Lender of Last Resort:
An Examination of the Federal Reserve's Primary Dealer Credit Facility

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Abstract

In response to strains in financial markets, the Federal Reserve instituted a lending program in March 2008 that marked the first time since the Great Depression that non-depository institutions received direct capital funding from the government. Recently mandated public disclosure gives us the ability to examine this previously confidential data. I explore the terms of these transactions in order to assess the determinants of the central bank's lending decisions during the crisis. I find that the lending terms were straightforward at the onset of this program, but became less clear following the bankruptcy of Lehman Brothers and its aftermath.

I. Introduction

In 2007, as housing prices began to fall, mortgage-backed securities (MBSs) and other collateralized debt obligations (CDOs) suffered losses. The balance sheets of financial institutions that were heavily invested in these instruments, including many of the largest and

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most systemically important ones, began to deteriorate. In response, the Federal Reserve (Fed) instituted several lending programs in order to facilitate the functioning of credit markets. In many ways, these emergency measures were unprecedented in the history of the Federal Reserve.

In March 2008, the near-collapse of Bear Stearns precipitated a run on the repo market.[1] In response, the Federal Reserve created a special credit facility known as the Primary Dealer Credit Facility, or PDCF (Appendix C provides a timeline of the most important events associated with the PDCF). The PDCF provided discount window-like financing to primary dealers—broker-dealers that play a special role in trading U.S. Treasury securities with the Fed and are therefore critical to the overall functioning of credit markets. Fulfilling its role as lender of last resort, the central bank created this facility to fill the vacuum created by the freezing up of the private repo market.

In response to requirements legislated in the Dodd-Frank financial sector reform bill, the Fed in December 2010 disclosed the lending details behind their liquidity and credit programs during the crisis. Through this disclosure, terms of PDCF transactions became publicly available and this paper will examine the factors that appear to have determined those terms.

There are several questions that one would like to answer when examining the terms of the Fed's lending. Were particular banks given sweetheart deals, or do terms seem to have been set in an objective and systematic way? Did the terms change over time as conditions in financial markets changed? More generally, given this rare look into the terms of repo transactions (since data on private repo transactions is so sparse), what can we learn about how the terms were set? For example, do financial institutions with differing levels of default risk end up paying for that

[1] A 'repo', or sale and repurchase agreement, is a short-term collateralized financing arrangement by which firms can raise funds. Further details regarding how repos work will be provided in later sections.

higher risk through a higher interest rate on the repo lending, or through a higher level of over-collateralization, i.e. 'haircut'? The manner in which the Federal Reserve served as a lender of last resort to these critical primary dealers will be explored.

Utilizing the data on the terms of 1,376 transactions, I find that the repo lending rate for all banks was identical. The rate was set at the primary credit rate—the rate that the Fed charges sound financial institutions for conventional discount window lending. Inconsistencies with the PDCF terms were based on the degree of over-collateralization of the transactions. Given this observation, I use a regression model to uncover the factors that accounted for the differences in the over-collateralization.

The primary dimension along which transaction terms differed was the degree of over-collateralization that was required of the borrowing financial institution. I find that there appears to have been two different regimes for determining the degree of over-collateralization, the regime prior to the bankruptcy of Lehman Brothers and the regime following its bankruptcy. In the prior regime, the overall degree of collateralization depended very tightly on the type of collateral being posted by the primary dealer. For example, a Treasury security required one level of over-collateralization (or haircut), an MBS required another level of over-collateralization, etc. This treatment appeared to be uniform across the various financial institutions. In the post-Lehman bankruptcy period, the determination of the degree of over-collateralization was much less closely tied to the types of collateral being posted. There is evidence that the financial stability of the financial institution as well as overall market volatility became more significant factors. These findings provide insight into the decision-making of the Fed in providing critical support to primary dealers and the broader financial markets. In addition, the findings attest to the systemic nature underlying the bankruptcy of Lehman Brothers

and the turmoil that ensued in its aftermath.

The paper will proceed as follows. Section 2 provides background behind the crisis and the run on the repo market. Section 3 discusses the economic theory behind the determination of the terms of repo transactions. Section 4 discusses how this data set was obtained and structured, as well as summary statistics on the program. Section 5 outlines the analytical model and its econometric methodologies. Section 6 discusses the results and analysis. Section 7 concludes with a discussion of the relevance of the findings and of current political events that will affect the outcome of this research.

II. Background

In recent decades, financial services have expanded outside the realm of traditional banking through the rise of a parallel banking system known as 'shadow banking'. Shadow banking refers to financial intermediation performed through securitization. These institutions are involved in the credit and liquidity transformation between investors and borrowers. Financial institutions involved in shadow banking include investment banks, broker-dealers, securities firms, hedge funds, and mortgage providers. The impact of this system has grown dramatically since the 1980s and has become a critical component of the global financial system today.

The shadow banking system has experienced this rapid growth at the expense of traditional banking. Blair (2010) tracks the historical ratio of total assets in the shadow banking system relative to total assets in the traditional banking system in Figure 1. The shadow banking size eclipsed the traditional banking realm in the early 2000s and steadily climbed until the crisis hit. The rise of shadow banking was attributable to the declining profitability of the traditional

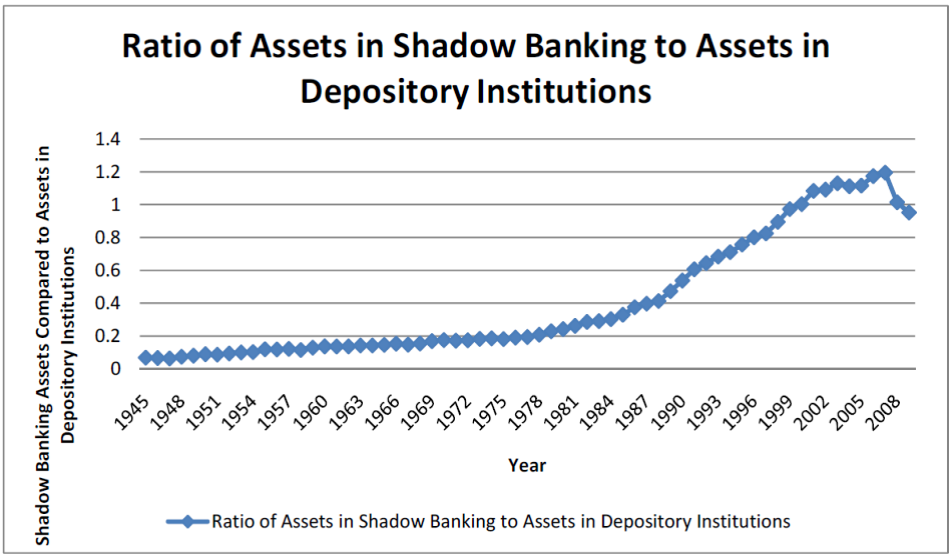

Figure 1: Author calculations based on United States Flow of Funds accounts. Source: Blair (2010).

banking sector in recent years. Traditional banks, which raise their capital through deposits, saw their profits squeezed as the emergence of money market funds[2] forced banks to compete for deposits by paying higher rates. In addition, securitization in the shadow banking system provided larger profit opportunity relative to the standard bank loan model. Shadow banks would obtain lending via short-term markets (repo), use proceeds to invest in mortgages, then structure these loans into investment vehicles that they could sell. These banks earned money through packaging and selling these instruments to investors, while traditional banks earned little by passively holding long-term loans on their balance sheets.[3]

All of this financial innovation by shadow banks took place outside the regulatory purview of the Federal Reserve; that is, because the shadow banks did not issue deposits, they fell outside Fed regulatory oversight and avoided the reserve requirements associated with traditional banks. As a result, shadow banks became highly levered and dependent on short-term

[2] A money market fund is a type of mutual fund that invests in low-risk securities, such as U.S. Treasuries and commercial paper.

