Stigma in Financial Markets

Evidence from liquidity auctions and discount window borrowing during the crisis*

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Abstract

We provide empirical evidence for the existence, magnitude, and economic impact of stigma associated with discount window liquidity provision by the Federal Reserve. We find that during the height of the financial crisis, banks were willing to pay at least 37 basis points (rising to nearly 150 basis points after Lehman's bankruptcy) on average to borrow from the Term Auction Facility (TAF) rather than the discount window. The incidence of stigma varied with bank characteristics and market conditions. Finally, we find that the day after borrowing from the discount window, banks faced higher borrowing rates. Banks borrowing from the TAF did not subsequently face higher borrowing costs. Our results have important implications for the provision of liquidity by central banks.

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In August 2007,... banks were reluctant to rely on discount window credit to address their funding needs. The banks' concern was that their recourse to the discount window, if it became known, might lead market participants to infer weakness—the so-called stigma problem. Bernanke (2009)

1 Introduction

An important role for central banks is to provide funding to solvent but illiquid banks during a general financial crisis or when banks are faced with idiosyncratic funding shocks. The Federal Reserve (henceforth Fed) employs the discount window (DW) for this task. Prior to 2008, however, there has been a low level of DW use by banks, even when they may have faced severe liquidity shortages. For example, with the onset of the 2007 financial crisis, few banks borrowed from the DW despite the Fed's urgings and reductions in the DW rate. The Fed lowered the penalty rate of DW borrowing twice during the crisis to encourage banks to rely on its facility, once in August 2007 and again in March 2008.

While banks' avoidance of the DW is often ascribed, as Chairman Bernanke does above, to the presence of DW stigma there is neither much of empirical supporting evidence for it, nor a well established theoretical framework.[1] The lack of information and empirical evidence about DW stigma creates policy uncertainty, since the response of banks to a change in the DW rate becomes difficult to estimate, thus hampering the Fed's effort to provide liquidity during times of crisis. Moreover, stigma is also potentially costly for banks, to the extent that they bypass cheaper sources of financing during times of great liquidity needs.

There is also a fair amount of anecdotal evidence, notably in financial press reports such as the ones following Deutsche Bank DW access in August 2007.[2] Yet, it should also be noted that it is not straightforward to theoretically rationalize stigma in financial market models. Only recently, some attempts have been made to do so. By accessing the DW, a bank may be sending a negative signal about its financial health to financial market participants. As a result, banks may prefer to pay more in order to avoid borrowing from the DW. For the

[1]There are potentially other explanations why banks did not visit the Dw. One alternative explanation for the unwillingness to borrow from the DW is that banks could potentially borrow at cheaper rates from the Federal Home Loan Bank (FHLB) system during that period, as shown by Ashcraft, Bech, and Frame (2009) who argue that the FHLB effectively acted as the Lender of Next-to-Last Resort.

[2]See *Fed fails to calm money markets* (Financial Times, August 20, 2007) and *Deutsche Bank loan decision boosts Fed* (Financial Times, August 21, 2007).

signaling story with respect to market participants to hold, two conditions must be satisfied. First, DW borrowing must be at least partially observable. In practice, this should not be the case. Although the Board of Governors reports every Thursday the total outstanding DW borrowing for each Fed District, the identity of DW borrowers are not made public. It appears well accepted, however, that banks are typically able to identify DW borrowers shortly after they access the DW. The second condition, is that accessing the DW sends a worse signal than borrowing on the market at a rate higher than the DW rate. This is in essence the approach taken by Ennis and Weinberg (2009) who assume in their theoretical model that DW borrowing may generate stigma on the asset market used by banks to finance themselves. In their model, a bank accessing the DW may be interpreted by participants on the asset markets as sending a negative signal about the quality of its assets. Similarly, Philippon and Skreta (2010) discuss a model of banks that borrow in the competitive private market where investors learn about the banks' private information by observing their participation decisions in government programs. The model implies that discount window participation should affect bank borrowing rates on inter-bank lending markets. These theoretical models rationalize DW as being stigmatized and result in DW avoidance. Moreover, as banks end up borrowing from the DW, it is also the case that they may face higher borrowing costs for inter-bank lending.

We provide empirical evidence for the existence, magnitude, and economic impact of stigma associated with discount window liquidity provision by the Fed. Prior to the empirical study reported in this paper, rigorous statistical evidence for the existence of stigma (in general not only with respect to DW borrowing) in financial markets is scarce.[3] We use a detailed and unique dataset of borrowing by banks at the Fed's Term Auction Facility (TAF) and DW to provide compelling empirical evidence of the existence, magnitude, and financial impact of DW stigma. The TAF was a liquidity facility created by the Fed in December 2007 almost entirely the same eligibility and collateral criteria as the DW. By lending term funds using an auction mechanism and market-determined rates, one of the Fed's objectives in designing TAF was to mitigate the DW stigma.[4] Furfine (2003) provides empirical evidence

[3]In other areas stigma has been more widely and extensively studied, such as unemployment, food stamps, tax evasion, etc. See e.g. Iannaccone (1992), Moffitt (1983), Lindbeck, Nyberg, and Weibull (1999), Lui (1986), Rasmusen (1996), Vishwanath (1989), among others. Finally, Bikhchandani, Hirshleifer, and Welch (1992) discuss stigma in the context of a model of information cascades.

[4]For further institutional details on the TAF implementation see Armantier, Krieger, and McAndrews (2008) as well as the FAQ on the Federal Reserve Bank of New York website `http://www.federalreserve.gov/monetarypolicy/taffaq.htm`

regarding DW stigma based on borrowing in the fed funds market. However, as discussed later, Furfine's evidence is based on a different time period and relies on a less precise methodology.

Rigorous empirical analysis requires first and foremost measurement. To achieve this, we define DW stigma as the maximum premium banks are willing to pay to avoid borrowing from the DW. We use a bid-level dataset of TAF auction participation to identify instances where banks choose to bid at the TAF at a rate higher than the prevailing DW rate. We find that many banks submitted bids above the DW rate at TAF auctions throughout the crisis, with an average premium of 37 basis points. In particular, banks frequently bid above the DW rate for a period of six months in 2008 when funding rates were higher at the TAF than at the DW. Therefore, bidding above the DW rate during this period implied that, with high probability, banks would pay more for TAF funds than the prevailing DW rate. Moreover, about half of the banks bidding above the DW rate did so regularly, indicating that the bidding behavior was not the result of idiosyncratic errors. These results provide robust evidence of the existence of stigma during the recent financial crisis. We then use the spread between the DW and TAF bid rates to provide a lower bound on the stigma premium, and we investigate characteristics associated with the size of this lower bound and its distribution across banks.

Since banks paid a DW stigma premium, it is interesting to ask whether the perception of DW stigma was justified. We therefore also examine whether and how inter-bank borrowing rates are affected after DW visits. To investigate the broader market impacts of going to the DW, we examine the effect of banks' DW visits on their borrowing rates. We find that, compared to a size-matched sample of banks that did not go to the DW, banks visiting the DW have borrowing rates that are higher by about 6 to 9 basis points on the day after their visits. Consistent with the hypothesis that TAF borrowing is not similarly stigmatized, we find that there is no statistically significant effect of TAF visits on banks' borrowing rates. These findings are consistent with DW stigma with respect to markets and the view that DW stigma may result from rational behavior anticipating market responses.

We also study the factors that determine a bank's choice of bidding above DW rates at TAF auctions. We find that banks who have large amounts of collateral pledged to the Fed or pledge more collateral prior to an auction, are more likely to bid above DW rates. The increase in collateral pledges may be an indication that banks are anticipating increased future funding needs. Consistent with this interpretation , when there is an increase in

funding liquidity risk, as measured by higher spread between the LIBOR and OIS rates and by higher volatility of interbank market rates, banks are more likely to bid above the DW rate.

We also measure the effect of stigma on bank's borrowing costs and find it was indeed substantial during the recent financial crisis. During the period when TAF stop-out rates were consistently higher than the DW rate, banks were willing to pay - as noted earlier - at least an additional 37 basis points, on average, at the TAF to avoid going to the DW. For banks that obtained TAF funding at these high rates, the additional cost was at least $ 26 million per auction and amounted to at least 12 % of their interest payments. After the bankruptcy of Lehman Brothers, the DW stigma premium rises to at least 150 basis points, implying a cost of at least $ 205 million per auction and at least 47 % of interest payments.

In the remainder of the paper, we describe in Section 2 the Fed's DW policy prior to and during the financial crisis, and the subsequent implementation of TAF. In Section 3, we discuss the methodology for inferring the existence of DW stigma and provide supporting empirical evidence. In particular, we discuss why a bank's TAF bid above the prevailing DW rate should be interpreted as evidence of stigma. In Section 4 we describe and estimate a probit model for examining the determinants of the probability that a bank will bid for TAF funds at a rate higher than the prevailing DW rate. In Section 5, we provide estimates of the lower bound on the magnitude of stigma. In section 6, we study the economic importance of DW stigma by estimating banks' shadow cost of avoiding the DW and the increased borrowing costs faced by banks visiting the DW. We provide concluding remarks in a final section.

2 The Supply of Liquidity by the Fed

In this section, we discuss how the Fed implements its lender of last resort function through DW operations, and provide a brief historical perspective of DW operations - emphasizing the issue of stigma. The Fed introduced the TAF during the crisis to complement the DW as a borrowing facility. We subsequently discuss the design features of TAF that were intended to mitigate the perception of stigma attached to borrowing from the Fed.

