3] There is no consensus in the literature regarding the appropriate goals of a monetary policy framework. Our explication is loosely based on Bindseil (2014), who also discusses additional objectives that we do not consider. For example, Bindseil (2014) includes adequate risk-adjusted financial returns on central bank assets as part of financial objectives.

[4] In a symmetric corridor system, the target rate lies in the middle of the rates for the standing lending and borrowing facilities. The benefits of such a system for liquidity management are discussed in Section 4.

[5] Since the market fed funds rate varied from trade to trade depending on the creditworthiness of borrowers and other factors, the Fed used a weighted average of market rates as its policy target. Prior to March 1, 2016, the EFFR was calculated as a weighted average based on fed funds transactions as reported to the Desk by fed funds brokers. Effective March 1, 2016, the EFFR calculation was changed from a weighted average mean to a volume-weighted median and the source data were changed to the FR 2420, *Report of Selected Money Market Rates.* The EFFR is published by the Desk on the morning of the business day following the day of the report.

[6] Under Regulation A, Extensions of Credit by Federal Reserve Banks, as of January 9, 2003, financially strong and well-capitalized banks can borrow under the Fed's primary credit program at a penalty rate above the target fed funds rate (rather than at a subsidized rate, as was the case prior to this regulation).

[7] In reality, the stigma associated with borrowing from the Fed deters banks from using the facility, resulting in some borrowing at market rates in excess of the primary credit rate (Armantier et al. 2015; Furfine 2001). Prior to 2003, discount window borrowers had to satisfy the Fed that they had exhausted private sources of funding and that they had a genuine business need for the funds, which likely contributed to the stigma. Since 2003, the discount window has been a "no questions asked" facility but the stigma has continued to exist.

[8] Theoretical models that incorporate a reserve maintenance period include Gaspar and Rodrigues-Mendizabal (2004) and Ennis and Keister (2008).

[9] In practice, the Desk managed reserve levels to meet required operating balances, which were equal to reserve requirements plus contractual clearing balances. These were the amounts that some banks voluntarily held at their Reserve Banks to defray the cost of Federal Reserve services (described in more detail in Section 2.2). For simplicity, we refer to "required operating balances" as "reserve requirements" for the remainder of this article.

[10] The Desk also forecast the supply of reserves from discount window lending, but, as previously mentioned, these amounts were generally small. See Meulendyke (1998) for further discussion of the Desk's daily operations.

[11] The Desk may also sell Treasury securities outright, but such transactions are extremely rare. In addition, the Fed may transact with foreign officials and international customers at market prices to make small adjustments to its portfolio without entering the market (see Box 1).

[12] Certain broker-dealers are designated primary dealers. These institutions must meet certain standards and serve as trading counterparties to the Federal Reserve Bank of New York in carrying out monetary policy. They also participate in auctions of government securities and make markets for these instruments.

[13] See Bernanke (2005).

[14] General collateral Treasury securities are those that have no special features, such as unusually high market demand.

[15] The repo rate is the Desk's 9 a.m. Primary Dealer Survey Treasury GC Repo rate. Prior to March 1, 2016, the EFFR was calculated by the Desk from broker submissions. Since then, the EFFR has been calculated based on borrowing data submitted by banks in FR 2420, *Report of Selected Money Market Rates.*

[16] Indeed, it could be challenging to explain the daily monetary operations even to experts, as implied by the Board's own description of the open market policy process (Board of Governors 1963).

Notes (Continued)

[17] See the European Central Bank *Monthly Bulletin* (2007).

[18] It is possible that, with a wider range of assets, more asset prices are distorted but there is less distortion for each asset.

[19] The ECB, in contrast, accepts a broad range of illiquid collateral but, to avoid distorting prices, uses objective and publicly available criteria in its asset selection and ensures that assets with similar properties are treated in a similar manner. See the European Central Bank *Monthly Bulletin* (2007).

[20] See Potter (2016) for a discussion of these issues.

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Review of New York Fed Studies on the Effects of Post-Crisis Banking Reforms

Richard K. Crump and João A. C. Santos

OVERVIEW

• The 2007-08 financial crisis prompted a series of regulatory reforms that affected banks in particular. A decade after the crisis, New York Fed economists launched a project to assess the effects of the reforms.

• This article reviews the resulting twelve studies, which analyzed the effects of the reforms on the cost of bank equity capital, on bank profitability and risk, and on liquidity.

• Most of the findings aligned with theoretical predictions or results of earlier studies of the reforms. However, some studies produced results that contrast with evidence in the academic literature.

• On the whole, the studies showed that banks did respond actively to the new regulations, suggesting that broadening the research to assess additional outcomes would be fruitful.

The financial crisis of 2007-08 exposed many limitations of the regulatory architecture of the U.S. financial system. In an attempt to address these limitations, a series of regulatory reforms have been instituted in the post-crisis period, especially in the banking sector. These reforms include tighter bank capital and liquidity rules, new resolution procedures for failed banks, the establishment of a stand-alone consumer protection agency, new requirements governing money market funds, and a move to central clearing of derivatives. As these reforms have been finalized and implemented, a healthy debate has emerged in the policy and academic communities over their efficacy in achieving the intended goals and any unintended consequences that might have arisen.

In 2017, the Federal Reserve Bank of New York initiated a project to examine the effects of the post-crisis reforms on bank performance and vulnerability. This project, which was completed in June 2018, consisted of twelve studies evaluating a wide set of regulatory changes, including the introduction of liquidity regulation, "living wills," the supplemental leverage ratio, market value accounting to measure bank capital, and the Consumer Financial Protection Bureau (CFPB), among others. Each study was carefully designed to

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identify how these regulatory changes affected the risk taking, funding costs, and profitability of banks, as well as their impact on liquidity in debt markets.

