The Run on Repo and the Fed's Response *

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Abstract

We document that the Financial Crisis of 2007-2008 was a repo run in two directions. Lenders holding privately-produced collateral in the repo market, e.g., mortgage-backed securities, ran to get their money back while borrowers who had supplied Treasuries as collateral wanted their Treasury collateral back. Firstly, we show that an increase in the haircut on a given type of collateral in the bilateral repo market resulted in those specific assets being taken to the Fed as collateral against loans from emergency facilities. Secondly, we find that the borrowers were especially eager to bring this collateral to the Fed in exchange for Treasuries. We show that banks most exposed to the Treasury shortage pre-crisis respond strongly to announcements of emergency programs that alleviated the scarcity of good collateral.

*We thank some traders who wish to remain anonymous for help in providing the haircut data used in this paper.

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1 Introduction

Ten years after the crisis began in the first quarter of 2007, there is no consensus on the cause of the crisis. Explanations abound. It is unfortunate that there is a lack of data on the shadow banking system, which makes it difficult to understand what happened. But, this lack of data is the defining feature of a banking system which was unknown prior to the financial crisis. Hence, it is called the "shadow" banking system. The absence of data does not mean that we cannot understand what happened, but it does make it harder. In this paper, we use repo haircut data from the bilateral repo market and study the dynamics of the financial crisis. We provide evidence of the run on repo by showing that the increase in haircuts on certain asset categories corresponded to banks taking those specific assets to the emergency lending facilities. In other words, there was a run on repo.

The sale and repurchase market (repo) was at the center of the Financial Crisis of 2007-2008 (see Gorton (2010), Gorton and Metrick (2012), Gorton and Metrick (2010a), and Gorton and Metrick (2010b)). In a repo contract a lender makes a short term cash loan in exchange for collateral. The amount by which the loan is less than the value of the collateral is called the haircut. For instance, a bond with $100 value and 10% haircut will allow the borrower access to $90 in repo financing. An increase in the haircut for a type of collateral, then, is economically equivalent to a reduction in the quantity of securitized borrowing can be done using a given amount of collateral. A market-wide rise in haircuts because of doubts about the privately-produced securities used as collateral results in a "run on repo", meaning that repo lenders want their cash back.

In this paper, we provide evidence of this run on repo during the last financial crisis. Specifically, we exploit data from the emergency lending facilities set up by the Federal Reserve in response to the crisis. These facilities allowed banks to bring collateral to the Fed in exchange for cash or Treasuries. Consistent with the run on repo view, we show that an increase in haircuts on a given type of collateral in the repo market resulted in these assets being brought to the Fed as collateral against emergency loans. In a difference-in-differences setting, we use changes in bilateral repo haircuts to explain bank-collateral-level borrowing from three facilities—the Term Auction Facility (TAF), Term Securities Lending Facility (TSLF), and Primary Dealer Credit Facility (PDCF). Our finding is robust to including proxies for shocks to bank capital and counter-party risk.

Having established that changes in repo haircuts account for collateral brought to the Fed, we further argue that emergency borrowers were especially interested in receiving Treasury collateral. Here we exploit differences between the three emergency liquidity programs. One of the programs—TSLF—provided borrowers with Treasury collateral, while the other two—TAF and PDCF—provided Fed Funds. In a triple difference setting, we find that the type of collateral brought to the TSLF was especially responsive to the changes in bilateral repo haircuts. In other words, when haircuts on privately produced collateral increased, borrowers were eager to bring this collateral to the Fed in exchange for Treasuries.

We interpret this finding as evidence for another type of run on repo—the run of repo borrowers to reclaim good collateral because of an acute shortage of collateral during the crisis. To directly test the hypothesis of specific success of TSLF, we look at bank stock returns on program announcement dates. In contrast to the announcement days of other emergency programs, banks stocks enjoyed statistically significant positive returns on days when significant details about TSLF were announced. What is more, we show that in the cross-section, banks that are more dependent on Treasury collateralized finance enjoyed larger positive returns on TSLF announcement days. To do this, we construct proxies of bank-level dependence on Treasury collateral by calculating bank stock return covariances with measures of aggregate Treasury shortage in the pre-crisis period.

What drives the apparent desire to receive Treasuries during the crisis? U.S. Treasuries are the best type of collateral because there are never doubts about their value. With limited Treasury supply, market participants that receive Treasury collateral in one transaction reuse it in an unrelated transaction with another counterparty, and so on. That is, there is significant rehypothecation. The number of times a given piece of collateral is reused in such a manner—the velocity of collateral—is akin to a "money multiplier." In principle, Treasury velocity can be infinite because haircuts are zero. In that sense Treasury velocity is not directly analogous to the money multiplier which is constrained by central bank reserve requirements. In practice, the Treasury multiplier is limited by institutional constraints.

It appears that the amount of rehypothecation is significant. For example, the Financial Stability Board (2017) finds that among the 13 largest global banks, collateral reuse was about 30 percent of the total assets of these banks, and peaked at around Euro 4.3 trillion in 2006. This implies a collateral velocity around 1.5.[1] Singh (2011) also provides a rough estimate of collateral velocity. He calculates that the velocity was four prior to the crisis. Other than such estimates, however, there is no data on rehypothecation. One reason is because repo collateral is not owned, but legally possessed, so it is off-balance sheet.[2] What is clear, though, is that if the velocity of Treasuries is greater than one, there cannot be enough Treasuries should all repo borrowers want their Treasuries back at the same time.

If the run on repo was driven by repo lenders seeking to obtain cash, banks would be content to borrow cash at an emergency lending facilities because they could repay lenders. On the other hand, if repo borrowers were seeking to regain possession of good collateral, emergency borrowers would be looking to borrow Treasuries, rather than Fed Funds. Of all the emergency facilities set up during the crisis, TSLF was the only one that allowed borrowers to access good collateral, rather than Fed Funds. Because TSLF borrowing was uniquely sensitive to changes in bilateral

[1] Collateral velocity is calculated as "...the ratio of 1 divided by 1 minus the re-use rate...where the re-use rate is defined as re-used collateral divided by collateral received that is eligible for re-use." (Financial Stability Board (2017))

[2] In recent work Fuhrer et al. (2016) study the post-crisis re-use of collateral in the Swiss Franc repo market. They found that prior to the crisis 10 percent of the interbank market was secured with re-used collateral. They further find that the re-use of collateral increases with the scarcity of collateral and vice versa.

repo haircuts, we argue that the run of repo borrowers to regain their high quality collateral was an important contributor to crisis dynamics.

Repo is divided into two different markets: tri-party repo and bilateral repo. In tri-party repo, a clearing bank stands between borrowers and lenders. Because the tri-party market is dominated by regulated institutions the data on tri-party repo is relatively complete.[3] In contrast, bilateral repo is the home of hedge funds, many types of offshore institutions, and other unregulated cash pools.[4] A 2004 industry survey found that bilateral repo was about three times as large as tri-party repo. See Gorton and Metrick (2015c). According to Baklanova et al. (2015): "Due to a lack of data, there is a wide range of estimates of total repo and securities lending activity. For example, total repo activity at its peak level before the 2007-09 financial crisis ranged from $5 to $10 trillion. In the current post-crisis era, our estimate of total repo activity is around $5 trillion and our estimate of the outstanding value of securities on loan is just under $2 trillion" (p. 4).

The bilateral and tri-party repo markets play distinct but related roles. The tri-party repo market is about funding, e.g., money market funds lend cash in exchange for collateral at the tri-party bank. (See, e.g., Singh (2014).) In turn, broker-dealers receive cash from the tri-party bank in exchange for collateral.

The bilateral repo market is a market for collateral. Collateral moves around in the economy for various purposes: collateral is needed for derivative transactions, for cross-border financial transactions, and for secured transactions undertaken due to counterparty risk in particular repo.[5]

One source of collateral is prime brokerage. Prime brokerage is a business of broker-dealer banks. Prime brokers offer a range of services including derivatives trading, stock lending, and financing for their customers, which are mostly hedge funds. Pre-crisis, prime brokerage was largely self-financed because the collateral posted by clients could be rehypothecated. So, the prime broker could re-use the customers' collateral to lend out or post for another reason. Pozar and Singh (2011, p. 4) argue that one source of collateral is asset managers: "The securities that asset managers invest in on behalf of households are seldom left lying around passively in portfolios. In order to capture their value as collateral, securities are routinely lent out for use in the shadow banking system, a fact households, whose securities are ultimately being lent, are oblivious to."

The role for the bilateral market as a market for collateral means that trades are negotiated on a trade-by-trade basis between the lender and the borrower, and haircuts can move quickly as we saw

[3] See Copeland et al. (2010) for a discussion of the pre-crisis tri-party system.

[4] The situation is the same post-crisis. Baklanova et al. (2017) study a cross-section of bilateral repo transactions in the first quarter of 2015. They find that " . . . more than half the trades in terms of dollar volume involve a bank or a broker-dealer, followed by hedge funds. The results differ from that of tri-party repo, where the money market funds and cash reinvestment arms of securities lending agents are the largest participants" (p. 2)

[5] Broker-dealers have to source collateral. Pozar and Singh (2011) call this search for collateral "collateral mining". According to Singh (2017): "About half the pledged collateral comes from the hedge funds industry; and the other source of pledged collateral is from pension funds, insurers, central banks, sovereign wealth funds, and others" (also see Singh (2011) and European Systemic Risk Board (2014)).

in the crisis (see Figure 1 and Gorton and Metrick (2012)). Indeed, when lenders started to worry about the value of the collateral they asked for higher haircuts, withdrawing from the "repo bank". This is the logic of Dang et al. (2012)—a crisis is a situation where information-insensitive debt becomes information-sensitive. In 2007-2008 the collateral backing repo came to be questioned, leading to the run on repo. From the second quarter of 2007 to the first quarter of 2009, net repo financing provided to U.S. banks and broker-dealers fell by nearly $900 billion, more than half of its pre-crisis total (based on incomplete Flow of Funds data). See Table 3 and Gorton and Metrick (2015c). This is distinct from the tri-party funding market where trades take place using standardized documentation and changing of haircuts is quite involved (and can take weeks).

Because of the lack of volume, price, and rehypothecation data on the bilateral repo market, it is not surprising that there are no empirical papers on the bilateral repo market other than Gorton and Metrick (2012).[6] Instead the focus has been on tri-party repo where there is data.

Krishnamurthy et al. (2014) look at tri-party repo and securities-lending market, focused most extensively on money-market mutual funds. They argue that money-market funds did not run on repo via the tri-party system during the crisis. Copeland et al. (2014) reach a similar conclusion.

We focus on the bilateral repo market not the tri-party market. It is certainly the case that "we lack data on the bilateral repo market, and thus the full picture on repo is yet to be assembled" (Krishnamurthy et al. (2014), p. 2382). The problem of a lack of data on repo is widely understood.[7]

The word "shadow" in the term "shadow banking" refers to the fact that there is a paucity of data available about this banking system. Indeed, had this system been measured and documented prior to the crisis there probably would not have been a crisis. The most acute data issue concerns the bilateral repo market. Repo finance is a multi-trillion dollar market.[8] As of January 2016, the Office of Financial Research of the U.S. Treasury estimated the bilateral repo market at between $3.2 trillion and $1.9 trillion. See Office of Financial Research (2016) Appendix Table B. These estimates, however, do not seem to include off-balance sheet collateral that is re-pledged. Pozar and Singh (2011) argue that when re-pledging is taken into account, the U.S. shadow banking system was $25 trillion and the end of 2007. It is hard to evaluate these numbers.

An absence of data, however, is not the same as an absence of a run in the bilateral market. The evidence in Gorton and Metrick (2015c) shows that extrapolating from the tri-party market does

[6] It is only now that data on the bilateral repo market is starting to be collected by the Office of Financial Research of the U.S. Treasury. See, e.g., Baklanova et al. (2016).

[7] For example, Baklanova et al. (2015) write: "High-quality data covering repo and securities lending activities are needed for regulators and policymakers to understand and monitor market developments, identify potential risks, and to conduct in-depth analysis of policy options" (p. 65).

[8] Hördahl and King (2008) report that at year end 2007 the gross amounts of repo outstanding at year end were "roughly $10 trillion in each of the U.S. and euro markets, and another $1 trillion in the U.K. repo market" (p. 37). Gorton and Metrick (2012) and Singh and Aitken (2010) also estimate the pre-crisis U.S. repo market size to be around $10 trillion. Copeland et al. have a much lower estimate. Post-crisis, the size of the bilateral repo market has declined.

not lead to the conclusion that repo runs in the bilateral market were not central to the crisis. Since money-market mutual funds make up only about two percent of the bilateral market, and the bilateral market is the main contributor to the $600 billion statistical discrepancy that disappeared during the crisis, it is not possible to draw conclusions about the repo run by focusing only on money-market mutual funds and other regulated institutions.

In Section 2 we summarize the main features of the Fed emergency lending facilities. Section 3 discusses lending data provided by the Fed, the bilateral haircut data, and the merging of the two datasets. In Section 4 we present our main empirical evidence: we show that changes in haircuts on specific asset classes caused banks to take those assets to the emergency lending facilities. We also demonstrate that borrowing from the TSLF was particularly sensitive to changes in repo haircuts. In Section 5 we argue that aggregate shortage of Treasuries was behind the specific success of TSLF. We characterize banks by their pre-crisis exposure to the scarcity of Treasuries and show that banks that are more dependent on collateralized finance enjoyed larger positive returns on TSLF announcement days. Section 6concludes.