2.1 The Discount Window

An important role of a central bank, is to serve as the Lender of Last Resort, by providing discretionary liquidity when the private supply of liquidity is inadequate to meet the demand from the banking system (see e.g. Freixas, Giannini, Hoggarth, and Soussa (1999)). Normally, solvent but illiquid banks should be able to obtain funding from banks with excess liquidity via the interbank market - see notably Selgin (1993).[5] However, the interbank market may be dysfunctional due to asymmetric information problems, so that even solvent banks are unable to obtain credit. In such a case, central banks may be in a better position to supply liquidity in a targeted manner to illiquid institutions using the DW.[6] In the U.S., the traditional way for the Federal Reserve Banks to provide emergency credit to individual banks or other depository institutions in their respective districts is through the DW.[7] DW lending is typically in the form of *"advances,"* which are loans evidenced by promissory notes of the borrowing bank and secured by adequate collateral.

Like any private lender, the Fed is concerned with managing its credit risk by adjusting the terms of discount window loans (i.e. the maturity and interest rate on the loan) and by stipulating a haircut on collateral it receives.[8] Historically, the Fed has changed the list of

[5]Although the distinction between illiquidity and solvency is emphasized in the literature, it may be difficult for the central bank to make such a distinction in practice, in part due to the rapidity with which decisions have to be made during crisis periods.

[6]The literature provides three reasons why the interbank market may fail. First, with incomplete markets, the interbank market may be unable to distinguish solvent and insolvent banks, whereas central banks may be better able to do so because of its supervisory relationship with banks. Berger, Davies, and Flannery (2000) find evidence that supervisory assessment of a bank's future performance is better than that of the market shortly after supervisors have inspected a bank. Second, Flannery (1996) argues that the central bank can provide sufficient liquidity to diversify risk across a large number of illiquid banks; in contrast, an individual bank's surplus may not be enough to lend to all illiquid banks. Rochet and Vives (2004) shows that if the interbank market loans contain a large adverse selection discount, as in Flannery (1996), then central bank should supplement ex-ante regulation with discount window loans at a very low rate. Third, Freixas, Giannini, Hoggarth, and Soussa (1999) point out that individual banks may hoard liquidity if they are concerned about losing access to funds in the future whereas central banks can simply increase the money supply.

[7]The term *"discount window"* is a historical legacy from the times when much of the Fed's lending was done by discounting (in the early years of the Fed, banks mainly borrowed via discounts by presenting eligible bills and receiving credit from the Fed in an amount equal to the value of the asset at maturity minus a *"discount"*). All depository institutions that maintain transaction accounts or nonpersonal time deposits subject to reserve requirements are entitled to borrow at the discount window. These include commercial banks, thrift institutions, and U.S. branches and agencies of foreign banks.

[8]The haircut is the amount by which value of collateral exceeds the value of the loan, expressed as a percent of loan value.

approved collateral infrequently.[9] Therefore, the Fed has primarily relied on changes in the terms of DW loans to manage its credit risk.

2.2 Discount Window Lending and Stigma: Some Historical Perspective

The question of stigma has been a lingering issue throughout the history of the DW. In theory, the DW loan rate should be set below the break-even loan rate of a private lender who is unable to discriminate between good and bad credit (see Flannery (1996)). Prior to 2003, banks in distress could borrow from the DW at a rate below the Fed target rate. However, a bank had to show the Fed it was in trouble in order to get funds from the DW - a procedure necessary precisely because the DW rate was below the fed funds rate. If the market learned that a bank had accessed the DW then it could logically conclude that the bank was indeed in trouble since this is what the Fed concluded. Hence, a consequence of setting rates below market, was that it clearly created a perception of stigma associated with DW borrowing as it indicated weakness both to competitors and to the Fed. These concerns deterred banks from DW borrowing even when they had an urgent need for funds.

In response to possible adverse effects of stigma, the Fed increased the DW rate in 2003 to a penalty rate of 100 basis points above the target rate.[10] The new DW is a *"no questions asked"* facility. Namely, the Fed does no longer have to establish a bank is in trouble to lend money. Further, eligibility for primary credit was restricted to generally sound institutions. In Regulation A, as revised in 2003, the Fed classified DW loans into seasonal credit, primary and secondary credit. Financially strong, well-capitalized banks borrow under the primary credit program while other banks use the secondary credit program and pay a higher rate. Seasonal credit is for relatively small banks with seasonal fluctuations in reserves. Our focus in this paper will be on the primary credit program.

[9] In 1999, the Fed expanded the range of acceptable collateral to include such items as investment-grade certificates of deposit and AAA-rated commercial mortgage-backed securities. Other acceptable collateral consists of U.S. Treasury securities, state and local government securities, collateralized mortgage obligations (AAA), consumer loans, commercial and agricultural loans, and certain mortgage notes on one-to-four family residences.

[10] The 2003 DW policy change was announced on January 6, 2003 and was implemented on January 9, 2003 (see: `http://www.federalreserve.gov/boarddocs/press/monetary/2003/20030106/default.htm`). See also `http://www.newyorkfed.org/aboutthefed/fedpoint/fed18.html` for details on the operations of the DW.

Reserve Banks determine eligibility for primary credit according to a uniform set of criteria, based mainly on the borrower's examination ratings and capital. Supplementary information, such as market-based information, also could be used to determine eligibility. Primary credit for overnight maturity ordinarily is extended with minimal administrative burden on the borrower at a rate which is equal to a spread above the target federal funds rate .

By employing an above-market rate and restricting eligibility to generally sound institutions, the Fed hoped that it would have a reduced need to review the funding situations of borrowers and monitor the use of funds borrowed in the primary credit program. The Fed stated that *"this reduced administration, in turn, is expected to make the DW a more attractive funding source for depository institutions when money markets tighten."*[11]

Despite these changes, with the onset of the 2007 financial crisis discussions and perceptions of stigma resurfaced. During the second half of 2007 financial institutions faced serious liquidity shortages (as revealed by increases in the LIBOR-OIS spreads) but did not borrow from the DW. This can be seen in Figure 1 which shows the average weekly DW primary credit outstanding in billions of dollars. The amount of DW credit outstanding prior to the bankruptcy of Bear Stearns in March 2008 was negligible. Similar evidence is reported in Figure 2 which shows the average number of banks receiving DW loans each month. We find that very few banks received DW loans prior to April 2008. The same figures show that TAF borrowing and participation was considerably higher than DW borrowing and participation, respectively, from December 2007 (when TAF was implemented) to March 2008, suggesting that banks had funding needs at this time but were reluctant to visit the DW, despite the fact that DW was cheaper than LIBOR, for example.

To encourage borrowing, the Fed reduced the DW spread over the target rate from 100 basis points to 50 basis points on August 17, 2007 and agreed to provide financing for terms as long as 30 days, renewable by the borrower.[12] In addition, the Fed issued public statements that DW borrowing would be viewed as a sign of strength for banks. However, as banks continued to avoid the DW, the Fed created the TAF facility in December 2007 to improve the Fed's ability to supply liquidity to the banking system. The desire to mitigate stigma has been cited as one reason for the creation of TAF, as we discuss further below (see also Armantier, Krieger, and McAndrews (2008)).

[11] See `http://www.newyorkfed.org/aboutthefed/fedpoint/fed18.html`.

[12] See `http://www.federalreserve.gov/newsevents/press/monetary/20070817a.htm`.

2.3 The Term Auction Facility

In response to persistently adverse liquidity conditions in the interbank markets, the Fed announced the creation of the Term Auction Facility (TAF) on December 12, 2007. The purpose of the TAF was to serve as a complement to the DW, providing sound depository institutions with term funding at interest rates set competitively through an auction mechansim. Prior to each TAF auction, the Fed announced the amount of funds to be allocated. An eligible financial institution could then submit up to two bids, each consisting of a rate-quantity pair.[13] Bids submitted at the highest rates were accepted first, and the market clearing rate, known as the stop-out rate, was determined so as to equalize the supply and the aggregate demand for term funding. The TAF belonged to the *"uniform-price"* (or single-price) class of auctions, whereby each bidder that submitted a bid at or above the stop-out rate received the funds it demanded, and was asked to pay the stop-out rate. A total of 60 TAF auctions were conducted roughly every two weeks between December 12, 2007 and March 8, 2010. The amount allocated at TAF auctions varied from $ 20 billion initially to $ 150 billion at the peak of the crisis. The terms of the funds allocated were either 28 or 84 days, with a few exceptions.

Since the TAF was introduced as a complement to the DW, the two standing facilities share a number of important features. As indicated in Table 1, where the two facilities are contrasted, funding is offered against the same collateral assets and using identical haircut calculations. In addition, during the period studied the same institutions - those deemed in sound financial condition by their District Reserve Bank - had access to both facilities.

The TAF and the DW facilities are also different in some respects. First, the borrowing rate at the TAF was set through competitive bidding at an auction, while the DW offers a posted price. Second, while most TAF auctions allocated funds for 28 or 84 days, the terms of DW loans varied from overnight to 90 days.[14] Third, TAF loans cannot be prepaid, while DW loans can be repaid at any point in time. Fourth, TAF bidding by an individual

[13] TAF auctions have a minimum bid rate which was equal to the Overnight Index Swap rate until January 12, 2009, and then to the rate of interest that banks earn on excess reserve balances (25 basis points as of January 2010).