In this article, we provide a brief review of the twelve studies, grouping them into three sections according to their main objective. Section 1 reviews the studies that focus on the cost of bank equity capital. Kovner and Van Tassel (2018) estimate the cost of equity capital for banks and nonfinancial corporations, and then investigate how the cost of equity capital for banks changed in response to the introduction of the Dodd-Frank Act (DFA). Cetorelli and Traina (2018) in turn explore the extent to which the DFA living wills help address the "too big to fail" (TBTF) problem by investigating the impact of the living wills on banks' cost of funding. Finally, Plosser and Santos (2018) ascertain the cost of bank capital regulation by studying the pricing of credit commitments with maturities below one year around the time of the Basel I and Basel II accords, making use of the differential treatment that the Basel accords gave to these commitments.

Section 2 reviews the studies that assess the reforms' effects on bank profitability and risk. Crump, Giannone, and Hundtofte (2018) tackle the latter by exploring the impact of the DFA on banks' overall risk as measured by the volatility of stock returns, while Choi, Holcomb, and Morgan (2018) investigate whether the supplemental leverage ratio (SLR) triggered risk shifting, possibly leading to an increase in bank risk. Fuster and Vickery (2018) investigate whether the regulatory change tying regulatory capital to securities' market value affected the risk of bank securities portfolios, and Fuster, Plosser, and Vickery (2018) assess the impact that regulatory oversight by the CFPB had on bank risk taking and profitability. Last, Pennacchi and Santos (2018) attempt to explain why banks, starting in the late 1970s, shifted to return on equity (ROE) as a performance benchmark instead of growth in earnings per share (EPS), the measure widely used among nonfinancial corporations. They then discuss how the most recent regulatory changes might impact banks' preferences.

Finally, in Section 3, we review the studies that investigate the liquidity effects of the post-crisis reforms. Roberts, Sarkar, and Shachar (2018) study the extent to which the liquidity coverage ratio (LCR) impaired banks' ability to create liquidity. The remaining three studies—Boyarchenko, Eisenbach, Gupta, Shachar, and Van Tassel (2018), Adrian, Boyarchenko, and Shachar (2017), and Boyarchenko, Costello, and Shachar (2018)—in turn attempt to ascertain the extent to which the post-crisis reforms have affected liquidity in debt markets.

As we discuss below, many of the findings of these studies align with theoretical predictions or with existing studies of the effects of post-crisis banking reforms. For example, they confirm that banks have engaged in risk shifting in response to the supplemental leverage ratio. Similarly, they find that banks have adopted practices, including classifying a larger share of securities as held-to-maturity, to "shield" themselves from the regulatory change tying regulatory capital to the market value of their securities investments.

Some of the studies, however, produced unexpected results and findings that run counter to the current academic and industry consensus. For example, one study finds that living wills increased the cost of bank equity capital but did not have a similar effect on the cost of debt. Another study concludes that post-crisis reforms did lower the relative risk of the largest banks, a finding that contrasts with existing evidence in the academic literature. A third study confirms that regulatory capital is indeed costly, but not to the extent that is often claimed by the banking industry.

A prevailing theme from the twelve studies is that regulation is an important driver of the banking business—or, to put it more succinctly, banks do respond actively and rapidly to changes in regulation—highlighting the importance of factoring in the expected responses of banks when designing regulation.

1. Effects on the Cost of Bank Equity Capital

The cost of bank equity capital has been the subject of much debate, in part because of banks' repeated claims that equity capital is expensive and that regulatory changes forcing them to use more equity capital will translate into higher interest rates on loans and mortgages. The three studies that we review in this section all speak to this debate. Kovner and Van Tassel (2018) estimate the cost of bank capital over the 1996-2017 time period and investigate how it changes in response to shifts in regulation. Cetorelli and Traina (2018) study the extent to which the DFA living wills help address the TBTF problem. Plosser and Santos (2018) in turn utilize the differential treatments that Basel I and Basel II applied to short-term commitments in order to ascertain the cost of bank capital regulation.

We start our review with Kovner and Van Tassel (2018). The authors focus on the capital asset pricing model (CAPM) for their baseline analysis, where the cost of capital is the risk-free rate plus a time-varying beta multiplied by a constant equity risk premium. In an attempt to identify the effect of regulations, they separate the last twenty years into different time periods marked by changes to bank regulation and run difference-in-differences panel regressions comparing changes in the cost of capital for banks and nonbanks. Since many recent financial regulatory reforms apply only to the largest banks, they also investigate whether changes in the cost of capital for the very largest banks relative to smaller banks are different from changes in the cost of capital for the very largest nonbanks and nonbank financials relative to smaller firms in the same industries. Last, in addition to comparing the relative cost of capital for different firms after the passage of the DFA with that in the period immediately before the DFA, they also compare it with the period before the Gramm-Leach-Bliley Act. To ensure that the results are not driven by changes to the composition of banks and public companies, they investigate a number of specifications that include firm fixed effects, as well as interest rate variables. In addition, they estimate expected returns using the Fama and French (1993) three-factor model as a robustness check.

Kovner and Van Tassel find that the cost of capital soared for banks during the financial crisis, averaging more than 15 percent on a value-weighted basis. Comparing the period following passage of the DFA with the time period immediately prior, they find that the cost of capital fell approximately 4.5 percent more for banks than for other firms. Further, the largest decline in expected returns came from the very largest banks. However, when the authors compare the post-DFA period with the period before the Glass-Steagall Act was repealed, they find that the cost of capital for nonbanks fell by 1-2 percent more than for banks. This outcome suggests that while post-crisis bank regulation may have reduced expected returns from post-crisis highs, the cost of capital for banks is higher than it was twenty years ago. Kovner and Van Tassel's finding hinges on the assumption that the relative cost of capital for banks did not change for reasons other than regulation. For example, if investors revalue the riskiness of financial intermediation assets at the same time that bank regulations are changing, these changes would be (spuriously) attributed to changes to regulation. However, when the authors compare banks with nonbank financial intermediaries, whose systemic risk is closer to that of banks, their main conclusions are unaffected. Finally, when they investigate the impact of stress testing on the cost of capital for banks, they find some evidence that stress tests have lowered the cost of capital for the largest banks, although not for those banks added more recently to the stress-testing exercises.

