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Hervé Alexandre, Catherine Refait-Alexandre, Larry D. Wall

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European banks and Fed liquidity facilities during the Global Financial Crisis: Good news for the bad and bad news for the good

Hervé Alexandre[a]

Catherine Refait-Alexandre[b]

Larry D. Wall[c*]

Abstract

The Fed operated various liquidity facilities during 2007-10 that were intended to alleviate financial system stress but could have been interpreted as an adverse signal. We analyze the response of the credit default swap market to the announcement and usage of these facilities by European banks. We find that Fed financial assistance tended to reduce market perception of risk if the information was related to Fed's liquidity policies and increased risk perceptions when the information was more about banks' riskiness. We also find the facilities reduced the perceived risk of publicly assisted banks but increased the perceived risk of banks that were not assisted.

Key words: Financial crisis, Federal Reserve lending facilities, European banks

JEL classification: E58, G21, G28

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[a] *DRM, University Paris Dauphine, Place du Maréchal de Lattre de Tassigny 75016 Paris, France. herve.alexandre@dauphine.psl.eu*

[b] *Université de Franche-Comté, CRESE, F-25000 Besançon, France*
30 avenue de l'Observatoire 25000 Besançon, France.
catherine.refait-alexandre@univ-fcomte.fr

[c] *Research Department, Federal Reserve Bank of Atlanta, 1000 Peachtree Street N.E, Atlanta, Georgia 30309-4470, USA. larry.wall@atl.frb.org*

* *Corresponding author: catherine.refait-alexandre@univ-fcomte.fr. Phone number: 33673006476*

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1. Introduction

Central banks were created in part to provide liquidity during periods of financial stress, such as occurred during the Global Financial Crisis in 2007-10, the eurozone crisis of the early 2010s, and the stresses associated with COVID-19 in the spring of 2020. The primary focus of many studies is their direct effect on bank activity, such as lending, and on their incentives to take excessive risk in the future.[1] However, the provision of liquidity may also have a signaling effect on banks and provide information to investors at a time when bank risk levels are difficult to assess. It can also have an impact on financial stability. That effect, if any, will depend on what new information is contained in the announcement of liquidity facilities and in the choice to borrow by individual banks.

The information associated with announcement of new or enhanced lending programs could be positive , that is to reduce market perceptions of banking and banking system risk to the extent it: (a) conveys new information about the central bank's willingness to supply liquidity, or (b) conveys positive information about the bank borrowers. Alternatively, it could convey negative information to the extent it signals that banks in aggregate or individually may be in worse financial condition than was understood by market participants. Market reactions could also be insignificant to the extent that the creation and usage of such facilities either conveys no new information or the positive and negative signals offset each other (such as the good information about increased willingness of central banks to lend being approximately equal to the bad news about the bank or banks condition).

Our paper aims to disentangle these effects by studying changes in credit default swap (CDS) spreads for European banks to evaluate both the market's interpretation of Fed facility creation and of European bank facility usage during the 2007-2010 period. Despite the large-scale use of the facilities by European banks, few studies examine their usage and none of these studies examine the

response of the markets for CDS markets to the creation of these facilities and their usage by European banks.[1] The advantage of studying European banks is that they lacked access to the Federal Home Loan Banks (an alternative quasi-public provider of dollar liquidity) which were an important source of funding for U.S. banks in 2007 and 2008. The advantages of the CDS market are that it more directly corresponds with the Fed's concern about financial stability and that there are some important European banks that have traded CDS but do not have publicly traded equity (government owned and cooperative banks).

We focus on the Fed's four most important crisis related facilities created for which we have individual bank data: Term Auction Facility (TAF), Term Securities Lending Facility (TSLF), Primary Dealer Credit Facility (PDCF), and Commercial Paper Funding Facility (CPFF). Additionally, we consider two other facilities: (a) the discount window for which we have individual bank data and (b) the swap lines with foreign central banks which were reopened during the crisis but for which we have aggregated data.[2] Our paper is the first to consider these different sources of liquidity supply simultaneously, thus providing a broad view. Our sample consists of all 36 European banking groups with outstanding CDS contracts over the period from December 2007 to July 2010. All these banks used one or more of the facilities and 32 banks used the TAF.

Overall, the results are consistent with the CDS market interpreting the announcement and usage of the facilities in a manner consistent with what would be expected given the market's information set. For the sample as a whole, the Fed's announcement of the TAF in December 2007 and its expansion of the number and size of some swap lines after Lehman Brother's bankruptcy in September 2008 are associated with significant reductions in the spreads. These two events shared

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[1] Benmelech (2012) provides some information on the level of foreign banks, including European banks, usage of the TAF and their choice of collateral for obtaining funds from the TAF. Buch et al. (2018) analyze the consequences of the TAF usages by German banks and find a positive influence of on lending. These results are in line with Kick et al. (2020) who find that the German banks with access to Fed liquidity programs benefited from lower rate on the interbank market and passed through lower lending rates to corporates. Helwege et al. (2017) analyze the reasons of the usage of Fed liquidity programs by US and Europeans banks.

two important commonalities: market participants already knew that there was significant distress in the financial system but could not be certain that the Fed would reply with the new or expanded liquidity facility. For the cross-section within our sample, the magnitude of the reaction to some announcements and some facility usage is more favorable for weaker banks (as proxied by banks that ultimately received assistance from their home government) than for the stronger banks. The facilities could be viewed as risk reducing for banks that were already recognized as being under severe stress. However, the facilities could be a negative signal for banks whose condition was more ambiguous.

The paper is organized as follows. Section 2 discusses how this paper contributes to the existing literature on lender of last resort, the global role of the Fed, the experience of European banks during the crisis and the general global financial crisis literature. Section 3 describes the economic context of the 2007-2010 period, provides an analysis of the Federal Reserve's liquidity programs and the usage of the facilities by European banks. Section 4 presents the data and the empirical model. Section 5 presents our main results and discusses some robustness checks. Section 6 concludes.

2. Literature review

This paper contributes to several literatures. One of these is the literature on the role of information in lender of last resort operations. Bagehot (1873) and Thornton (1807) developed early principles for the operation of a lender of last resort, with their recommendations often summarized by what has been called Bagehot's rule to "lend freely at a penalty rate on good collateral."[3] As discussed below, this principle was widely followed by Fed facilities. Nevertheless, an early problem with bank's usage of the Fed's discount window was that of stigma, the belief that borrowing from the discount window would send an adverse signal. Carlson and Rose (2017) explain that this problem was due to a combination of funds being lent at an above market rate and uncertainty about bank conditions. However, a central bank following Bagehot (1873) and Thornton (1807) could in principle have encountered the same problem, so there must be more to the story and indeed, there

is. Both Bagehot (1873) and Thornton (1807) add the condition that loans should only be given to sound banks.[4] Smith and Wall (1992) observe that if central banks followed such a policy, then borrowing from the lender of last resort could send a positive signal. That is that the central bank, based on its information – potentially including confidential information – has a favorable view of the bank's prospects.[5] However, Fed lending is unlikely to send such a positive signal because the Federal Reserve has a long history of lending to failing banks (Schwartz, 1992). We add to this literature with the new result that, given a history of central bank lending to failing banks, strong banks are less positively (or more negatively) affected by the Fed's announcement of some facilities and by the banks' usage of some facilities.

The paper also contributes to a literature on the effect of lender of last resort facilities on European banks during the crisis. Fender and McGuire (2010) suggest that European banks were engaged in substantial maturity transformation in their U.S. dollar denominated portfolios. This left many European banks exposed to the heightened concerns in the interbank funding market, dislocations in the FX swap market starting in August 2007 and later to disruptions in money market funds' ability to provide funding. Benmelech (2012) documented the heavy usage of the Term Auction Facility by European banks to help meet these banks U.S. dollar obligations. We add to this literature by examining the signal sent by central bank lending programs on the financial condition of individual European banks. The banks continued usage of the Fed facilities suggests that on net the facilities helped in stabilizing the banks' condition. However, the magnitude and sometimes the direction of the signaling effect in some cases depended upon how the market likely perceived the condition of the individual bank at the time of the announcement of the facility and/or its usage by the bank.

Third, the paper contributes to the literature on the effect of the Fed's crisis related facilities. Four papers examine the effect of the Fed's facilities on bank equity returns during this period. Cyree et al. (2013) find mixed results depending upon the type of borrower and the timing of the borrowing

for a sample of U.S. domestic banks. Blau et al. (2016) find significantly negative abnormal returns related to the use of the discount window and Term Auction Facility (TAF), also for a sample of domestic banks. Hu and Zhang's (2020) analysis of domestic and foreign banks finds negative abnormal returns for borrowing at the discount window but not for the TAF. Additionally, Acharya et al. (2017) show that domestic and foreign primary dealers with lower cumulative equity returns over the entire period were larger users of the Term Securities Lending Facility (TSLF) and Primary Dealer Credit Facility (PDCF).

This paper improves on the literature about the Fed's facilities in two ways. First, existing studies focus on equity returns whereas CDS spreads are a better measure of whether the actions reduced stress in financial market.[6] Equity values would be a good proxy for reduced stress if the Fed's actions only affected the mean of investors' estimate of bank values. However, to the extent the Fed's facilities also affects the higher order moments of investors' estimate, an increase in equity prices need not imply reduced market stresses. In contrast, CDS spreads as measures of the credit riskiness of banks directly addresses the market concerns about banks' stability. Thus, one of the main contributions of the paper is to provide an analysis of CDS market.