[14] The DW offered only overnight loans until the 17th of August 2007, after which the terms were extended to 30 days. On March 17, 2008 the terms of the DW loans were once again extended to 84 days. Primary credit was reduced to 28 days loans on January 14, 2010, and returned to the historical overnight term on March 18, 2010. Since its inception, the TAF has offered funds for a term 28 days. Longer term loans (typically 84 days) have also been auctioned at the TAF between August 11, 2008 and November 30, 2009.

participant was limited to 10 % of the amount offered by the Fed.[15] Fifth, TAF awards were credited to the winning bidders only three days after the auction. This delay was expected to mitigate any perception that TAF participation was primarily motivated by an urgent need for funding.

To sum up, TAF and DW borrowing may be considered close substitutes. In fact, the differences between the two facilities, and more specifically the possibility of early repayments, tend to make the DW a more flexible borrowing mechanism for banks.

3 Incidence of Stigma

In this section, we describe our methodology to assess the existence of stigma associated with DW borrowing. In a first subsection we describe the tests for the presence of DW stigma. The second subsection covers the empirical tests.

3.1 Testing for the Presence of DW Stigma

Consider a bank, say bank A, on the day (typically Monday) of a 28-day TAF auction. Imagine bank A wishes to borrow funds from the Fed for a term of 28 days starting on the following Thursday (the TAF settlement date). Bank A then faces choice. It can either place a bid at the TAF or decide to access the DW on the TAF settlement day. Observe that, if rational, bank A should first attempt to get the funds from the TAF at a favorable rate. Indeed, the option to turn to the DW on Thursday is still available to bank A, if it learns on Wednesday that its TAF bid was rejected.

Further, we argue that in the absence of DW stigma, bank A should place a bid at the TAF at a rate below the DW rate.[16] To rationalize this argument, we make the weak assumption that each bank has a maximum willingness to pay (MWTP) for funds from the Fed. The MWTP is therefore equal to the rate above which a bank would not borrow any funds from

[15]The TAF also has a minimum bid amount requirement. The minimum amount was initially set at $ 10 million, and then rapidly reduced to $ 5 million on February 1, 2008. There is no minimum requirement at the DW, but in practice, this difference can be considered minor. Few banks take loans at the DW for amounts less than the TAF minimum, and banks that lack the collateral to make the minimum TAF bid generally have balance sheets that appear likely to allow them to post more collateral if needed.

[16]In fact, given the added flexibility of the DW (most importantly, the prepayment option), one could argue that, absent DW stigma, a bidder should submit a TAF bid strictly below the DW rate.

the Fed.[17] The MWTP may differ across banks depending on their respective funding needs and on the rates at which they can borrow from the market. We can then show that it is a dominated strategy for bank A to bid above its MWTP, that is, bank A has nothing to gain in bidding above its MWTP.[18]

To see this, consider Figure 3 where we illustrate the three outcomes that are possible when bank A bids above its MWTP, depending on the stop-out rate of the auction. First, if the stop-out rate is above the bid of bank A (outcome 1 in Figure 3), then bank A's bid is rejected, just like it would have been rejected if bank A had bid its MWTP. Second, if the stop-out rate is below the MWTP of bank A (outcome 2 in Figure 3), then bank A does as well by bidding at or above its MWTP. In Figure 3 we can see that the gains accruing to the bank are the same in either situation. Finally, if the stop-out rate is between the MWTP and the bid of bank A (outcome 3 in Figure 3), then the price paid by bank A (the stop-out rate) is above its MWTP. Bank A incurs the losses indicated in Figure 3 and therefore, it would have been strictly better off bidding its MWTP.

In summary, a bidder cannot do better by bidding above its MWTP.[19] This result forms the basis of our empirical methodology: absent DW stigma, a rational bank should never bid above the DW rate. We will therefore interpret a bid above the DW rate as evidence of stigma.

An alternative methodology for estimating the incidence of DW stigma has been proposed by Furfine (2003) who test empirically whether there is stigma associated with borrowing from the DW after 2003. Furfine (2003)'s empirical approach essentially consists in comparing the DW rate with the rates at which banks transact federal funds on the market. He argues that if banks borrow fed funds for overnight maturity at a rate above the DW rate, then this may be interpreted as evidence of DW stigma. Using data covering a period of 3 months after the

[17] We are not trying to derive a formal game theoretic auction model as in e.g. Wilson (1979). The MWTP should therefore not be interpreted as a bidder's private demand function for funds from the Fed as may be the case in these auction models. We only impose enough structure to show that, absent DW stigma, a bank should not bid above the DW rate. In more formal share auction models with a uniform price mechanism similar to the one used for the TAF, it is well known that bidders shade their bids (see e.g. Ausubel and Cramton (2002)). Therefore we will not assume that banks bid exactly their MWTP.

[18] The rationale is similar to showing that bidding above one's value is a dominated strategy at a second price single unit auction.

[19] A bidder could rationally bid above its MWTP only if it believes that the third outcome has a probability zero to occur. After September 2008, every TAF auction was under-subscribed and therefore settled at the minimum bid rate. It may therefore be argued that TAF participants did place a zero probability on the third outcome in these auctions. Although we do not necessarily agree with this argument, we will eliminate all under-subscribed auctions from our analysis.

January 9, 2003 implementation of the new DW policy, Furfine (2003) finds evidence of DW stigma. Aside from the fact that Furfine (2003)'s data may not span a period long enough to allow banks time to adjust to the new DW rules, we see two potential problems with his empirical approach.

First, the fed funds market and the DW cannot be compared directly as they are not perfect substitutes. In particular, while borrowing from the DW requires collateral, the fed funds market is uncollateralized. Second, fed funds transactions are not observed directly. Instead, they need to be inferred using an algorithm. This is because every fed funds transaction is settled over Fedwire, the real-time gross settlement system operated by the Fed. The difficulty resides in identifying which of the Fedwire transactions are actually Fed Funds trades. To do so, Furfine (2003) devised an ingenious algorithm, which despite its appeal is still prone to measurement error. In particular, although the algorithm appears to perform adequately to estimate the "effective" fed funds rate (i.e. the quantity-weighted average rates of trades arranged by the largest brokers), it may generate noise by keeping transactions that are not fed funds trades and by discarding actual fed funds trades. In particular, nothing guarantees the accuracy of the algorithm for the transactions in the upper tail of the rates distribution. However, these are precisely the transactions (i.e. those with high rates) that Furfine (2003)'s approach relies upon to test for DW stigma.

3.2 Empirical Evidence on the Existence of DW Stigma

We plot in Figure 4 the fraction of banks participating in at a TAF auction that bid above the DW rate on the day of the auction, for the twenty-one TAF auctions in our sample. We find that this fraction is greater than zero in all but two auctions implying that some banks bid above the DW rate at virtually every TAF auction. Between March and October 2008, the fraction of banks bidding above the DW rate has been large (more than 60 percent) with a generally increasing trend. The first row of Table 2 shows that, of $1,540$ bank-auction pairs in the sample, bids above the DW rate occurred 56 percent of the time. As explained in the previous subsection, we interpret this result as conclusive evidence of DW stigma during the 2007-2008 crisis period.

A possible objection to our reasoning is that, in the absence of DW stigma, banks could behave out of equilibrium and bid above the DW rate if the expected cost of doing so is zero. This might occur if, with high probability, banks expect the stop-out- rate to be below the

DW rate. Figure 4 provides evidence to refute this argument. Indeed, after the reduction in the DW rate on March 16, 2008, 12 of the subsequent 14 TAF auctions (indicated by solid circles in Figure 4) settled above the DW rate. In other words, borrowing funds from the Fed was actually less expensive at the DW than at the TAF for a sustained period of time in 2008 (nearly 6 months). Therefore, banks making high bids at the TAF during this period faced a high probability that their actual borrowing rate would exceed the DW rate.

Moreover, it does not appear that bids above the DW rate could be explained by several banks making occasional bidding mistakes. Figure 5 shows that some banks tend to repeatedly bid above the DW rate. In particular, the median vertical line in Figure 5 shows that 50 % of banks that submitted a bid above the DW rate did so at 2/3 or more of the TAF auctions at which they participate.[20] Moreover, 38 out of 178 TAF participants submitted bids above the DW rate at every auction in which they participated.

Figure 4 clearly exhibits two different regimes of bidding behavior. Prior to March 16, 2008, when the Fed reduced the DW penalty rate, bidding above the DW rate was rare. After this date, bidding above the DW rate became frequent. Under the assumptions made in the previous section, this regime shift may be explained by a simple mechanical effect. Lowering the DW penalty makes the DW more affordable, but it is unlikely to substantially affect a bank's MWTP for funds from the Fed. As a result, after the change in DW policy, a larger number of banks should have a willingness to pay (WTP) above the DW rate, and should therefore be more likely to submit a bid above the new DW rate.

In summary, we find that bidding above prevailing DW rates is frequent and widespread at the TAF during the crisis and occurs even at auctions where the stop-out rate was expected to exceed the DW rate with high probability. These results provide strong evidence of the existence of DW stigma during the 2007-2008 crisis.

4 Determinants of DW Stigma

Having documented that some banks exhibit DW stigma, we now attempt to identify the factors that may influence the incidence of DW stigma. To do so, we estimate a probit model with bank specific random effects. In a first subsection we discuss the model specification, while in the second we report the empirical results.

[20] On average, this group of banks participated at more than 8 of the 21 auctions in our sample.