2 The Emergency Lending Facilities

During the 2007-2008 Financial Crisis the Federal Reserve introduced a number of temporary emergency facilities to address pressures in various financial markets. At one point there were nine temporary liquidity facilities in place.[9] In this paper we focus on the three most important facilities—the Term Auction Facility (TAF), the Term Securities Lending Facility (TSLF), and the Primary Dealer Credit Facility (PDCF)—that allowed depository institutions or primary dealers to borrow against collateral outside the usual discount window. The Term Asset-Backed Securities Loan Facility (TALF) began operation in March 2009, so it begins after the period that will be our focus. See Ashcraft et al. (2012) for more details on TALF.

Table 1 summarizes the main characteristics of the three programs and Figure 1 shows the relative size of each program. TSLF was a security-for-security exchange. The borrower offered a bond as collateral, e.g., a mortgage-backed security, and received a Treasury bond in exchange. TAF and PDCF, on the other hand, lent banks cash against collateral. The cash could be used to repay repo borrowings. TAF (and the Feds Term Discount Window Program) was only available to depository institutions. TSLF and PDCF were both open to primary dealers only. PDCF was a standing facility whereas TSLF was an auction facility. A standing facility is usually viewed as being subject to stigma, which may have limited the effectiveness of PDCF. See, e.g., Armantier et al. (2015).

TAF opened on December 12, 2007 and the final auction was held March 8, 2010, with credit maturing on April 8, 2010. The TSLF was announced on March 11, 2008, and the first auction

[9] https://www.newyorkfed.org/medialibrary/media/markets/Forms_of_Fed_Lending.pdf

took place on March 27, 2008, Schedule 1 collateral (i.e., Treasuries, agency MBS and agency securities) auctions were suspended on July 1, 2009 and auctions against Schedule 2 collateral (Schedule 1 collateral and other highly rated securities) were suspended on February 1, 2010. PDCF was announced on March 16, 2008 and closed on February 1, 2010.[10]

Since TAF was only open to depository institutions, the U.S. broker-dealers were excluded from using it.[11] Foreign banks, however, are essentially universal banks and they could make use of TAF. According to Benmelech (2012) "foreign banks accounted for 58 percent of TAF lending, with a total amount of $2.2 trillion, compared to $1.6 trillion for U.S. banks" (p. 4). Benmelech (2012) also notes that most of the financial institutions that were eligible pledged asset-backed and mortgage-backed securities (ABS), suggesting "that the meltdown of the structured finance market and the severe deterioration in the credit ratings of ABSs necessitated liquidity. . . " (p. 5). Commercial loans were the most popular pledged collateral, which will be important below.[12]

The TSLF was introduced on March 11, 2008 (Bear Stearns was acquired by JP Morgan on March 16, 2008). TSLF was designed to alleviate stress in financing collateral in money markets by allowing less-liquid, lower quality, collateral to be exchanged for Treasuries. Since the TSLF was a security-for-security exchange it did not increase the size of the Fed balance sheet and did not have to be sterilized. As a result, it could be increased in size quickly. TSLF reached $150 billion in its first month.

The PDCF was introduced on March 16, 2008. Adrian et al. (2009) provide more detail on the Primary Dealer Credit Facility.

There are differences between the facilities, aside from the fact that TSLF was a bond-for-Treasury exchange. The maturity of PDCF was overnight and the facility could be accessed daily. Maturities for borrowing from TAF and TSLF were longer. TAF was 28-84 days and TSLF was 28 days. Shortly after Lehman the remaining investment banks became bank holding companies and could access TAF, so they could obtain term borrowing from TAF or TSLF. PDCF also accepted lower quality collateral than TSLF. We summarize the types of collateral brought to the three facilities in Tables 4 and 5.

[10] For more details see Fleming (2012) and Armantier et al. (2012).

[11] The remaining broker-dealer banks (Goldman and Morgan Stanley) became bank holding companies on September 22, 2008.

[12] Also, see Armantier et al. (2012).

	TAF	TSLF	PDCF
full name	Term Auction Facility	Term Securities Lending Facility	Primary Dealer Credit Facility
program active	12/2007-4/2010	3/2008-8/2009	3/2008-5/2009
loan term	28 or 84 days	28 days	overnight
timing	Bi-weekly auctions, typically on Monday morning. Loans settle Thursdays.	Weekly auctions, typically Wednesday or Thursday afternoon. Loans settle day after auction.	Standing facility. Daily borrowing.
eligible institutions	Prime credit eligible depository institutions	Primary dealers	Primary dealers
accepted collateral	Any collateral accepted at Discount Window	Originally, Treasury, Agency, and AAA rated MBS and ABS. Starting 9/14/2008 collateral that can be pledged on the tri-part repo market.	Originally, investment-grade securities. Starting 9/14/2008 collateral that can be pledged on the tri-party repo market.
borrowers receive	Fed Funds	General Collateral	Fed Funds
haircut	Discount Window haircuts.	Open Market Operation haircuts for collateral that is eligible for OMOs	Open Market Operation haircuts for collateral that is eligible for OMOs
prepayment	Not allowed.	Not allowed.	Not applicable.
pricing	Fed announced maximum lending amount per auction. Eligible institutions submitted bids in terms of quantity and interest rate. Maximum of two bids per participant, and limit on total amount awarded to single institution. The auction rate was set as the lowest rate such that total borrowing would be at or below cap. All borrowers paid the same rate.	Fed announced maximum lending amount per auction. Eligible institutions submitted bids in terms of quantity and interest rate. Maximum of two bids per participant, and limit on total amount awarded to single institution. The auction rate was set as the lowest rate such that total borrowing would be at or below cap. All borrowers paid the same rate.	Loans made at the prime credit rate, subject to a further usage fee after 45 days of borrowing. No quantity limit. Prime credit rate was lowered to Fed Funds Target + 25bps in 3/2008.

Table 1: Characteristics of the three emergency liquidity programs. Source: FAQs on Federal Reserve website (`https://www.federalreserve.gov/monetarypolicy/expiredtools.htm`)

2.1 Pricing

The three programs differed in how loans were priced and in how quantities were determined. Two of the programs, TAF and TSLF, allocated loans by holding regularly scheduled auctions. The third, PDCF, was a standing facility. Figure 5 summarizes the rates paid and quantities borrowed.

TAF and TSLF used similar auction mechanisms. Before each auction the Fed announced a maximum amount to be lent (the cap). Each eligible institution could submit up to two bids specifying the interest rate they would be willing to pay for a given amount of funds or collateral. The Fed then picked the lowest rate such that the total borrowing would be at or below the announced cap. All participants who received a loan paid this single rate on their borrowing. The Fed further imposed constraints on the total amount of borrowing done by any single institution.

What should we expect the interest rates on emergency loans to look like? TAF borrowers received Fed Funds (i.e., cash) in return for their collateral. Absent frictions in the Fed Funds market we would therefore expect the rate paid on TAF loans to track the effective Fed Funds rate. This is confirmed in Figure 5. The only exception is immediately after Lehman failure when rates on TAF loans spiked well above the funds rate. TAF facility maxed out in all auctions prior to the Lehman failure, after which the Fed increased the cap and the remaining auctions were all under-subscribed.

TSLF borrowers, in contrast, received General Collateral (i.e., Treasuries) from the Fed. We therefore expect the rate paid on TSLF to be correlated with the GC Repo-Treasury spread. Like in the case of TAF, the Fed adjusted the borrowing cap auction-by-auction. Total borrowing was typically below the cap, with the exception of the auctions following Lehman failure. Naturally, the auctions where the supply cap was binding were the ones where prices spiked.

Unlike the auction-based facilities, the PDCF was a standing facility where each eligible institution (primary dealer) could get financing at the Fed discount window rate. There was a further penalty fee after 45 days of using PDCF, but no daily cap. In the pre-crisis period the Fed discount window rate was set at target Fed Funds rate plus 100 basis points. In an attempt to reduce the stigma associated with borrowing from the discount window, the Fed reduced the discount rate spread to 25 basis points in 3/16/2008, where it stayed through the time-period studied in this paper, until 2/19/2010.

2.2 Margins

The three programs also differed in the margins (margins equals one minus the haircut) applied to various types of collateral. TSLF and PDCF used a program-specific margin table, while TAF used the discount window margins table. The margins depended both on type of collateral as well as maturity.

Because the characteristics in the margins tables are not identical to the categories reported in the Fed data we cannot calculate the exact haircuts applied to each type of collateral. We instead match the reporting categories to margins data and find equal-weighted averages.

As shown in Table 19 in the Appendix, average haircuts the Fed applied were small, and similar across the three programs.

There were also some changes to the margins during the crisis. Notably, right after Lehman failure the Fed expanded the breadth of collateral eligible for emergency lending. However, there were almost no changes in haircuts applied within collateral categories during the time-period we study.

3 Emergency Borrowing Data, Bilateral Haircut Data

Our main empirical evidence studies bank-level changes in emergency borrowing against specific types of collateral as a function of bilateral repo haircuts. In this section we discuss data sources, and the data construction process. Specifically, we discuss the emergency borrowing data provided by the Fed, its match to the bilateral haircut data, and an econometric methodology to determine distinct regimes in haircut data during the crisis.

3.1 Data Provided by the Fed

The Fed provides loan-level data for each of the three emergency facilities discussed above. For each loan they report borrower bank name, loan date, clearing date, maturity date, interest rate, and value of collateral submitted. The amount of collateral provided by the borrower is further broken down by collateral type (Treasury, MBS, Corporate, Loans, etc.) and collateral rating (AAA, AA, etc.). The two sets of categories are slightly different across the three programs, as evident in the summary Tables 4 and 5. These tables show the prevalence of various types of collateral in the programs. Note that the totals over type and rating do not always add up to the same number. This is because many types of collateral did not have a credit rating.

3.2 Bilateral Haircut Data, Matching Haircuts to Fed Collateral Categories

We use the same bilateral repo haircut data studied in Gorton and Metrick (2012). The data was supplied by traders who wish to remain anonymous. The haircuts are on transactions between high quality dealer banks and would be higher for, say, hedge funds borrowing cash against collateral.

In order to study the effect of changes in private market repo haircuts on borrowing from the emergency facilities we need to match repo haircut data with the borrowing data provided by the

Fed.

While the Fed collateral data is reported by both type and rating of collateral, the categories in our private repo haircut data are a mixture of collateral quality and collateral type. Because of this incongruity we perform the regression analysis based on two separate matches–one by collateral rating and the other by collateral type.

We seek to match each Fed collateral category to every repo haircut category that could contain the collateral in question. In other words, we pick the haircut data categories so as to maximize the probability that the true haircut is included in the match. This minimizes the probability of missing a haircut change, but potentially introduces noise by including irrelevant haircut changes.

One unit in the regressions will be the amount of borrowing from a specific facility against a given type of collateral. The effective haircut used in the regressions is a simple average of haircuts matched to that type of collateral. Note that a number of the Fed collateral categories are matched to no haircut data. In most cases this is because these assets were never financed with repo, such as commercial loans or equity. In other cases—such as U.S. Treasuries—the haircuts never increased from zero so there would be no right-hand-side variation to exploit in the regressions.

The program-by-program match is reported in the Appendix Tables 16-18. We plot the time-series of total borrowing in the matched categories in Figure 4. In the following we briefly describe the quality of match for each program.

- **TAF.** The collateral type categories Commercial Loans, Commercial and Residential Mortgages, and Consumer Loans are not matched to haircut data and make up 57% of the total borrowing.

  In terms of collateral rating categories, Other Investment Grade (22% of the borrowing) and Treasury/Agency (11% of the borrowing) are not matched to haircut data.

- **TSLF.** Here we have the best match with haircut data. The majority of borrowing was collateralized by Agency and non-Agency MBS, both of which are matched to the haircut data. Only Muni, Treasury, International, and Other are not matched, accounting for a total of 5% of the borrowing.

  Similarly, only Treasury is unmatched among the collateral rating categories.

- **PDCF.** The unmatched collateral type categories Equity, Municipal, and Other represent 48% of the total borrowing. All other collateral categories that are over 1% of the total are matched to the haircut data.

  Collateral rating categories Equity and Unavailable make up 38% of the total. However, nearly all other collateral rating categories are matched with haircut data.

Figure 4 graphically portrays the amounts matched based on collateral and ratings. For each program the percentage matched is stable across the sample period.

3.3 Breakpoints in Haircut Data

In our empirical analysis we seek to understand the differences in emergency borrowing behavior across different stages of the financial crisis. In order to categorize the crisis period into different regimes we follow Gorton et al. (2015a) who study the recent crisis from an econometric perspective. The authors use a method proposed by Bai (2010) to find common breaks in the panels of various characteristics of bank-produced money. Bai's methodology looks for a date such that the average square residuals from the mean in the resulting two subsamples are minimized. To find the second breakpoint, the algorithm again looks for a date such that the square residuals across the three resulting subsamples are minimized. We apply Bai's method to the panel of haircuts to uncover two most important breakpoints in the haircut data. The two most important breakpoints are:

#	Date	Lower Bound	Upper Bound
1	06/10/2008	05/27/2008	06/17/2008
2	09/05/2008	08/29/2008	09/05/2008

Table 2: Breakpoints in Haircut data.

The upper and lower bounds in the table provide the 95 percent confidence intervals in terms of dates. The #2 breakpoint is just prior the Lehman failure, which occurred on September 15, 2008. We call this breakpoint the "Lehman Breakpoint."

3.4 Matching Borrower Data

For our empirical approach we also need to match borrowers across the three programs. We match bank names across the three programs and collapse borrowing to the level of bank holding companies (if applicable). For instance, borrowing by both Bank of America NA and Bank of America Securities LLC would be combined under the same entity.