Kovner and Van Tassel's study is most closely related to the literature that investigates the impact of recent regulatory changes on banks' Tobin's q (the total market value of banks' assets divided by the book value of those assets) and cost of equity capital. Minton, Stulz, and Taboada (2017) estimate the cost of capital for banks from 1987 to 2006 using both a three- and a five-factor model and argue that after the size factor is included, the price of risk for the largest banks (those greater than $50 billion) is similar to that of smaller banks. Calomiris and Nissim (2014) attribute the changes in market-to-book values of banks after the crisis to a decline in the value of intangibles rather than a reflection of changing regulations. Huizinga and Laeven (2012) in turn argue that lower levels of market-to-book values for large banks after the financial crisis reflect asset revaluations, particularly for real estate loans at larger banks.

Cetorelli and Traina (2018) investigate the extent to which living wills help address the TBTF problem that has plagued the U.S. banking industry ever since the Comptroller of the Currency stated, following the demise of Continental Illinois Bank in 1984, that the eleven largest banks in the United States were too big to fail and would not be allowed to do so.[1] Section 165(d) of the DFA requires that banks with more than $50 billion in assets submit annual resolution plans. Such plans, commonly known as living wills, must outline substantive strategies the banks will implement to achieve rapid and orderly resolution should they experience financial distress or failure. Regulators can approve a living will, or reject it until the bank develops a sufficiently robust strategy. Rejections may come with stiff penalties, such as higher capital or liquidity requirements or forced changes in organizational structure. Regardless of whether a living will passes regulatory scrutiny, the bank must disclose a substantial part of it to the public. Hence, the living will treatment (that is, the requirement to produce a living will) is arguably economically meaningful both de jure and de facto and should therefore lead to lower TBTF subsidies and a higher cost of capital.

To investigate this hypothesis, Cetorelli and Traina start by developing a method for measuring a bank's cost of capital using regulatory filings, financial statements, and analyst forecasts, applying the methodology developed by Claus and Thomas (2001) and Gebhardt, Lee, and Swaminathan (2001) to banks. To help with identification, they rely on the regulation's staggered implementation: banks at $250 billion or more in total assets produced the first set of plans in July 2012, those with assets at or above $100 billion did so in July 2013, and those above $50 billion had until December 2013. Further, because treated banks are typically much larger and more complex than their untreated peers, the authors use the synthetic control approach pioneered in Abadie and Gardeazabal (2003) and Cavallo et al. (2013) to better balance the comparison between the two groups. This technique reweights untreated banks so that they match the cost-of-capital levels and trends, as well as important covariates such as size, of treated banks.

Cetorelli and Traina find that living wills reduce TBTF subsidies, and that the size of the effect is economically significant at around 20 basis points, or about 10 percent of total funding costs. Consistent with bailouts benefiting equity holders, the bulk of the effect comes from an increase in the cost of equity capital. The authors do not find evidence of a statistically significant impact on either the cost of nondeposit debt finance or the cost of deposit funding. While the former effect is contrary to the expectation that living wills are an effective mechanism for dealing with TBTF, Cetorelli and Traina argue that the absence of an effect on the cost of deposits was expected given the presence of deposit insurance.

The authors find qualitatively similar results when they consider the date that living wills were first announced as their relevant event date. Further, their findings are robust to variations in the synthetic control methodology, particularly in the choice of matching variables. Last, they find that treated banks significantly lower their leverage ratios, a result the authors argue is consistent with treated banks reducing their expectation of being bailed out in the event of distress.

Cetorelli and Traina's paper is related to the recent literature investigating whether post-crisis banking reforms have eliminated the perception of TBTF by investors. Acharya, Anginer, and Warburton (2016) find no change in bond credit spreads in an event window around the passage of the DFA, which the authors interpret as indicating there was no change in how markets perceive TBTF as a result of the new law. Afonso, Blank, and Santos (2018) document that following the announcement of the "single point of entry" strategy in December 2013, rating agencies revised downward their expectations of government support, consistent with Cetorelli and Traina's conclusion that the DFA was effective at dealing with TBTF. However, Afonso, Blank, and Santos also find that neither bond spreads nor CDS spreads of bank parent companies have widened relative to the corresponding spreads of their affiliated banks since the announcement of the single point of entry strategy, suggesting that investors remain skeptical about the effectiveness of the DFA at dealing with TBTF.

The last study we review in this section is Plosser and Santos (2018), which estimates the cost of regulatory capital building using the differential treatments that Basel I and Basel II gave to commitments with maturities shorter than one year. The Basel I Accord, introduced in 1988, assigned a risk weight for each on-balance-sheet exposure and specified a credit conversion factor for off-balance-sheet exposures (for example, credit commitments). Commitments to lend to corporations with an original maturity in excess of one year were treated as off-balance-sheet exposures and the undrawn portion of the commitment received a 50 percent conversion factor. In contrast, commitments with an original maturity of up to one year received a 0 percent conversion factor. To the extent that bank capital is costly, this difference should have made credit lines with maturities of less than one year at origination relatively less expensive following the introduction of Basel I. The Basel II Accord, which was finalized in June 2004, sought to reduce, but not entirely eliminate, the "special" treatment these 364-day facilities received.

The Basel Accords appear to have significantly influenced the marketplace. Up until the early 1990s, there was little evidence of 364-day facilities in the market. However, soon after Basel I, these instruments became prevalent. Their popularity then waned with the passage of Basel II.

Plosser and Santos compare banks' pricing of commitments with maturities below one year with their pricing of commitments with maturities above one year around Basel I, controlling for loan-, borrower-, and bank-specific factors as well as market conditions known to explain commitment pricing; a similar exercise is performed around Basel II. They investigate both the undrawn fee and the all-in-drawn spread of commitments. Since the Basel Accords' "special" treatment of short-term commitments applies only to the portion of the commitment that is undrawn, one would expect the effects to be more pronounced on undrawn fees.