4.1 Model Specification

We estimate a probit model with a bank specific random effect where the dependent variable $y_{i,t}$ equals 1 when bank $i \in \{1, .., 137\}$ submits a bid above the DW rate at TAF auction $t \in \{1, ..., 21\}$. The sample includes all bank-auction pairs for 28-day, fully subscribed TAF auctions.[21] We first estimate a baseline model including bank and market characteristics, as follows:

$$\begin{aligned} y_{it} \;=\; & \alpha_0 + \alpha_1 \text{Log of assets} + \alpha_2 \text{Log of pledged collateral} \\ & + \alpha_3 \text{Pledged collateral increased} \\ & + \alpha_4 \text{Bank bid at previous auction} + \alpha_5 \text{Awarded funds at previous auction} \\ & + \alpha_6 \text{Bid above DW at previous auction} \\ & + \alpha_7 \text{Fed funds standard deviation} + \alpha_8 \text{LIBOR-OIS spread} + \varepsilon_{it} \end{aligned} \tag{4.1}$$

The exact definition of the variables appears in the Appendix. The specification includes three groups of variables. They pertain to (a) individual bank characteristics, (b) auction related variables and finally (c) proxies for market funding conditions. These characteristics include the *Log of assets*, *Log of pledged collateral* and *Pledged collateral increased*, where the latter two proxy for banks' expected funding needs (we also considered several other bank-level explanatory variables which yielded similar results). The sign of α_1 indicates whether, after controlling for bank funding needs and market conditions (which are accounted for in the regression), bigger banks bid more or less aggressively than smaller banks. Likewise, positive α_2 and α_3 imply that banks with more collateral pledged at the DW, and banks that increased the amount of collateral they pledge from the previous TAF auction are more likely to bid above the DW rate. The coefficients α_4 through α_6 examine whether a banks past bidding behavior increases or decreases the incidence of DW stigma. For example, since banks' funding needs may be persistent, we include variables related to banks' behavior at the previous auction. A positive sign on α_6 implies that a banks' perception of stigma is persistent. Likewise, a positive α_4 isolates the effect of first time and non-returning TAF bidders. Conversely, we might expect that α_5 may be negative as funding in previous auctions may decrease the need of funding, and hence decrease bidding above the DW rate. Finally, the last two measure how market conditions affect the incidence of DW stigma. Following

[21] The population of banks used in the probit analysis consists of TAF bidders. Therefore, we do not include banks that were eligible to bid for the TAF but chose not to do so.

Vives (2010) we expect α_7 and α_8 to be positive as well. He shows that an increase in stress indicators such as the LIBOR-OIS spread raises the probability of a crisis and increases the impact of bad news (i.e. a discount window visit that becomes public). This is because public news has a multiplier effect on asset prices beyond its informational content as each agent anticipates the reaction to bad news of other agents and so everyone becomes more cautious in acting.

Since interest rate policy changes affect the market rates, and therefore banks' outside opportunity cost of funds, we also re-estimate the baseline model after adding two variables controlling for (1) the March 16, 2008 reduction in DW penalty rate, and (2) changes in the Fed target rate. These variables are: *After DW rate change*, which equals 1 after March 16, 2008, and *Fed funds target rate*, which is the level of the fed funds target.

In our final specification, we further account for banks' recent DW activity. The objective is to examine whether the incidence of DW stigma depends on how frequently banks have used the DW as a source of funding recently, both individually and collectively. Thus, we include the following variables in the regression. *Days in last week bank took DW loan* is the number of days that the bank took out DW loans in the week prior to the TAF auction. *Banks taking DW loans week before* refers to the total number of banks that received DW loans in the week prior to the TAF auction.

4.2 Empirical Results

Results from estimating the baseline model are reported in column 1 of Table 3. In terms of individual characteristics, it appears that the incidence of stigma is more frequent among smaller banks (i.e. banks with fewer assets) since α_1 in equation (4.1) is negative. This result may imply that small banks have a higher DW stigma rate. Alternatively, it may simply reflect the fact that during the crisis small banks had a higher WTP for funds from the Fed, as they may have found it more difficult than their larger counterparts to fund themselves on the market. Once we control for size, we find that banks with more collateral pledged at the DW, and banks that increased the amount of collateral they pledge from the previous TAF auction are more likely to bid above the DW rate.[22] These results are consistent with

[22] Although, the two variables *"log of assets"* and *"log of pledged collateral"* are relatively highly correlated ($\rho = 0.622$) they each seem to capture different information about TAF bidding and they do not seem to create an autocorrelation problem. In fact the estimated parameters do not change significantly when one of the two variables is excluded.

the fact that, as they are bidding aggressively, these banks anticipate they will receive funds at the TAF auction, and therefore plan to have the necessary collateral pledged.

Considering a banks' past bidding behavior, the regression results suggest that first time and non-returning TAF bidders are more likely to exhibit DW stigma. Since α_4 is negative in equation (4.1), the probability to bid above the discount rate is lower when a bank participated at the previous TAF auction. In contrast, DW stigma seems to affect returning bidders equally, regardless of whether or not they were awarded funds at the previous TAF auction. Moreover, consistent with our prior result that the incidence of DW stigma is persistent (see Figure 5), we find that a bank is 65 % more likely to bid above the DW rate if it also did so at the previous auction.

Market conditions significantly affect the incidence of DW stigma. The coefficients on the volatility of fed funds rates and the LIBOR-OIS spread are found to be positive and significant - which conforms with the theoretical arguments of Vives (2010). According with intuition, the incidence of DW stigma appears more frequent when there is greater uncertainty about the rates at which banks can obtaining funds and when the market risk premium is high, as banks may find it more difficult to find a viable alternative to borrowing from the Fed.

The impact of policy changes on the incidence of DW stigma is reported in column 2 of Table 3. We find that, consistent with Figure 4, more banks are likely to bid above the DW rate after the DW penalty rate had been reduced on March 16, 2008. In addition, we find that the effect of the target rate is positive and significant, indicating a decrease in the incidence of DW stigma when the Fed lowers the target rate. Interpreting this result is not trivial, as changes in the target rate may produce two opposite effects. First, as the DW rate varies along with the target rate, one could expect that lowering the target rate would lead more banks to bid above the DW rate. To hold, this argument requires that a bank's MWTP for funds from the Fed remains unaffected by such a policy change. A modification of the Fed target rate, however, is generally expected to ease market conditions. As a result, the bank's MWTP for funds from the Fed could drop, in which case banks would be less prone to bid above the DW rate. The results of the probit model suggest that this second effect dominates.

We next estimate the effects of banks' recent DW activity on the incidence of stigma. As indicated in column 3 of Table 3, all else equal, a bank is less likely to bid above the DW

rate the greater the number of times in the previous week that it visited the DW. Such behavior suggests that, in the short term, DW stigma declines with the number of recent DW visits. The model also controls for the number of banks which took DW loans during the week prior to a TAF auction. Our estimation results suggest that an increase in the number of banks taking out DW loans is associated with a higher incidence of DW stigma. This counterintuitive result may be explained by a confounding factor: as the increase in the number of banks accessing the DW may also reflect a worsening in market conditions.

To conclude this section, we observe that results from estimating various specifications of the econometric model reported in Table 3 attest to the robustness of our conclusions. Indeed, both the significance and the magnitude of most of the estimated parameters remain very similar regardless of the specification.

5 The Magnitude of the DW Stigma Premium

The economic importance of DW stigma depends on its magnitude. Having shown the existence of DW stigma, we now estimate a lower bound for the magnitude of the DW stigma premium and analyze the determinants of this lower bound. In the first subsection we discuss methodological issues related to estimating the magnitude of the stigma premium. In the second subsection, we report estimates of lower bounds on the DW stigma premium and the variation of this bound during the crisis period.

5.1 Methodology

We define the *"DW stigma rate"* as the highest interest rate a financial institution is willing to pay in order to avoid borrowing at the DW. By extension, we define the *"DW stigma premium"* as the difference between the DW stigma rate and the DW rate. As illustrated in Figure XX, we only define these variables when a bank exhibits DW stigma, that is, when the DW stigma premium is positive.

Observe first that we make a distinction between the DW stigma rate and what we previously referred to as a bank's MWTP to borrow funds from the Fed. The former may be interpreted as a bank true cost of borrowing at the DW, while the latter reflects the bank outside option (e.g. the rates it can obtain on the market). Prior to the implementation of the TAF program,

a bank would therefore only access the DW when its MWTP would exceed its DW stigma. Note also that we do not impose any restrictions on the determinants of the DW stigma rate. It may vary across financial institutions (depending e.g. on the bank specific needs and financial health) and over time (depending e.g. on general economic conditions).

As defined, the DW stigma rate (and by extension the DW stigma premium) is a latent variable. Proxies for the DW stigma rate, such as the rates paid on the market, the bids at the TAF, and DW borrowing, can only provide a lower bound on the DW stigma rate. For instance, a financial institution paying x % above the discount rate on the market may have been willing to pay even more to avoid borrowing from the DW. Likewise, it is easy to show that, in the presence of DW stigma, a bank should not bid above its true cost of borrowing at the DW (i.e. the DW stigma rate).[23] As a result, we can only hope to approximate the DW stigma rate and premium from below.

The lower bound we adopt for a bank DW stigma rate on the day of a TAF auction is its TAF bid. More specifically, as illustrated in Figure XX , we calculate what we call the *"effective DW stigma premium"* as the difference between a bank's highest bid rate at a given TAF auction (i.e. the maximum of its two bids at the auction) and the DW rate. Again, this variable is only defined when there is actual evidence of DW stigma, that is, when a bank bids above the DW rate. In other words, the effective DW stigma premium is only defined when strictly positive.