We then match the resulting banks to Bloomberg tickers and Markit CDS IDs. We merge in daily market cap data from Bloomberg, and daily 5-year CDS rates from Markit.

Table 20 shows the top 100 largest borrowers with the associated Bloomberg and Markit identifiers. The top 100 is constructed by calculating the average daily dollar value of borrowing outstanding. In all, 83% of the total loan volume outstanding corresponds to banks that are have both market cap and CDS data available. We plot the value-weighted averages of these variables in Figure 1. As one could expect, the market cap and average CDS rates are strongly negatively correlated during the crisis period.

3.5 Data Construction

As summarized in Table 1, the three programs operated on separate schedules. TAF loans were made at bi-weekly auctions, TSLF held weekly auctions, and PDCF was accessible daily.

In order to study borrowing from the three facilities we construct a week-borrower-collateral level panel data set. For each collateral category, we calculate the private market repo haircut as the equal-weighted average of all the matched repo haircuts. Because we have two separate haircut matches, we end up with two week-borrower-collateral level panel data sets. In regression analysis we use the two in parallel.

The timing in the regressions is contemporaneous. That is, we regress weekly changes in bank-collateral-program level borrowing on changes in right hand side variables during the same week. The exception to this rule is TAF, which held auctions on Monday mornings. Here we lag the amounts borrowed by a week, so that borrowing done at the Monday morning auction corresponds to the previous week's changes in explanatory variables.

4 The Run on Repo and the Emergency Lending Facilities

We now turn to examining the determinants of the timing of specific collateral being pledged at the various Federal Reserve emergency lending facilities by specific banks. We will use the change in haircuts on various asset classes in the bilateral repo market to see if these changes cause that specific type of collateral to be pledged at emergency lending facilities. An increase in haircuts is tantamount to a withdrawal of cash because the intermediary has to fund the short-fall (by selling the assets for example), and if it cannot then it would go to an emergency lending facility. This would be evidence of the run on repo.

Our empirical strategy is to use cross-sectional variation within collateral-specific haircuts across different haircut regimes to account for changes in borrowing from Fed facilities. In general, we run regressions like:

$$\Delta\text{Amount}_{i,j,t} = \beta_{HC}\Delta\text{Haircut}_{j,t} + \beta_{OIS}\Delta\text{LIB-OIS}_{i,t} + \beta_{Cap}\Delta\text{Cap}_{i,t} + \beta_{CDS}\Delta\text{CDS}_{i,t} + \epsilon_{i,j,t}$$

where the right hand side variables are further interacted with dummies indicating the breakpoints in haircut data described in Section 3.3. This allows for the dynamics of emergency borrowing to differ across different stages of the crisis.

We also attempt to allow for alternative explanations of emergency borrowing. One alternative explanation is that the house price declines constituted a negative shock to bank equity (via the decline in value of mortgage-backed securities banks held) which then motivated banks to sell assets,

causing fire sales (since new debt and equity could not be issued).[13] It is not clear, however, that this explanation can explain why certain banks at certain times would take certain assets to the emergency lending facilities. Furthermore, borrowing at an emergency lending facility does result in delevering and thus a higher capital ratio. A bank's balance sheet does not shrink when it borrows against its collateral at an emergency lending facility, so the bank's capital ratio does not improve.

A second alternative explanation is that the losses on mortgage-backed securities affecting banks were unobservable, making counterparty risk important, fears of which then caused the inter-bank market to freeze up, again leading to borrowing from emergency lending facilities and to fire sales since banks could not borrow and lend in the interbank market.[14] Again, this hypothesis has no predictions about which collateral is taken to emergency lending facilities at specific times.

With regard to shocks to bank equity, we include the change in each bank's market capitalization. With regard to counterparty risk we include the change in the Libor-OIS spread as a general measure of counterparty risk and the change in each bank's five year CDS rate to measure each bank's specific risk as perceived by the market. Figure 1 shows the time series of aggregate market cap of banks in the sample, and the value-weighted CDS index. As we would expect, these two series are strongly negatively correlated during the crisis. The three hypotheses, the run on repo, shock to bank capital, and counterparty risk, are not mutually exclusive.

We include the most granular fixed effects possible with bank-program-collateral level fixed effects. Standard errors are clustered both on week and on borrower.

Our main hypothesis is that banks increased emergency borrowing against affected collateral, that is in the collateral categories where the haircuts increased the most that week. If the market-based haircuts increase on a category of assets, then the bank must fund the additional amount itself. For

[13]The Treasury (2009) held that: "An initial fundamental shock associated with the bursting of the housing bubble and deteriorating economic conditions generated losses for leveraged investors including banks...The resulting need to reduce risk triggered a wide-scale deleveraging in these markets and led to fire sales." And a discussion of the crisis by leading American financial economists French et al. (2010) p. 67 argued: "A bank that simply suffers large losses may be forced to reduce its risk by selling assets at distressed or fire-sale prices. If other banks must revalue their assets at these temporarily low market values, the first sale can set off a cascade of fire sales that inflicts losses on many institutions. Thus, whether through defaults or fire sales, one troubled bank can damage many others, reducing the financial system's capacity to bear risk and make loans." Kilponen and Milne (2007): The main trigger of the financial markets turmoil in the second half of 2007 has been the concern that the write down of sub-prime mortgage securities... will erode bank capital... (p. 7). Another example, of many, is Bullard et al. (2009) who write that: "'...banks and other financial firms began to realize significant losses on their investments in home mortgages and related securities in the second half of 2007. Those losses triggered a full-blown financial crisis..."' (p. 403). And, there are many others.

[14]For example, Bullard et al. (2009) write: "...the most important type of risk to the financial system has been 'counterparty risk'..." (p. 407). Acharya and Merrouche (2013) speaking of U.K. banks writes: Our broad conclusion is that events unfolding since August 9, 2007 increased the funding or rollover risk of banks, in response to which banks, especially the weaker ones, hoarded liquidity. Given their increased opportunity cost of giving up liquidity to other banks, interbank rates rose in both secured and unsecured markets, suggestive of interest rate contagion through the interbank market (p. 108-109). Taylor (2009) argues that the crisis was mainly associated with an increase in counterparty risk, and not a shortage of liquidity. Also see Jorion and Zhang (2009). And there are many others.

example, suppose that initially there was a zero haircut so that a lender lent $100 and received a bond with a market value of $100 as collateral. If, the next day, haircuts for that type of bond rise to ten percent, then the bank must return $10 to the lender. Where does this $10 come from? One possibility is to sell the bond rather than fund it in the repo market (i.e., in a fire sale). Another possibility is to use the bond as collateral (if it is eligible) and borrow from an emergency lending facility and repay the repo lender.

4.1 Bilateral Haircuts and Collateral Taken to Fed

Our main evidence with regard to the run on repo is in Tables 6 and 7. Here we are exploiting the full cross-sectional data available. Namely, the left hand side variable measures the total amount of borrowing done by a given bank in a given week, using a specific type of collateral. In order to maintain comparability across banks we normalize borrowing in each category by the bank's market cap in August 2007. In other words, all quantities on the left hand side are expressed as shares of market cap.

Consistent with the main hypothesis, we find that changes in haircuts have strong explanatory power over emergency borrowing. For instance, consider the fourth regression in Table 6. The coefficient on the change in the haircut interacted with the Lehman breakpoint is $1,500$. This means that a 10% increase in haircuts associated with a given collateral type would increase borrowing by $10\% * 1500/1000 = 15\%$ in terms of the bank's August 2007 market cap.[15]

The variable for counterparty risk, the change in LIBOR-OIS, is also significant as is the measure of bank risk, the change in the bank's CDS premium. Combining the interaction terms with the pure change, shows these variables to be positive, but small. Shocks to bank capital are not significant.

Table 7 shows that this effect is concentrated in the largest 20 banks in terms of borrowing.[16] Only the Lehman breakpoint interacted with haircuts is statistically and economically significant. Changes in LIBOR-OIS and bank CDS are not significant, nor is the change in market cap.

4.2 Special Success of TSLF

We next turn to the differences between the three programs. As we noted in the Introduction, two of the programs provided borrowers with Fed funds, while TSLF provided Treasury collateral. We now show that borrowing from TSLF was uniquely sensitive to changes in haircuts.

The results in Table 8 reveal that borrowing in all three programs responds to changes in the

[15] the division by 1000 is because the amounts borrowed are in thousands but market cap is in millions.

[16] In the Appendix Tables 21 and 22 we show the regressions with no breakpoints, and with two breakpoints and the associated interaction terms included.

haircuts on specific asset types after the Lehman break. However, the statistical and economical significance is strongest for TSLF. Borrowing from TAF responds positively and weakly significantly to increases in haircuts when data are matched by collateral type. Borrowing from PDCF shows a negative response in the first period, and is statistically significant after the Lehman breakpoint.

Table 9 includes all three programs in one panel and interacts the three programs with the Lehman indicator and the change in haircuts (a triple diff). TSLF remains very significant. TAF is weakly significant in one specification.[17] PDCF, the standing facility, is not important, perhaps consistent with stigma. The results with respect to TSLF are consistent with the findings of Hrung and Seligman (2015). Hrung and Seligman (2015) study the impact of changes in the supply of U.S. Treasuries from all sources on the GC repo to fed funds spread. They conclude that the TSLF was uniquely effective in mitigating the effects of the crisis, meaning unique in terms of the sources for Treasuries not comparing facilities. In other words, it mattered how Treasuries got into the market.

5 Bilateral Repo and Collateral Re-Use

In the previous section we established that bilateral haircuts explain the composition of collateral brought to the Fed, particularly in the case of TSLF. In this section we argue that what made TSLF special was that it provided Treasuries, rather than Fed Funds.

We first discuss rehypothecation and the shortage of Treasuries, setting the stage for the importance of TSLF. We then turn to event study evidence to establish the unique success of TSLF. Unlike TAF and PDCF, announcement days of TSLF saw sizable and statistically significant positive returns on bank stocks. Finally, we seek to provide direct evidence for the Treasury scarcity view by studying the cross-section of bank stock response to emergency program announcements.

5.1 Treasury Rehypothecation

Pre-crisis rehypothecation of Treasury collateral was related to the shortage of Treasuries and AAA-rated bonds.[18] Many authors have discussed the shortage of safe debt prior to the crisis, e.g., Gourinchas and Jeanne (2012) and Caballero and Farhi (forthcoming). See Caballero et al. for a review of the literature. During the crisis because of a flight-to-quality Treasuries were scarce, as evidenced by the a decline in Treasury general collateral rates; see Hrung and Seligman (2015).

A significant reason for the scarcity prior to the crisis was the large demand for Treasuries from foreigners. Bernanke, Bertaut, DeMarco, and Kamin (2012): "...a large share of the highly rated

[17] After Lehman the remaining investment banks (Goldman and Morgan Stanley) became bank holding companies and hence eligible for TAF.

[18] Treasuries have a convenience yield, consistent with their role as money. See Singh and Aitken (2010) and Mon for background on rehypothecation. See Gorton (2017) for a review of the literature on this.

securities issued by U.S. residents from 2003-2007 was sold to foreigners - 55 percent. This share was even higher than in the 1998-2002 period - 22 percent - even though total net issuance of apparently safe assets rose from $3.1 trillion in the first period to $4.5 trillion in the second period. (The net issuance of private label AAA-rated asset-backed securities outstanding, including MBS, rose from $0.7 trillion in the first period to $2 trillion in the second.)" (p. 8).

Gorton and Muir (2016) provide evidence of this shortage by showing, in a difference-in-differences setting, that an increase in the convenience yield on Treasuries causes repo fails. A "repo fail" is said to occur when one side of the repo contract fails to perform. In particular, when at maturity of the repo the borrower asks for his Treasury back and the lender does not have it.[19]

The increase in repo fails is likely related to collateral chains that develop with rehypothecation. Fleming and Garbade explained such chains: "...a seller may be unable to deliver securities because of a failure to receive the same securities in settlement of an unrelated purchase. This can lead to a daisy chain of cumulatively additive fails: As failure to deliver bonds to B cause B to fail on a sale of the same bonds to C, causing C to fail on a similar sale to D, and so on" (p. 43).[20]

5.2 TSLF Specialness

If the crisis was spurred by lenders in the repo market demanding their cash back, then banks might well be indifferent between obtaining cash by borrowing from TAF or PDCF, or borrowing Treasuries at TSLF. In the first case, banks could repay cash to lenders. In the second case, banks could refinance their repo positions using Treasuries as collateral because Treasury haircuts stayed at zero. If, however, there is a need for Treasuries because of the Treasury rehypothecation multiplier being greater than one, then TSLF is more important. We will see that when going to TSLF to obtain Treasuries, banks took the assets whose haircuts just went up.

Table 10 shows dates with significant announcements on the three emergency facilities, and summarizes the news. We restrict the sample to days where the programs were first announced, or expanded in size or scope. Further, we exclude September 15th, 2008 because it coincides with Lehman failure. We also exclude October 6, 2008 because the announcements on emergency facilities were made simultaneously with announcement of the introduction of interest on excess reserves.

In Table 12 we summarize bank stock returns on these announcement days. The sample consists

[19] Before May 2009 there was no explicit penalty for a repo fail. There was lost interest though when a lender did not return the collateral on time. In May 2009 the Treasury Market Practices Group introduced a "dynamic fails charge." See Garbade et al. (2010).

[20] Note that the chain need not be entirely a repo chain. It could, for example, end when a party posts the Treasuries as collateral in a derivatives transaction, in which case the posting party cannot ask for its return. The chain can only unwind to the extent that it involved repo. Otherwise an agent would have to purchase Treasuries in the market to return to a repo borrower.

of all the banks that borrowed from any of the emergency lending facilities and have stock return data available from Bloomberg. As Table 12 makes clear, only TSLF announcement days saw large and statistically significant effects on the returns on bank stocks. The market viewed TSLF as an uniquely important emergency lending facility.