Second, the interpretation of the results in the prior papers is complicated by the fact that domestic banks had access to the Federal Home Loan Banks (FHLBs). Ashcraft et al. (2010) find that the FHLBs provided funding at a lower all-in cost than the Federal Reserve in 2007 and the first half of 2008. Thus, the market might reasonably question why any domestic bank found it necessary to borrow from the Fed in 2007 or the first half of 2008. As a result, U.S. banks were not the largest users of Fed facilities during 2007 and early 2008. This paper's focus on European banks avoids the contamination introduced by US banks access to the FHLBs. European banks had a large need for U.S. dollar (USD) funding starting in the fall of 2007 but unlike domestic banks, the European banks could not access FHLB funding. Hence, European banks were some of the largest users of Federal

Reserve's lending facilities, with their aggregate borrowing peaking at over $900 billion. Despite the large-scale use of the facilities by European banks, few studies examine their usage and none of these studies examine the response of the CDS markets to the creation of these facilities and their usage by European banks. This paper fills this gap in the literature by focusing on European banks that lacked access to the FHLBs.

3. Federal Reserve liquidity programs and their usage by European banks

3.1. The creation of the Fed's liquidity programs

The stress in U.S. dollar markets began when BNP Paribas suspended redemptions from three investment funds on 9 August 2007, causing a spike up in risk premiums as measured by the overnight indexed swap (OIS).[7] The Federal Reserve took measures to encourage discount window borrowing but, the risk premium remained high and the anticipated increase in borrowing did not materialize according to Cecchetti (2009). Thus, the Federal Reserve announced plans on December 12, 2007, to auction 28-day loans through the Term Auction Facility (TAF). The TAF was designed to reduce the stigma associated with borrowing from the Fed, in part because its structure made it an ineffective source of funds for banks currently suffering from a run.[8] This announcement was coordinated with announcements that the Federal Reserve would provide U.S. dollars to the European Central Bank (ECB) and Swiss National Bank via a Central Bank Liquidity Swap (CBLS) to lend to banks in their jurisdictions.[9] The funds provided by these swap lines were available both to the banks in the sample and most other European banks which lacked access to Fed facilities. The creation of the TAF helped bring the Libor – OIS spread down.[10] However, mortgage market conditions continued to deteriorate.

The weakening conditions were adversely impacting some primary dealers, leading the Fed to announce the Term Securities Lending Facility on 11 March 2008. The TSLF allowed primary dealers to exchange certain mortgage-backed securities (MBS) for Treasury securities that could be

more easily financed in repo markets.[11] The date of the first auction was set for 27 March 2008. The TSLF, however, came too late to save Bear Stearns, which was acquired by J.P. Morgan on 16 March 2008, with assistance from the Federal Reserve. After this near failure, the Federal Reserve created the Primary Dealer Credit Facility (PDCF) on 16 March 2008 to provide primary dealers with loans at the primary credit rate on a "broad range of investment-grade debt securities."[12] The Federal Reserve sought to make the TSLF more effective around key financing dates by announcing the creation of the TSLF Options Program (TOP) on 30 July 2008.[13]

Once again market conditions appear to have stabilized for a while, but they took a dramatic turn for the worse when Lehman Brothers Holding Incorporated filed for bankruptcy on 15 September 2008. Lehman's bankruptcy caused losses to holders of its commercial paper, which in turn led to the collapse of one prime money fund. That collapse sparked a general run on prime funds which crippled these funds ability to lend to European banks (see Kacperczyk and Schnabl, 2010). The Federal Reserve responded to the market turmoil in a variety of ways. On 19 September 2008 the Federal Reserve Board announced the creation of the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF). The Federal Reserve established CBLS lines with the Sveriges Riksbank, Danmarks Nationalbank, and the Norges Bank on 24 September. The next day, the Federal Reserve actions announced the Commercial Paper Funding Facility (CPFF), which provided a liquidity backstop to eligible U.S. issuers of unsecured and asset-backed commercial paper. On 13-14 October, the Fed announced that it would remove the caps on its CBLS lines with the Bank of England, the ECB, and the Swiss National Bank. The usage of the various new facilities declined as market conditions improved in 2009 and most facilities were terminated in 2010.

3.2. Usage of Federal Reserve programs by European banks

Forty-nine European banks used the Fed's facilities from 2007 to 2010 (see Table 1).

Table 1. Operations lead by the Federal Reserve to European Banks for each liquidity program

Program	Period (Granting of facilities)	Total Amount worldwide (millions of USD)	Total Amount to European Banks (millions of USD) (% of total amount worldwide)	Maximum % of the FED balance sheet attained for European banks (month and dollar value, millions of USD)*	Number of operations to European Banks	Number of European Banks involved
TAF	12/07 to 03/10	3,818,411	1,944,419 (50.9%)	13.91% (07/08; 126,000)	929	45
TSLF	03/08 to 07/09	2,005,697	1,183,079 (59.0%)	13.56% (09/08; 136,919)	283	8
TOP	08/08 to 06/09	196,995	97,904 (49.7%)	1.47% (11/08; 31,544)	16	6
PDCF	03/08 to 10/08	8,950,992	514,305 (5.7%)	13.41% (04/08; 118.873)	129	7
AMLF	10/08 to 11/08	217,350	238 (0.1%)	0.006% (11/08; 139)	2	1
CPFF	10/08 to 10/09	738,263	318,325 (43.1%)	6.24% (10/08; 107.861)	531	26
Total	12/07 to 03/10	15,927,708	4,058,271 (25.5%)	30.12% (04/08; 267,088)	1890	49

*The % represents the ratio between the total amounts granted during one month for each operation and the average total assets during the same month.

European banks borrowed more from the TAF than from any other program with 45 banks using the facility, 929 times and obtaining a cumulative loan total of $1.9 trillion, which represents 50.9 percent of the total amount of funds loaned. Given that loans were of varying maturities, Table 1 also provides an alternative measure of the scale of borrowing, the ratio of the maximum amount outstanding at any one time relative to the total amount of assets on the Fed's balance sheet at that time. By this measure, Table 1 shows European banks borrowings through the TAF in July 2008 totaled $126 billion, which was 13.9 percent of the Fed's balance sheet.[14] Table 1 also shows that European banks accounted for 25.5% of the lending from all the Fed's liquidity programs and, at their peak, accounted for over 30% of the Fed's balance sheet. Figure 1 shows that the amounts borrowed by European banks from all facilities, the CBLS lines and the discount window loans increased until April 2008. Borrowings resumed their climb after the failure of Lehman, reaching a peak of almost $900,000 billion in December 2008. Thereafter, the amounts fell to zero by early 2010. Meanwhile, we can observe that the one-month Libor started to increase in September 2008 with a peak in October 2008.

Figure 1. European usage of facilities, discount window operations and Central Bank Liquidity Swaps (CBLS) from 2007 to 2010
Monthly average, amount outstanding, millions of USD – Libor USD 1 month
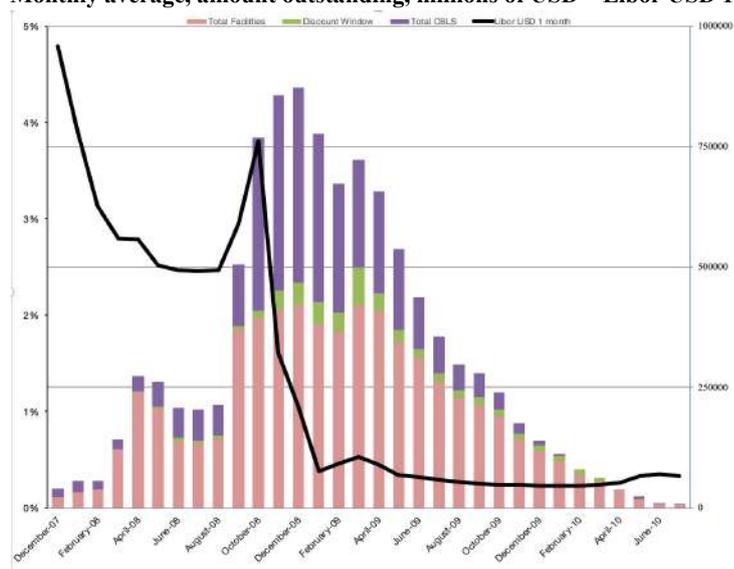
Data source: Federal Reserve

The Federal Reserve's first two liquidity programs allowed European banks with U.S. branches to borrow directly from the Federal Reserve through the TAF program or indirectly from the CBLS by borrowing dollars from the central bank of their home country. Figure 2 shows that the amounts borrowed through the TAF by European banks peaked at over $160 billion in April 2009. Federal Reserve conducted 502 liquidity swap operations with 6 central banks in Europe from December 2007 to May 2010. The ECB drew by far the largest amount. Total worldwide usage of the dollar swap lines peaked in early 2008 at over $600 billion with a peak of over $400 billion due to the various European central banks.

Figure 2. Lending facilities extended to European banks (millions of USD)
Average outstanding amounts per month
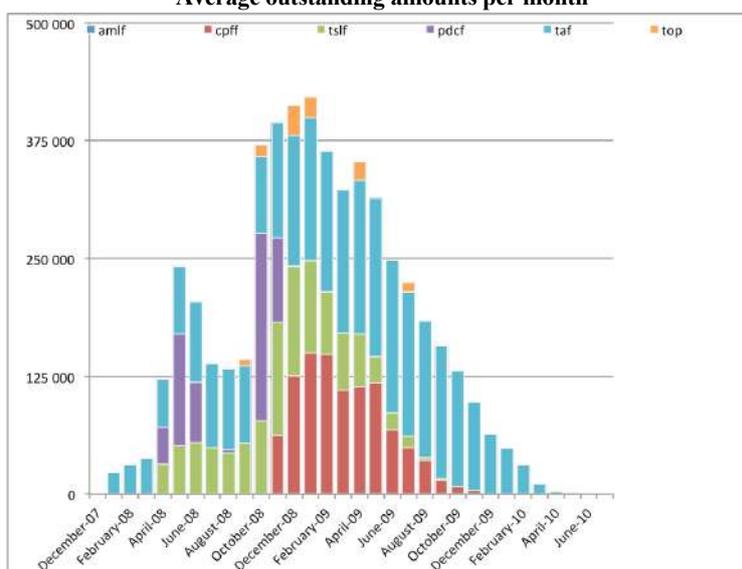
Data source: Federal Reserve

Although the CBLS were important for reaching European banks that did not have U.S. operations, swap lines were a more expensive source of funds than the TAF after Lehman's failure according to Goldberg et al. (2011). Hence, European banks with U.S. operations would have preferred to borrow from the TAF rather than from the central bank of their home country.