As defined, the effective DW stigma premium may therefore be considered a legitimate lower bound for the DW stigma premium. This approach, however, has limitations. In particular, although we may be able to identify the determinants of the effective DW stigma premium, those may not automatically extend to the DW premium. As illustrated in Figure XX for instance, TAF bids, and therefore the effective DW stigma premium, could vary (e.g. across banks or over time) while the DW stigma rate could remain unchanged. In other words, the DW stigma premium and its lower bond could vary independently of each other.

5.2 Empirical Results

As explained in the methodology section, the DW stigma premium can only be approximated from below by a lower bound. We plot in Figure 6 the effective DW stigma premium, averaged

[23]The argument is essentially the same we used to show that, in the absence of DW stigma, a bank should not bid above the DW rate.

over all banks bidding at an auction. We find that, except for the auction conducted just after the bankruptcy of Lehman Brothers, the average effective DW stigma premium is relatively stable. In particular, it has remained virtually unchanged around 37 basis points during the eight auctions conducted in summer 2008, a period during which TAF funding was more expensive than the DW rate.

We further observe from Figure 6 that the average effective DW stigma premium suddenly jumps from 36 to 143 basis points after Lehman Brothers filed for bankruptcy. To understand this result, recall that at the time, there was grave concern about which would be the next bank to fail. In these times of heighten tension and scrutiny, it therefore appears natural that banks were willing to go to great expense in order to avoid showing any signs of weakness. In particular, our results suggest that banks were willing to pay a substantial premium in order to avoid borrowing from the DW which, if detected, might have been interpreted as a sign of financial troubles.

In contrast to Figure 4, we do not see any evidence of a structural break after the March 16, 2008 reduction in the DW penalty rate. Earlier, we found that the policy change increased the incidence of DW stigma, as an expanded set of banks had a MWTP for funds from the Fed at a rate higher than the DW rate. The expected impact of the policy change on the average effective DW stigma premium, however, is ambiguous. On the one hand, the group of banks which already experienced DW stigma before the policy change now have a larger effective DW stigma premium. On the other hand, there is a new group of banks which had not previously experienced DW stigma, with low effective DW stigma premia. The combination of these two effects is ambiguous and no clear prediction can be made about how a reduction of the DW penalty rate impacts the average effective DW stigma.

To better understand the determinants of the effective DW stigma premium, we regress a bank's effective DW stigma premium at an auction on a number of explanatory variables, including a bank specific random effect. The set of explanatory variables are identical to those used in Table 3. The results of the baseline model reported in Table 4 reveal that several bank characteristics have significant power to explain a bank's effective DW stigma premium. In particular, we find that small banks are not only more likely to experience DW stigma (see previous section), but they also appear to have a larger effective DW stigma. More precisely, our results suggest that a 1 % increase in log assets, is associated with a 5.25 basis points reduction in the effective DW stigma. Once we control for size, we find a higher effective DW stigma premium for banks with large amounts of collateral pledged at the DW,

and banks that post additional collateral compared to the previous TAF auction. Consistent with earlier conclusions, these results may reflect the idea that banks anticipating greater need to borrow TAF funds are willing to incur a greater DW stigma premium.

The outcomes of the baseline model also suggest that a bank's effective DW stigma premium is correlated with its past bidding behavior at the TAF. In particular, it appears that banks that experienced DW stigma at the previous auction have a larger effective DW stigma premium. As we shall see next, however, the magnitude of this effect declines once we control for market conditions and recent DW activity. According with intuition, we also find that the magnitude of stigma seems to increase when market risk premium increases, as measured by the LIBOR-OIS spread. The market variables, however, are not sufficient to fully explain the sharp increase in effective DW stigma observed after the bankruptcy of Lehman Brothers. Indeed a dummy variable controlling for this event is estimated to be highly significant and substantial in magnitude (more than 100 basis points). In other words, our results suggest that the banks' reactions to the failure of Lehman Brother is not fully explained by deteriorations in market conditions at the time.

Next, we augment the baseline model by controlling for policy variables (column 2 in Table 4). Consistent with Figure 6, we find that, on average, the March 16, 2008 change in the DW penalty rate did not have a significant effect on the effective DW stigma premium. In contrast, our results suggest that the effective DW stigma premium increased slightly as the Fed lowered its target rate during the crisis. Finally, we find from results reported in column 3 of Table 4 that the number of visits by a bank to the DW the week prior to a TAF auction reduces that bank's effective DW stigma premium. This result is similar to that found with the incidence of stigma in Table 3. We also find that, all else equal, the effective DW stigma premium is positively correlated with the number of banks taking DW loans the week prior to a TAF auction. Although possibly surprising, this result may reflect the fact that the number of banks visiting the DW captures deteriorations in market conditions.

6 The Economic Cost and Market Impact of DW Stigma

The economic importance of DW stigma also depends on the banks' shadow cost of DW avoidance. In the first subsection, we provide estimates of the aggregate shadow cost to the

banking sector of obtaining more expensive funds in order to avoid borrowing at the DW. In the second subsection, we provide a complementary estimate of the economic costs of stigma. Specifically, we estimate the additional borrowing costs incurred by banks who visit the DW, given the perception of stigma attached to DW borrowing.

6.1 Shadow Cost of DW Stigma

To evaluate how much avoiding the DW costs to the banks, we first conduct a counterfactual exercise for each bank that bids above the DW rate at a given TAF auction, by considering a situation in which the bank would pay its own bid. In other words, we assume that the bank is the auction's marginal bidder that sets the auction stop-out rate. We then subtract the DW rate from the bank's TAF bid rate and multiply the difference by the amount of funds bid by the bank. Since the bank under consideration bid above the DW rate, the amount represents how much more a bank risked paying to meet its funding need at the TAF instead of taking the loan at the DW. As a result, the measure obtained may be interpreted as the potential cost of DW stigma.

The results of the exercise are reported in Table 5 Panel A. They indicate that the total potential cost was around $ 18 million per auction on average, or equivalently $ 0.4 million per bank at each auction where it experienced DW stigma. When expressed in relative terms, the potential cost represented roughly 12 % of the potential interest payments made by these banks when visiting the TAF. All of these measures increased greatly after the bankruptcy of Lehman Brothers. Indeed, the average potential cost per bank shot up to $ 2.1 million dollars after the Lehman bankruptcy, which, when expressed in relative terms, correspond to nearly half of the banks' interest payments.

In addition to the potential cost of DW stigma, we also calculate the realized cost by looking exclusively at the 12 TAF auctions that settled above the DW rate. For each of these auctions, we calculate the difference between the stop-out- rate and the DW rate and multiply the difference by the amount of funds actually awarded to the banks. This number represents how much more each of the banks that received funds actually paid at the TAF instead of going to the DW. We find in Table 5 Panel B that the realized cost relative to DW stigma is smaller than the potential cost during the full sample and each subsample (for example, during the summer of 2008, realized costs are $ 5.5 million per auction, or $ 0.1 million per bidder, compared to $ 15.9 million per auction and $ 0.26 million per bidder in potential

costs). The only case where realized costs exceed potential costs is during the auction after Lehman Brothers failed. There, the average potential cost per bank was $ 2.05 million while the realized cost was $ 2.41 million. The realized cost was higher in this situation because the TAF stop-out- rate was sufficiently higher than the DW rate that some banks with TAF bid rates above the DW rate, but lower than the stop-out rate, did not receive funds.

6.2 The Impact on Interbank Markets

The analysis above indicates that banks perceive that DW stigma exists when they are making their TAF bidding decision, so a natural question is whether these banks are justified in their beliefs. Anecdotal evidence about DW stigma posits that banks are subject to higher rates in the interbank market or depressed asset prices due to concerns about credit risk. Ennis and Weinberg (2009) focus on the ability for a bank to sell its assets in a separate market after visiting the DW. Our results indicate that any stigma associated with TAF visits is smaller than the stigma associated with DW visits. Therefore, we also estimate the market impact of banks' TAF visits, with the expectation that TAF borrowing should have lower or no market impact.

We calculate the impact of visiting the DW or TAF on banks' borrowing rates by estimating an equation of the following form:

$$\begin{aligned} y_{it} &= \beta_0 + \beta_1 DW_{it-2} + \beta_2 DW_{it-1} + \beta_3 DW_{it} + \beta_4 DW_{it+1} \\ &\quad + \beta_5 DW_{it+2} + \gamma_2 D2_i + \ldots + \gamma_n Dn_i + \epsilon_{it} \end{aligned} \tag{6.1}$$

where y_{it} is the proportional change in overnight fed funds market borrowing rate for bank i at date t, $DW_{i\tau}$ equals one if bank i visits the DW on date τ, and the Dj_i's are binary variables equal to 1 if bank j = bank i and zero otherwise.[24] The β coefficients give the estimated difference in the dependent variable between banks that visit the DW on date τ and those that do not. By varying τ relative to t, we can examine the difference in quotes associated with going to the DW prior to or after date t.

The equations are estimated over all DW eligible financial institutions between January 2, 2007 and January 4, 2010 using OLS. Standard errors are block-bootstrapped to further

[24]We have also examined the impact of DW and TAF visits on banks' credit default swap contracts and stock return but did not find any statistically significant effect.

eliminate over-rejection due to the time-series elements of the data, as suggested by Bertrand, Duflo, and Mullainathan (2004).