5.3 Bank Exposure to Scarcity and TSLF Use

In this subsection we provide evidence that obtaining Treasuries to use to unwind rehypothecation chains was a motivation to use TSLF. We investigate the cross sectional heterogeneity of banks with regard to their exposure to the scarcity of Treasuries prior to the crisis. Banks exposed to Treasury scarcity are likely banks exposed to rehypothecation chain risk. These banks are more likely to have reused Treasuries and need to return the Treasuries to their owners during the crisis. We ask which banks were more prone to using TSLF by first looking at an event study and then we examine bank usage of TSLF as a function of their pre-crisis exposure to Treasury scarcity.

Specifically, we carry out a two stage process. Firstly, we use bank stock return data over the period 2000-2007 to calculate each bank's return beta with respect to measures of Treasury scarcity. Secondly, we use these cross-sectional measures to account for bank-level response on TSLF announcement days.

The best measure of Treasury scarcity is aggregate repo fails with respect to Treasuries. A repo fail occurs when either side to a repo transaction cannot consummate the deal at maturity. Gorton and Muir (2016) show that repo fails are a function of the convenience yield on Treasuries (in a difference-in-difference context). Aggregate Treasury repo fails is therefore a direct measure of scarcity. As shown in Figure 3, Treasury repo fails started to become significant around 2000.

Another measure is a spread that captures the convenience yield on Treasuries. The spread is the GC repo rate minus the Fed Funds rate. GC stand for general collateral, which consists of U.S. Treasuries that are essentially equivalent. GC repo is a repo collateralized by U.S. Treasuries.[21] Fed Funds is an uncollateralized loan. So, in general, the GC repo rate should be below the Fed Funds rate. But a shortage of Treasuries will further reduce the GC repo rate, so the change in the spread (which is what we use) is a measure of the convenience yield.

In the second step, we regress bank-level returns on announcement days on the exposure betas. These betas are calculated before the event days, and therefore constitute valid conditioning information. We further control for market betas estimated in the same pre-crisis window.

[21] Singh (2014): "Note that the obligation is to return equivalent collateral, that is to say securities of the same type and value terms, but not the original security." (p. 6)

In sum, the two stage process is:

$$r_t^i = a + \beta^i_{\text{Treasury Fails}} \Delta\text{Treasury Fails} + \eta_t^i \quad (1)$$

$$r^i_{\text{Program Event Days}} = \alpha + \gamma\widehat{\beta}^i_{\text{Treasury Fails}} + \left(\gamma_{\text{Mkt}}\widehat{\beta}^i_{\text{Mkt}}\right) + \epsilon_i \quad (2)$$

Table 14 shows that banks with a large negative Treasury Fails beta—banks which tend to do poorly when there are a lot of Treasury fails—respond positively to TSLF announcements.

Results in Table 15 weakly show that banks with a high Δ(GC-FF spread) beta—banks which tend to do poorly when the GC-FF spread opens up—respond positively to TSLF announcements[22]. However, the relationship with Δ(GC-FF Spread) beta becomes statistically insignificant when controlling for the corresponding market beta.

We illustrate this finding with a scatterplot in Figure 6. The x-axis is the Treasury fails beta and the y-axis is the TSLF announcement day return. If a bank does poorly when there are a lot of Treasury fails it has a large negative fails beta. So we would expect the banks with largest negative betas to do the best during TSLF announcement days, meaning a negative slope. The scatterplot shows the returns of the 100 largest banks in the sample. Note that only primary dealers were allowed to access TSLF—these banks are denoted with larger red dots in the figure. However, even banks that did not enjoy direct access to TSLF benefited from the increased supply of good collateral, as the Treasuries obtained by primary dealers worked their way through rehypothecation chains.

6 Conclusion

The lack of data is the defining feature of a banking system which was unknown prior to the financial crisis. Hence, it is called the "shadow" banking system. The absence of data does not mean that we cannot understand what happened. In this paper, we use repo haircut data from the bilateral repo market and study the dynamics of the financial crisis. We provide evidence of the run on repo by showing that the increase in haircuts on certain asset categories corresponded to banks taking those specific assets to the emergency lending facilities. In other words, there was a run on repo.

There was also significant rehypothecation resulting in TSLF being uniquely important. Prior to the crisis Treasuries were scarce. Consistent with this scarcity we find that TSLF was uniquely important during the crisis. The unique significance of TSLF is consistent with a rehypothecation

[22]GC-FF spread constitutes a one-way arbitrage. When the GC rate is higher than Fed Funds rate, Fed Funds lenders can just lend at the repo market, and receive collateral. However, when collateral is scarce, lenders are willing to accept a much lower rate on GC lending in order to get hold of Treasuries. Figure 1 shows that the spread is typically zero or negative.

multiplier greater than one. This means that there was also a run on U.S. Treasuries among parties in rehypothecation chains. Parties in the chain wanted their Treasuries returned, but lenders did not have them and failed. This run corresponds to a run for Treasuries. Treasuries are money too in the wholesale banking system. Finally, we confirm that the banks most exposed to Treasury scarcity benefited the most from announcements that TSLF was expanded in terms of acceptable collateral, extended in time.

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7 Tables

Category	2007Q2	% Total	2009Q1	% Total	Change
Statistical Discrepancy	642	35%	63	7%	-579
Net ROW	519	28%	53	5%	-466
MMF	435	24%	578	59%	143
Municipal	144	8%	129	13%	-15
GSE	48	3%	97	10%	49
Other Mutual Funds	43	2%	24	3%	-18
Non-financial	9	0%	7	1%	-1
Pensions	4	0%	3	0%	-1
Insurance	7	0%	17	2%	11
Total	**1,851**		**973**		**-878**

Table 3: Repo Funding. 2007Q1 and 2009Q1. Billions of USD. Source Financial Accounts of the United States.

Table 4: Types of Collateral Used in the Programs. Classifications as reported in Fed data. Amounts in millions USD. Lehman Break refers to the third breakpoint in haircut data, on September 5th, 2008. Table sorted by total amount of collateral in category.

	Total			After Lehman Break			
Collateral Type	TAF	TSLF	PDCF	TAF	TSLF	PDCF	Total
Agency MBS	654	5,335	680	547	4,080	93	6,669
Commercial Loans	5,114			3,400			5,114
ABS	3,334	780	799	2,023	662	573	4,913
Corporate Instruments	1,127	1,190	2,345	641	1,190	2,194	4,662
Other MBS	1,207	2,003	872	514	999	470	4,081
Equity			2,174			2,174	2,174
Munis	407	255	1,394	192	255	1,341	2,056
Commerical Mortgages	1,772			1,152			1,772
Residential Mortgages	1,761			1,233			1,761
Consumer Loans	1,590			1,221			1,590
Other	0	0	1,133	0	0	1,133	1,134
International	800	1	13	634	1	13	814
Treasury, Agency	291	179	132	173	82	115	601
Loans			123			123	123
Total	18,055	9,743	9,665	11,730	7,270	8,227	37,463

Table 5: Types of Collateral Used in the Programs. Classifications as reported in Fed data. Amounts in millions USD. Lehman Break refers to the third breakpoint in haircut data, on September 5th, 2008. Table sorted by total amount of collateral in category.

	Total			After Lehman Break			
Collateral Rating	TAF	TSLF	PDCF	TAF	TSLF	PDCF	Total
AAA	3,431	2,527	1,952	1,919	1,407	1,413	7,910
Agency MBS		5,335	680		4,080	93	6,015
BBB-B	403	549	1,436	297	549	1,293	2,388
Equity			2,174			2,174	2,174
Other Investment Grade	1,747			924			1,747
A	702	449	564	543	449	490	1,715
AA	641	364	539	353	364	474	1,545
Treasury, Agency	894	179	132	688	82	115	1,205
CCC or lower			491			491	491
A1-A3		339	72		339	67	411
Loans			123			123	123
Total	7,819	9,743	8,161	4,723	7,270	6,733	25,723

7.1 Bank-Collateral-Program Level Regressions

Table 6: Bank-Collateral-Program Level Regressions. Weekly data 12/21/2007 to 1/30/2009. The left hand side variable is the change in amount borrowed by a given bank from a given program, collateralized by a type of collateral. The left hand side variable is the change in amount borrowed by a given bank from a given program, collateralized by a type of collateral, normalized by borrower market cap on 8/1/2007. Standard errors in all specifications double-clustered by week and bank. Fixed effects included on the borrower-collateral level.

	Collateral Rating			Collateral Type		
	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount
Δ Haircut	-39.69	-31.75	-9.647	98.19	94.74	117.8**
	(-0.32)	(-0.28)	(-0.09)	(1.54)	(1.68)	(2.04)
Lehman X Δ Haircut	1355.6***	1303.7***	1197.2***	1583.8***	1493.9***	1305.4***
	(4.78)	(5.28)	(5.01)	(7.07)	(7.95)	(6.33)
Indicator Lehman	-4.112	-3.797	-3.401	-4.183	-4.013	-3.389
	(-0.93)	(-0.80)	(-0.67)	(-0.94)	(-0.75)	(-0.64)
Δ Libor-OIS Spread		72.90**	62.93*		81.57**	70.33*
		(2.17)	(1.84)		(2.20)	(1.92)
Lehman X Δ Libor-OIS		-68.63**	-58.93*		-74.50**	-63.87*
		(-2.10)	(-1.76)		(-2.10)	(-1.81)
Δ Market Cap		11.30	-22.89		4.236	-42.52
		(0.29)	(-0.64)		(0.11)	(-1.04)
Lehman X Δ Market Cap		-16.89	29.00		-16.97	60.66
		(-0.40)	(0.67)		(-0.35)	(1.05)
Δ CDS			-23.19**			-26.93**
			(-2.44)			(-2.29)
Lehman X Δ CDS			26.13**			34.64***
			(2.58)			(2.82)
Observations	3624	3624	3624	2801	2801	2801
R^2	0.061	0.066	0.070	0.065	0.071	0.079

t statistics in parentheses
30 Oct 2017
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 7: Bank-Collateral-Program Level Regressions. Top 20 Borrowing Banks. Weekly data 12/21/2007 to 1/30/2009. The left hand side variable is the change in amount borrowed by a given bank from a given program, collateralized by a type of collateral, normalized by borrower market cap on 8/1/2007. Standard errors in all specifications double-clustered by week and bank. Fixed effects included on the borrower-collateral level.

	Collateral Rating			Collateral Type		
	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount
Δ Haircut	-35.56	-32.51	-10.54	105.2	102.4	126.9*
	(-0.30)	(-0.31)	(-0.10)	(1.59)	(1.75)	(2.08)
Lehman X Δ Haircut	1514.3***	1455.3***	1337.5***	1807.9***	1698.8***	1472.7***
	(4.80)	(5.06)	(4.53)	(6.93)	(7.22)	(5.60)
Indicator Lehman	-4.971	-4.517	-4.167	-4.534	-4.398	-3.815
	(-0.75)	(-0.63)	(-0.51)	(-0.81)	(-0.66)	(-0.59)
Δ Libor-OIS Spread		93.03*	79.03		86.63*	71.94
		(2.00)	(1.57)		(1.85)	(1.51)
Lehman X Δ Libor-OIS		-88.21*	-74.55		-78.60*	-64.68
		(-1.95)	(-1.51)		(-1.76)	(-1.41)
Δ Market Cap		14.97	-26.13		17.70	-37.53
		(0.27)	(-0.52)		(0.36)	(-0.73)
Lehman X Δ Market Cap		-21.82	32.74		-32.38	59.07
		(-0.38)	(0.56)		(-0.55)	(0.83)
Δ CDS			-22.77*			-27.23*
			(-1.91)			(-1.99)
Lehman X Δ CDS			25.54*			35.01**
			(2.05)			(2.47)
Observations	2536	2536	2536	2101	2101	2101
R^2	0.063	0.068	0.071	0.066	0.071	0.079

t statistics in parentheses
30 Oct 2017
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

7.2 Program-by-Program Bank-Collateral Level Regressions.

Table 8: Programs Separately on Bank-Collateral level. Weekly data 12/21/2007 to 1/30/2009. The left hand side variable is the change in amount borrowed by a given bank from a given program, collateralized by a type of collateral, normalized by borrower market cap on 8/1/2007. Standard errors in all specifications double-clustered by week and bank. Fixed effects included on the borrower-collateral level.