European banks took a large fraction of the TSLF (see Table 1), borrowing $1.2 trillion from March 2008 to July 2009. The loans borrowed by Europeans banks represent 59.0% of

the total TSLF granted by the Fed. However, with access to the TSLF limited to primary dealers, only eight banks were involved: Barclays, Deutsche Bank, Royal Bank of Scotland, Crédit Suisse, UBS, BNP-Paribas, HSBC and Dresdner Bank. TSLF Option Program was even less used (6 banks). Figure 2 shows European usage of the TSLF peaked in October 2008, and European usage of the TOP peaked in November 2008.

Only 7 European banks accessed the PDCF program as the program was limited to primary dealers. These 7 banks borrowed $514 billion which is 5.7% of the total amount granted by the Federal Reserve (see Table 1). Figure 2 shows that European banks usage of PDCF was important in April 2008 and in September 2008 but fell rapidly in 2009. The usage of the AMLF program by European banks was minimal with only one European user (Crédit Suisse), borrowing less than $250 million (see Table 1 and Table A.1. in Appendix). European banks took a large fraction of the CPFF program, borrowing over $318 billion from October 2008 to August 2009. During this period, the European banks borrowed 43.1% of the total CPFF granted by the Fed. 26 banks were involved (see Table 1). Access to the CPFF was limited to firms that had been active in the commercial paper market between January and August 2008.

4. Data and empirical method

4.1. Analytical framework and data sample

4.1.1. Analytical framework

We analyze the effect of Fed's announcement of the creation of the facilities and European banks' usage of those facilities on market participants perception of the risk of bank failures. The information contained in the FED's behavior is particularly crucial at a time when there was a great deal of opacity about the banks' real risk.

A decrease in the CDS spread would reflect perceptions of a lower risk of individual banks failing and is consistent with the Fed's financial stability goals. An increase in spreads would

suggest an increase in the perceived risk of failures and would be contrary to the Fed's financial stability goals. We also analyze how the CDS market reacted when one bank obtained funds from a Fed facility. We consider the four main facilities (TAF, TSLF, PDCF and CPFF)[15].

An important question is whether market participants obtained information about the creation and usage of the facilities. Market participants knew about the creation of the facilities as the Federal Reserve issued a public statement announcing each of them. However, individual bank's usage of the facilities was not disclosed until 2011. This raises the question of what did other market participants know about individual bank usage and when did they know it. Like the other papers in this literature, our maintained hypothesis is that other market participants were able to learn about individual bank's usage of Fed facilities immediately after it occurred. Armantier et al. (2011) find support for the hypothesis that banks believed other market participants would learn about facility usage. Specifically, they find that banks paid a higher rate to use the TAF rather than the discount window (because the discount window had greater stigma than TAF). Additionally, Cyree et al.'s (2013), Blau et al.'s (2016), and Hu and Zhang's (2020) analyses find significantly negative abnormal returns related to banks' borrowing from the Fed.[16] One hypothesis is that market participants learned about the usage of the facilities through changes in the borrower's participation in other funding markets. For example, if a bank is aggressively bidding for funds prior to the settlement day for funds for a Fed facility but is inactive after the settlement that would suggest the bank had used the facility. Additionally, the Federal Reserve provided a weekly report with the amount lent out in each Federal Reserve District for the TAF, CPFF and discount window which could help in identifying borrowers.

4.1.2. Sample

Forty-nine European banks obtained funding from the facilities we consider, including six that are subsidiaries of a group (including one state-owned group: Hypo Real Estate Group, and one non-banking group: BMW), three that are state-owned banks and six that are mutual banks (most of which

are German Landesbanks). They represent a very high percentage of European banks, as most of European banks operating in the United-States benefited from the Federal Reserve lending facilities. We aggregate facilities usages up to the group level as the CDS reference debt is for the parent of the group and drop the groups which do not have outstanding CDS contracts which reduces the sample to 36 banking groups (hereafter, often referred to simply as "banks"). Twenty-five banks have their headquarters in the Eurozone, five in the UK, three in Sweden, two in Switzerland and one in Denmark. We identify the banks that obtained government support using Factiva and find twenty-two banks received a bailout or were nationalized. We first consider a period starting on 1st of December 2007 – at the beginning of the FED emergency facilities – and ending on 31 July 2010 – when all the loans were paid back. The analysis also focuses on three subperiods with each new subperiod corresponding with an intensification of the crisis that led to the Fed initiating a new facility or set of facilities. The first subperiod, which we will call before Bear Stearns starts shortly before the creation of the TAF and ends shortly before the collapse of Bear Stearns (from 01/12/07 to 09/03/08 included). The second subperiod, which we call the collapse of Bear Stearns, starts shortly before Bearn Stearns acquisition by JP Morgan Chase and ends shortly before the Lehman bankruptcy (from 10/03/08 and 09/14/08). The third subperiod is the period when market distress was the greatest: between Lehman Brother's collapse (15/09/08) and the release of the results of the Supervisory Capital Assessment Program or SCAP (07/05/09). The SCAP was the Federal Reserve's stress test of the largest U.S. banks and the release of its relatively favorable findings helped contribute to a substantial reduction in financial market stresses.

4.2. Baseline model

4.2.1. Dependent variable

The dependent variable (*CDS Variation*) is the ratio of the change in the CDS spread (or premium) to its initial value:[17]

$$CDS\ Variation_{i,t} = (CDS\ Spread_{i,t} - CDS\ Spread_{i,t-1})/CDS\ Spread_{i,t-1}$$

The spread of a CDS varies according to the default risk of the debtor in question, increasing if the risk increases and vice versa. The CDS spread is expressed as a percentage of the nominal. We use the daily CDS spreads for the senior debt, maturity 5 years. We use the daily iTraxx Index as a benchmark of the global evolution of the CDS market. Both the iTraxx index and individual bank CDS data are obtained from Markit. Figure 3 presents the CDS spreads levels from December 2007 to September 2009 for Barclays (the European bank that borrowed the most from the Fed's facilities) and for the all sample (mean). We can see that the minimum was about 0.5 pb in December 2007 and that the maximum was about 2.5 pb in March 2009. The Index ITraxx goes from a bit less than 50 to about 200.

Figure 3. Time evolution of CDS spread from Dec. 2007 to Sept. 2009 (daily value)

4.2.2. Independent variables

Detailed data on the usage of Fed facilities is obtained from the Board of Governors of the Federal Reserve System website.[18] The model includes a binary variable for the announcement of each of the four liquidity facilities by the Federal Reserve: *TAF Announcement, TSLF Announcement, PDCF Announcement*, and *CPFF Announcement* (equal to 1 the date of the considered announcement and to 0 otherwise). The Fed announcement of the TAF was coordinated with announcement by 6 other

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central banks. Thus, it is possible that news leaked out from one of the central banks. So, for *TAF Announcement* we also include binary variables for the two days after the announcement, and the prior two days.

The measure of facility usage is the total amount a bank has outstanding from a facility on any given date. This may differ from the amount obtained in the most recent draw because a bank may have more than one outstanding draw from a facility, such as first borrowing funds from the TAF with an 84-day maturity, then the following month drawing funds from the TAF with a 28-day maturity. The total amount outstanding is measured by program for each day and for each bank (divided by total assets): *TAF Outstanding, TSLF Outstanding, PDCF Outstanding* and *CPFF Outstanding.*

The fact that a bank has received government support may have an impact on the market response. We consider the dummy variable *Assisted* equal to 1 if a bank received such a support (and 0 otherwise). *Public assistance Announcement* equals 1 the day the support was announcement (and 0 otherwise). We consider the interaction term *Public assistance Announcement* x *Assisted*. All the announcements of government support occurred after the collapse of Lehman Brothers.

Along with the new facilities offering loans to domestic offices of banks, European banks had two other ways of obtaining U.S. dollar funding from the Federal Reserve. First, any European bank that was eligible for the TAF could have also borrowed through the discount window. *Discount Window* equals 1 for the bank at the date the loan was granted (and 0 otherwise). European banks could also borrow indirectly from their own central bank through the central bank swap lines: *Start* is a binary variable equal to 1 the day of the beginning of the swap program with the central bank in each bank's home country (and equal to 0 the other days). The swap program with ECB and Swiss National Bank started on 17/12/2007. The swap program with Bank of England started on 18/09/08, the program with Danmarks Nationalbank started on 26/09/08 and the program with Sveriges Riksbank (Sweden) started on 15/10/08. We also insert the date on which the cap on the

amount of the swap lines was removed for Bank of England, European Central Bank and Swiss National Bank (14/10/2008). *Remove* equals 1 on this day for the banks headquartered in countries depending on these three central banks, and equals 0 otherwise.

We also consider monetary policies of the various central banks in Europe. The variable *BoE Interaction* takes a value of 1 for banks headquartered in the UK on the day the Bank of England announces a policy rate change and otherwise takes a value of 0. In the same way, we consider *ECB Interaction*, *SNB Interaction*, *RiskBank Interaction* and *Danmarks NationalBank Interaction*.