Table 6 shows results from estimating equation (6.1) for the proportional change in overnight interbank market borrowing rates for banks' DW visits (Column 1) and TAF visits (Column 2). The β coefficient estimates are reported in each row under *DW Visit* and *TAF Visit*. The first two rows of estimates ($t-2$ and $t-1$) show the impact of the two days prior to visiting the DW or TAF. These results should only be significant if a bank's counterparties receive a signal about a bank's future plans to visit the DW or TAF or if there is reverse causality (i.e. changes in the dependent variables drive the bank to visit the DW or TAF). The next three rows (t through $t+2$) show the difference in the dependent variable on the day of a bank's DW or TAF visit or on the two days after visiting the DW or TAF. We include the two days after visiting the DW or TAF to allow for gradual discovery of a bank's DW participation by the market.

Results reported in column 1 of Table 6 indicate that prior to visiting the DW, a bank does not experience significantly higher changes in its borrowing rate. On the day a bank visits the DW, however, their borrowing rate increases by 3 %, on average, relative to banks that do not go to the DW. Since the average borrowing rate was about 3 % in our sample, this result indicates an increase in borrowing rates of 9 basis points (i.e. 3 % of 3 %) on the day of the DW visit. This increase partially reverses on the two days after a bank visits the DW, but these effects are not statistically significant. Moreover, the cumulative change in borrowing rates is still positive.

Results reported in column 2 of Table 6 indicate that, in contrast to DW visits, there is no increase in borrowing rates after banks participate in the TAF auctions. This result implies that the market does not perceive TAF borrowing to be a negative signal about banks' financial strength and is consistent with the Fed's expectations in designing the TAF facility.

To examine if our results are robust to alternative econometric methodologies, we further implement a matched sample analysis of banks' DW and TAF visits. Specifically, we pair each bank visiting the DW to another bank that is similar in asset size but never visited the DW during our sample. We use a similar procedure to pair each bank visiting the TAF to another bank of similar asset size that never visited the TAF. In each case, the matched bank is required to borrow from the overnight fed funds market for at least 40 percent of the

days during which the DW or TAF visiting bank also borrowed in the fed funds market. We then estimate the difference in the percent change in the fed funds borrowing rates between the DW or TAF visitor and the corresponding matched bank.

Table 7 reports results from this analysis. Column 1 shows results for DW visits and column 2 shows results for TAF visits. We find that the results are qualitatively similar to those reported in Table 6. In particular, banks visiting the DW visit face increased borrowing rates of more than 2 percent (equivalent to an average increase of 6 basis points in the sample) compared to their matched banks, but banks visiting TAF face no statistically significant increase in borrowing rates. Neither DW nor TAF visitors exhibit a change in borrowing rates prior to their visits. Unlike the prior results, banks visiting the DW also suffer an additional 2 percent increase in borrowing rates on the day after its visit.

Overall, we find compelling evidence that banks visiting the DW have higher borrowing rates subsequent to their visits whereas banks borrowing from TAF auctions do not suffer a similar increase in their borrowing costs. These results provide an economic rationale for why banks were reluctant to visit the DW during the crisis but borrowed freely from TAF auctions.

7 Conclusion

As the opening quote from Chairman Bernanke suggests, it has been argued that the perception of stigma attached to borrowing from the DW complicates the Fed's efforts to supply liquidity to banks. In this paper, we provided rigorous evidence of the existence and incidence of DW stigma during the financial crisis that emerged in 2007. We find that banks preferred were willing to pay an average of 37 basis points more to borrow from the Fed's Term Auction Facility than from the DW. Moreover, our results are consistent with the hypothesis we find that the perception of stigma has real effects in asset markets . In particular, banks' interbank borrowing rate is higher the day after a DW visit. Our results have policy implications for central banks regarding the best mechanism to supply liquidity during crisis periods.

It should be emphasized that, while our analysis pertains to central bank liquidity supply during crisis periods, the relevance of DW stigma also applies to normal periods. Modern central banks conduct monetary policy by keeping interest rates within a *"corridor"* where

the floor of the corridor is given by the standing deposit facility rate (or the interest on excess reserves, in the Fed's case) and the ceiling is the DW rate. The existence of DW stigma implies that the ceiling of the corridor is higher than intended by monetary policy; moreover, to the extent that the magnitude of stigma is unknown, there is uncertainty regarding the ceiling's location. Clearly, understanding DW stigma is important for monetary policy implementation even in normal times.

Our results also have implications beyond the question of the Fed (or any central bank for that matter) liquidity supply since the issue is neither isolated to the supply of liquidity nor is it isolated to the U.S.. For example, as the financial sector was recovering from the crisis, banks that held off returning the government's financial assistance were branded by the financial press as having TARP stigma.[25] Moreover, as Llewellyn (2008) and Lumsdaine (2009) note, in the case of Northern Rock, the run of deposits began immediately after it was announced that the bank had sought liquidity assistance from the Bank of England and that the regulatory authorities had declared that the bank was solvent.

Our paper examines the behavior of banks who bypassed the discount window and borrowed at higher rates at the TAF. The Fed discontinued the TAF program in 2010. What might be the role of the discount window going forward? One view is that the discount window is an important commitment device of the central bank even if it is not used widely during crisis periods. For example, Acharya, Gromb, and Yorulmazer (2010), argue that the discount window is useful even if banks do not borrow from it. This is because the discount rate sets an upper limit to the rents that banks with surplus liquidity can squeeze out of banks that need liquidity but have weak market power. In their model, central banks do not lend in equilibrium but rather change the outside option of banks needing liquidity, thus forcing surplus banks to adjust their liquidity supply.

[25]The article entitled *An offer US banks could not refuse* (Financial Times, May 15, 2009) describes how original TARP distribution was structured to minimize stigma and *Repaying TARP* (Financial Times, May 18, 2009) discusses how it failed to avoid creating a stigma.

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Appendices - Data and Variable Descriptions

A Data Description and Sources

The data may be grouped into three categories: TAF auction activity data, DW activity data, and data regarding bank balance sheets, asset prices of banks, and market interest rates. The sample period for all data series is from January 2, 2007 to January 31, 2010.

Disaggregated TAF bid data come from the New York Fed and contains observations of bid amount, award amount, and bid rate for all bids submitted by each bank at each TAF auction. Aggregate TAF statistics for stop-out rate, minimum bid amount, and term come from the Federal Reserve Board. The universe of TAF eligible banks and collateral postings by banks on each auction date come from the New York Fed. The TAF data is available from December 17, 2007, the start of the facility, to September 22, 2008, the first TAF auction after the collapse of Lehman Brothers.

Loan level information on bank DW access comes from the New York Fed. This dataset contains the loan amount, interest rate, planned duration of the loan (i.e. the term that the bank wants the loan for), the actual duration in the event of prepayment, and type of loan – either primary, secondary, or seasonal. We examine DW activity from January 2, 2007 to January 31, 2010.

Bank asset values are obtained from the Fed's Call and Thrift Reports. The fed funds effective rate and standard deviation are reported by the New York Fed Markets Group. Three month US LIBOR rates are from the British Banker's Association. The three month Overnight Indexed Swap (OIS) rate is obtained from Bloomberg. Bank stock prices are from CRSP. Five-year, senior CDS spreads are from Markit. For each financial institution, the CDS contract with the largest number of quotes over the sample period is used to mitigate illiquidity premia. The weighted average overnight fed funds borrowing rate is inferred from the Fedwire transactions journal. *Days in last week bank took DW loan* is the number of days that the bank took out DW loans in the week prior to the TAF auction. *Banks taking DW loans week before* refers to the total number of banks that received DW loans in the week prior to the TAF auction, and *Fed funds target rate*, which is the level of the fed funds target. Finally, *After DW rate change*, is a dummy variable which equals 1 after March 16, 2008 and *After DW Penalty Change* equals 1 for each auction after the change in the DW

primary credit rate penalty spread.

B Variable Definitions

In section 4 we investigate how individual bank characteristics impact the incidence of stigma. In the empirical analysis we use the following variables defined as follows: (1) *Log of assets* refers to the log of quarterly assets as reported to the bank's regulator, (2) *Log of pledged collateral* is the log of total collateral pledged to the Fed prior to each TAF auction, and (3) *Pledged collateral increased* is a dummy variable equal to equals 1 if the bank increased their its pledged collateral from the previous auction. The following dummy variables indicate whether banks had funding needs at the prior auction and, if so, whether they were successful in obtaining funds: (4) *Bank bid at previous auction* equals 1 if the bank bid at the previous TAF auction, and (5) *Awarded funds at previous auction* equals 1 if the bank was awarded funds at the previous TAF auction. Finally, the following dummy variable indicates whether the bank's bid at the prior auction reflected an incidence perception of DW stigma: (6) *Bid above DW at previous auction* equals 1 if the bank bid above the DW rate at the previous TAF auction.

Figure 1: Amount of DW and TAF Credit Outstanding

Average, weekly TAF (solid line) and DW Primary Credit (dashed line) outstanding in billions of US dollars. Both series are reported in the Fed's H.4.1. The dates of the purchase of Bear Stearns and the bankruptcy of Lehman Brothers are indicated by the vertical lines.