The authors find that commitments with maturities of up to one year, including 364-day facilities, became relatively less expensive following the passage of Basel I. Both the undrawn fees and all-in-drawn spreads on these commitments decline relative to those of commitments with maturities longer than one year. The decline in undrawn fees is 5-6 basis points, or roughly 15 percent of average undrawn fees, whereas the decline in all-in-drawn spreads is 15-25 basis points, or 5-7 percent of the typical spread. Their investigation of the pricing of commitments around Basel II yields exactly the opposite results on both undrawn fees and all-in-drawn credit spreads. These findings are robust and appear to be driven by the Basel Accords because a placebo test based on the pricing of commitments with maturities above one year but below two years does not yield similar evidence. These results also highlight that bank capital regulation is effective at changing the lending policies of banks.

Plosser and Santos estimate that banks are willing to pay at least 4 cents to reduce regulatory capital by one dollar. While this result suggests that the cost of regulatory capital is lower than banks have indicated, it is only a lower bound on what they might be willing to pay.

This study is most closely related to Kisin and Manela (2017), which also attempts to infer the cost of regulatory capital by exploiting a loophole in regulation that exempted banks from holding capital against assets in an asset-backed commercial paper conduit. Two other related papers are Kashyap, Stein, and Hanson (2010) and Van den Heuvel (2008).

In sum, Kovner and Van Tassel (2018) show that the DFA lowered the cost of equity capital for banks (in particular larger banks) relative to nonfinancial corporations, although the cost still remains higher than in the period before the Gramm-Leach-Bliley Act. Cetorelli and Traina (2018) in turn show that living wills increased the cost of equity capital for large banks relative to smaller banks. These findings appear to be inconsistent, but they may derive from differences in the control periods; the former study compares the cost of equity capital post-DFA with that of the pre-DFA period, while the latter focuses on the narrower period around the time that living wills were implemented. Finally, Plosser and Santos (2018) show that regulatory capital is costly, although not as costly as banks claim it to be, and that banks do pass a portion of this cost onto corporate borrowers.

2. Effects on the Profitability and Risk of Banks

Historically, the impact of regulation on the risk and profitability of banks has been the subject of much debate. The studies we review in this section examine this relationship through the lens of the post-crisis regulatory reforms. Crump, Giannone, and Hundtofte (2018) tackle the first issue by investigating the impact of the Dodd-Frank Act on bank risk. Choi, Holcomb, and Morgan (2018) investigate whether the supplemental leverage ratio triggered risk shifting, possibly leading to an increase in bank risk. Fuster and Vickery (2018) in turn investigate whether the regulatory change tying regulatory capital to the market value of securities affected the allocation and risk of banks' securities portfolios. Fuster, Plosser, and Vickery (2018) investigate whether the Consumer Financial Protection Bureau's regulatory oversight has significantly affected the supply of credit or bank risk taking and profitability. Last, Pennacchi and Santos (2018) attempt to explain the preference of banks for using return on equity as a performance benchmark, in contrast to nonfinancial corporations that rely on the growth in earnings per share, and then discuss how the recent regulatory changes might impact banks' preferences.

Crump, Giannone, and Hundtofte (2018) begin by revisiting the academic debate about stock return predictability. However, in contrast to the majority of the literature, which focuses on estimating the conditional mean, their study instead assesses whether economic and financial variables can provide predictive content about the future *distribution* of stock returns. The authors utilize the methodology introduced in Adrian, Boyarchenko, and Giannone (2017) to construct conditional density forecasts based on a wide variety of predictor variables considered in the literature. Across a number of empirical exercises, they find that realized volatility, particularly the realized volatility of financial sector stock returns, has strong predictive content for the future distribution of market returns. They argue that this is a robust feature of the data since all of their results are obtained with real-time analyses using stock return data since the 1920s.

Building on these results, Crump, Giannone, and Hundtofte then focus on the volatility of bank equity as the financial condition most relevant to broad market risk. They pursue a difference-in-differences-in-differences empirical design, comparing the changes in equity volatility of the largest banks (those over the DFA $50 billion threshold for designation as a systemically important financial institution) with that of banks under the threshold and with other large nonbank firms. They find a material relative reduction in market volatility, with the largest banks experiencing about 9 percent differentially lower volatility in the post-DFA period. On the basis of this result, they conclude that recent regulatory reforms of the financial system are associated with an improvement in the relative risk of large banks.

Crump, Giannone, and Hundtofte's study is related to the recent literature assessing the health of banks before and after the crisis. Sarin and Summers (2016) look across a variety of measures and argue that the evidence is, at best, mixed. Chousakos and Gorton (2017) examine market-to-book ratios across advanced economies and find that the low post-crisis valuations of bank equities have been surprisingly persistent compared with previous financial crises.

Choi, Holcomb, and Morgan (2018) investigate a long-standing conjecture that banks will sidestep (risk-invariant) leverage limits by simply shifting to riskier, higher-yielding assets. Concerns about such risk shifting first emerged after U.S. bank regulators imposed leverage limits in the mid-1980s, and have resurfaced with the recent imposition of the supplementary leverage ratio rule on the largest U.S. banks.

The SLR evolved from concerns that "advanced approach" firms—firms that use internal risk estimates for risk-based capital purposes—might underestimate their risk. The Basel Committee recommended a leverage rule as a backstop in 2010, and U.S. regulators proposed their version (the SLR) in 2012 and finalized it in 2014. The rule requires advanced approach firms to maintain a minimum of 3 percent Tier 1 capital per total leverage exposures (including off-balance-sheet assets), while those advanced approach banks designated as global systemically important banks (G-SIBs) are required to hold a minimum of 5 percent.

Banks bound by the SLR limit have two options: increase Tier 1 capital or decrease the total leverage exposures. If a bank chooses to raise more (costly) capital, one way to offset the increased costs is by shifting from safer, lower-yielding assets to riskier, higher-yielding ones. If instead the bank chooses to reduce its assets, the least costly way to do so would be by shedding assets with low yields, such as reserves. In both cases, the bank's share of risky assets relative to safe assets should rise, as should its average yield across assets.