[3] Certain traditional banks began to pursue securitization around this time in order to generate higher profits, so long as their shadow banking services remained outside the Fed regulatory jurisdiction of the parent company's commercial banking arm.

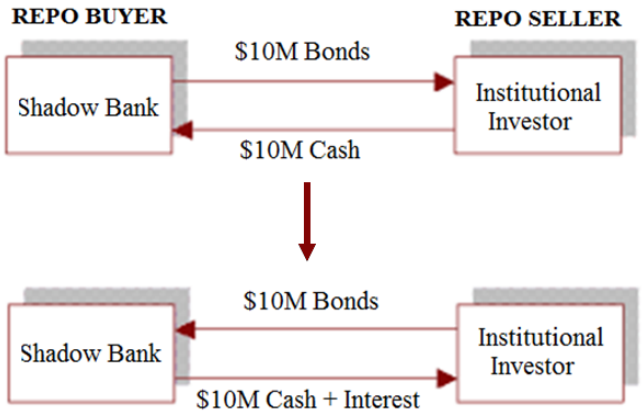

Figure 2: Basic repo transaction structure.

financing during the sector's rise.[4]

Without the means of short-term capital through deposits, shadow banks pursue alternative financing options, primarily through sale and repurchase, or 'repo', agreements. In a repo transaction, the shadow bank obtains funds by selling securities to a lender in exchange for cash, while contractually promising to repurchase the securities from the lender at a predetermined price and date. Then, on that date, the shadow bank repurchases the securities and pays the predetermined price, which is typically the initial cash amount plus interest. Because these were short-term (largely overnight) transactions, in order for the shadow bank to maintain the capital structure of the investment vehicle it created through this financing, it would each day have to secure a new repo contract in order to roll over the financing.

Figure 2 shows the structure of a basic repo transaction. In the top half of the figure, the shadow bank (borrower) sells $10M in bonds to the institutional investor (lender) in exchange for cash of equal value. This cash to the borrower is important in order to finance its security portfolio and perform securitization services. The shadow bank needs short-term capital to create these special investment vehicles. Failure to secure rollover repo financing would necessitate that

[4] See "Preliminary Findings of Shadow Banking."

the investment vehicles try to sell its securitized collateral at fire-sale prices, a contagion that occurred in the crisis that is discussed later in this section.

The bottom half of the figure shows the payments that occur when the securities are repurchased by the borrower, typically done the next day. The shadow bank pays $10M to the lender with additional interest and the institutional investor returns $10M of the bonds to this borrower. This transaction is comparable to a secured loan, but repos involve an actual transfer of ownership of capital between the two parties.

Repos are viewed as safe and liquid investments for both parties since, for banks, they maintain a short-term nature and, for investors, they are secured by the underlying collateral in the event of borrower default. Since the 1980s, this market has come to represent a huge source of financing for shadow banks, with trillions of dollars being exchanged on a daily basis.[5] Whereas traditional banks are able to fund their day-to-day operations through depository capital, these deposit-less banks receive liquidity through this means.

A specific group of financial institutions that relies heavily on the repo market is primary dealers. These are designated banks and securities broker-dealers that serve as trading counterparties with the Federal Reserve.[6] These institutions (e.g. J.P. Morgan, Goldman Sachs) serve as market makers in fixed-income securities, trading U.S. government and other securities as a means of carrying out federal monetary policy. Primary dealers utilize the repo market to short-term finance their security portfolios as well as obtain securities to meet investor demands in secondary securitization markets.[7]

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[5] See Gorton (2010b). Data on the repo market is not official or public, but the U.S. repo market has been estimated to be roughly the same size as the total assets in the U.S. traditional banking system at $10 trillion.
[6] The list of primary dealers during the PDCF period can be found in Appendix A. The current list can be found at http://www.newyorkfed.org/markets/pridealers_current.html.
[7] See "Primary Dealer Credit Facility."

During the recent crisis, a bank panic occurred in the repo market. This panic was different than previous panics in U.S. banking history. Rather than a public, large-scale run on traditional banks, with consumers lining the streets demanding their deposits, this crisis was of a different nature.

How did the run occur? During the housing boom, financial innovation spawned the creation of mortgage-related products and through securitization, these investments were disseminated throughout the financial system. In addition to securitizing these instruments, such as MBSs and CDOs, shadow banks would keep these assets on their balance sheets as collateral for capital financing. There was repo investor appetite for these asset classes given their profitable returns, with the U.S. housing market undergoing a sustained period of growth.

However, as the housing market began to decline in 2007, many of these assets began to lose value. Repo lenders began to distrust the quality and liquidity of these collateral securities. The lenders also became increasingly concerned about counterparty risk—would the financial institution be able to complete the repo transaction by returning the cash in exchange for the collateral? In the event that they couldn't, the lender would take possession of the collateral, and would perhaps have to sell it at a loss if they needed to quickly convert it to cash. In response to these concerns, lending in the repo market quickly dried up. As this lending dried up, the borrowers, including the systemically important primary dealers, ran into difficulty rolling over the repo financing. As this occurred, the borrowers were forced to liquidate their assets, perhaps at a loss, to come up with cash. In short, there was a run on the repo market—lenders became nervous and withdrew their lending.[8]

On March 16, 2008, liquidity problems spurred the near-collapse of primary dealer Bear

[8] For more information detailing the run on the repo market, see Gorton and Metrick (2010a).

Stearns.[9] At this time, the Fed became worried that a credit scarcity could cause large collateral security selloffs, causing security prices to plummet and haircut levels to rise, as repo lenders aggressively pulled out of the market. It was believed that continued suppression of financing to primary dealers would drastically limit their ability to provide liquidity to a broad range of financial markets. In response, on March 17th, the Fed announced the creation of an emergency credit facility known as the Primary Dealer Credit Facility.[10] The program would provide direct repo funding to these primary dealers based on a wide range of collateral in an effort to alleviate the strain and withdrawal experienced in the broader repo market. Appendix A lists all eligible primary dealers and documents the full extent of their involvement in the facility.[11]

This program marked the first time since the Great Depression that the Fed had lent directly to non-depository institutions. As Adrian, Burke, and McAndrews (2010) assert, "before the creation of the PDCF, primary dealers had no access to a lender-of-last resort credit facility. Yet in modern financial crises, dealers are the institutions most likely to experience liquidity shortages." The United States had established regulatory mechanisms to fix structural issues that prevented bank runs in the traditional banking realm[12], but this new unregulated shadow banking sector had recreated conditions for a new type of bank panic to develop. The PDCF was the policy that the Fed put in place to stop this panic.