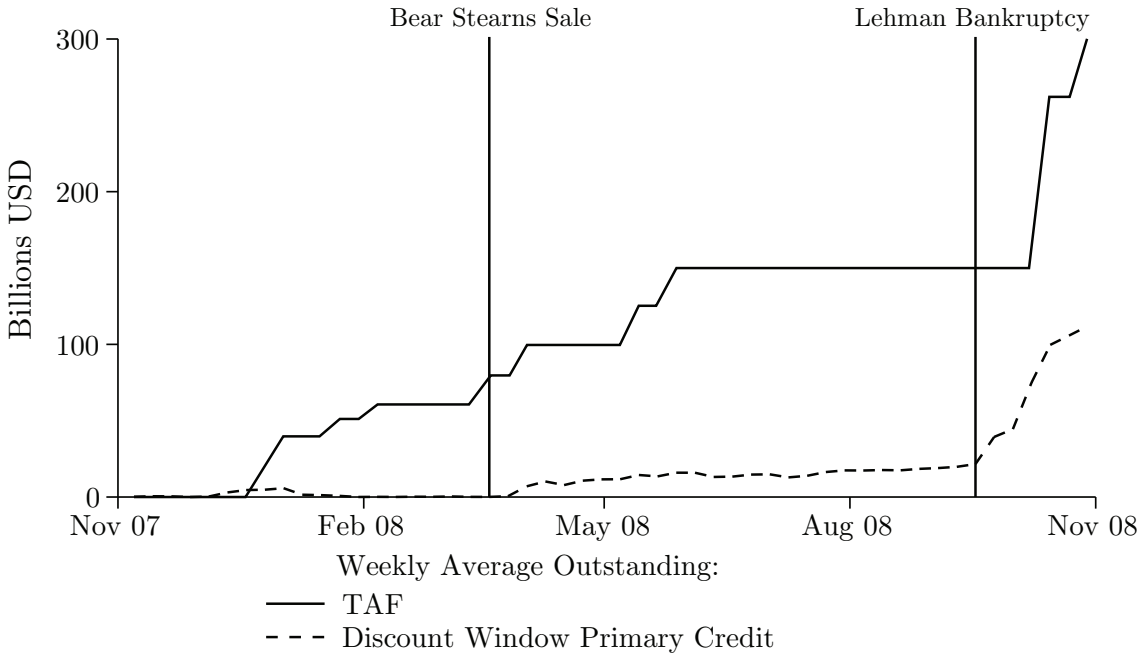

Figure 2: Participation at TAF and DW

Average, monthly TAF (solid line) and DW (dashed line) participation. TAF figures are reported by the Federal Reserve Board, and DW participation is derived from the Fed System *Monthly Report on Credit and Liquidity Programs*. The dates of the purchase of Bear Stearns and the bankruptcy of Lehman Brothers are indicated by the vertical lines.

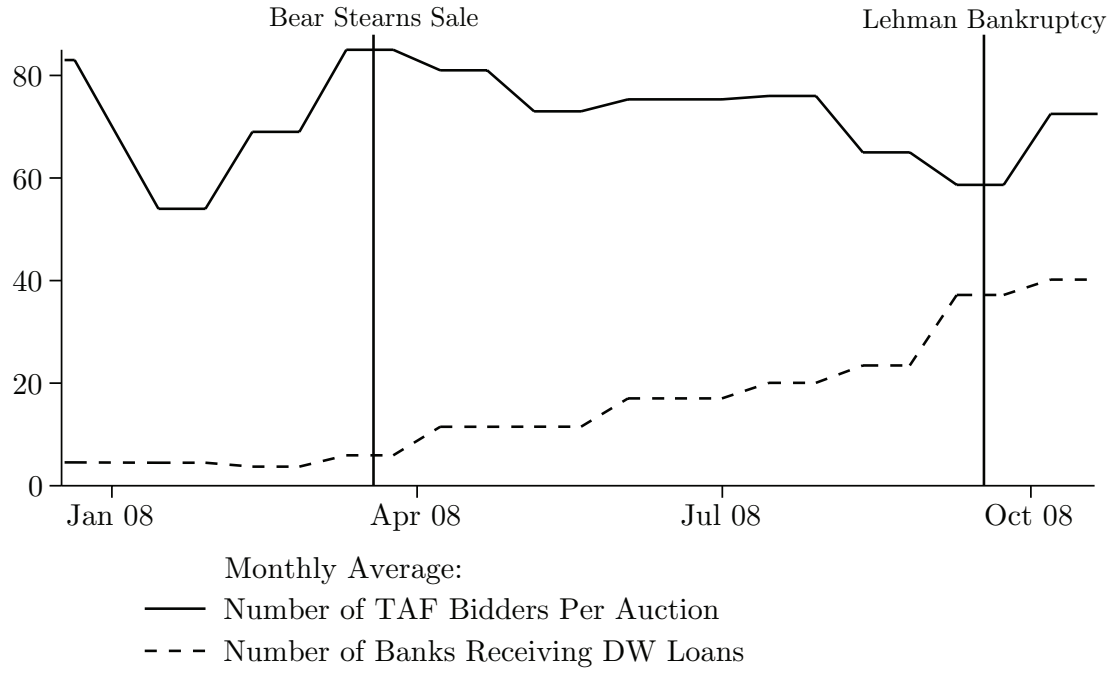

Figure 3: Bidding Above Willingness to Pay is Never Optimal

If a bank bids above its willingness to pay at a TAF auction, three potential outcomes could result depending on the stop-out rate at the auction. In each of the outcomes the bank does at least as well, and in outcome 3 does strictly better, if it bids at or below its willingness to pay (WTP) for funds from the Fed.

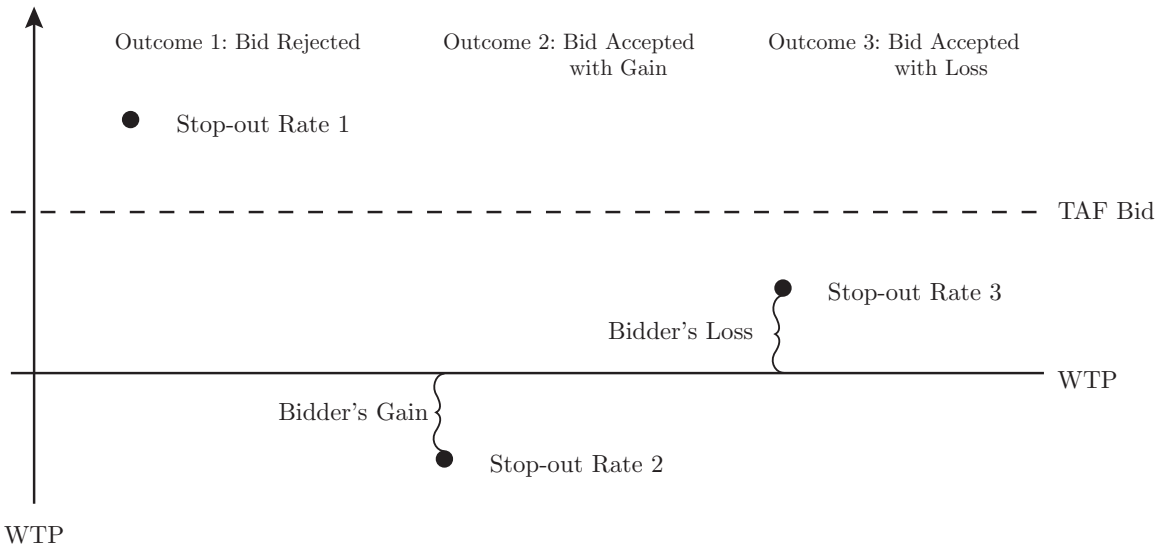

Figure 4: TAF Auction Bids Above the DW Rate

The fraction of banks that bid above the DW primary credit rate on the day of the TAF auction. If a bank submits two bids, only the higher of the two bids is considered. Auctions with a stop-out rate above the DW primary credit rate are indicated by solid circles, while auctions with a stop-out rate below the DW primary credit rate have hollow circles. The reduction in the DW penalty from 50 to 25 basis points on March 16, 2008 is indicated by the first vertical line and the date of the Lehman Brothers bankruptcy, September 15, 2008, by the second vertical line. Stop-out rate is reported by the Federal Reserve Board. All other values are FRBNY calculations.