Choi, Holcomb, and Morgan look for evidence of risk shifting around the new leverage rule using difference-in-differences analysis. The treated group comprises the fifteen advanced approach bank holding companies ("banks") subject to the new rule. These firms, by definition, are very large, with at least $250 billion in total assets or $10 billion in foreign exposures. The control group comprises the eighteen banks with assets between $50 billion and $250 billion not covered by the new rule. Though smaller, these banks are officially large per the DFA and thus face similar regulatory environments apart from the application of the SLR rule. Using standard difference-in-differences regressions with time and institution fixed effects and a parsimonious set of controls (including lagged risk-based capital ratios and assets), they compare portfolio and overall risk measures before and after the SLR was finalized in September 2014.

They find strong evidence of risk shifting. After finalization of the SLR, covered banks shift their portfolios toward riskier assets (as measured by the ratio of risk-weighted securities to total securities or the ratio of risk-weighted trading assets to trading assets) compared with other large banks not subject to the rule. The average yields of securities held by banks subject to the SLR also increase by more, consistent with the reach-for-yield hypothesis. The shifts are sizable and tend to be larger at banks more constrained ex ante by the leverage limit.

Despite the finding that SLR banks shift toward riskier, higher-yielding assets, the authors find no evidence of higher overall risk at these banks. They resolve this apparent conflict by showing that leverage at the SLR banks *also* fell, particularly at the most constrained SLR banks, suggesting that the higher capital required under the new rule offset the risk shifting.

The Choi, Holcomb, and Morgan study contributes to an emerging literature investigating the response of banks to the leverage rule. Allahrakha, Cetina, and Munyan (2016) find that U.S. banks decreased repo borrowing following the SLR rule and, consistent with Choi, Holcomb, and Morgan's findings, shifted toward riskier (more volatile) collateral. Bicu, Chen, and Elliott (2017) and Kotidis and van Horen (2018) find illiquidity effects in the U.K. repo market after the imposition of a leverage limit, while Bucalossi and Scalia (2016), studying European banks, find no such effects. The present paper is closest to Acosta Smith, Grill, and Lang (2017), who find a shift toward riskier assets by European banks in response to the Basel leverage rule proposal, but no increase in overall risk.

The use of fair value accounting for bank capital regulation has trended upward over time, motivated by concerns that accrual accounting data may not reflect the current economic value of bank assets and liabilities. Fuster and Vickery (2018) investigate how banks respond to the use of fair values for capital regulation by studying the effects of a recent policy change tying regulatory capital directly to the market value of bank securities portfolios.

Historically, unrealized gains and losses on investment securities classified as "available for sale" did not count toward bank regulatory capital because of the accumulated other comprehensive income (AOCI) filter.[2] However, as part of the implementation of the Basel III capital accord, the AOCI filter was removed for a set of the largest U.S. banking organizations. For these banks, fluctuations in securities market values now flow through directly to regulatory capital, leading to volatility in capital ratios when asset prices change. The AOCI filter has been removed according to a step function, with the percentage of AOCI counted toward regulatory capital set at 20 percent in calendar year 2014 and rising by 20 percent per year until full phase-out of the filter for affected banks in 2018.

Fuster and Vickery investigate two questions: first, does the removal of the AOCI filter lead to lower risk taking in bank investment securities portfolios; and second, do banks take steps to reclassify securities or otherwise shift the composition of assets in ways that minimize the effect of the removal of the AOCI filter but do not substantively reduce fundamental bank risk?

To disentangle the effects of the AOCI rule from other recent regulatory changes, the authors take advantage of the staggered removal of the AOCI filter and investigate changes in risk within a class of securities that have the same regulatory capital risk weights and LCR weights (since other rule changes, including the LCR and the leverage ratio, should induce substitution across asset types but not within types). Even more finely, the use of security-level data from the Federal Reserve's FR Y-14Q capital assessments and stress-testing information collection allows them to examine changes in holdings and accounting classification for affected and non-affected banks *for a given security* as the rule change is implemented.

Fuster and Vickery find little to no reduction in the riskiness of securities held by banks subject to the AOCI rule. For example, the removal of the AOCI filter did not lead to lower duration of the agency mortgage-backed securities (MBS) or Treasury securities portfolios, or a decline in the average yield of either type of securities holdings. They do find, however, that banks engage in more risk management of their securities portfolio (for example, they are more likely to use derivatives to hedge their risk exposures) following removal of the filter. In addition, they find that banks actively classify a larger share of securities as held-to-maturity to "shield" them from the AOCI rule (by 20 percent to 38 percent, depending on the specification). Although reclassifying securities in this way reduces the volatility of regulatory capital, it does not mitigate the fundamental risks of the assets being held. Given that there are obstacles to selling securities classified as held-to-maturity, such reclassification may in some circumstances even increase risk, if it reduces the liquidity of the bank's assets during periods of stress.

The Fuster and Vickery paper is closely related to an emerging literature studying the effects of the removal of the AOCI regulatory capital filter, in particular Chircop and Novotny-Farkas (2016), Kim, Kim, and Ryan (2017), and Hamilton (2018). Chircop and Novotny-Farkas (2016) employ an event study approach around announcement dates related to the AOCI rule and find that bank stock returns reacted negatively to news that the rule was more likely to go into effect. Kim, Kim, and Ryan (2017) find evidence of a reduction in securities portfolio risk owing to the AOCI rule (in contrast to the findings in Fuster and Vickery), but they and Hamilton (2018) also find evidence of a shift from available-for-sale to held-to-maturity within securities portfolios. Compared with these two papers, Fuster and Vickery's analysis is able to more directly measure the types of risk embedded in bank securities portfolios based on the characteristics of individual securities, and to identify the effects of the regulatory change more cleanly when examining shifts in securities classification.

Since its establishment, the Consumer Financial Protection Bureau has been the subject of intense debate. Some have praised the agency, citing the benefits of consumer safeguards; however, others have argued that the CFPB raises compliance costs, increases uncertainty and legal risk, and ultimately raises costs and reduces the availability of financial services to consumers. Fuster, Plosser, and Vickery (2018) contribute to this debate by investigating whether the CFPB's supervisory and enforcement activities have significantly affected the supply of credit or bank risk taking and profitability.