4.2.3. Model specification

The model for the change in individual bank CDS spreads is:

$$
\begin{aligned}
CDS\ Variation_{i,t} = \ & \beta_0 + \beta_1 TAF\ Announcement_t + \beta_2 TAF\ Outstanding_{i,t} \\
& + \beta_3 TSLF\ Announcement_t + \beta_4 TSLFF\ Outstanding_{i,t} + \beta_5 PDCF\ Announcement_t \\
& + \beta_6 PDCF\ Outstanding_{i,t} + \beta_7 CPFF\ Announcement_t + \beta_8 CPFF\ Outstanding_{i,t} \\
& + \beta_9 Public\ assistance\ Announcement \times Assisted + \beta_{10} Discount\ Window_{i,t} \\
& + \beta_{11} Start_{i,t} + \beta_{12} Remove_{i,t} + \beta_{13} BoE\ Interaction_{i,t} \\
& + \beta_{14} ECB\ Interaction_{i,t} + \beta_{15} SNB\ Interaction_{i,t} + \beta_{16} RiksBank\ Interaction_{i,t} \\
& + \beta_{17} Danmarks\ NationalBank\ Interaction_{i,t} + \beta_{18} Control_{i,t} + \epsilon_{i,t}
\end{aligned}
$$

Along with the facilities variables, the model includes the addition of three control variables. As a proxy for the bank's size, we use bank's total assets. We use the daily iTraxx Index as a benchmark of the global evolution of the CDS market[19]. Finally, we include a measure of the riskiness of U.S. financial markets: the daily value of the Chicago Board Options Exchange Volatility Index (VIX). We use a panel data analysis with fixed effects. Hausman test rejects random effects. We estimate the coefficient with the Arellano robust estimators method. It corrects for heteroskedasticity and autocorrelation.

4.3. Descriptive statistics

Summary statistics for the dependent variable are provided in Tables 2a and 2b and for the control variables in Table 2c. Table 2a summarizes the distribution of *CDS Variation* over the entire sample period for the entire sample and broken down by whether the bank was nationalized (or benefited from a bail-out) or not (assisted banks vs. unassisted banks).

Table 2. Summary statistics

Table 2a. Variation of CDS spreads over the total period
The sample consists of 36 European banks from 12/01/2007 to 07/31/2010. This table reports means, min, max and standard deviations (total, within and between). There is no statistically significant difference between assisted banks and unassisted banks.

	Obs.	Mean	Min	Max	St. Dev.	St. Dev Within	St. Dev. Between
CDS Variation (%)	22754	0.28	-55.30	117.39	5.66	5.66	0.12
CDS Variation for assisted banks (%)	13702	0.27	-55.30	94.23	5.49	5.49	0.09
CDS Variation for unassisted banks (%)	9052	0.31	-43.66	117.39	5.90	5.91	0.15

Table 2b. Variation of CDS spreads over subperiods: Sub-Periods before the Bear Stearns collapse, between the Bear Stearns collapse and the Lehman Brothers collapse and after Lehman Brothers collapse
The sample consists of 36 European banks from subperiod 1 (12/2007 to 03/2008), subperiod 2 (03/2008 to 09/2008) and subperiod 3(09/2008 to 05/2009). This table reports means, min, max and standard deviations (total, within and between) and tests of differences between the different sub-periods. All the differences are significant at the 1% level (***)

	Obs.	Mean	Min	Max	St. Dev.	St. Dev Within	St. Dev. Between
Subperiod 1	2069	$1.58^{***/***}$	-38.66	117.39	$7.49^{***/***}$	7.53	0.42
Subperiod 2	4307	$0.06^{***/***}$	-43.66	40.47	$5.83^{***/***}$	5.85	0.28
Subperiod 3	5577	$0.41^{***/***}$	-55.30	94.23	$7.00^{***/***}$	7.02	0.21

Table 2c. Summary statistics – Independent variables
The sample consists of 36 European banks from 12/01/2007 to 07/31/2010. This table reports means, min, max and standard deviations. Total assets are given in billions of USD. For the variables of amount outstanding, statistics are based on non-null values. Amounts outstanding are given in % of Total Assets. Total assets are given in thousands of MUSD.

	Full sample				
	Obs.	Mean	Min	Max	Std.
TAF Outstanding (in %)	9714	0.47	$2.70.10^{-2}$	2.45	0.46
TSLF Outstanding (in %)	1950	0.47	$6.92.10^{-3}$	3.19	0.59
PDCF Outstanding (in %)	129	0.16	$2.00.10^{-3}$	1.95	0.21
CPFF Outstanding (in %)	2810	0.78	$8.45.10^{-4}$	6.55	1.07
Total assets (in billions of USD)	41882	958.53	77.89	3807.90	848.58
Variation iTraxx$_t$ (%)	694	0.16	-26.17	15.57	38.59
VIX	670	30.13	15.67	80.74	12.51

The spread variations are on average positive (equal to 0.28%). This trend is in line with the financial situation of the European banks between 2007 and 2010. Table 2b presents the evolution among the three-subperiods and shows that the increase in the CDS spreads was the strongest during

the first subperiod. The thirty-two of the banks in the sample which obtained funds from the TAF program with individual banks obtaining funds from an average of 19.9 different auctions. All the assisted banks obtained funds from this facility except Dansk Bank. The average outstanding loans equal to 0.47% of the total assets (0.54% for assisted banks). Eight banks participated in the TSLF program using the facility 34.1 times on average. The banks that benefited from TSLF were all G-SIBs and four received government assistance. The outstanding loans were in average equal to 0.47% of the total assets. Seven banks borrowed from the PDCF program using the facility on average 21.5 times with three of the banks having received government assistance. The average Primary Dealer Credit Facility is equal to 0.16% of the total assets (0.085% for the assisted banks). As with TSLF, all the banks that benefited from this program were designated by the Financial Stability Board as globally systemically important banks (G-SIBs). Given the systemic importance of these banks, they may have benefited from greater implicit guarantees by their home country. Nineteen banks used the CPFF program, averaging 12.79 uses per bank with thirteen of these banks receiving assistance. The outstanding loans were in average equal to 0.78% of the total assets. Twenty-four banks borrowed from Discount Window, with seventeen of these banks ultimately receiving government assistance. The banks borrowing from the window used it an average 33.96 operations between December 2007 and July 2009, with the average outstanding loans equal to 0.34% of the borrowing bank's total assets (0.35% for the assisted banks).

5. Empirical results

5.1. Baseline results

Column (1) in Table 3 presents the results of the base regressions on the full period. The other columns (2, 3 and 4) present the results for the whole sample over three different sub-periods. The comments focus on the subperiods given the substantial differences between them.

Table 3. Full Period and Three Subperiods Regressions. Baseline estimations

The full sample consists of 36 European banks from December 2007 to July 2010 (Full period). Three sub-periods are considered: December 2017 to March 2008; from March 2008 to September 2008; from September 2008 to May 2009. The dependent variable is the daily relative variation of the CDS spread. The panel data regressions with fixed effects are based on the Arellano robust estimators. The t-stat is in parentheses. For TAF Announcement, we provide the sum of the coefficients. Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level.

	Full Period	Before Bear Stearns	Collapse of Bear Stearns	Collapse of Lehman Brothers
	(1)	(2)	(3)	(4)
TAF Announcement	−7.58***	−7.91***		
	(−4.55)	(-4.25)		
TAF Outstanding	2.47	−92.75	30.93	−92.25**
	(0.19)	(−1.53)	(0.66)	(−2.16)
TSLF Announcement	3.61***		3.44***	
	(3.70)		(3.65)	
TSLF Outstanding	11.74*		75.52	0.97
	(1.88)		(0.92)	(0.08)
PDCF Announcement	3.37***		2.90**	
	(3.34)		(2.55)	
PDCF Outstanding	10.45		−93.13	−40.09
	(0.13)		(−0.50)	(−0.41)
CPFF Announcement	−1.67			−1.01
	(−1.41)			(−0.86)
CPFF Outstanding	19.49*			5.53
	(1.80)			(0.36)
Public assistance Announcement x Assisted	−3.58*			−3.44
	(−1.78)			(−1.62)
Discount Window	−0.14	2.91**	0.45	−1.15*
	(−0.53)	(2.15)	(0.62)	(−1.70)
Start	−1.52*	−0.64		−4.53*
	(−1.82)	(−1.22)		(−1.71)
Remove	−11.28***			−9.37***
	(−6.31)			(−5.63)
BoE Interaction	−1.14**	−2.37**	2.76	−1.89***
	(−2.56)	(−2.16)	(1.05)	(−3.34)
ECB Interaction	−0.84***		−0.77*	−1.08***
	(−3.21)		(−1.68)	(−3.78)
SNB Interaction	−0.59			−0.56*
	(−1.50)			(−1.86)
RiksBank Interaction	−1.14	3.05		−2.34
	(−1.10)	(1.02)		(−1.50)
Danmarks NationalBank Interaction	−0.01		0.35	1.02***
	(−0.32)		(1.33)	(22.34)
CDS Market Control	0.83***	0.75***	0.90***	0.99***
	(13.71)	(11.86)	(11.77)	(11.94)
Size Control	$0.45.10^{-3}$**	$1.22.10^{-3}$*		$0.63.10^{-3}$
	(2.93)	(1.59)		(0.83)
Financial Distress Control	$−1.06.10^{-2}$***	$8.82.10^{-2}$*	$3.35.10^{-2}$*	$−7.01.10^{-2}$***
	(−2.84)	(1.73)	(1.69)	(−9.28)
Intercept	0.04	−2.75***	−0.78*	3.15***
	(0.27)	(−2.81)	(−1.79)	(4.01)
Observations	*21837*	*1919*	*4120*	*5379*
Adjusted R²	*0.3426*	*0.2413*	*0.3708*	*0.3212*

5.1.1. Before Bear Stearns Collapse

At the start of the sub-period before Bear Stearns collapse market participants would have been aware of elevated market stresses from the high levels of the Libor-OIS spread. The creation of the TAF and swap lines provided a signal of central bank concern about this spread and a determination to reduce liquidity strains in the financial system. The market response to the TAF announcement is shown by economically and statistically significantly negative coefficient on *TAF Announcement* indicating an over 8 percent drop in CDS spreads. This finding suggests that the Fed's creation of the TAF reduced market concern about bank's stability. The rest of the period is marked by small increases in the European banks usage of the TAF and slight declines in the size of the swap lines (Figure 2). Perhaps reflecting the relative calm, the coefficient on the amount outstanding is not statistically significant. European banks usage of the discount window was minimal (Figure 1) but the coefficient on the binary variable for usage indicates that usage led to a statistically significant increase of almost 3% in CDS spreads. This result confirms that a bank's use of the discount window is perceived as risk increasing by the market during the early stages of the crisis (see for instance Armantier et al., 2011). The rapid reaction of the Bank of England, that decreases the Official Bank Rate before the Bear Stearns collapse, leads to a reduction of the CDS spread of British banks.