III. Theory

How were these PDCF transactions structured? The program was based on tri-party

[9] Bear Stearns was merged with J.P. Morgan for $10/share and was financed by a $30 billion Fed emergency loan.
[10] The Fed held the legal authority to introduce this measure based on section 13(3) of the Federal Reserve Act of 1913, which permits the Federal Reserve in "unusual and exigent circumstances" to extend credit to institutions on an emergency basis when these institutions are unable to obtain adequate credit accommodations from other banks.
[11] All loans extended were repaid in full to the Fed, with interest, in accordance with the terms of the transaction.
[12] Since 1913, the discount window has served as an emergency lending facility for ailing depository banks. More importantly, in 1934, the U.S. government introduced deposit insurance (through the FDIC) which protects against large-scale consumer deposit withdrawals.

repurchase agreements, in which a clearing bank serves as an administrative intermediary for the two repo parties. For the PDCF, the primary dealers were the borrowers, the Federal Reserve Bank of New York was the lender, and the clearing bank oversaw the collateral pricing and the terms of each contract.[13] This third party worked in conjunction with the Fed in verifying that the borrower had pledged sufficient eligible collateral behind each loan.

In addition to the lending rate (the interest that must be paid when the cash is repaid), another important element of the transaction is the 'haircut' that is applied to the repo. A repo haircut is essentially the extent of over-collateralization on a loan, measured as the percentage difference between the lender cash value and borrower collateral value. In a stable repo market, when default concerns are minimal, there are no haircuts on repo contracts. Borrower A would receive $100 cash from lender B in exchange for $100 in security collateral. In an unstable market, where haircuts are introduced, if lender B demands $105 collateral in exchange for $100 due to market distrust, then the transaction involves a 5% haircut.

The size of a haircut is a function of various risks associated with the transaction:

$$\text{Haircut} = F(\text{collateral risk, market risk, counterparty risk})$$

Collateral risk addresses the volatility of the underlying collateral value. Market risk represents market volatility, which affects the risk and liquidity of the pledged collateral asset classes. Counterparty risk represents the default risk of the borrower itself. With this PDCF data, we have the ability to identify collateral risk based on the collateral composition disclosed. An analytical model can be built to explain the impact that these tranches hold on haircut levels. Proxies can be used to assess market risk and counterparty risk, which will be discussed later in this paper.

Rather than over-collateralizing loans, an alternative for lender protection could be to

[13] The two tri-party clearing banks in the U.S. market are JPMorgan Chase and Bank of New York Mellon.

raise repo rates, giving the investor a higher loan return. However, a haircut specifically addresses the risk involved with collateral liquidity, whereas a higher repo rate does not. A haircut creates a buffer for the lender and offers protection in case that security must be quickly resold at a loss in the event of borrower default.[14] Increasing risks would typically warrant that a lender demand significantly higher haircuts on repo transactions. Indeed, it was precisely these higher haircuts by private repo lenders that made it so difficult for the borrowers to continue to roll over their financing. Thus, in the case of the Fed, it faced an important trade-off when determining haircut levels. A higher haircut would provide better protection against losses for the central bank, but a lower haircut would put more liquidity back into the repo market, as primary dealers would have to contribute less collateral to obtain capital funding.

The remainder of the paper examines how the Fed administered these PDCF haircuts. I will try to answer a variety of questions. Was there homogeneity across all banks? Were different classes of collateral treated differently? Which risks seemed to affect haircut levels most? Did the policy change over time?

IV. Data

Federal Disclosure

In an initiative to redress the regulatory failures of the crisis, the Dodd-Frank Wall Street Reform and Consumer Protection Act was passed by Congress and signed into effect by President Obama on July 21, 2010. This legislation aimed to install new financial oversight mechanisms to fortify the U.S. banking system. Of particular importance for this study, there was a provision in the law that ordered the Fed to disclose, by December 1, 2010, details about

[14] The haircut amount charged in the PDCF is lower than those applied by private lenders during the crisis. If not, dealers would not use the PDCF due to cheaper cost of financing elsewhere. See Gorton and Metrick (2010a).

transactions associated with many of its emergency credit and liquidity programs, including the PDCF. As a result, on that date the public was for the first time granted access to specific details behind the Federal Reserve's lending practices.[15] The data released for the PDCF included details of every transaction administered as part of that lending facility.

Data Organization

For the program's first few months, the PDCF collateral base was primarily restricted to U.S. Treasuries, investment-grade debt securities, and agency-backed mortgage products. However, in September 2008, major repo participant Lehman Brothers appeared to be on the brink of bankruptcy. The Fed foresaw that this event could put other banks at risk, renew strains in financial markets, and further impair primary dealers' ability to obtain financing.[16] As a result, the Fed expanded the collateral base for the PDCF on September 15th to include all securities that were typically eligible under private tri-party repo agreements. Among the newly allowed collateral tranches were speculative bonds[17], loans, equity, short-term debt, and unrated securities.

Because the composition of the collateral was a key determinant of the haircut that was set for each transaction, the analysis below must be divided into two periods—the period prior to September 15th, i.e. the 'Pre-Lehman' period, when allowable collateral was much more restricted, and the period following September 15th, i.e. the 'post-Lehman' period, when a much broader set of collateral classes was permitted.

In addition, the data reveals that the Fed administered a homogenous haircut to all banks

[15] For all programs whose data was released, details for each loan included the borrower, the date of credit extension, the interest rate, collateral information, and any other relevant terms for that specific program. For the PDCF, the data provided is organized based on credit ratings of collateral securities and its data disclosure snapshot can be found in Appendix B.
[16] See "In the Former C.E.O.'s Words."
[17] Speculative bonds are bonds that hold ratings below BBB- based on S&P credit rating methodology.

at the beginning of the program. For the first 10 days (March 17-26), haircuts were marked at a fixed 5% level across banks, regardless of the identity of the bank or the collateral composition. The Fed at that time also accepted ineligible collateral, such as uncategorized and unrated bonds, when transacting with some entities.[18] For the purpose of this study, this data range has been excluded, since it does not aptly reflect the program's haircut policy as a whole.

Lastly, there were several broker-dealers that were granted rights to additionally transact with the PDCF through their securities subsidiaries.[19] For example, Citigroup's London-based broker-dealer subsidiary was extended credit through the PDCF following Citigroup's capital injection by the U.S. government.[20] This credit was also granted to Goldman Sachs and Morgan Stanley's subsidiaries in order to provide liquidity support as they transitioned into bank holding companies on September 21, 2008. Following the announced acquisition by Bank of America, Merrill Lynch also received this subsidiary funding on September 21st. All subsidiary haircuts were issued at a premium relative to the haircuts applied to the parent firm. So as not to detract from the original haircut policy, these data points have also been excluded from the study.

Data Summary

Figure 1 charts the largest banks involved in the PDCF. A list of all primary dealers and their aggregate borrowing from the PDCF can be found in Appendix A. The program scope was massive, with some banks receiving more than $1 trillion in direct loans from the Fed.[21] It is noteworthy that the banks that most heavily borrowed from the PDCF were in fact the ones most

[18] The Federal Reserve stated in its disclosure that there were "isolated cases of transactions in which the collateral did not meet the requirements of the program as specified at that time. In all such cases, the Federal Reserve worked with all relevant parties including the clearing bank that administered the collateral to guard against any recurrence of similar problems."

[19] The terms extended to these authorities were similar to that of the original PDCF and their data was therefore released with the program disclosure as well.

[20] On November 24, 2008, the Treasury Department, Federal Reserve and FDIC announced it would protect troubled-bank Citigroup against potential losses on a $306 billion pool of troubled assets.