The CFPB was established in 2011 with a consumer financial protection mandate and with broad authority over both banks and nonbanks. In addition to its rule-making authority, the CFPB has the power to supervise and conduct examinations of financial firms and to pursue enforcement actions for breaches of federal consumer financial protection law.

The identification strategy employed by Fuster, Plosser, and Vickery makes use of the fact that small depository institutions with less than $10 billion in total assets are generally exempt from CFPB supervision. Consumer protection oversight of these small banks instead falls to the firm's prudential supervisor (for example, the Office of the Comptroller of the Currency in the case of national banks and national savings associations), the primary mission of which is safety and soundness, rather than consumer financial protection.

The authors use a difference-in-differences approach, examining outcomes before and after July 2011, when the CFPB began operations, and comparing commercial and savings banks subject to CFPB oversight with those below the $10 billion size threshold.[3] They analyze loan-level mortgage lending outcomes, growth and composition of bank balance sheets, and bank noninterest expenses.

Fuster, Plosser, and Vickery find little evidence that CFPB oversight significantly reduces the overall volume of mortgage originations, or that banks subject to CFPB oversight reject a higher fraction of mortgage applications. They do, however, find some evidence that CFPB oversight is associated with a shift in the composition of mortgage lending. In particular, CFPB-supervised banks have experienced a moderate drop in market share among mortgages insured by the Federal Housing Administration. These loans tend to be riskier because they are made to lower-income borrowers and generally involve small down payments. There is also some evidence of a drop in lending to other groups of borrowers that were found to have exhibited higher credit risk historically. Offsetting these declines, CFPB-supervised banks substitute toward large loans in the "jumbo" segment of the mortgage market, where borrowers tend to have higher incomes.

Taken together, this evidence provides some support for the view that heightened supervisory scrutiny related to consumer financial protection has led to some "de-risking" of bank activities, and in particular, affected bank lending to riskier borrowers. Fuster, Plosser, and Vickery find no evidence that CFPB supervision reduces asset growth or increases noninterest expense components, although the confidence bounds on many of these estimates are relatively wide.

The Fuster, Plosser, and Vickery paper is closely related to a recent literature that attempts to investigate the causal effects of financial supervision. Agarwal et al. (2014) show that supervisors may implement regulation inconsistently depending on their institutional design and incentives. Hirtle, Kovner, and Plosser (2016) study the effects of greater prudential supervision of bank holding companies (BHCs) based on whether a BHC is large relative to other banks in its Federal Reserve District and find that supervision reduces riskiness with little trade-off in growth. These papers, however, all focus on prudential supervision, whereas Fuster, Plosser, and Vickery study supervision and enforcement of consumer financial protection laws, a key focus of policy in the decade since the global financial crisis.

Finally, Pennacchi and Santos (2018) attempt to explain banks' preference for using return on equity to track their performance. They start by noting that, traditionally, both nonfinancial corporations and banks emphasized performance targets linked to their earnings per share, but starting in the 1970s banks shifted toward ROE. Stock market investors account for the difference because market-to-book values of bank stocks react more to ROE announcements than to EPS announcements, while the reverse occurs for nonfinancial firms. In addition, the authors find that banks' market-to-book equity became relatively insensitive to EPS only after the 1980s.

Pennacchi and Santos attempt to explain banks' preference for ROE using a structural model of a bank that rationally maximizes its shareholders' value in excess of the shareholders' contributed capital. The model has several key components. First, the bank's deposits are insured by the government. Second, the bank has "charter" or "franchise" value that derives from its ability to pay interest on insured deposits at a rate that is below a competitive risk-free rate. Third, the bank must pay corporate income taxes.

According to their model, banks that maximize shareholder value reduce their initial choice of amount of capital when they face increasing competition that erodes their charter value, and this reduction is greater in magnitude when the bank is subject to fixed-rate deposit insurance than when it is subject to fairly priced deposit insurance. In that setting, if a bank did not adjust its capital, EPS growth would be negative but small in magnitude owing to the mechanical effect from greater competition that decreases the bank's deposit spread and reduces its net interest margin. However, when the bank rationally reduces its capital, EPS growth worsens further. Moreover, the magnitude of the decline in EPS growth is greater when the bank is subject to fixed-rate deposit insurance than when it is subject to fairly priced deposit insurance.

With regard to ROE, if a bank did not adjust its capital, ROE growth would be negative, though slightly smaller in magnitude compared with EPS growth. Interestingly, however, when a bank rationally reduces its initial capital in response to greater competition, the consequence for ROE growth is exactly opposite that for EPS growth. Specifically, the bank's rational reduction in capital causes a rise in ROE growth that can easily offset the mechanical decline from a lower net interest margin. Moreover, the resulting rise in ROE growth is greater when the bank has fixed-rate deposit insurance than when it has fairly priced deposit insurance.

Banks' preference for ROE arises because ROE makes banks look better when they rationally respond to greater competition in the presence of fixed-rate deposit insurance. Pennacchi and Santos argue that this matches the conditions banks experienced in the United States. Historically, the effective deposit insurance premiums that the Federal Deposit Insurance Corporation (FDIC) has charged banks have been only mildly linked to risk. Further, starting in the late 1970s money market funds, a direct competitor for bank deposits, experienced rapid growth. Competition in the banking sector further intensified in the 1980s following states' decisions to lift restrictions on branching within their borders and to permit out-of-state institutions to acquire their banks.

Pennacchi and Santos note that one implication of their analysis is that the typical bank's performance based on ROE after Basel III is worse than if it were based on EPS, and that if minimum capital standards continue to rise, we might expect banks to de-emphasize ROE in favor of EPS. The Pennacchi and Santos paper is related to Haldane and Alessandri (2009) and Begenau and Stafford (2016), which also attempt to explain banks' preference for an ROE performance metric. However, Haldane and Alessandri (2009) attribute that preference to lower capital and greater bank asset risk, while Begenau and Stafford (2016) suggest that banks manipulate ROE upward through leverage because stock market investors (inefficiently) focus on ROE.