5.1.2. Bear Stearns collapse

The start of this period is marked by concerns that Bear Stearns could fail, followed shortly thereafter by Bear's acquisition by JP Morgan with the Fed's help. The TSLF was announced just as Bear Stearns liquidity problems started to intensify and was taken by some investors as being directed at supporting Bear Stearns. The PDCF was announced shortly after Bear Stearns collapse.

Thus, the potential exists for the Fed's announcements to be taken as providing adverse news about the condition of the large banks with investment banking operations that were eligible for these two programs. The coefficients on the announcement variables *TSLF Announcement* and *PDCF*

Announcement are statistically significant, and each indicates an increase in CDS spreads of 3.4% and 2.9% respectively. Taken at face value, these results are consistent with these announcements resulting market participants' perception of increased risk of bank failure.

The period between Bear Stearns collapse and Lehman Brothers collapse starts with a jump in demand by European banks for Fed liquidity after Bear Stearns collapse. However, shortly thereafter the total amount of liquidity obtained by European banks from the Fed declined but remained at elevated levels (Figure 1). European banks' usage of the TSLF remained relatively constant between May and September 2008 (Figure 2). The change in CDS spreads induced by the amount of TSLF outstanding is not statistically significant. The usage of the TSLF by European banks with primary dealers was potentially constrained by Fed limits on the size of the auctions but these banks' usage of the PDCF faced no such caps—albeit the rate paid on the PDCF increased with prolonged usage. Figure 2 shows a jump in PDCF usage shortly after Bear Stearns collapse and a subsequent collapse to near zero prior to the failure of Lehman Brothers. However, the coefficient of the amount of PDCF outstanding is not significant either. European banks made somewhat greater usage of the discount window during this period but the coefficient on the *Discount Window* is insignificant. The decision of the ECB to decrease its refi rate was welcome by market participants, leading to a significant reduction of the CDS spreads for banks in the Euro zone.

5.1.3. Collapse of Lehman Brothers

The third subperiod is the period when market distress was the greatest: between Lehman Brother's collapse and the release of the results of the Supervisory Capital Assessment Program. This period is marked by a dramatic increase in liquidity strains in financial markets, a major expansion of Fed lending programs and increase in their usage by European banks. One of the ways in which the Fed provided additional liquidity was the creation of the CPFF. The announcement of the CPFF, *CPFF Announcement*, is associated with an insignificant change in CDS spreads. The Fed also

increased both the number of countries with swap lines and removed the limits on the swap lines with the Bank of England, European Central Bank and Swiss National Bank. Both changes resulted in statistically significant and economically large decreases in CDS spreads. Banks whose home country was added to the list with swap lines, (*Start*), experienced a drop in their CDS spreads of 4.5 percent on the announcement and the banks headquartered in countries where the limits had been removed (*Remove*) showed a drop of 9.4 percent.

European banks usage of the various Fed liquidity facilities spiked shortly after Lehman's failure but started decreasing in 2009. Figure 2 shows that European banks usage of the TAF remained elevated into late 2009 but their use of the other Fed liquidity facilities declined starting in early 2009. The variable for amount of TAF outstanding suggests a significant decline in CDS spreads: one percent amount outstanding to totals assets leads to a decrease of 0.92 percent. The amount of liquidity that European banks obtained via the TSLF auctions increased after the crisis but soon started decreasing and became almost zero by the summer of 2009 (Figure 2). European banks usage of the PDCF jumped immediately after Lehman's failure, becoming the single largest provider of liquidity to European banks in October 2008 despite being only available to the six European primary dealers (Figure 2). However, PDCF usage significantly decreased in November and was relatively small thereafter. None of the variables for usage of the TSLF or PDCF have statistically significant coefficient. The CPFF program provided significant additional liquidity in October 2008 and again in January 2009 but otherwise only relatively small amount through May 2009 (Table 1). However, given the longer maturities of funds provided by the CPFF, the amount outstanding under this program remained substantial well into 2009. The coefficient on CPFF usage is statistically significantly positive indicating usage was associated with increase perceptions of risk but only on the all period – column (1).

The coefficient on public assistance to the banks is negative as expected, albeit it is only statistically for the entire sample. The decisions of the ECB, the BoE and the SNB to decrease the rate of their main refinancing operations lead to a significant reduction in the CDS spreads, but the Danmarks NationalBank reduction of its rate increased the CDS spread of the Danske bank.

5.1.4. Overall findings

The question for the Fed was whether the announcement of the various liquidity facilities would reduce market concerns about the condition of the banks. The results suggest it depends upon the information content of the announcement. Announcements that primarily conveyed new information about the Fed's willingness to support banks led to lower CDS spreads, announcements that primarily conveyed information about bank's conditions led to increased spreads. The initial TAF and swap line announcements came when the market knew about liquidity stresses but did not know how the Fed would respond. The later swap line announcements also came when liquidity stresses were apparent but the Fed's willingness to expand its international operations was less clear. Consistent with most of the information content relating to Fed policy, the TAF and swap line announcements resulted in lower CDS spreads.

In contrast, the Fed had established its willingness to act before the TSLF and PDCF, but what was arguably less clear is the extent of distress at the primary dealers. Consistent with this interpretation, the announcements of the TSLF and PDCF, are associated with significant increases in CDS spreads. The announcement of the CPFF came when the market both knew of extreme liquidity stresses and the Fed's determination to help mitigate those stresses and did not have a significant effect on spreads.

In terms of the banks concern that usage would send a negative signal about their condition, the evidence is less clear as the coefficients on usage variables are often insignificant. When they are significant, they confirm the results about announcement: on the third period, usage of TAF is

associated with reduction of CDS spreads and on the full period, TSLF and CPFF usages are associated with higher spreads. However, as the next section shows, these responses depend in part on what the market knows about the bank.

5.2. Government assistance

Twenty-two banks out of the thirty-six benefited from government assistance. We assume that the bailout should convey positive information about the banks that were assisted, resulting in a drop in their CDS spreads on the day the support was announced. The baseline integrates a binary variable equal to 1 on the day of the announcement of the public assistance, 0 otherwise. As predicted, the coefficient on the interaction term *Public Assistance Announcement x Assisted* is negative, but only on the full period (Table 3, column 1). Furthermore, we hypothesize that market participants interpretation of the Fed's programs was influenced by the financial condition of the borrowing banks. We use whether the bank was one of the 22 banks that received assistance as a proxy for the bank's overall financial condition.[20] Our maintained assumption with this proxy is that market participants' views of the bank's relative financial strength is highly but not necessarily perfectly correlated with whether the bank received assistance. We also assume that market participants did not know with certainty that any bank would ultimately receive capital assistance or be nationalized until after the event. If market participants knew with certainty that a bank would not be allowed by its home country to fail with losses to bondholders, the CDS contracts on that bank should have been worthless.

We test two hypotheses. First, assisted banks are predicted to have a larger negative (or smaller positive) response to the announcement of the Fed facilities. These banks should have been perceived at greater risk of illiquidity and so would benefit more from the Fed's lending programs. Second, the usage of the facilities sends a less positive (or more negative) signal about the banks

that did not receive assistance (unassisted banks). Market participants are assumed to already regard the set of assisted banks as being weak but would still be looking for additional information about the condition of the banks that ultimately went unassisted. Thus, use of the facilities could convey more adverse information about the condition of the unassisted banks[21].

Table 4. Assisted vs. Unassisted banks regressions

Two subsamples are considered: assisted banks (22 banks) and unassisted banks (14 banks). We consider the full period (from December 2007 to July 2010) and three sub-periods are considered (December 2017 to March 2008; from March 2008 to September 2008; from September 2008 to May 2009). The dependent variable is the daily relative variation of the CDS spread. Control variables are those used in Table 3. The panel data regressions with fixed effects are based on the Arellano robust estimators. The t-stat is in parentheses. Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level. For TAF Announcement, we provide the sum of the coefficients. In bold the coefficients that are significantly different (at the 10% level) between the two sub-populations.