[21] Figures include rollover transactions, in which established repo contracts are carried over for subsequent days.

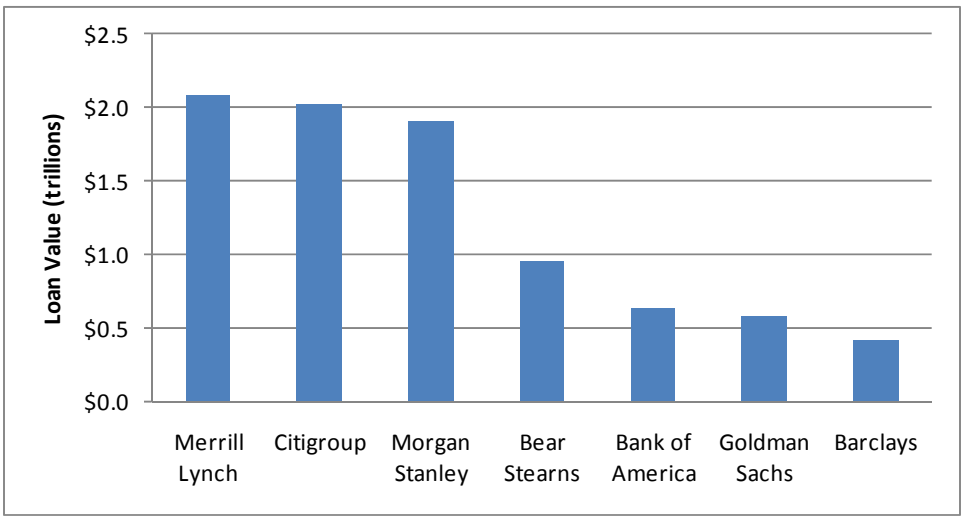

Figure 1: Aggregate PDCF loan amounts (largest borrowers).

in peril at this time. In particular, among the heavy borrowers were: Merrill Lynch, which was eventually acquired by Bank of America; Citigroup, which received a capital backstop from the government; and Morgan Stanley and Goldman Sachs, which were forced to become bank holding companies during the crisis.

Figure 2 tracks the total loans outstanding during the time period. It is evident from the figure below that there was significant activity in the initial months of the PDCF due to the repo market turmoil following the fall of Bear Stearns. The activity declined steadily over the next few months as stability in the financial markets temporarily strengthened.[22] Dealers were able to return to repo financing through the public markets and were able to draw down borrowing through the PDCF.

However, in September of 2008, the bankruptcy of Lehman Brothers returned panic to financial markets, as PDCF borrowing spiked again. Primary dealers faced funding shortages in public markets and the PDCF continued to be a short-term capital lifeline to these institutions.

Figure 3 breaks down the composition of total collateral posted over the time period.

[22] See Adrian, Burke, and McAndrews (2010).

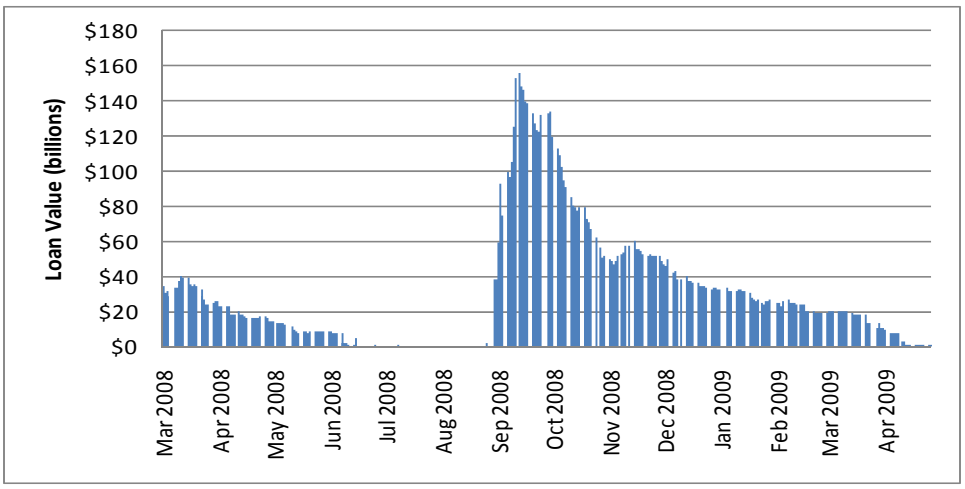

Figure 2: Aggregate PDCF loans outstanding.

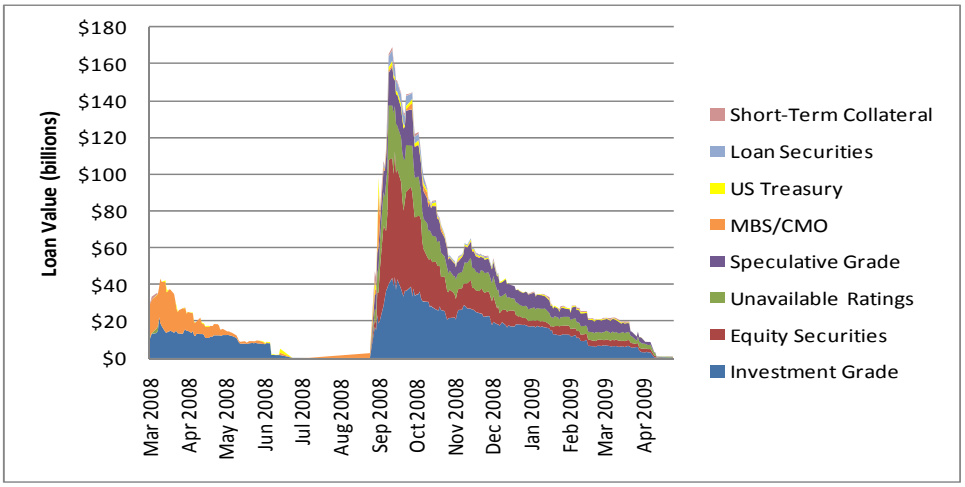

Figure 3: Aggregate PDCF collateral composition outstanding.

Investment-grade debt and MBSs were the primary components of pre-Lehman collateral, as expected. Following the September policy change that allowed for a broader set of collateral classes, the collateral composition became heavily saturated with riskier assets, as equity, unrated securities, and speculative grade securities began to account for a substantial share of collateral in repo agreements.

Figure 4 lists the aggregate collateral composition divided among the two periods. The discrepancy between them is striking. Agency-backed mortgage products and investment-grade

Pre-Lehman Period	
US Treasury / agency	1.2%
MBS/CMO: agency-backed	40.9%
AAA - BBB (High grade)	56.9%
BB - Lower (Speculative grade)	0.0%
A1 - A3 (Short term)	0.3%
Ratings unavailable	0.4%
Uncategorized investment grade	0.2%
Loans	0.0%
Equity	0.0%

→

Post-Lehman Period	
US Treasury / agency	1.4%
MBS/CMO: agency-backed	1.1%
AAA - BBB (High grade)	34.6%
BB - Lower (Speculative grade)	16.0%
A1 - A3 (Short term)	0.8%
Ratings unavailable	18.2%
Loans	1.5%
Equity	26.4%

Figure 4: Aggregate PDCF collateral composition, pre-Lehman and post-Lehman periods.