Summing up, Choi, Holcomb, and Morgan (2018) find strong evidence of risk shifting in response to the supplemental leverage ratio, but this change did not lead to higher overall risk at SLR banks because these banks lowered their leverage at the same time. Crump, Giannone, and Hundtofte (2018) find a more favorable effect of regulation on banks. They find that the equity volatility of these large banks is differentially lower than it was pre-crisis when compared with changes over the same period for smaller banks or large nonbank firms. Fuster and Vickery (2018) reveal a potential adverse effect of using market information to value banks' equity capital. They find that banks increase hedging and classify more securities as held-to-maturity following the removal of the AOCI filter, which limits their ability to sell these securities. However, Fuster, Plosser, and Vickery (2018) do not find evidence that would support the claims of some analysts that CFPB oversight has had a large impact on banks' businesses, including their supply of mortgages. Last, Pennacchi and Santos (2018) argue that banks have started to emphasize ROE to the detriment of EPS growth in response to the erosion in their charter value brought about by the growing competition from nonbanks in the 1970s and the branch deregulation of the 1980s.

3. Effects on Liquidity

An important function of the financial system is to provide liquidity to consumers, corporations, and other economic agents. Banks play a pivotal role in this function both through their own liquidity creation and by providing the necessary support for other financial intermediaries to contribute to liquidity in the financial system. In this section, we review four studies that investigate whether post-crisis regulatory reforms interfere with these roles of banks. Roberts, Sarkar, and Shachar (2018) investigate whether the liquidity coverage ratio reduces the ability of banks to create liquidity. In turn, three studies—Boyarchenko, Eisenbach, Gupta, Shachar, and Van Tassel (2018), Adrian, Boyarchenko, and Shachar (2018), and Boyarchenko, Costello, and Shachar (2018)—investigate whether post-crisis reforms interfere with the role banks play supporting liquidity in the debt markets.

One response to the financial crisis was the introduction of liquidity regulation for banks. A component of this regulation, the LCR, aims to promote the short-term resilience of the liquidity risk profile of banks by ensuring that they maintain sufficient unencumbered high-quality liquid assets (HQLA) that can be converted into cash easily and immediately in private markets to meet their liquidity needs for a thirty-calendar-day liquidity stress scenario. Roberts, Sarkar, and Shachar (2018) investigate a potential downside of the LCR—harm to banks' ability to create liquidity.

The effect of the LCR on liquidity creation depends on how banks respond to the regulation. Prior to implementation of the LCR, most banks did not meet its requirements and so the direct effect may be to reduce the liquidity mismatch (as was intended) and liquidity creation by banks subject to the LCR. However, because the liquidity preferences of banks and the contours of the LCR differ, banks may have an incentive to undo the direct effects. For example, banks may increase the portfolio weights of their non-HQLA assets by substituting high-yield corporate bonds (that are unconstrained by HQLA) for investment-grade bonds (that are constrained). Even within the HQLA portfolio, banks can choose between assets with similar risk-adjusted returns but different HQLA weights. Thus, the question of whether liquidity creation decreases for banks subject to the LCR must be answered through empirical analyses.

Roberts, Sarkar, and Shachar examine liquidity creation by LCR and non-LCR banks using variations of the liquidity measures designated as the liquidity mismatch index (LMI) in Bai, Krishnamurthy, and Weymuller (2018) and as "BB" in Berger and Bouwman (2009). Both measures are defined as liquidity-weighted liabilities minus liquidity-weighted assets, with the liquidity weights either derived from market prices (as with LMI) or pre-specified (as with BB). The authors exploit the differential implementation of the LCR for so-called full LCR banks with assets greater than $250 billion (which had to start implementation by January 2015) and modified-LCR banks with assets between $50 billion and $250 billion (which had to start implementation by January 2016).

They find that LCR banks had lower liquidity creation than non-LCR banks post-2013, primarily because of greater holdings of liquid assets and reduced holdings of illiquid assets. Holdings of commercial and residential real estate loans as well as the "high run-off" category of liabilities decline for LCR banks in comparison with non-LCR banks relative to the pre-2013 period. Interestingly, the authors detect a post-LCR shift in LCR bank portfolios toward GNMA (Government National Mortgage Association) MBS rather than GSE (government-sponsored enterprise) MBS, which are economically similar assets with different LCR weights. Since this shift is not attributable to relatively greater issuance of GNMA or relative price effects, it likely indicates an LCR effect on bank portfolio choice.

The Roberts, Sarkar, and Shachar paper is most closely related to Bai, Krishnamurthy, and Weymuller (2018) and Berger and Bouwman (2009) in that it relies on the liquidity measures that those papers have developed. In contrast to those papers, whose focus is on understanding the factors that drive banks' creation of liquidity, Roberts, Sarkar, and Shachar focuses on understanding the impact of the LCR on this important function of banks.

Adrian, Boyarchenko, and Shachar (2017) study whether the ability of regulated institutions to intermediate in the corporate bond market changed in the wake of post-crisis regulatory reforms. The authors utilize the supervisory version of the Trade Reporting and Compliance Engine (TRACE), which allows them to focus on the relationship between bond-level liquidity and financial institutions' balance sheet constraints.

They find that post-crisis regulation has had an adverse impact on bond-level liquidity. Prior to the financial crisis, bonds traded by more levered institutions and by institutions with investment-bank-like characteristics were more liquid, but this relationship reversed after the financial crisis. In addition, institutions that faced more regulations after the crisis reduced their overall volume of trade and have less ability to intermediate customer trades. This reversal is consistent with the view that more stringent leverage regulation and more regulation of investment banks reduce the ability of financial institutions to provide liquidity to the market overall. However, these effects have not translated into a decrease in the liquidity of corporate bonds, on average, because the share of corporate bond liquidity provision by more regulated dealers has fallen at the same time.