	TAF		TSLF		PDCF	
	Δ Amt. R.	Δ Amt. C.	Δ Amt. R.	Δ Amt. C.	Δ Amt. R.	Δ Amt. C.
Δ Haircut	385.4***	263.0*	52.01	127.1	-5049.3***	-3685.6***
	(3.40)	(1.91)	(0.31)	(1.62)	(-4.47)	(-8.00)
Lehman X Δ Haircut	359.2***	525.7*	2748.2***	2279.8***	5086.0***	3448.2***
	(3.81)	(1.99)	(5.17)	(6.18)	(4.49)	(6.36)
Indicator Lehman	-0.943	-2.677	-9.911	-6.552	-12.73	-5.020
	(-0.76)	(-1.03)	(-0.84)	(-0.68)	(-1.32)	(-0.84)
Δ Libor-OIS Spread	27.16**	30.70**	202.9	169.7	-67.62	-115.8
	(2.09)	(2.12)	(1.65)	(1.63)	(-0.95)	(-1.45)
Lehman X Δ Libor-OIS	-26.01**	-32.42**	-196.3	-159.5	70.19	123.6
	(-2.23)	(-2.56)	(-1.62)	(-1.57)	(0.98)	(1.54)
Δ Market Cap	13.53	-9.994	25.67	13.18	-259.6	-220.3
	(0.42)	(-0.29)	(0.46)	(0.34)	(-1.47)	(-1.49)
Lehman X Δ Market Cap	-9.912	5.768	-25.86	-2.083	281.8	271.6*
	(-0.35)	(0.17)	(-0.36)	(-0.03)	(1.59)	(1.84)
Δ CDS	3.137	1.646	-2.253	-6.419	-37.15***	-53.58***
	(0.32)	(0.18)	(-0.08)	(-0.24)	(-3.11)	(-5.95)
Lehman X Δ CDS	-0.478	3.167	5.702	14.79	39.22***	59.36***
	(-0.04)	(0.32)	(0.19)	(0.56)	(3.24)	(6.36)
Observations	1669	1271	1411	1312	690	335
R^2	0.053	0.081	0.076	0.074	0.407	0.375

t statistics in parentheses
19 Oct 2017
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 9: Bank-Collateral Level Regressions with TSLF Separated out. Weekly data 12/21/2007 to 1/30/2009. The left hand side variable is the change in amount borrowed by a given bank from a given program, collateralized by a type of collateral, normalized by borrower market cap on 8/1/2007. Standard errors in all specifications double-clustered by week and bank. Fixed effects included on the borrower-collateral level.

	Collateral Rating			Collateral Type		
	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount
Δ Haircut	-9.647	8.242	4.922	117.8*	122.7*	122.1*
	(-0.09)	(0.07)	(0.04)	(2.04)	(2.12)	(2.11)
Lehman X Δ Haircut	1197.2***	286.3		1305.4***	291.5	
	(5.01)	(1.17)		(6.33)	(1.31)	
Indicator Lehman	-3.401	-3.452	-4.134	-3.389	-3.491	-3.695
	(-0.67)	(-0.70)	(-0.91)	(-0.64)	(-0.70)	(-0.71)
Lehman X Δ Haircut X TSLF		2492.6***	2775.9***		2049.6***	2332.1***
		(4.25)	(5.85)		(7.62)	(8.01)
Lehman X Δ Haircut X TAF			819.6**			604.9*
			(2.86)			(2.14)
Lehman X Δ Haircut X PDCF			8.601			-332.3
			(0.05)			(-1.29)
Δ Libor-OIS Spread	62.93	61.16	60.99	70.33	68.92	68.75
	(1.84)	(1.78)	(1.79)	(1.92)	(1.87)	(1.87)
Lehman X Δ Libor-OIS	-58.93	-57.80	-57.27	-63.87	-62.99	-62.74
	(-1.76)	(-1.71)	(-1.70)	(-1.81)	(-1.77)	(-1.76)
Δ Market Cap	-22.89	-19.83	-20.29	-42.52	-41.17	-41.33
	(-0.64)	(-0.56)	(-0.57)	(-1.04)	(-1.00)	(-1.01)
Lehman X Δ Market Cap	29.00	23.92	26.98	60.66	53.54	56.54
	(0.67)	(0.57)	(0.64)	(1.05)	(0.95)	(0.99)
Δ CDS	-23.19*	-23.36*	-23.20*	-26.93*	-27.06*	-26.94*
	(-2.44)	(-2.48)	(-2.45)	(-2.29)	(-2.12)	(-2.06)
Lehman X Δ CDS	26.13*	26.02*	26.16*	34.64**	34.28*	34.54*
	(2.58)	(2.67)	(2.70)	(2.82)	(2.64)	(2.41)
Observations	3624	3624	3624	2801	2801	2801
R^2	0.070	0.085	0.086	0.079	0.086	0.087

t statistics in parentheses
30 Oct 2017
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

8 Program Effectiveness

Table 10: Event Days. Announcement late in the day on 9/14/2008 excluded because it coincides with Lehman bankruptcy. Announcement on 10/6/2008 excluded because interest on excess reserves announced on same day.

Date	Program	Include	Description
03/16/2008	PDCF	Y	Facility announced. Minimum six months, until September 2008.
07/30/2008	PDCF	Y	Facility extended through January 30, 2009.
09/14/2008	PDCF		Eligible collateral broadened.
12/02/2008	PDCF	Y	Program extended through April 30, 2009.
02/03/2009	PDCF	Y	Program extended through October 30, 2009.
06/25/2009	PDCF	Y	Program extended through February 1, 2010.
12/12/2007	TAF	Y	Facility announced.
03/07/2008	TAF	Y	Size announcement. Increase.
05/02/2008	TAF	Y	Size announcement. Increase.
07/30/2008	TAF	Y	Introduction of 84-day loans. Scheduling announcement.
10/06/2008	TAF		Size announcement. Increase. Also, interest on excess reserves announced.
03/11/2008	TSLF	Y	Facility announced.
03/20/2008	TSLF	Y	Details of first auction clarified. Schedule 2 collateral will be accepted.
05/02/2008	TSLF	Y	Expanded collateral authorized by FOMC.
07/30/2008	TSLF	Y	TOP program announced. TSLF extended through January 30, 2009.
08/08/2008	TSLF	Y	TOP program details announced.
09/14/2008	TSLF		Expanded collateral. Increase in auction frequency.
12/02/2008	TSLF	Y	Program extended through January 30, 2009.
02/03/2009	TSLF	Y	Program extended through October 30, 2009.

Table 11: Bank Stock Returns on Program Event Days. *Ex Post* Top 20 borrowers from the three facilities combined.

Bank	TAF	TSLF	PDCF	t(TAF)	t(TSLF)	t(PDCF)
Bank of America Corp	1.047	3.313	0.800	0.325	1.783	0.476
Royal Bank of Scotland Group P	3.117	5.091	1.436	0.558	2.615	1.353
Citigroup Inc	0.498	4.941	-0.759	-0.289	2.494	0.213
Barclays Plc	-2.717	0.406	1.452	0.582	0.215	-1.218
Deutsche Bank AG	1.737	2.838	-0.718	-0.346	1.936	1.082
Wells Fargo & Co	2.652	4.314	0.746	0.361	2.761	1.435
HBOS Plc	-3.308	3.141	2.786	0.908	1.253	-0.934
JPMorgan Chase & Co	3.805	3.336	0.445	0.242	2.403	2.317
Merrill Lynch & Co Inc	3.759	6.610	0.502	0.178	2.866	1.152
Wachovia Corp	7.095	8.660	1.211	0.276	2.414	1.399
Credit Suisse Group AG	0.159	2.169	1.131	0.630	1.598	0.099
Societe Generale SA	-1.389	0.221	-0.131	-0.057	0.136	-0.779
Goldman Sachs Group Inc	-0.408	2.265	1.171	0.714	1.826	-0.278
UBS AG	-2.246	1.132	-0.430	-0.210	0.781	-1.414
Morgan Stanley	1.057	6.186	1.758	0.698	3.249	0.469
Commerzbank AG	0.550	1.947	-0.974	-0.417	1.179	0.304
BNP Paribas SA	-0.497	0.380	0.489	0.232	0.255	-0.305
Mitsubishi UFJ Financial Group	-1.265	-1.114	-0.220	-0.164	-1.018	-1.055
UniCredit SpA	0.056	0.047	-0.114	-0.051	0.030	0.032
Dexia SA	-1.020	1.631	1.165	0.435	0.863	-0.492
Total	0.634	2.876	0.587	0.363	2.348	0.438

Table 12: Bank-Level Event Study. Daily returns 2007-2011. Sample consists of all banks that borrowed from Fed Facilities and have stock returns available from Bloomberg. Standard errors clustered by day.

	Daily Return				
TAF	-0.00606			-1.178	
	(-0.02)			(-1.73)	
TSLF		2.256*		3.059***	
		(2.49)		(3.49)	
PDCF			0.496	-1.097	
			(0.43)	(-0.95)	
Any Program					1.192
					(1.54)
Constant	-0.0372	-0.0498	-0.0392	-0.0460	-0.0478
	(-0.59)	(-0.79)	(-0.62)	(-0.73)	(-0.76)
Observations	184262	184262	184262	184262	184262
R^2	0.000	0.001	0.000	0.002	0.001

Table 13: Returns on Emergency Lending Program Announcement Event Days. Fama-French Banking and Trading industry returns.

Date	TAF	TSLF	PDCF	F-F Banking	F-F Trading
12/12/2007	Y			-1.96	0.63
03/07/2008	Y			0.48	-0.27
03/11/2008		Y		8.29	7.40
03/17/2008			Y	-0.14	-6.09
03/20/2008		Y		7.14	8.24
05/02/2008	Y	Y		-0.23	0.59
07/30/2008	Y	Y	Y	2.28	1.81
08/08/2008		Y		3.33	3.70
12/02/2008		Y	Y	7.85	4.95
02/03/2009		Y	Y	-3.78	0.90
06/25/2009			Y	2.23	1.52

Table 14: Pre-Crisis Betas and Response to Facility Announcements. Treasury Repo Fails Betas. Betas calculated using daily return data from 2000-2007.

	TAF		TSLF		PDCF	
β Fails Total	-0.893	-1.000	-16.53***	-7.393*	-12.86**	-8.876
	(-0.44)	(-0.44)	(-4.31)	(-2.01)	(-3.03)	(-1.92)
β Market		-0.0376		3.212***		1.402*
		(-0.11)		(5.76)		(2.00)
Constant	0.148	0.171	2.207***	0.186	0.551*	-0.331
	(1.43)	(0.72)	(11.34)	(0.48)	(2.56)	(-0.68)
Observations	98	98	98	98	98	98
R^2	0.002	0.002	0.162	0.379	0.087	0.124

Table 15: Pre-Crisis Betas and Response to Facility Announcements. GC-FF Spread Betas. Betas calculated using daily return data from 2000-2007.

	TAF		TSLF		PDCF	
β GC-FF	0.0684	0.0669	1.141*	0.129	0.469	-0.0881
	(0.24)	(0.23)	(2.02)	(0.26)	(0.77)	(-0.14)
β Market		0.00518		3.652***		2.011**
		(0.02)		(6.77)		(2.97)
Constant	0.141	0.138	2.090***	-0.110	0.494*	-0.717
	(1.33)	(0.62)	(9.81)	(-0.30)	(2.15)	(-1.54)
Observations	98	98	98	98	98	98
R^2	0.001	0.001	0.041	0.353	0.006	0.090

Figure 1: Haircut Index. Matched banks' market cap and value-weighted CDS rate. Fed Funds target and effective rate. Libor-OIS, GC Repo-Treasury, and GC Repo-Fed Funds spreads. Red vertical lins depict haircut data breakpoints. Haircut index is the equal-weighted average of haircuts in nine categories. Market Cap is in billions USD. CDS in percent. Effective and target Fed Funds rate in percent. Libor-OIS and General Collateral-1m Treasury spreads in percent.

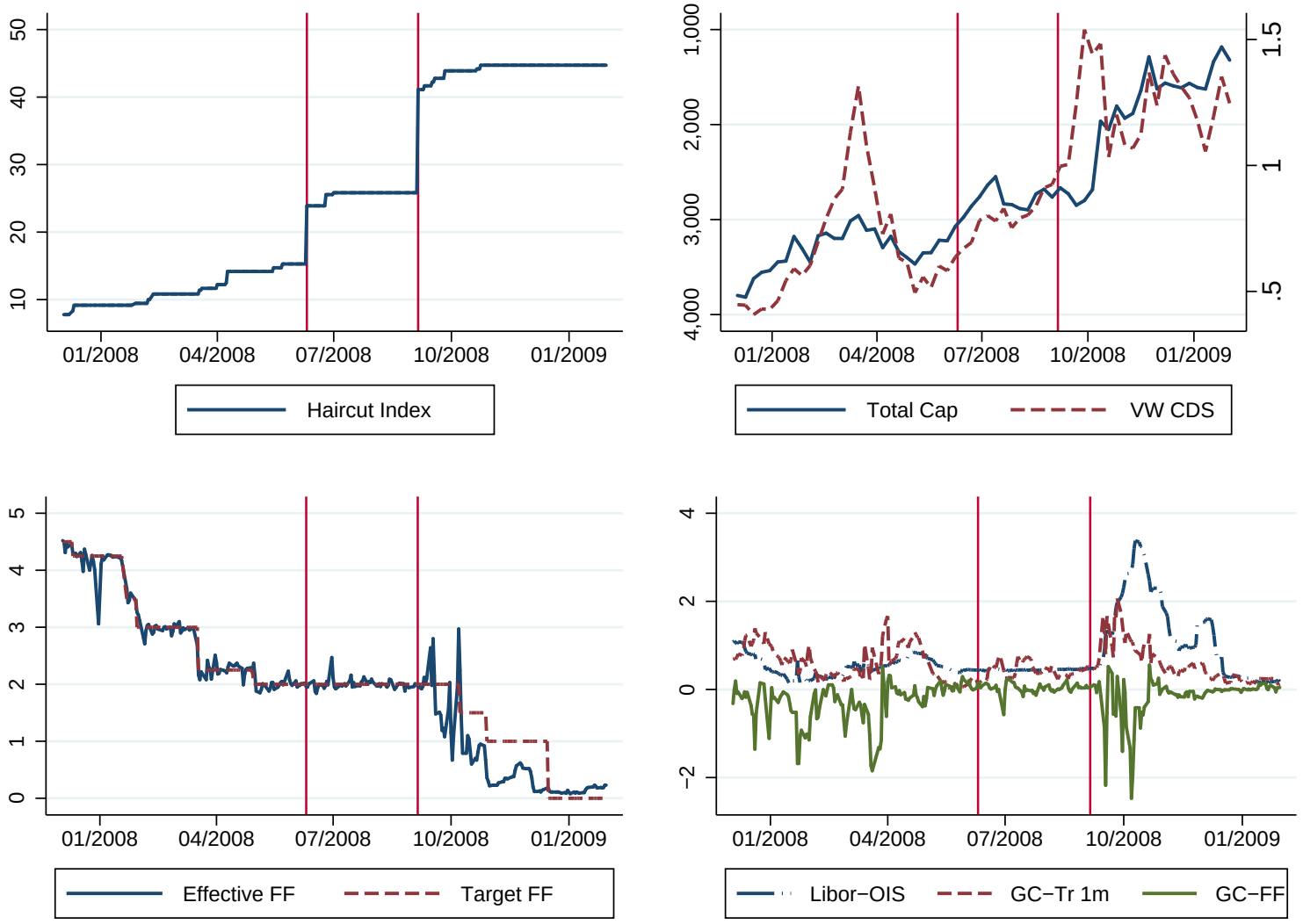


Figure 2: Asset side of Fed balance sheet. Red vertical lines depict haircut data breakpoints. Until the Lehman breakpoint Fed sterilized emergency lending operations by selling Treasuries. After Lehman the Fed substantially increased balance sheet size as it gained the ability to pay interest on excess reserves to control effective Fed Funds rate.