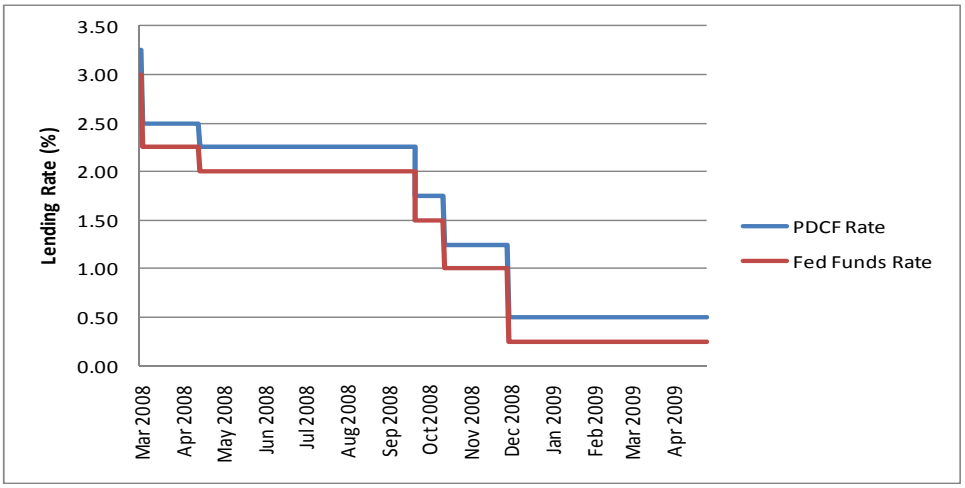

Figure 5: PDCF repo rate over time.

debt securities made up nearly 97% of the total collateral pledged in the pre-Lehman period.[23] However, those two amounts dropped to 36% following the collateral base expansion. Instead, the post-Lehman period showed a substantial proportion in these riskier asset classes. The chart demonstrates how the Fed had to relax their lending standards in order to continue to serve as a liquidity backstop.

Lastly, figure 5 charts the repo rate administered under the PDCF. The PDCF repo contracts were structured based on the primary credit rate. This rate has been set at a 25 basis point premium above the federal funds rate, i.e. the overnight inter-bank lending rate. As

[23] As noted earlier, several line items for Pre-Lehman period (uncategorized investment grade, short-term securities, unavailable ratings) were done in the first 10 days of the program and have been excluded in the regressions.

discussed previously, the Fed maintained a homogenous repo rate across borrowers due to the fact that haircuts could offer additional protection to repo depositors in the event of security collateral selloffs, whereas higher repo rates could not.

V. Methodology

The data set examined for this model is time-series cross-sectional data, better known as panel data.[24] Panel data analysis is used to examine the behavior of firms and there are different econometric approaches to modeling this behavior. Such methods include constant coefficients, random effects, and fixed effects models.[25] This study employs a fixed effects model that controls for unique attributes of the dealers that do not vary across time and are not subject to randomness.

Because different classes of collateral carry different levels of risk, it is plausible that the composition of the collateral for a particular transaction is a key determinant of the overall haircut that is specified for that transaction. In that spirit, the baseline regression model is:

$$H_{it} = \beta^{MBS}\, share^{MBS} + \beta^{AAA}\, share^{AAA} + \beta^{AA}\, share^{AA} + \beta^{A}\, share^{A} + \beta^{BBB}\, share^{BBB} + \beta^{vix} vix + u_i + \varepsilon_{it}$$

'H_{it}' represents the haircut level for the transaction with dealer *i* at time *t*, '$share^k$' represents the share of collateral type *k*, 'β^k' represents the regression coefficient for that share, 'vix' represents the market volatility price (which will be discussed later in this section) and 'β^{vix}' represents its regression coefficient, 'u_i' represents the fixed effect component for dealer *i*, and 'ε_{it}' represents the error term, which is assumed to have zero mean and be uncorrelated across time and across

[24] The panel data for this study is unbalanced and not collected at regular, equally-spaced intervals. Some firms only maintain PDCF activity over certain blocks of time during the period. As a result, there is not a data point for every time unit across all firms.

[25] Random effects models assume the variation across individuals to be random and uncorrelated with the model. Constant coefficients models assume there to be no significant effect from cross-sectional units or the time-series.

dealers. If dealer *i* is consistently given a higher haircut, perhaps due to higher default risk, the fixed effect u_i would be positive.

The study uses risk proxies in the regression to better assess haircut amounts. For the baseline, the VIX represents a measure of stock market volatility that will be used to reflect overall market risk. A high VIX price implies high volatility and uncertainty in financial markets. It is therefore included in the regression to assess the impact of market risk on haircut levels.

It is worth noting that including every collateral share in the regression would introduce a problem of perfect multicollinearity, since those regressors would always sum to one. As a result, the regression tests must exclude one collateral share and then all share coefficients should be interpreted relative to the excluded share. For this study, the Treasury collateral tranche has been excluded since it is the safest security pledged and thus the easiest to compare with other tranches. Consequently the share coefficients are interpreted as the differential between the haircut level that is applied to that asset class and the haircut level that is applied to Treasuries. For example, a 0.05 coefficient for the 'mbs' tranche means that MBS collateral required a haircut that was 5 percentage points higher than the haircut applied to Treasury bonds.

VI. Results/Analysis

As mentioned previously, the data has been analyzed for two different periods, based on the policy change following the bankruptcy of Lehman Brothers:

Pre-Lehman Period

This section reports the results for the Pre-Lehman period. Table 1 provides the regression model output. The columns in Table 1 give the regression results of different specifications. The first column is the 'baseline' specification. Before analyzing the coefficients,

Table 1
Regression Results: Pre-Lehman Period
March 17 - September 11, 2008

Collateral	Baseline	Excluding CW[1]	CDS - Excluding CW[1,2]
mbs	0.0005	0.0468	0.0453
	(0.03)	(41.18)*	(23.20)*
aaa	0.0653	0.0563	0.0552
	(4.84)*	(54.00)*	(27.70)*
aa	0.0474	0.0559	0.0448
	(2.93)*	(44.98)*	(7.23)*
a	0.0495	0.0562	0.0539
	(3.01)*	(44.58)*	(23.33)*
bbb	0.0341	0.0566	0.0549
	(1.60)	(34.75)*	(22.92)*
lnvix	0.0830	-0.0011	-0.0051
	(5.03)*	(-0.82)	(-2.24)*
cds5			-0.0630
			(-0.80)
constant	-0.2248	0.0169	0.0317
R-squared	0.1048	0.9456	0.9357
N =	265	251	128

Note: Numbers in parentheses beneath the coefficients represent t-statistics.
* Statistically significant at 5% level.
[1] Data set reduced due to inconsistent data with Countrywide Securities.
[2] Smaller sample size due to limited information on acquired dealers.

we note that the explanatory power of the model under the baseline is quite small, with an R-squared of 0.10. In order to determine why, Figure 1 charts the error terms from the regression. There is one dealer (Countrywide Securities) for which the model is unable to account for a significant part of the variation in haircuts. That is, the haircuts for Countrywide Securities spiked in mid-June for reasons that the regressors cannot account for. Interestingly, these abnormal error terms coincide with a political scandal[26] that broke out at the company during

[26] In mid-June 2008, it was revealed that Countrywide Financial had improperly provided mortgage financing to numerous DC politicians at favorable, noncompetitive rates through a program called "FOA", or "Friends of Angelo", named for Countrywide's chief executive Angelo Mozilo. Politicians involved with these illicit benefits included Chairman of the Senate Banking Committee, Senator Christopher Dodd and Chairman of the Senate Budget Committee, Senator Kent Conrad.