	Full period		Before Bear Stearns		Collapse of Bear Stearns		Collapse of Lehman Brothers	
	Assisted	Unassisted	Assisted	Unassisted	Assisted	Unassisted	Assisted	Unassisted
TAF Announcement	**−9.47*****	**−4.59**	**−10.40*****	**−4.01**				
	(−5.00)	**(−1.59)**	**(−5.95)**	**(−1.08)**				
TAF Outstanding	7.87	−25.37	−121.44	−50.94	56.14	−57.68	−88.98*	−93.73
	(0.56)	(−0.76)	(−1.68)	(−0.44)	(1.20)	(−0.57)	(−1.91)	(−0.76)
TSLF Announcement	3.90***	2.89*			3.55***	2.84*		
	(3.09)	(1.89)			(2.99)	(1.83)		
TSLF Outstanding	**−42.74**	**19.64****			49.00	118.33	−108.32	7.92
	(−1.50)	**(2.24)**			(1.23)	(0.71)	(−1.23)	(0.79)
PDCF Announcement	2.89***	4.09**			1.50*	4.22*		
	(2.82)	(2.19)			(1.78)	(1.88)		
PDCF Outstanding	9.12	−17.58			**−1552.06*****	**−85.70**	−71.30	−93.97
	(−0.01)	(−0.31)			**(−6.75)**	**(−0.90)**	(−0.07)	(−0.94)
CPFF Announcement	−1.77**	−1.39					−0.99	−1.00
	(−2.01)	(−0.52)					(−1.13)	(−0.36)
CPFF Outstanding	15.40	28.81					−7.91	32.54
	(1.23)	(1.24)					(−0.45)	(0.70)
Public assistance Announcement	−3.60*						−3.48	
	(−1.77)						(−1.58)	
Discount Window	**−0.22**	**2.99*****	2.07*	4.90*	**0.22**	**5.06****	−1.21*	1.62
	(−0.78)	**(3.01)**	(2.11)	(1.69)	**(0.30)**	**(2.77)**	(−1.73)	(0.87)
Start	−1.91*	−0.73	−1.12**	0.45			−7.09	−1.90
	(−1.67)	(−0.68)	(−2.26)	(0.37)			(−1.40)	(−1.34)
Remove	−12.96***	−8.65**					−10.77**	−7.20**
	(−6.65)	(−2.54)					(−5.77)	(−2.28)
BoE Interaction	−1.11***	−1.12*	−2.90***	−1.79	0.21	5.55	−1.21**	−2.54***
	(−2.01)	(−1.67)	(−11.98)	(−0.19)	(0.18)	(1.16)	(−2.25)	(−4.80)
ECB Interaction	−0.73***	−1.09*			−0.40	−1.62	−1.01***	−1.22
	(−2.93)	(−1.68)			(−1.03)	(−1.40)	(−3.71)	(−1.68)
SNB Interaction	**−1.16*****	**0.00**					**−0.94*****	**−0.03**
	(−5.08)	**(0.01)**					**(−3.05)**	**(−0.09)**
RiksBank Interaction		−1.14		2.72				−2.50
		(−1.05)		(0.86)				(−1.69)
Danmarks NationalBank Interaction	−0.04				−1.02		1.08***	
	(−0.87)				(−0.06)		(21.75)	
Intercept	−0.11	0.08	−2.40**	−3.36	−1.46**	0.20	3.67**	2.51
	(−0.56)	(0.34)	(−1.9)	(−1.62)	(−2.58)	(0.29)	(2.07)	(0.90)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	13150	8687	1152	767	2460	1660	3260	2119
Adjusted R²	0.4011	0.2695	0.3775	0.1523	0.4438	0.2847	0.3457	0.2843

The Table 4 provides the results of estimation where the sample is split into the assisted and unassisted subsamples. Consistent with the first hypothesis, the coefficient on *TAF Announcement* is significantly higher in absolute value (more negative) for the assisted banks. This result is in line with the fact that the *CPFF announcement* and *Start* have a significant negative impact on the CDS spreads only for assisted banks. The coefficients of *TSLF and PDCF announcements* are not statistically significant. Regarding to European central banks's main refinancing rate, the results provide some support for the first hypothesis as *SNB Interaction* has a coefficient significantly different and higher in absolute value (more negative) for the assisted banks, and as the coefficient of *BoE Interaction* is significant only for these banks during the first period.

The results are also consistent with the second hypothesis. The coefficient on *Discount Window* is only significantly different from zero – and positive – for the unassisted banks in the full period as in Subperiod 2; same for the coefficient of *TSLF Outstanding* over the whole period. The reduction of perceived credit risk induced by *TAF Outstanding* is only significant for the assisted banks during the third sub-period; same for *PDCF* Outstanding. These results are in line with Song and Uzmanoglu (2016) who show that unhealthy banks suffered from a higher increase in their CDS spread after the announcement of the TARP program.

5.3   *Robustness checks*

As a robustness check we separate the banks into those designated as G-SIBs and all other banks, because the G-SIBS may benefit from a perception that these banks are more likely to receive government support. We also recognize that only those banks with primary dealer status had access to the TSLF and PDCF. In the event, all the primary dealers were also G-SIBs, so we only re-estimated the equations for the GSIB and non-GSIB. These results are generally similar but where differences emerge, we see a strong reaction among the G-SIB banks (Table 5).

Table 5. G-SIBs vs. non-G-SIBs regressions

Two subsamples are considered: G-SIBs (15 banks) and non-G-SIBs (21 banks). We consider the full period (from December 2007 to July 2010) and three sub-periods are considered (December 2017 to March 2008; from March 2008 to September 2008; from September 2008 to May 2009). The dependent variable is the daily relative variation of the CDS spread. Control variables are those used in Table 3. The panel data regressions with fixed effects are based on the Arellano robust estimators. The t-stat is in parentheses. For TAF Announcement, we provide the sum of the coefficients. Asterisks denote statistical significance at the 1% (***), 5% (**), or 10% (*) level. In bold the coefficients that are significantly different (at the 10% level) between the two sub-populations.

	Full period		Before Bear Stearns		Collapse of Bear Stearns		Collapse of Lehman Brothers	
	G-SIBs	Non-G-SIBs	G-SIBs	Non-G-SIBs	G-SIBs	Non-G-SIBs	G-SIBs	Non-G-SIBs
TAF Announcement	**−13.92*****	**−3.82***	**−15.34*****	**−4.61***				
	(−6.44)	**(−2.03)**	**(−6.73)**	**(−2.01)**				
TAF Outstanding	14.90	−5.06	−72.27	−75.10	79.76	8.23	−102.77**	−144.30**
	(1.13)	(−0.37)	(−0.61)	(−1.17)	(1.55)	(0.15)	(−2.54)	(−2.29)
TSLF Announcement	4.95**	2.85**			4.87**	2.59**		
	(2.85)	(2.49)			(2.91)	(2.27)		
TSLF Outstanding	20.10**				30.71		10.78	
	(2.45)				(0.46)		(0.62)	
PDCF Announcement	3.14	3.50***			2.90	2.88**		
	(1.49)	(3.32)			(1.23)	(2.41)		
PDCF Outstanding	26.58				68.48		−73.49	
	(0.36)				(0.34)		(−0.86)	
CPFF Announcement	−2.03	−1.37					−1.18	−0.84
	(−0.79)	(−1.37)					(−0.44)	(−0.83)
CPFF Outstanding	**45.48*****	**−4.05**					**46.37*****	**−14.81**
	(5.84)	**(−0.30)**					**(4.05)**	**(−0.84)**
Public assistance Announcement	−6.77	−1.58					−5.98	−1.67
	(−0.10)	(−0.75)					(−1.51)	(−0.72)
Discount Window	0.05	−0.47	2.71	2.72**	0.56	−0.73	−1.32***	−0.75
	(0.22)	(−0.93)	(1.35)	(2.33)	(1.05)	(−0.85)	(−3.23)	(−0.90)
Start	−0.47	−2.07	−0.11	−1.20			−2.12	−5.83
	(−0.61)	(−1.63)	(−0.17)	(−1.61)			(−1.20)	(−1.49)
Remove	−14.06***	−9.47***					−11.56***	−7.94***
	(−5.71)	(−3.89)					(−4.96)	(−3.49)
BoE Interaction	−1.54**	−0.99*	−2.45	−2.47***	3.01	1.65	**−2.84*****	**−1.33*****
	(−2.31)	(−2.06)	(−1.13)	(−10.93)	(0.65)	(1.48)	**(−5.52)**	**(−2.56)**
ECB Interaction	−0.89	−0.83**			−1.03	−0.63	−1.24*	−0.99***
	(−1.72)	(−2.77)			(−1.78)	(−0.98)	(−2.02)	(−3.30)
SNB Interaction	−1.09**						−1.13***	
	(−2.48)						(−3.47)	
RiksBank Interaction	**0.64*****	**−1.96****	5.32***	1.75			**−1.30***	−2.48*
	(3.35)	**(−2.27)**	(7.31)	(0.39)			**(−1.78)**	(−1.80)
Danmarks NationalBank Interaction		0.09*				0.93***		
		(1.84)				(2.73)		
Intercept	−0.28	0.04	−0.96	−2.51*	−0.33	−0.91*	1.23	6.91***
	(−0.96)	(0.11)	(−0.89)	(−1.96)	(−0.38)	(−1.78)	(0.73)	(6.13)
Control	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	8692	13145	704	1215	1610	2510	2119	3260
Adjusted R^2	0.4971	0.2503	0.4948	0.1517	0.5711	0.2601	0.4663	0.2391

To check the robustness of our estimations, we also consider the date of any usage of the facility for one bank. We insert variables equal to 1 the day of the loan date and equal 0 for any other day. This variable captures the bank's need for additional funding on that date. We also consider the date of each bank's first usage of the facility. Arguably a bank's first usage of a facility

conveys the newest information about the bank's need for assistance in obtaining funding, the bank's willingness to access Fed facilities to obtain those funds and (to a lesser degree) the bank's qualification for access to the facilities. The main difference in this specification is that usage of PDCF is associated with lower CDS spreads by market participants during the second period.

As another robustness test, we used the Libor-OIS spread as an alternative measure of market risk for U.S. dollar securities. We reran the baseline model using this spread but excluding VIX because the two risk measures are highly correlated. All the qualitative results are unchanged.

6. Conclusion

Financial crises are low frequency events with potentially first order effects on the wealth of individual agents and on social welfare. Although these crises are typically started by a shock to wealth, that effect of that shock is exacerbated as private agents seek to shift their portfolios towards safer and more liquid assets. Such portfolio changes further increase the strains on those parts of the financial system that are providing credit and/or liquidity transformation. In response, central banks have been assigned a major role in mitigating crises, especially the parts arising from portfolio changes. In part this assignment reflects central bank's ability to respond endogenously in near real time and in part reflects the fact that the response is likely to involve the creation of additional money. Yet the duty of central banks to respond promptly to emerging crises using its best judgment suggests a potentially high value from understanding the effectiveness of its actions in prior crises.