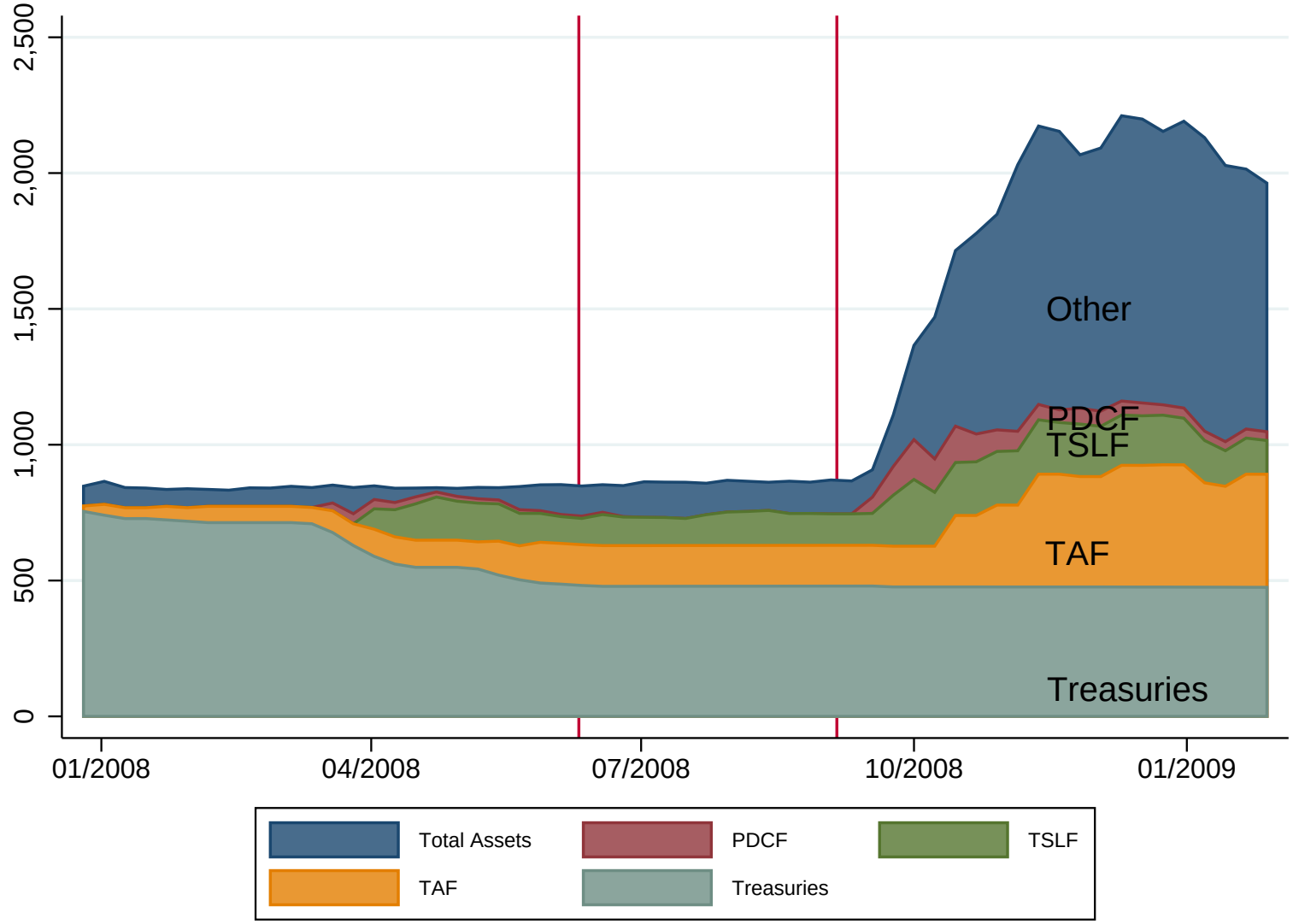


Figure 3: Primary Dealer Treasury Fails to Receive or Deliver.

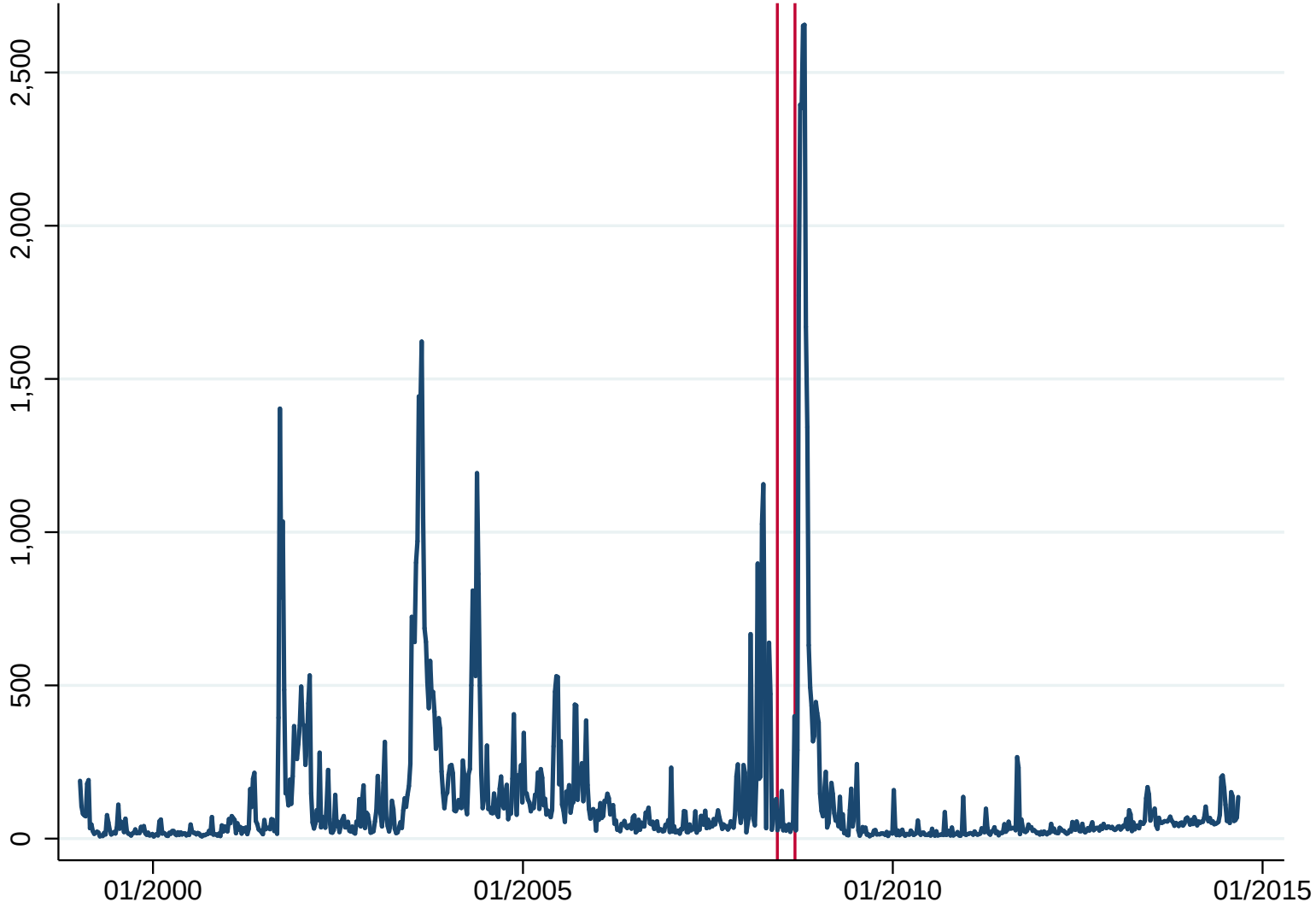


Figure 4: Total amount of borrowing outstanding from each facility. Amounts in billions of USD. Share of total borrowing matched to haircut data denoted by green and red lines. Repo haircut data breakpoints denoted with vertical red lines.

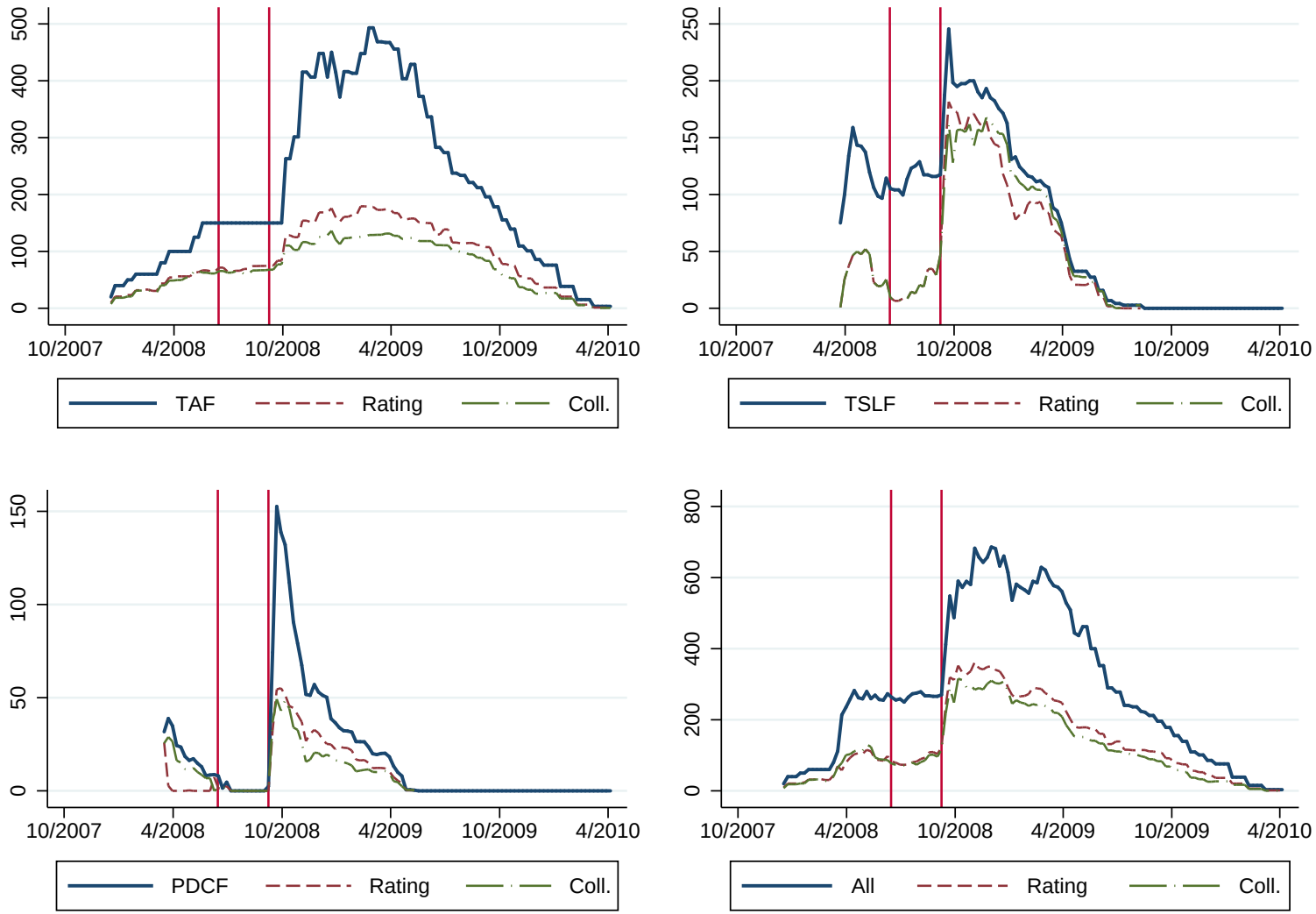


Figure 5: Auction Prices and Quantities. All rates reported in annualized percent terms. TSLF and TAF rates calculated as value-weighted averages across loans. Auction limits and total amounts borrower reported in billions of USD.