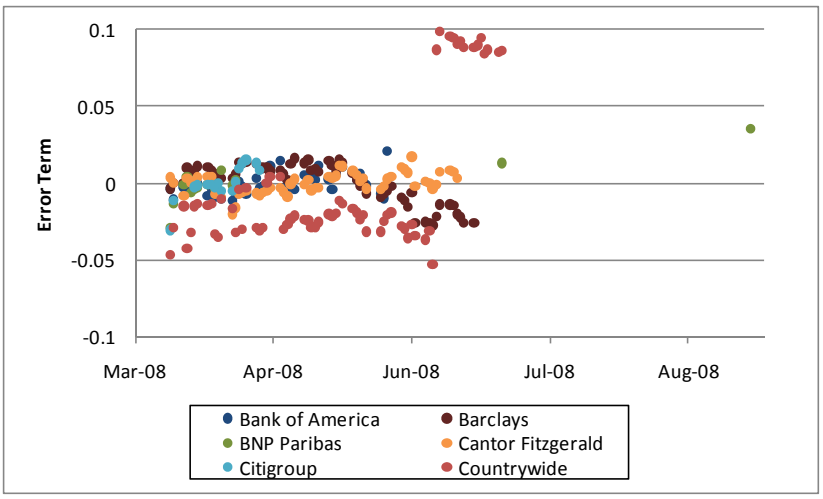

Figure 1: Model error chart across banks—'baseline' specification.

that time period. It is plausible that the higher haircuts were directly attributable to the scandal. In order to eliminate the impact that these observations have on the regression coefficients, I remove them from the sample in the 'Excluding CW' column.

In looking at this column, the model has substantially improved its predictive power. The model now has an R-squared value of 0.96, meaning the model can explain 96% of the variation in haircut levels. For this reason, the model is more accurately assessed based on the 'Excluding CW' column.

We find that the coefficients of the collateral tranches (MBS, AAA-BBB) are statistically significant for this specification that excludes the abnormal Countrywide observations. Moreover, the magnitudes of the coefficients seem reasonable. For example, the 0.0468 coefficient on 'mbs' means that MBS collateral[27] required a haircut that was 4.7 percentage points higher than the haircut on Treasuries. The other four classes of collateral—AAA, AA, A, BBB—all appear to have required a haircut that was about 5.6 percentage points higher than the haircut on Treasuries.

[27] The 'mbs' tranche represents all mortgage-backed securities and collateralized mortgage obligations issued by government-sponsored enterprises (GSEs), such as Fannie Mae and Freddie Mac.

It is worth considering why AAA-BBB asset classes appear to have shared similar haircut treatments. On an overnight basis, the values of these tranches are affected all by the same interest rates, so the risk that the collateral values would change abruptly due to a jump in interest rates should be comparable. However, the credit risk associated with these asset classes should vary in a non-trivial way; for example, one would expect that BBB securities would demand higher loan protection than AAA securities. In addition, BBB would be thought to be less liquid than AAA, and would thus call for a higher haircut amount. However, we find that the clearing bank did not take these subsequent factors into account, and treated these tranches in a uniform way.

It is also worth considering why 'mbs' would receive a lower coefficient relative to these other asset class tranches. Even though the underlying assets pledged were seen to be risky after the housing market decline, the government-sponsored entities (GSEs) supplying this tranche were believed to be implicitly backed by the government.[28] Due to this support, these assets could have been deemed as holding lower risk to the Fed than investment-grade debt.

Turning back to the results, once the model is adjusted to exclude Countrywide outliers, the market volatility proxy ('lnvix') is found to have no significant impact to haircut levels. Another risk factor that can be assessed in this model is bank counterparty risk. This can be done by tracking the credit default swaps (CDSs)[29] for each primary dealer. To examine whether this counterparty risk proxy was a significant factor in determining haircuts, the third column shows the results when each dealer's CDS price, labeled as 'cds5', is included in the regression. In order

[28] This is seen throughout the summer of 2008, as the Federal Reserve enacted backstop measures to protect these GSEs. It was not until September 7th, 2008 that the major GSE entities (Fannie Mae and Freddie Mac) were officially placed under control as conservatorships of the federal government.

[29] A credit default swap represents a swap contract in which a buyer receives credit protection for an underlying security and a seller guarantees that security payment in return for a series of insurance payments (known as the spread). The CDS price reflects the spread level. For this study, the 5-year CDS market price was used, a common metric for a firm's default risk.

to use CDS data for this regression, there are some limitations due to sparse information from Bear Stearns and Countrywide, firms that were acquired during the PDCF time period. There is thus a reduced sample size for the model when using CDS data. It is worth noting that we continue to exclude the Countrywide outliers in the regression reported in the third column.

The collateral coefficients in this third specification are again statistically significant. The 'cds5' coefficient is not statistically significant, indicating that counterparty risk appears to have played an insignificant role in setting the haircuts. However, market risk, as proxied by 'lnvix', is found to be statistically significant with a negative coefficient in the regression reported in the third column, as opposed to its insignificance in the second column.

These pre-Lehman regression results suggest that there was a rather straightforward formula utilized to set up the haircut levels associated with the eligible collateral tranches. Collateral risk was the primary determinant behind haircut setting. There is some evidence that market risk may have played a factor too based on the regression using the CDS data subsection.

Post-Lehman Data

As discussed before, the bankruptcy of Lehman Brothers in September 2008 triggered deepening stress in the repo market. The Fed responded by expanding the asset types that banks could post as collateral for PDCF borrowing. Table 2 below presents the regression results after the eligible collateral base was expanded.

The 'baseline' column will be the focus of our analysis. The collateral tranches have been grouped for this regression due to the large number of tranches now eligible under the program. While 'mbs' remains the same, AAA-BBB bonds are lumped together into the 'igrade' category, 'speculative' includes all BB and below bonds, 'shortterm' reflects all short-term collateral (A1-A3) accepted, 'na' reflects all debt collateral that was unrated, and 'loans' and 'equity' reflect

Table 2
Regression Results: Post-Lehman Period
September 15, 2008 - May 12, 2009

Collateral	Baseline	Without Outliers[1]
mbs	-0.0044	-0.0028
	(-0.29)	(-0.21)
igrade	0.0004	0.0017
	(0.03)	(0.13)
speculative	0.0251	0.0247
	(1.66)	(1.93)
shortterm	0.0082	0.0052
	(0.44)	(0.32)
na	-0.0027	0.0003
	(-0.18)	(0.02)
loans	0.2762	-0.0127
	(14.15)*	(-0.39)
equity	-0.0030	0.0016
	(-0.20)	(0.12)
lnvix	0.0027	0.0032
	(2.60)*	(3.63)*
cds5	-0.0440	0.0501
	(-2.08)*	(2.41)*
constant	0.0613	0.0559
R-squared	0.4426	0.2722
N =	690	669

Note: Numbers in parentheses beneath the coefficients represent t-statistics.
* Statistically significant at 5% level.
[1] Pertains to Morgan Stanley loans.

those respective security types.