This study follows a number of other empirical studies that seek to develop such a better understanding by empirically examining central bank actions during the global financial crises. In particular, this paper investigates market reactions to the creation and usage of Federal Reserve liquidity facilities from 2007 to 2010 for European banks. Although the facilities were designed to

improve market function and help banks by easing liquidity strains, other outcomes were possible. The creation of the facilities could have been taken as a sign that the central banks had adverse private information on the condition of the banks. Further, the usage of the facilities by individual banks could have been taken to mean the bank was losing access to funding from some other market participants, causing even more participants to withdraw funding. In particular, the market reaction could be different once a bank was announced to benefit from a government support.

Overall, our results suggest that the market's reaction to central bank announcements is sensitive to the context of the announcement. The TAF and start of the swap lines occurred at a relatively calm time in which the Fed's announcement did not convey much new information on the status of the financial system, everyone knew that risk spreads where high and the end of the year was approaching. However, these programs did convey new information about the central banks' willingness to experiment in providing new liquidity and resulted in lower CDS spreads. On the other hand, the TSLF was announced before Bear Stearns collapse and was an extension of existing Fed lending practices. It, along with the PDCF, appears to have conveyed less information about the Fed's willingness to provide liquidity and more information about the condition of the financial system. Thus, the information content in the announcement of the TSLF and PDCFD may have worked against the Fed's goals of calming markets. In terms of the usage of facilities by the banks, the evidence from financial markets is consistent: the usage of TAF led to a decrease in CDS spread whereas the usage of CPFF led to an increase in CDS spreads.

Our results also suggest that this negative impact is driven by the banks that did not benefit from a public assistance, because their use of Fed facilities convey more negative information. On the contrary, the Fed liquidity program is associated with lower CDS spreads for banks that benefited from a public assistance and were likely already judged to be among the weakest banks by market participants.

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Appendix

The FED emergency programs

TAF Program

The TAF was an extension of the Federal Reserve's traditional discount window lending through its primary credit program.[22] The key differences were: (a) that the loans initially had a fixed maturity of 28 days (with later auctions including fixed maturities up to 84 days) whereas the borrowing through the primary credit facility discount window lending was normally overnight (but the maximum was extended to 30 days), (b) the total amount issued in any one auction was limited whereas the total amount discount window lending throughout the Federal Reserve System was not subject to such a quantitative cap, and (c) the rate paid by the borrower was set by auction whereas the rate paid on primary credit was fixed. One important similarity of the TAF and other discount window lending is that the Federal Reserve would consider lending on any sound asset subject to a haircut. The date, aggregate amount and maturity of each TAF auction were announced in advance. Additionally, the amount available to any one borrower was also subject to a preannounced maximum. The minimum bid rate was set at the overnight indexed swap (OIS) rate until January 12, 2009 and thereafter was set at the rate the Federal Reserve paid on excess reserves (which was a constant 25 basis points during the operation of the TAF).[23] The rate actually paid by all banks was the stop-out rate, which is the rate at which the aggregate amount being auctioned was sold out. All bids in excess of the stop-out rate were fully allocated (up to the single borrower limit). Bids at the stop-out rate were filled on a pro-rata basis. The final TAF auction was held on 8 March 2010 and the last loans matured on 8 April 2010. All loans issued under the TAF were repaid in full. The auction details were announced in advance. The auction was typically held on a Monday, the results announced to the winning banks on Tuesday and the loans were settled on Thursday.

Central bank swap lines

Central bank swap lines have long been used for a variety of purposes according to Hooyman (1994). During the crisis, swap lines were used to supply dollars that foreign central banks could lend to their banks. In return for supplying dollars to a foreign central bank, the Federal Reserve would receive an equivalent value of that foreign central bank's currency. The transaction was reversed at a specified future date. Both transactions took place at the prevailing exchange rate in the market at the start of the transaction. The foreign central bank retained all the credit risk associated lending to its commercial banks. Goldberg et al. (2011) discuss the various procedures that foreign central banks then used to lend the money to their banks that needed U.S. dollars. Some central banks relied exclusively on auctions to distribute the dollars using procedures similar to the TAF auctions. The Bank of England, European Central Bank and Swiss National Bank switched from a bidding process to a non-competitive, full allotment auction at a fixed price when caps on the swap lines were removed. The fixed price for these allotments was U.S. dollar OIS + 100 basis points, this price exceeded the stop-out

rate for the TAF auctions. The auctions conducted by the Bank of England, ECB and Swiss National Bank tended to coincide with the dates of TAF auctions of amounts of similar maturities.

Term Securities Lending Facility – TSLF – and TSLF Options Program – TOP

The TSLF was intended to help primary dealers obtain financing for their securities portfolio by allowing them to pledge investment grade securities temporarily as collateral for obtaining U.S. Treasury securities according to Fleming et al. (2009). The U.S. Treasury securities could then be used by banks as collateral for obtaining funds in the private market on better terms than they could have using their original securities holdings. For example, a primary dealer could pledge highly rated, non-agency mortgage-backed securities and receive U.S. Treasury securities which were more readily acceptable to private lenders. The TSLF was different from the TAF in that the TSLF was only open to primary dealers whereas the TAF was open to all U.S. banks, U.S. branches and agencies of foreign banks that maintain deposits subject to reserve requirements. The primary dealers "serve first and foremost, as trading counterparties of the Federal Reserve Bank of New York."[24] The primary dealers play an important, ongoing role in the U.S. Treasury securities market, but they need not be headquartered in the U.S. nor need they be a commercial bank. Although not a requirement, primary dealers also tended to be important dealers in a wide variety of other fixed income markets. Access to the TSLF was sold via an auction with dealers bidding to pay a fixed fee in return for access to a given amount a given dollar amount of securities U.S. Treasury securities for one month with the dealer posting securities that were (presumably) less acceptable to private lenders. Winning bidders paid a single rate, the lowest bid rate accepted in the auction. Minimum fee levels were set to encourage primary dealers to reduce their usage as markets improved. Some financial markets become more volatile around certain key dates, especially quarter end. The TOP facility was created to give primary dealers the right, but not the responsibility to draw on the TSLF around such dates. These options for 7 days usage of the TSLF were auctioned subject to a minimum fee for winning the auction and a fixed rate fee if the option is exercised.

Primary Dealer Credit Facility – PDCF

The PDCF was like the TSLF in that both facilities were intended to ease financing conditions for primary dealers. The principal difference was that under the PDCF the primary dealers were borrowing overnight funds from the Federal Reserve as needed rather than bidding in an auction to be able to obtain Treasury securities for 28 days. Adrian et al. (2009) describe the PDCF as in many ways similar to the Federal Reserve's discount window for lending to banks. The price of the PDCF was the discount rate, but this rate increased after 45 days of usage to encourage primary dealers to rely on market-based funding. Primary dealers were also required to post collateral subject to a haircut, as was the case with the TSLF and the discount window. The set of acceptable collateral for the TSLF and PDCF varied through time. After Lehman's failure the range of acceptable collateral for the PDCF included some non-investment grade securities and equities, neither of which was acceptable for the TSLF.

Asset-backed commercial paper money market mutual fund liquidity facility – AMLF

The AMLF was intended to increase the liquidity of the asset-backed commercial paper (ABCP) market and provide a means for money market mutual funds to obtain liquidity for their holdings of ABCP according to Duygan-Bump et al. (2013). Under this program the Federal Reserve issued non-recourse loans to commercial banks to buy commercial paper from money market funds.[25]

Commercial Paper Funding Facility – CPFF

The CPFF was intended to stabilize short-term funding markets and prevent liquidity driven defaults by issuers according to Adrian et al. (2011). The facility purchased commercial paper rated A1/PA/F1 or higher from issuers who registered with the Federal Reserve Bank of New York. The issuer had to be U.S. based, however, it could have a foreign parent. The actual buyer of the commercial papers was a special purpose vehicle created by the Federal Reserve called the CPFF LLC. The CPFF LLC purchased qualified commercial paper from issuers using non-recourse funding supplied by the Federal Reserve. The all-in cost of the funding was three-month OIS plus 200 basis points for unsecured commercial paper and three-month OIS plus 300 basis points for asset-backed commercial paper.

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[1] Examples of papers examining bank responses to central bank liquidity provision during the financial crisis include Berger et al. (2017) for the U.S., Kick, Koetter, and Storz (2020) for Europe. Examples of papers studying liquidity provision during the eurozone crisis include Andrade (2019) and Carpinelli and Crosignani (2021). Examples from the 2020 pandemic include Altavilla et al. (2023) for European bank lending and Nozawa and Qiu (2021) for the U.S. bond market.

[2] See Aizenman, Ito, and Pasrichaca (2022) for an analysis of US dollar central bank swap lines during the COVID-19 crisis.

[3] See for example the announcement of "The New Bagehot Project" at the Yale Program on Financial Stability (see https://newbagehot.yale.edu/about/project). In fact, as Conti-Brown (2014) observes, this rule is nowhere to be found in Bagehot (1873) famous book *Lombard Street*. Bagehot (1873), albeit roughly similar recommendations are made at various points. See Bordo (1990) and Humphrey (1989) for a discussion of development of lender of last resort, including early contributions by Thornton and Bagehot.

[4] Thornton (1807, p. 156) says that loans should not be granted to "those who misconduct their business". Bagehot (1873, p. 97) talks about refusing to lend on "bad bills or bad securities" as the "great majority" are "'sound' people".

[5] Goodhart (1987) observes that for banks suffering from "illiquidity will in most cases already be under suspicion about … solvency." This valid comment implies that a loan from the central bank will generally not be a perfect signal, but it does not justify lending when the bank seeking liquidity assistance is clearly insolvent.

[6] See for instance Fiordelisi et al. (2014).

[7] The spread largely results from the difference in credit risk premiums between LIBOR in which the principle of the deposit is at risk and the OIS spread in which the notional principle is not at risk.