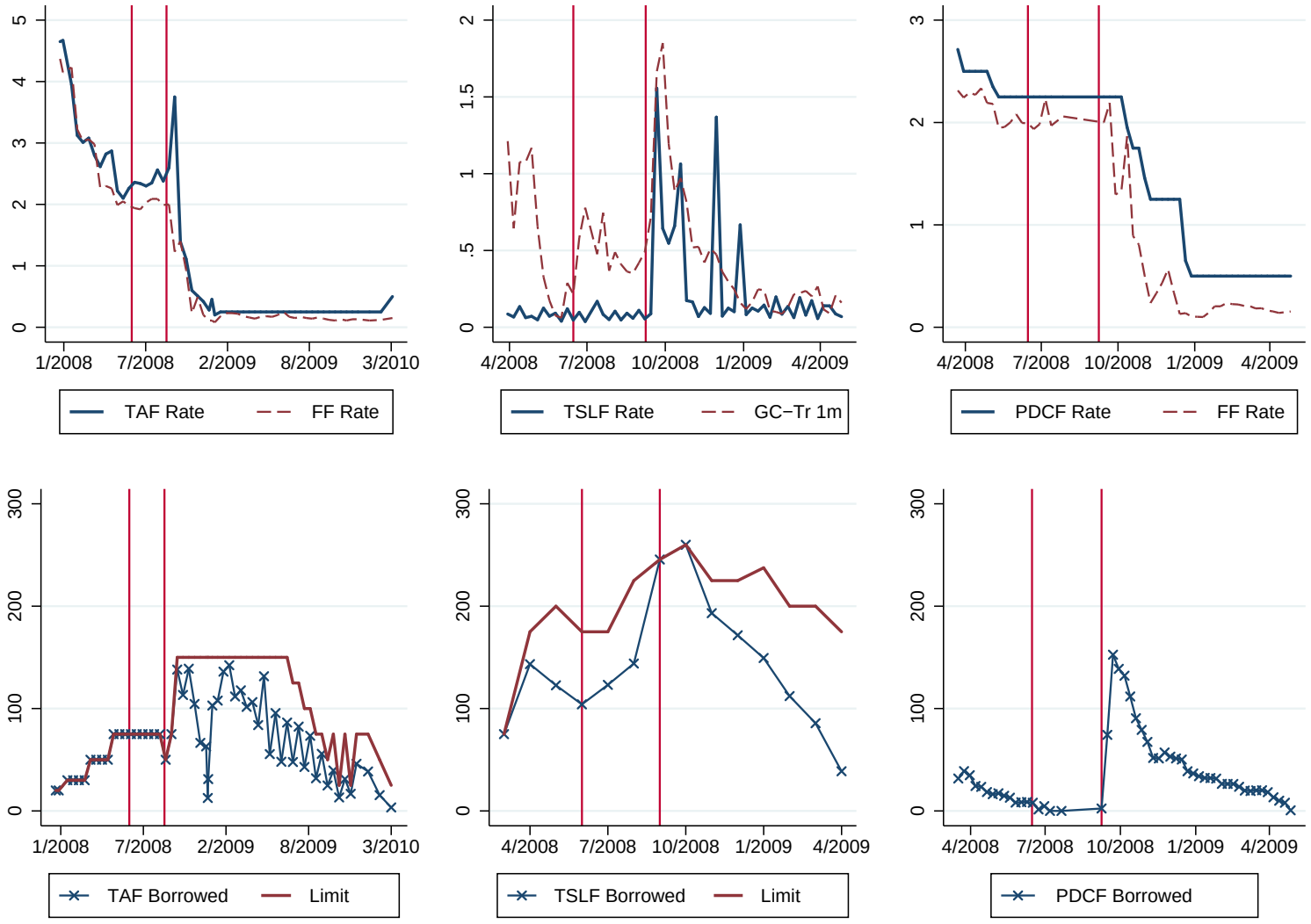
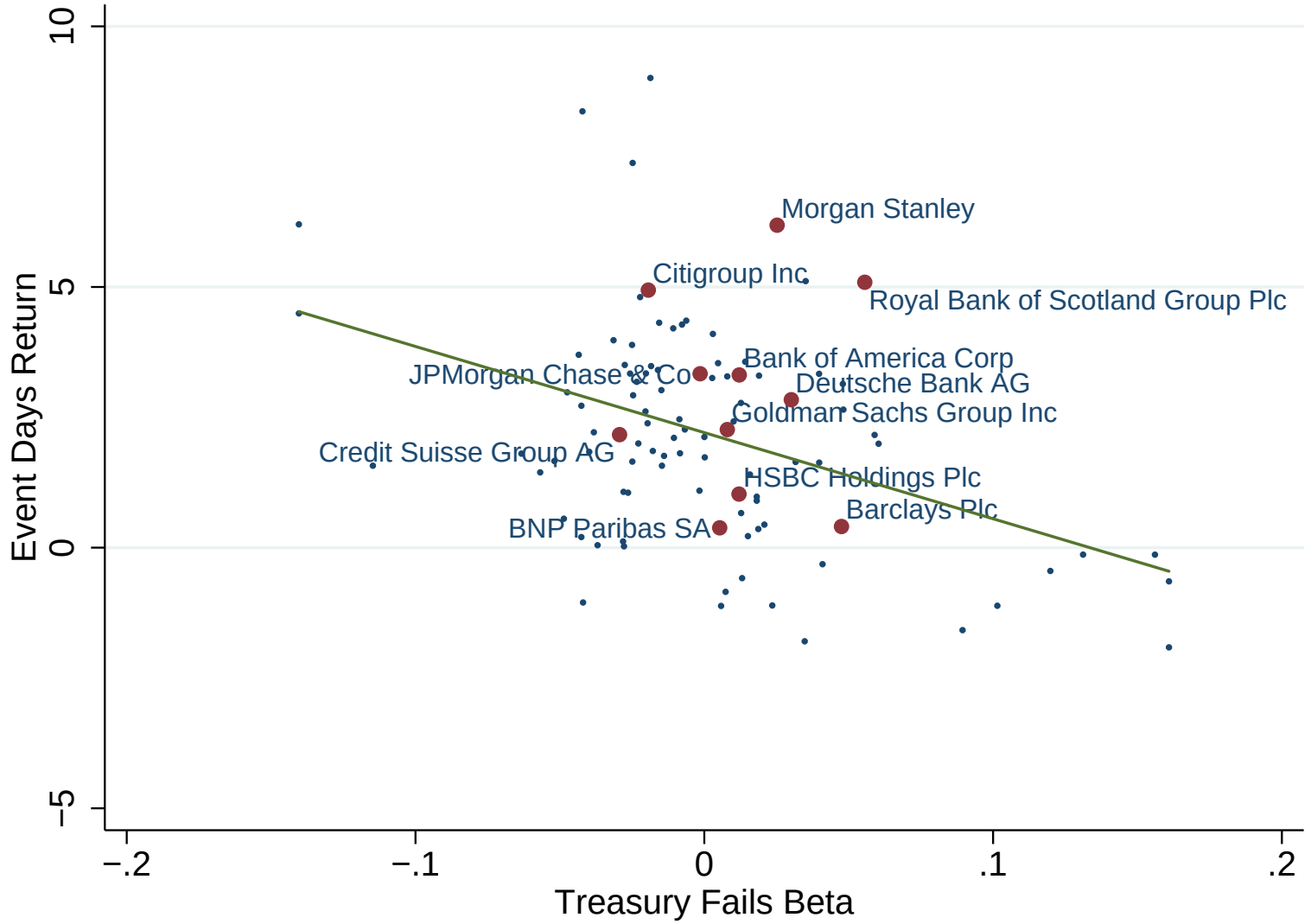


Figure 6: Treasury Fails Betas and Response to TSLF Announcements. Betas calculated using daily bank stock return data from 2000 to 2007. Banks eligible to borrow from TSLF marked in red.



Appendix

Table 16: TAF match to haircut categories. Nine categories of private repo haircut data in columns.

	BBB+ / A Corporates	AA-AAA Corporates	A-AAA ABS-Auto / CC / SL	AA-AAA ABS-RMBS / CMBS	Below AA ABS-RMBS / CMBS	AA-AAA CLO	Unpriced ABS / MBS / All Sub-Prime	AA-AAA CDO	Unpriced CLO / CDO
Collateral Rating									
Treasury, agency									
Other AAA		1	1	1		1		1	
Aa/AA		1	1	1		1		1	
A	1		1		1				
Baa/BBB	1				1				
Other investment-grade									
Collateral Type									
Commercial loans									
Residential mortgages									
Commercial real estate loans									
Consumer loans									
U.S. Treasury/agency securities									
Municipal securities									
Corporate market instruments	1	1				1		1	1
MBS/CMO: agency-guaranteed				1					
MBS/CMO: other				1	1		1		
Asset-backed securities			1	1	1		1		
International securities									

Table 17: TSLF match to haircut categories. Nine categories of private repo haircut data in columns.

	BBB+ / A Corporates	AA-AAA Corporates	A-AAA ABS-Auto / CC / SL	AA-AAA ABS-RMBS / CMBS	Below AA ABS-RMBS / CMBS	AA-AAA CLO	Unpriced ABS / MBS / All Sub-Prime	AA-AAA CDO	Unpriced CLO / CDO
Collateral Rating									
U.S. Treasury/agency									
MBS/CMO: agency backed				1					
Aaa/AAA		1	1	1		1		1	
Aa/AA		1	1	1		1		1	
A	1		1		1				
Baa/BBB	1				1				
Ba/BB									
B									
Caa/CCC or Lower									
P-1/A-1									
P-2/A-2									
P-3/A-3									
Collateral Type									
U.S. Treasury/agency									
Municipal									
Corporate	1	1				1		1	1
MBS/CMO: agency backed				1					
MBS/CMO: other				1	1		1		
Asset-backed			1	1	1		1		
International									
Other									

Table 18: PDCF match to haircut categories. Nine categories of private repo haircut data in columns.

	BBB+/ A Corporates	AA-AAA Corporates	A-AAA ABS-Auto / CC/SL	AA-AAA ABS-RMBS /CMBS	Below AA ABS-RMBS/CMBS	AA-AAA CLO	Unpriced ABS / MBS / All Sub-Prime	AA-AAA CDO	Unpriced CLO / CDO
Collateral Rating									
US Treasury / agency									
MBS/CMO: agency-backed				1					
Aaa/AAA		1	1	1		1		1	
Aa/AA		1	1	1		1		1	
A	1		1		1				
Baa/BBB					1				
Ba/BB					1				
B					1				
Caa/CCC or Lower					1		1		1
P-1/A-1									
P-2/A-2									
P-3/A-3									
Ratings unavailable									
Uncategorized investment grade									
Loans									
Equity									
Collateral Type									
U.S. Treasury / agency									
Municipal									
Corporate market instruments	1	1				1		1	1
MBS/CMO: agency-backed									
MBS/CMO: other				1	1		1		
Asset-backed			1	1	1		1		
International									
Equity									
Loans									
Other									

Table 19: Average margins used by Fed emergency lending programs. Margins were a function of both type of collateral used, and maturity of collateral. We merge the margin tables to categories of collateral reported in the loan-level data. In this table we report the average margins that apply to each category in during the sample period of the regressions, 12/2007-2/2009. TSLF and PDCF used a program-specific haircut table. TAF used the regular discount window haircuts. Source: Fed website.

Collateral Type	**TAF**	**TSLF**	**PDCF**
Treasury, Agency	0.95	0.97	0.97
Agency MBS	0.95	0.95	0.95
International	0.91	0.94	0.94
Corporate	0.95	0.94	0.94
Municipal	0.95	0.94	0.94
Other MBS	0.95	0.94	0.93
ABS	0.95	0.94	0.92
Collateral Rating	**TAF**	**TSLF**	**PDCF**
Treasury, Agency	0.95	0.97	0.97
Agency MBS	0.96	0.95	0.95
AA	0.95	0.94	0.94
A	0.95	0.94	0.94
AAA	0.95	0.94	0.94
BBB-B	0.95	0.94	0.93
CCC or lower			0.92

Table 20: Top 100 Banks in Data by day-times-dollar amount borrowed. Mean amount refers to average borrowing outstanding in the sample period. Bloomberg and Markit identifiers (if available).