The results for the baseline regression in the first column indicate that none of the collateral asset classes are statistically significant, with the exception of loans. The overall predictive power of the model drops as well, with the model now accounting for only 42% of the haircut variation. The second column shows the results when Morgan Stanley loan outliers, which will be discussed later in this section, are removed from the regression. In contrast to the prior period, the coefficients that proxy for market risk and default risk ('lnvix' and 'cds5') are statistically significant and hold a positive impact in influencing haircut levels. The 0.0501

coefficient on the 'cds5' tranche means that a 100 basis point increase in the CDS price resulted in a haircut that was 5 percentage points higher than the haircut on Treasuries.[30] The interpretation on the 'lnvix' tranche is different[31], but the 0.0032 coefficient translates to a 0.32 basis point increase on haircut levels based on the market volatility VIX price.[32] Although this is statistically significant, in economic terms it is very small.

Whereas the pre-Lehman results suggest that a rather straightforward formula was used to determine haircut levels, the post-Lehman results here suggest that haircut levels were set in a less obvious manner. Why are these results so different?

One possible reason that the different asset classes for collateral seemed to have little explanatory power for the post-Lehman haircuts is that the heterogeneity of the assets within each asset class increased. For example, if the Fed perceived some MBS as rather safe, and other MBS assets as quite risky, then they might demand higher haircuts for the latter. Consequently, a transaction that featured a significant share of risky MBS would have a higher haircut and a transaction with a significant share of safe MBS would have a lower haircut, and the regression coefficient on MBS will be imprecise.

Another example of collateral heterogeneity would be under the 'loans' tranche. Loans hold a significant impact on haircut levels in the baseline regression. However, this tranche is largely skewed due to a subset of Morgan Stanley transactions. Morgan Stanley, at that time, was facing abnormally high haircut levels, coupled with a high proportion of loan security collateral in their repo contracts. When loans were posted as collateral in other banks' transactions, there

[30] CDS spreads are marked at a price that reflects the annual protection premium as a percentage of the notional amount of the CDS contract. For example, a CDS that is priced at 2.0 reflects a 2% (or 200 basis points) insurance payment per annum relative to the notional value.

[31] The variable 'lnvix' represents the natural logarithm of the VIX market price. The manner in which to interpret a log-transformed explanatory variable is to multiply the coefficient by ln(1.01) in order to determine its real effect on haircut levels.

[32] The VIX maintained a price range of $16 - $81 on the Chicago Board Options Exchange during the PDCF period.

Table 3
Regression Results: Post-Lehman Period
September 15, 2008 - May 12, 2009

Collateral	Baseline	Collateral	Baseline
mbs	0.0009	a1	0.0383
	(0.06)		(2.06)*
aaa	0.0066	a2	-0.1046
	(0.48)		(-2.44)*
aa	-0.0072	a3	-1.4060
	(-0.50)		(-2.41)*
a	-0.0001	na	0.0004
	(-0.01)		(0.03)
bbb	-0.0025	loans	0.2836
	(-0.18)		(15.48)*
bb	-0.0085	equity	-0.0006
	(-0.56)		(-0.05)
b	0.0785	lnvix	0.0023
	(4.97)*		(2.41)*
ccclower	0.0138	cds5	-0.0723
	(0.94)		(-3.60)*
		constant	0.0616
R-squared	0.3976	N =	690

Note: Numbers in parentheses beneath the coefficients represent t-statistics.
* Statistically significant at 5% level.

was no noteworthy effect on haircut levels. This unusual treatment of the Morgan Stanley loan tranche collateral motivated the removal of those observations in the regression reported in the second column of Table 2. This is an example where lack of collateral transparency proves to be a limitation to this study, as we cannot determine exactly what types of loans were pledged under this tranche at any point.

One way to examine whether heterogeneity within asset classes is what accounts for the statistically insignificant shares is to ungroup the assets that were previously lumped together. Through this it can be seen if individual tranches held significant impacts. In Table 3, the groups have been broken out and presented based on the baseline specification. The collateral regression results remain unclear, while ‘lnvix’ and ‘cds5’ coefficients continue to remain statistically

significant. The coefficients on short-term securities are statistically significant, but it is worth noting that these three tranches represent less than 1% of total collateral.

Overall, the coefficients on the proxies for market volatility and default risk provide evidence of systemic issues in the marketplace altering the Fed's perception of overall lending risk. Collateral risk is no longer found to hold the same deterministic effect on haircut levels as it did in the pre-Lehman period.

VII. Conclusion

The collapse of major banks during the financial crisis 2007-2009 changed the economic landscape and jeopardized the solvency of other major financial institutions across the world. The Federal Reserve stepped in as lender of last resort with extraordinary measures and was effective in preserving the liquidity of primary dealers and in mitigating widespread liquidity shortages in lending markets.[33]

The implementation of the Dodd-Frank Act led to transparency behind the central bank's crisis actions. Data on the transaction terms of PDCF lending was made publicly available for the first time, allowing this study to examine a credit market—the repo market—for which very little publicly available evidence was previously available.

The Lehman Brothers bankruptcy was a clear dividing line in the nature of PDCF lending. Prior to the bankruptcy, acceptable forms of collateral were rather limited. Using a regression model I was able to show that the haircut levels that were established for transactions prior to the Lehman Brothers bankruptcy were tightly tied to the types of collateral that were

[33] Copeland, Martin, and Walker (2010) performed a study on tri-party repos from July 2008 to January 2010 and found the level of haircuts and repo funding to be stable in this market at that time. This finding greatly differs from the broader repo market, as shown in Gorton and Metrick (2010a), where haircut levels, repo rates, and withdrawal amounts spiked across collateral asset classes.

posted for the repo transactions. This suggests that the Fed perceived that the greatest risks from these transactions were collateral risks.

Following the Lehman Brother bankruptcy, a much broader set of asset classes was allowed as collateral for PDCF repo borrowing. Moreover, the determinants of the haircuts imposed on repo borrowing from the PDCF appear to have changed. The types of collateral seemed to have much less important role in determining the haircut, whereas a market volatility measure, the VIX, and measures of dealer default risk, CDS prices, played a more significant role. This is consistent with the idea that the Fed became much more concerned about counterparty risk following the collapse of Lehman Brothers.

In the future, additional information on Federal Reserve emergency lending that would allow a fuller understanding of the terms of Fed lending may become available. There are several legislative measures that are currently being considered that would force the Fed to reveal additional information.

First, on March 31, 2011, the Federal Reserve released information detailing which banks received Fed discount window lending between August 2007 and March 2010. This was in accordance with a court order from a Bloomberg LP lawsuit[34] seeking bailout information under the Freedom of Information Act of 2008. The disclosure marked the first time in the program's 98-year history that this information was made public. Additionally, in the Dodd-Frank Act, Congress had excluded discount window lending from disclosure requirements, but ruled that the Fed going forward must disclose all future program borrowings after July 21, 2010.[35]

Second, Senator Rand Paul and Representative Ron Paul teamed up and introduced

[34] Case identified as *Bloomberg L.P. v. Board of Governors of the Federal Reserve System* (2008).
[35] The data availability going forward will be lagged two years in order to eliminate any immediate adverse effect on these institutions from discount window lending.

comprehensive legislation on January 26, 2011 to both houses of Congress that calls for a full audit of the Federal Reserve System before the end of 2012 by the U.S. Government Accountability Office. Titled the "Federal Reserve Transparency Act of 2011", the legislation would seek to provide further clarity behind the Fed's emergency program, such as greater granularity behind the collateral tranches of the PDCF. This legislation is currently under review by a Congressional committee.