[8] TAF funds were only auctioned on a biweekly basis, (later weekly), the funds were not available until three days after the bank placed its bid and the amount was subject to single borrower limits.

[9] The Fed's announcement is available at http://www.federalreserve.gov/newsevents/press/monetary/20071212a.htm.

[10] See for instance Syrstad (2014), McAndrews et al. (2017) and Tamakoshi and Hamori (2014).

[11] The Fed's announcement is available at http://www.federalreserve.gov/newsevents/press/monetary/20080311a.htm.

[12] The Fed's announcement is available at http://www.federalreserve.gov/newsevents/press/monetary/20080316a.htm.

[13] The Fed's announcement is available at http://www.federalreserve.gov/newsevents/press/monetary/20080730a.htm.

[14] Appendix Table A.1. lists the European banks that borrowed from the Fed programs and give total usage of each facility by bank.

[15] We drop the AMLF operations from our econometric analysis, as only one European bank (Crédit Suisse) was involved and for a relatively small amount ($238 million). We also dropped TOP operations because the banks were only buying options to access the TSLF. Once the options were exercised, the operation appeared in the bank's TSLF participation.

[16] However, Bui et al. (2020) show that the stock price informativeness is reduced after a bank benefited from a TAF, increasing the correlation between the stock returns.

[17] See in Appendix Table A.2. the definition of the variables and the source of the data.

[18] The home page for facilities is: https://www.federalreserve.gov/monetarypolicy/expiredtools.htm.

[19] More precisely, we use the relative variation of the spread of iTraxx Europe 5 years Index.

[20] An alternative way of incorporating this information would be to use standard financial information, such as bank capital and loan loss ratios. However, the usefulness of these ratios is reduced by bank's accounting for losses during the period which was widely criticized as being "too little, too late."

[21] We acknowledge one weakness of splitting the sample into these two groups—the coefficient estimates of some variables may depend upon only one or two banks. Our sample contains only eight primary dealers, four of which received assistance. Additionally, our binary variables for the first usage of a facility may also depend upon very few observations as most banks first usage of a facility came in the period in which the facility was announced and only a small number initiating use in a subsequent period.

[22] The Board of Governors announced the TAF in a Press Release dated December 12, 2007, available at http://www.federalreserve.gov/newsevents/press/monetary/20071212a.htm. The Board of Governors web page on the Term Auction Facility provides a high level discussion of the facility and links to the data on its usages (see http://www.federalreserve.gov/newsevents/reform_taf.htm). Armantier et al. (2008) discuss the development and provide data on the operation of the TAF through May 2008. Allen et al. (2017) provide an analysis of the TAF, especially after October 2008.

[23] The terms of the TAF as of January 12, 2009 are discussed by the Federal Reserve Board in "Term Auction Facility Questions and Answers" available http://www.federalreserve.gov/monetarypolicy/taffaq.htm.

[24] A discussion of the primary dealers from the Federal Reserve Bank of New York may be found at http://www.ny.frb.org/markets/prideralers_policies.html. The current list of primary dealers with links to historical changes is also available from the Federal Reserve Bank of New York at http://www.ny.frb.org/markets/prideralers_current.html#tabs-1.

[25] When the Federal Reserve makes a loan, it ordinarily requires that the borrower posts collateral. However, should the borrower default and the collateral prove insufficient to cover the loan, the Federal Reserve had recourse to the borrower's other assets. Under the AMFL, however, the Federal Reserve would not have recourse to the bank's other assets should the bank default.

Table A.1. List of European Banks that obtained funds from Federal Reserve liquidity facilities and total amount borrowed from Dec. 2007 to March 2010 (*In MUSD*)

*If the bank is a subsidiary, the name of its group is given in brackets. * and ** mean respectively state-owned bank and mutual bank. The banks of the column (2) benefited from neither PDCF nor TOP operations. ***: Crédit Suisse is the only bank that has benefited from AMLF (238 MUSD). Source: Federal Reserve*

(1) / (2)	Country	CDS	Total	TAF	TSLF	PDCF	CPFF	TOP
Barclays	GB	Y	836,787	232,283	186,561	410,437		7,506
Deutsche Bank	DE	Y	374,186	76,882	276,878	500		19,926
RBS	GB	Y	506,507	170,650	291,315		3,747	40,796
Crédit Suisse***	CH	Y	272,290	5	260,536	1,500		10,010
UBS	CH	Y	287,202	55,500	121,771	35,400	74,531	
BNP-Paribas	FR	Y	158,503	31,275	41,187	66,375		19,666
Bank of Scotland	GB	Y	180,920	180,920				
Dexia	BE	N	158,643	105,167			53,476	
Dresdner Bank (Commerzbank Group)	DE	N	135,331	123,328	1,282	93	10,627	
Société Générale	FR	Y	124,377	124,377				
Bayerische Landesbank Giro*	DE	Y	112,535	108,190			4,345	
Fortis	BE	N	100,492	58,650			41,842	
Westlb*	DE	N	86,606	78,406			8,200	
Unicredit	IT	Y	64,093	62,210			1,883	
Commerzbank	DE	Y	55,451	51,161			4,290	
Natixis	FR	Y	55,069	32,817			22,252	
HSH Nordbank**	DE	Y	54,736	52,550			2,186	
DEPFA (Hypo Real Estate Group*)	IE	N	46,798	46,798				
DZ Bank**	DE	Y	41,776	39,477			2,299	
Allied Irish Banks – AIB	IE	Y	41,303	34,700			6,603	
ABN-Amro	NL	Y	36,270	1,500			34,770	
HypoVereinsBank – HVB (Unicredit Group)	DE	N	35,490	34,490		650		
Rabobank**	NL	N	25,900	23,751			2,150	
Standard Chartered	GB	Y	25,100	25,100				
CIC	FR	N	23,910	23,910				
Landesbank Baden Wuerttemberg**	DE	Y	22,580	22,580				
BBVA	ES	Y	22,205	22,205				
Erste Group Bank	AT	Y	21,966	17,000			4,966	
Abbey National (Santander Group)	GB	N	18,999	18,999				
Eurohypo (Commerzbank)	DE	N	13,255	13,255				
KBC Bank & Verzekering	BE	Y	11,007	4,788			6,220	
ING Group	NL	Y	10,878	5			10,873	
Lloyds TSB	GB	N	10,506	10,506				
HSBC	GB	Y	10,056	4,000	3,550		2,506	
BMW Bank (BMW Group)	DE	N	9,600	3,350			6,250	
Santander Group	ES	Y	9,191	9,191				
Skandinaviska Enskilda Banken – SEB	SE	Y	8,915	8,915				
Norddeutsche Landesbank**	DE	Y	8,499	8,230			269	
Governor & Company of The Bank of Ireland	IE	Y	6,073	6,073				
Svenska Handelsbanken	SE	Y	5,961				5,961	
Crédit Agricole	FR	Y	5,500	5,500				
Danske Bank	DK	Y	5,461				5,461	
Landesbank Hessen-Thurin – Helaba**	DE	Y	4,549	4,549				
Banco Espirito Santo	PT	Y	1,521				1,521	
Banco Popular	ES	Y	1,200	1,200				
Caja Madrid	ES	N	1,035	1,035				
Caixa Geral De Depositos*	ES	Y	447				447	
Nordea Bank	SE	Y	50	50				
Intesa Sanpaolo	IT	Y	6	6				

Table A.2. Variable definitions

	Name	Definition	Source
Dependent variable	CDS Variation	Daily relative variation of the CDS spread	Markit
TAF	TAF Announcement	Variable equal to 0 for any day except the day the program was announced	Federal Reserve
	TAF Outstanding	Amount of outstanding / total assets	Federal Reserve
TSLF	TSLF Announcement	Variable equal to 0 for any day except the day the program was announced	Federal Reserve
	TSLF Outstanding	Amount of outstanding / total assets	Federal Reserve
PDCF	PDCF Announcement	Variable equal to 0 for any day except the day the program was announced	Federal Reserve
	PDCF Outstanding	Amount of outstanding / total assets	Federal Reserve
CPFF	CPFF Announcement	Variable equal to 0 for any day except the day the program was announced	Federal Reserve
	CPFF Outstanding	Amount of outstanding / total assets	Federal Reserve
Public assistance	Public assistance Announcement	Variable equal to 0 for any day except the day a government support was announced	Factiva
	Assisted	Variable equal to 1 for any bank that benefited from a government support	Factiva
	Discount Window	Variable equal to 1 the day of any trade of an operation for a bank (0 otherwise)	Federal Reserve
	Start	Variable equal to 1 the day of the beginning of the swap program with the central bank in each bank's home country (0 otherwise)	Press release
	Remove	Variable equal to 1 the day the cap on the swap lines amount was removed by BoE, ECB and SNB for the relevant banks (0 otherwise)	Press release
Central Banks	BoE Interaction	Variable equal to 1 for banks headquartered in the UK on the day the Bank of England announces a policy rate change and 0 otherwise	Press release
	ECB Interaction	Variable equal to 1 for banks headquartered in the Euro zone on the day the ECB announces a policy rate change and 0 otherwise	Press release
	SNB Interaction	Variable equal to 1 for banks headquartered in Switzerland on the day the Swiss National Bank announces a policy rate change and 0 otherwise	Press release
	RiskBank Interaction	Variable equal to 1 for banks headquartered in Sweden on the day the RiskBank announces a policy rate change and 0 otherwise	Press release
	Danmarks NationalBank Interaction	Variable equal to 1 for banks headquartered in Denmark on the day the Danmarks NationalBank announces a policy rate change and 0 otherwise	Press release
Control variables	Size Control	Total Assets	Bankscope
	CDS Market Control	Relative variation of the spread of iTraxx Europe 5 years Index	Markit
	Financial Distress Control	Daily value of the Chicago Board Options Exchange Volatility Index (VIX)	CBOE