Rank	Bank	Bloomberg ID	Markit ID	Mean amount	Initial Cap
1	Bank of America Corp	BAC US	BACF	38,870	211,331
2	Citigroup Inc	C US	C	27,762	231,741
3	Royal Bank of Scotland Group P	RBS LN	RBOS	24,416	111,493
4	Deutsche Bank AG	DBK GR	DB	23,269	71,296
5	Barclays Plc	BARC LN	BACR	19,185	90,063
6	Merrill Lynch & Co Inc	MER US	MER	17,383	63,420
7	Wells Fargo & Co	WFC US	WFC	16,916	115,762
8	Credit Suisse Group AG	CSGN VX	CRDSUI	16,135	77,237
9	JPMorgan Chase & Co	JPM US	JPM	15,316	150,825
10	Wachovia Corp	WB US	WB	14,909	89,194
11	Goldman Sachs Group Inc	GS US	GS	13,743	76,669
12	UBS AG	UBSN VX	UBS	12,966	118,212
13	Bear Stearns Cos LLC	2942331Q US	BSC	12,544	13,737
14	Lehman Brothers Holdings Inc	LEHMQ US	LEH	12,475	32,282
15	Morgan Stanley	MS US	MWD	12,266	67,763
16	Dresdner Bank AG	DRB GR	DRSDNR	12,065	27,511
17	HBOS Plc	HBOS LN	HBOS	10,924	71,439
18	Norinchukin Bank	NORZ JP	NORBK	10,001	
19	Societe Generale SA	GLE FP	SOCGEN	8,858	79,379
20	Dexia SA	DEXB BB	DEXGRP	7,301	32,843
21	Countrywide Financial Corp	CFC US		6,446	16,152
22	Regions Financial Corp	RF US	RF	6,136	21,562
23	BNP Paribas SA	BNP FP	BNP	5,727	103,277
24	UniCredit SpA	UCG IM	UCBAG	5,119	87,222
25	Mitsubishi UFJ Financial Group	8306 JP	MITSUFJ	4,987	110,833
26	Hypo Real Estate Holding AG	HRX GR	HREH-HREBAG	4,933	8,114
27	Bayerische Landesbank	BLGZ GR		4,608	
28	Fortis Bank SA/NV	FBAVP BB	FORTIS-Banque	4,484	49,523
29	Credit Agricole SA	ACA FP	ACAFP	4,429	62,394
30	Cooperatieve Centrale Raiffeis	RABO NA		3,940	
31	BB&T Corp	BBT US	BBT	3,920	21,261
32	State Street Corp	STT US		3,765	26,727
33	US Central Federal Credit Unio	1016Z US		3,667	
34	KeyCorp	KEY US	KEY	3,546	13,585
35	Toronto-Dominion Bank	TD CN	TD	3,514	46,170
36	Sumitomo Mitsui Financial Grou	8316 JP	SUMIBK	3,453	66,524
37	Fifth Third Bancorp	FITB US	FITB	3,379	19,923
38	Allied Irish Banks Plc	ALBK ID	AIB	3,185	22,764
39	Royal Bank of Canada	RY CN	RY	3,080	64,882
40	HSH Nordbank AG	9000Z GR	HSH	2,997	
41	WestLB AG	WESTLB GR	WESTLB	2,970	
42	National City Corp	NCC US		2,929	16,722
43	Banco Santander SA	SAN SM	SANTNDR	2,890	116,283
44	SunTrust Banks Inc	STI US	STI	2,352	27,439
45	Ally Financial Inc	ALLY US	ALLYFI	2,269	
46	Mizuho Financial Group Inc	8411 JP	MIZUHO	2,251	75,006
47	Bank of Nova Scotia	BNS CN	BNS	2,243	45,522
48	Landesbank Baden-Wuerttemberg	2525Z GR	LBW	2,204	
49	DZ Bank AG Deutsche Zentral-Ge	DZBK GR		2,020	
50	First Horizon National Corp	FHN US		1,989	4,003

Rank	Bank	Bloomberg ID	Markit ID	Mean amount	Initial Cap
51	Sovereign Bank/Wyomissing PA	15019Z US		1,854	
52	Standard Chartered Plc	STAN LN	STAN	1,818	44,977
53	Banco Bilbao Vizcaya Argentari	BBVA SM	BBVSM	1,695	86,484
54	Arab Banking Corp/Bahrain	ABC BI	ARABBC	1,691	2,020
55	Marshall & Ilsley Corp	MI US	MI	1,636	8,619
56	Governor & Co of the Bank of	BKIR ID		1,624	18,925
57	Comerica Inc	CMA US	CMA-Bank	1,553	8,019
58	ABN AMRO Group NV	3584485Z NA	AAB	1,500	
59	National Australia Bank Ltd	NAB AU	NAB	1,500	49,653
60	MetLife Inc	MET US	MET	1,389	40,855
61	Discover Financial Services	DFS US		1,347	10,919
62	PNC Financial Services Group I	PNC US	PNC	1,316	23,075
63	Natixis	KN FP	CCBP-NATIXI	1,212	25,720
64	Sparkassen- und Giroverband He	8142178Z GR		1,137	
65	Credit Mutuel-CIC Group	CMUT FP		1,117	
66	Canadian Imperial Bank of Comm	CM CN	CM	1,079	28,662
67	Erste Group Bank AG	EBS AV	ERGBA	1,064	23,414
68	Washington Mutual Inc	WAMUQ US	WM-FinCorp	1,026	33,298
69	Norddeutsche Landesbank Giroze	2531Z GR		942	
70	First Niagara Financial Group	FNFG US		874	1,398
71	BOK Financial Corp	BOKF US		866	3,359
72	Associated Banc-Corp	ASBC US		838	
73	Skandinaviska Enskilda Banken	SEBA SS	SEB	815	22,437
74	Zions Bancorporation	ZION US		802	8,140
75	HSBC Holdings Plc	HSBA LN	HSBC	793	214,894
76	Westpac Banking Corp	WBC AU	WSTP	775	40,586
77	Colonial BancGroup Inc	CBCGQ US		700	3,435
78	Bank of Montreal	BMO CN	BMO	682	30,768
79	M&T Bank Corp	MTB US		661	11,423
80	Beal Financial Corp	6385Z US		653	
81	First BanCorp/Puerto Rico	FBP US		633	749
82	KBC Groep NV	KBC BB	KBC Intl Fin NV	611	47,101
83	Sumitomo Mitsui Trust Holdings	8309 JP	SUMIBK	554	7,871
84	Wilmington Trust Corp	WL US		535	2,695
85	First Commonwealth Financial C	FCF US		531	696
86	Gulf International Bank BSC	3541088Z BI		524	
87	Cantor Fitzgerald LP	5658Z US		516	
88	Texas Capital Bancshares Inc	TCBI US		508	521
89	PrivateBancorp Inc	PVTB US		505	575
90	Lloyds Banking Group Plc	LLOY LN	LBGP	493	63,377
91	Itau Unibanco Holding SA	ITUB4 BZ	ITAU	492	27,190
92	Capmark Financial Group Inc	24956Z US	CAPFIN	485	
93	Glacier Bancorp Inc	GBCI US		483	1,033
94	MidFirst Bank	6578Z US		457	
95	Daiwa Securities Group Inc	8601 JP	DAIWA	440	14,416
96	Bank Hapoalim BM	POLI IT	HAPOAL	436	5,841
97	Huntington Bancshares Inc/OH	HBAN US	HBAN-NatBank	425	7,047
98	Shinkin Central Bank	8421 JP	ZESHBK	400	1,487
99	Synovus Financial Corp	SNV US		395	4,010
100	Doral Financial Corp	DRL US	DORL	392	1,270

9 Internet Appendix

9.1 No Breakpoints

Table 21: Bank-Collateral-Program Level Regressions. No Breakpoint Indicators. Weekly data 12/21/2007 to 1/30/2009. In addition to the Lehman breakpoint, these specifications include a dummy for the first breakpoint identified by the Bai (2010) algorithm. The left hand side variable is the change in amount borrowed by a given bank from a given program, collateralized by a type of collateral. The left hand side variable is normalized by borrower market cap on 8/1/2007. Standard errors in all specifications double-clustered by week and bank.

	Collateral Rating			Collateral Type		
	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount
Δ Haircut	348.1	324.1	292.1	221.1	205.4	187.7
	(1.21)	(1.28)	(1.31)	(1.51)	(1.61)	(1.68)
Δ Libor-OIS Spread		7.872	7.281		13.33	12.08
		(1.39)	(1.45)		(1.35)	(1.44)
Δ Market Cap		9.239	22.81		5.528	33.61
		(0.91)	(1.29)		(0.30)	(1.12)
Δ CDS			3.892			8.088
			(1.96)			(2.01)
Observations	3624	3624	3624	2801	2801	2801
R^2	0.048	0.051	0.053	0.049	0.055	0.061

t statistics in parentheses
30 Oct 2017
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

9.2 Two Breakpoints

Table 22: Bank-Collateral-Program Level Regressions. Two Breakpoint Indicators. Weekly data 12/21/2007 to 1/30/2009. In addition to the Lehman breakpoint, these specifications include a dummy for the first breakpoint identified by the Bai (2010) algorithm. The left hand side variable is the change in amount borrowed by a given bank from a given program, collateralized by a type of collateral, normalized by borrower market cap on 8/1/2007. Standard errors in all specifications double-clustered by week and bank. Fixed effects included on the borrower-collateral level.

	Collateral Rating			Collateral Type		
	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount
Δ Haircut	-71.85	-75.97	6.731	301.6	245.5	344.1
	(-0.10)	(-0.12)	(0.01)	(0.78)	(0.73)	(1.05)
2nd Breakpoint X Δ Haircut	39.97	30.78	-43.73	-227.6	-176.0	-266.1
	(0.06)	(0.05)	(-0.07)	(-0.61)	(-0.55)	(-0.85)
Indicator 2nd Breakpoint	-2.564	-1.507	-0.382	-0.708	-0.423	1.188
	(-0.46)	(-0.24)	(-0.06)	(-0.11)	(-0.05)	(0.15)
Lehman X Δ Haircut	1347.5***	1317.5***	1225.2***	1607.4***	1519.6***	1346.0***
	(5.00)	(5.48)	(5.32)	(7.32)	(8.04)	(6.67)
Indicator Lehman	-2.697	-3.520	-3.501	-3.315	-3.929	-3.770
	(-0.58)	(-0.59)	(-0.51)	(-0.65)	(-0.56)	(-0.61)
Δ Libor-OIS Spread		83.72*	74.52		90.35*	77.49
		(2.23)	(1.95)		(2.16)	(2.01)
2nd Breakpoint X Δ Libor-OIS		-304.1**	-296.0**		-253.8**	-245.9**
		(-3.06)	(-2.98)		(-2.75)	(-3.06)
Lehman X Δ Libor-OIS		224.6*	225.5*		170.5*	174.9*
		(2.60)	(2.71)		(2.21)	(2.59)
Δ Market Cap		-14.38	-62.56		-21.70	-92.42
		(-0.20)	(-0.99)		(-0.32)	(-1.50)
2nd Breakpoint X Δ Market Cap		41.70	76.45		53.59	105.8
		(0.53)	(1.08)		(0.69)	(1.50)
Lehman X Δ Market Cap		-33.25	-8.086		-44.99	4.444
		(-0.92)	(-0.22)		(-1.22)	(0.10)
Δ CDS			-25.51*			-33.54*
			(-2.55)			(-2.18)
2nd Breakpoint X Δ CDS			11.01			18.55
			(1.60)			(1.38)
Lehman X Δ CDS			17.43			22.69**
			(1.93)			(3.33)
Observations	3624	3624	3624	2801	2801	2801
R^2	0.062	0.068	0.071	0.066	0.072	0.081

t statistics in parentheses

30 Oct 2017

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

9.3 Bank-Collateral Level Regressions

Table 23: Bank-Collateral Level Regressions. Weekly data 12/21/2007 to 1/30/2009. Amount borrowed normalized by market cap on 8/1/2007. Standard errors in all specifications double-clustered by week and bank.

	Collateral Rating			Collateral Type		
	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount
Δ Haircut	-1.517	0.0752	11.07	39.94	39.39	47.23*
	(-0.04)	(0.00)	(0.30)	(1.47)	(1.44)	(1.70)
Lehman X Δ Haircut	647.6**	583.6**	543.8**	764.5***	660.1***	525.9***
	(2.54)	(2.53)	(2.39)	(3.62)	(4.43)	(4.02)
Indicator Lehman	-1.457	-1.356	-1.201	-2.268	-1.636	-1.342
	(-0.55)	(-0.51)	(-0.46)	(-0.76)	(-0.39)	(-0.33)
Δ Libor-OIS Spread		27.25	24.54		37.52	34.17
		(1.27)	(1.27)		(1.51)	(1.59)
Lehman X Δ Libor-OIS		-22.84	-20.23		-30.98	-28.21
		(-1.09)	(-1.07)		(-1.36)	(-1.39)
Δ Market Cap		10.66	-10.15		1.790	-29.26
		(0.42)	(-0.46)		(0.06)	(-1.01)
Lehman X Δ Market Cap		-9.074	15.58		21.41	70.48
		(-0.34)	(0.61)		(0.55)	(1.64)
Δ CDS			-15.32**			-19.17***
			(-2.66)			(-2.86)
Lehman X Δ CDS			16.46**			24.56***
			(2.66)			(2.97)
Observations	5167	5167	5167	3839	3839	3839
R^2	0.044	0.046	0.047	0.043	0.046	0.050

t statistics in parentheses
19 Oct 2017
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 24: Bank-Collateral Level Regressions restricting to top 20 borrowers. Weekly data 12/21/2007 to 1/30/2009. Amount borrowed normalized by market cap on 8/1/2007. Standard errors in all specifications double-clustered by week and bank.

	Collateral Rating			Collateral Type		
	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount	Δ Amount
Δ Haircut	3.516	6.167	17.77	65.97*	65.10*	75.73*
	(0.06)	(0.12)	(0.35)	(1.91)	(1.76)	(1.79)
Lehman X Δ Haircut	803.2**	705.6**	645.4**	963.8***	802.2***	621.6***
	(2.56)	(2.50)	(2.28)	(3.40)	(4.47)	(4.68)
Indicator Lehman	-2.001	-1.628	-1.306	-2.825	-1.811	-1.213
	(-0.45)	(-0.34)	(-0.22)	(-0.56)	(-0.28)	(-0.18)
Δ Libor-OIS Spread		42.48	36.34		50.73	43.77
		(1.14)	(1.03)		(1.31)	(1.29)
Lehman X Δ Libor-OIS		-35.86	-29.91		-41.43	-35.60
		(-0.99)	(-0.87)		(-1.19)	(-1.15)
Δ Market Cap		12.15	-19.18		3.390	-45.54
		(0.28)	(-0.49)		(0.08)	(-1.14)
Lehman X Δ Market Cap		-10.61	28.43		29.61	112.2
		(-0.23)	(0.62)		(0.49)	(1.61)
Δ CDS			-17.64*			-24.32***
			(-2.01)			(-3.61)
Lehman X Δ CDS			19.33*			32.35***
			(2.07)			(3.93)
Observations	2847	2847	2847	2300	2300	2300
R^2	0.044	0.047	0.048	0.043	0.047	0.053

t statistics in parentheses
19 Oct 2017
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$