If additional evidence is released in response to these initiatives, we will be able to gain even greater insight into the functioning of the Federal Reserve's lending practices.

Appendix A

List of Primary Dealers (as of March 17, 2008) based on PDCF holdings:

Company	Aggregate Loan Amount (billions)	Number of Loans
Banc of America Securities LLC	$638.9	118
Barclays Capital Inc.	410.4	74
Bear, Stearns & Co., Inc.	960.1	69
BNP Paribas Securities Corp.	66.4	43
Cantor Fitzgerald & Co.	28.1	61
Citigroup Global Markets Inc.	2,020.2	279
Countrywide Securities Corporation	77.0	75
Credit Suisse Securities (USA) LLC	1.5	2
Daiwa Securities America Inc.	0.4	1
Deutsche Bank Securities Inc.	0.5	1
Dresdner Kleinwort Securities LLC	0.1	1
Goldman, Sachs & Co.	589.3	85
J.P. Morgan Securities LLC	3.0	3
Lehman Brothers Inc.	83.3	10
Merrill Lynch Government Securities Inc.	2,081.4	226
Mizuho Securities USA Inc.	42.3	108
Morgan Stanley & Co. Incorporated	1,912.6	212
UBS Securities LLC	35.4	8
	$8,951.0	**1,376**

Additional notes:

1. Institutions that were not part of PDCF but still primary dealers at that time:
   Greenwich Capital Markets, Inc.
   HSBC Securities (USA) Inc.

2. The following changes were made to the primary dealer list during the PDCF period:

   Jul 15, 2008 - Countrywide Securities Corporation was removed from the list as a result of their acquisition by Bank of America Corporation.

   Sep 22, 2008 - Lehman Brothers Inc. was deleted from the list of primary dealers.

   Oct 1, 2008 - Bear, Stearns & Co. was deleted from the list of primary dealers as a result of their acquisition by J.P. Morgan Securities Inc.

   Feb 11, 2009 - Merrill Lynch Government Securities Inc. was deleted from the list of primary dealers as a result of the acquisition of Merrill Lynch & Co., Inc. by Bank of America Corporation.

Source: Primary Dealers List, Federal Reserve Bank of New York.

Appendix B

Sample screenshot of the format of the data released by the Federal Reserve:

Primary Dealer Credit Facilty (PDCF) Data

Loan Date	Borrower	Loan Amount (billions)	Interest Rate	Total Collateral	US Treasury / agency	MBS/CMO: agency-backed	Aaa/AAA	Aa/AA	A	Baa/BBB
Mar 17 2008	Barclays Capital Inc.	2,000.0	3.25	2,100.0	1.5	2,098.5	0.0	0.0	0.0	0.0
Mar 17 2008	Bear, Stearns & Co., Inc.	28,000.0	3.25	29,400.0	0.0	21,675.1	5,983.8	706.5	463.0	571.6
Mar 17 2008	Countrywide Securities Corporation	1,525.0	3.25	1,601.3	3.6	1,118.6	0.0	0.0	0.0	0.0
Mar 17 2008	Deutsche Bank Securities Inc.	500.0	3.25	525.0	0.0	0.0	0.0	0.0	0.0	0.0
Mar 17 2008	Morgan Stanley & Co. Incorporated	2,000.0	3.25	2,100.3	0.0	0.0	0.0	0.0	0.0	0.0
Mar 17 2008	BNP Paribas Securities Corp.	500.0	3.25	525.0	525.0	0.0	0.0	0.0	0.0	0.0
Mar 18 2008	Bear, Stearns & Co., Inc.	27,500.0	2.50	28,875.0	0.0	21,830.5	5,503.0	694.0	424.8	422.8
Mar 18 2008	Citigroup Global Markets Inc.	500.0	2.50	524.9	0.0	0.0	457.3	58.9	8.7	0.0
Mar 18 2008	Countrywide Securities Corporation	1,000.0	2.50	1,050.3	0.0	152.8	736.3	84.7	39.4	37.0
Mar 18 2008	Goldman, Sachs & Co.	100.0	2.50	106.1	0.0	0.0	0.0	0.0	0.0	0.0
Mar 18 2008	Lehman Brothers Inc.	1,606.0	2.50	1,686.3	0.0	0.0	0.0	0.0	111.3	525.0
Mar 19 2008	Bear, Stearns & Co., Inc.	25,000.0	2.50	26,250.0	0.0	17,953.4	6,343.9	761.6	478.9	574.7
Mar 19 2008	Citigroup Global Markets Inc.	500.0	2.50	525.0	0.0	0.0	464.9	51.5	8.6	0.0
Mar 19 2008	Countrywide Securities Corporation	1,000.0	2.50	1,050.2	0.0	0.0	928.4	71.3	50.5	0.0
Mar 19 2008	Lehman Brothers Inc.	2,300.0	2.50	2,415.1	0.0	0.0	765.8	161.6	454.2	5.9
Mar 20 2008	Barclays Capital Inc.	1,000.0	2.50	1,050.5	0.0	0.0	3.3	127.0	219.8	700.4
Mar 20 2008	Bear, Stearns & Co., Inc.	25,500.0	2.50	26,775.0	0.0	18,122.0	6,628.2	775.6	531.1	567.1
Mar 20 2008	Citigroup Global Markets Inc.	1,500.0	2.50	1,575.4	0.0	0.0	1,293.6	51.5	169.7	60.6
Mar 20 2008	Countrywide Securities Corporation	1,300.0	2.50	1,365.1	0.0	91.5	1,017.5	146.4	74.3	35.4
Mar 20 2008	Lehman Brothers Inc.	2,300.0	2.50	2,415.0	0.0	0.0	2.2	81.8	34.8	367.5
Mar 20 2008	Merrill Lynch Government Securities Inc.	100.0	2.50	105.0	0.0	0.0	0.0	0.0	21.0	82.1

Appendix C

Primary Dealer Credit Facility Timeline

March 16, 2008 – Bear Stearns signs merger agreement with J.P. Morgan.

March 17 – Fed implements Primary Dealer Credit Facility.

March 27 – PDCF homogenous haircut policy changes—haircuts begin to vary from 5.0%.

Mid-June – Countrywide Financial political loan scandal revealed.

July 1 – Bank of America finalizes acquisition of Countrywide Financial.

September 7 – Federal takeover of government-sponsored entities Fannie Mae and Freddie Mac.

September 14 – Bank of America announces acquisition of Merrill Lynch.

September 15 – Lehman Brothers files for bankruptcy protection.

September 15 – Federal Reserve expands PDCF collateral base to include all collateral eligible in tri-party repurchase agreements with clearing banks.

September 16 – Barclays Capital agreement to purchase core operations of Lehman Brothers.

September 21 – PDCF expands to include broker-dealer subsidiaries of Goldman Sachs, Merrill Lynch, and Morgan Stanley.

November 23 – Citigroup also granted subsidiary lending abilities through PDCF following the announcement of further federal government backstop assistance.

May 12, 2009 – Final transaction date under the PDCF.

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