The Adrian, Boyarchenko, and Shachar study is related to a number of recent empirical papers that have examined post-crisis changes in corporate bond market liquidity. These papers have come to mixed conclusions on the impact of regulatory reforms. Bessembinder et al. (2016) and Bao, O'Hara, and Zhou (2016) find decreased liquidity during idiosyncratic stress events; Anderson and Stulz (2017) find evidence of decreased liquidity during systemic events as measured by extreme values of the VIX. In contrast, Trebbi and Xiao (2015) and Adrian et al. (2016) conclude that aggregate bond market liquidity remains largely unaffected by post-crisis regulation. A drawback to these studies is that they rely on indirect measures of the effect of regulation on corporate bond market participants, whereas Adrian, Boyarchenko, and Shachar (2017) directly link the trading behavior of market participants to their balance sheet constraints.

Boyarchenko, Costello, and Shachar (2018) study the decision of financial institutions to participate in either the cash or the derivatives markets to allocate credit risk to individual corporate entities, and how regulatory changes have affected that decision. The paper's key innovation is the construction of a weekly data set of changes in financial institutions' holdings of both corporate bonds *and* credit default swaps (CDS). These data are observed at a higher frequency and at a more granular level than in prior work in the academic literature.

The authors find that institutions change their participation decisions in these markets in response to changes in the regulatory environment. Global systemically important banks—the banks most affected by changes in regulation—are less likely to use CDS contracts but they hedge a greater fraction of their corporate bond transaction flow in the CDS market since January 2014. Similarly, G-SIBs increase the volume and frequency of their transactions in single-name CDS after the single-name contract becomes eligible for clearing (which lowers its capital requirement). The results suggest that regulatory constraints play an important role in determining which markets an institution uses to change its exposure to corporate credit risk.

The paper by Boyarchenko, Costello, and Shachar is most closely related to the literature that has investigated the relationship between the use of credit derivatives and fundamental credit exposures. This literature has found mixed results as to whether financial institutions use CDS or other credit derivatives extensively for hedging purposes. In fact, Boyarchenko, Costello, and Shachar find that institutions rarely use both the CDS market and the corporate bond market in the same week.

Boyarchenko, Eisenbach, Gupta, Shachar, and Van Tassel (2018) study a wide variety of basis trades that, since the crisis, have experienced sizable and persistent deviations from parity. The authors first investigate the role of post-crisis regulations by calculating the implied ROE on each trade under the pre-crisis regulatory regime and its post-crisis counterpart. They show that the implied ROE of these basis trades is significantly lower in the post-crisis period and infer that post-crisis changes to regulation and market structure have increased the cost of participation in spread-narrowing trades for regulated institutions, creating limits to arbitrage.

The authors further argue that regulated broker-dealers are not only more constrained to participate in arbitrage trades themselves but also less able to provide funding to their clients participating in these trades. They show that among hedge funds with a G-SIB prime broker, those that use leverage show a significant decline in assets under management and lower returns compared with funds that do not use leverage. Moreover, the number of funds obtaining leverage from G-SIB-affiliated prime brokers has declined relative to the number of funds obtaining leverage from other types of prime brokers. Taken together, these results suggest a pass-through of regulation from the directly affected sector to other parts of the financial sector that rely on the regulated sector for funding, execution, and clearing services.

The Boyarchenko, Eisenbach, Gupta, Shachar, and Van Tassel study joins a number of recent studies that have focused on the role that regulatory constraints on intermediaries play in perpetuating deviations from arbitrage. Avdjiev et al. (2016) shows that deviations from covered interest rate parity (CIP) are strongly correlated to the dollar financing costs of global banks. A related paper, Du, Tepper, and Verdelhan (2018), argues that the expected profitability of CIP trades is much lower after controlling for banks' balance sheet costs. Similarly, Boyarchenko et al. (2018a) and Boyarchenko et al. (2018b) show that, after the introduction of SLR in the United States, the break-even levels of Treasury–swaps spreads and credit bases are much lower (more negative) than prior to the crisis. In the equity market, Jylhä (2018) shows that tighter leverage constraints, induced by changing initial margin requirements, correspond to a flatter relationship between market betas and expected returns.

In sum, all four of the studies investigating the effect of post-crisis regulatory reforms on liquidity show that the constraints that financial institutions face shape their decisions regarding market participation. This effect, in turn, appears to have had a negative impact on market and funding liquidity and liquidity creation.

4. Final Remarks

The financial crisis of 2007-08 triggered an unprecedented number of regulatory reforms, particularly affecting the banking sector. Sufficient time has elapsed since the implementation of many of these reforms to offer an opportunity to investigate their effects. This investigation is important not only to ascertain whether the reforms achieved their intended goals but also to determine whether they have had unanticipated consequences, positive or negative. Assessing the effects of reforms is important for another reason: It provides us with valuable information about how financial institutions, and markets more generally, respond to regulation—an important consideration when evaluating adjustments to post-crisis regulatory reforms and future changes to financial regulation.

The twelve studies reviewed in this article represent an effort by a set of New York Fed economists to contribute to the ongoing debate on the effects of the post-crisis reforms. By design, these studies focus on effects related to banks' risk taking, funding costs, and profitability, as well as liquidity in debt markets—representing only a small subset of the potential outcomes triggered by these regulatory reforms. The evidence unveiled by these papers suggests that deepening our understanding of the effects of post-crisis reforms on these issues as well as expanding our investigation into other areas, including banks' provision of credit, the securitization of credit, and the role of shadow banking, just to name a few, are likely fruitful areas for future research.

Notes

[1] See "U.S. Won't Let 11 Biggest Banks in Nation Fail," *Wall Street Journal*, September 20, 1984, and O'Hara and Shaw (1990) for further details on the Comptroller of the Currency's announcement.

[2] Under U.S. accounting rules, securities are classified as "trading assets," "held to maturity," or "available for sale." Unrealized changes in the fair value of available-for-sale securities do not affect net income; however, they contribute to AOCI, which is a component of equity on the balance sheet of the bank. Until recently, however, bank capital rules included an AOCI filter, which meant that AOCI was not counted toward bank regulatory capital.

[3] Note that this approach only measures the effect of CFPB supervision and enforcement; it does not identify the impact of new regulations issued by the CFPB, which would generally apply to both groups of lenders.

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