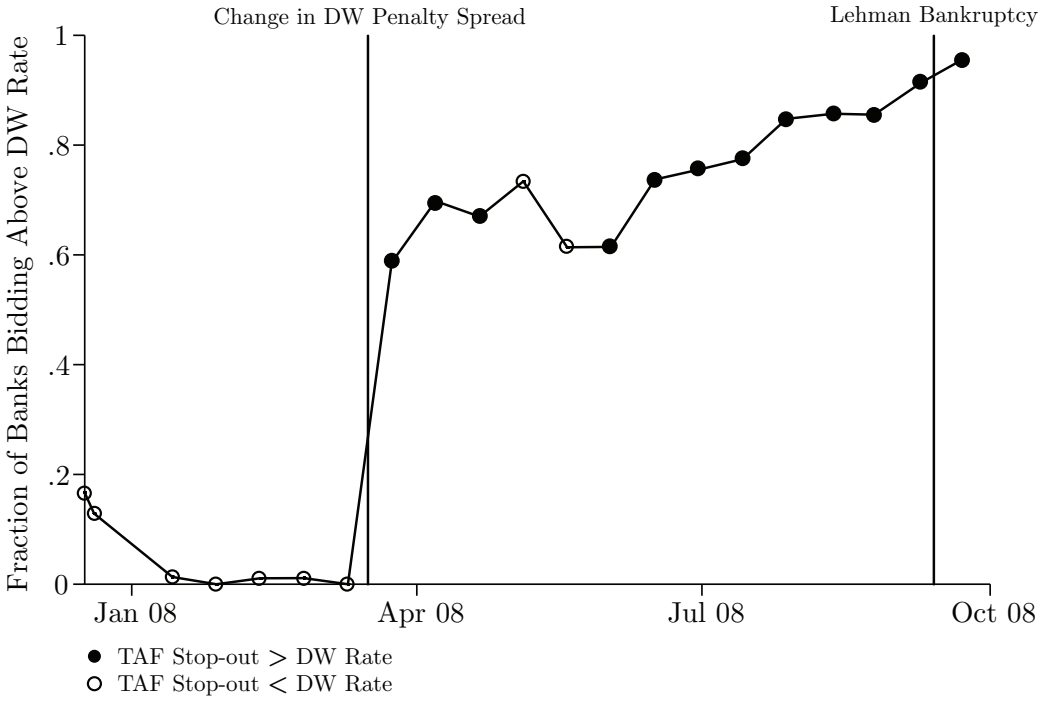

Figure 5: Banks Bidding Above DW Rate - Frequency Distribution

The distribution of the percent of auctions in which a bank bids above the DW primary credit rate. X-axis values are calculated as 100*(number of auctions where a bank bids above the DW rate)/(number of auctions where the bank submitted a bid) for those banks which bid above the DW rate at least once. The median line indicates that more than half of all banks submitting bids above the DW rate did so at least 67 % of the time. The 25th percentile line indicates that 25 % of banks that submitted a bid above the DW rate did so at 50 % of the auctions in which they participated. 38 out of 178 TAF participants submitted bids above the DW rate at every auction in which they participated

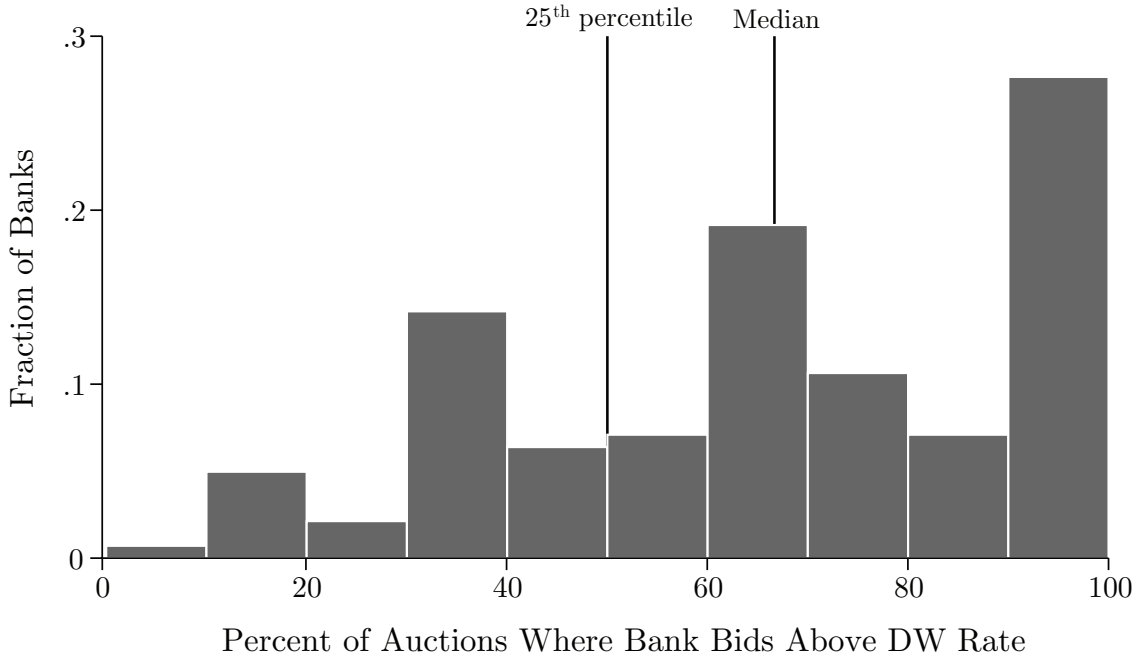

Figure 6: Mean Effective Stigma Premium

The effective stigma premium is calculated as the mean positive difference between TAF bid rates and the primary credit rate across those banks that bid above the DW rate. Solid, black circles indicate that the auction stopped out above the primary credit rate; hollow circles indicate that it stopped out below. The reduction in the DW penalty from 50 to 25 basis points on March 16, 2008 is indicated by the first vertical line and the date of the Lehman Brothers bankruptcy, September 15, 2008, by the second vertical line.

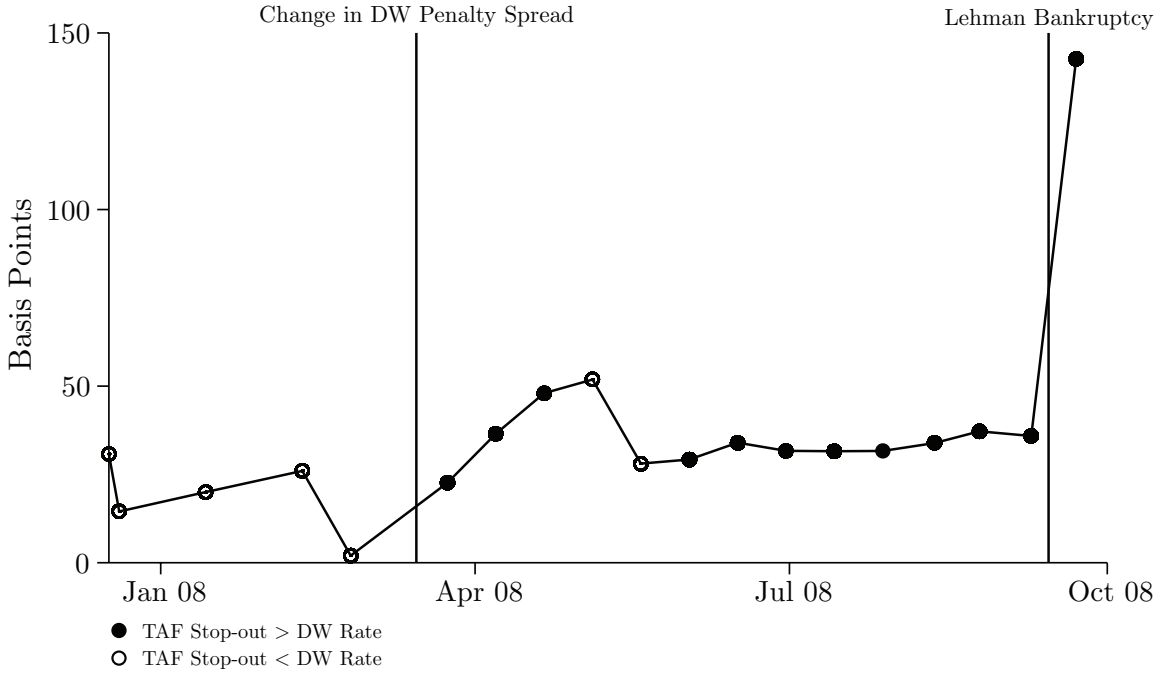

Table 1: Comparison Between TAF and DW

Similarities

	Term Auction Facility	**DW**
Collateral	Same as DW for 28 day loans, additional overcollateralization of 25 % required on 84-day loans	Same set of collateral allowed as 28-day TAF auctions
Eligible Bank	Primary credit eligible banks that also have enough collateral to make minimum TAF bid	All banks with reserve account and high supervisory rating
Minimum bid or loan amount	$ 5 million	None

Differences

Frequency	Generally once every two weeks	Any time during normal business hours
Loan Term	Generally 28 or 84 days	Overnight through 90 days, renewable by borrower (up to 30 days before March 17, 2008)
Maximum bid or loan amount	10 percent of total auction size or up to available collateral (whichever is smaller)	Up to available collateral
Prepayment	Not permissible	Permissible
Rate	Auction based stop-out rate or minimum rate	Spread over fed funds target (target+50 bp until March 16, 2008; target+25 bp after)

Table 2: Summary Statistics

Variable	Bank-Auction Pairs	Mean	Median	Standard Deviation	Min	Max
Bid above discount window rate	1540	0.56	1	0.50	0	1
Log of assets	1508	9.74	9.81	1.89	4.87	14.16
Log of pledged collateral	1537	7.60	7.96	2.05	2.28	11.47
Increase in pledged collateral	1540	0.49	0	0.5	0	1
Bid at previous auction	1540	0.67	1	0.47	0	1
Awarded funds at previous auction	1540	0.41	0	0.49	0	1
Fed funds standard deviation	1540	0.25	0.15	0.20	0.06	0.92
LIBOR-OIS spread	1540	0.55	0.46	0.24	0.23	1.25

Table 3: Estimation of Probit Models: 28-day, Fully Subscribed Auctions

Dependent variable equals 1 when bank bids above DW, primary credit rate. The baseline model appears in equation (4.1 and the regressors are defined in the Appendix. The sample includes all bank-auction pairs for 28-day, fully subscribed TAF auctions. The standard errors are corrected for heteroskedasticity. Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Probit: Dependent Variable Equals 1 When Bank Bids Above DW Rate
28-day, Fully Subscribed TAF Auctions

	(1)	(2)	(3)
VARIABLES	Baseline	Policy Change	DW Participation
Log of assets	-0.15***	-0.20**	-0.20**
	(0.05)	(0.09)	(0.08)
Log of pledged collateral	0.15***	0.21***	0.17**
	(0.04)	(0.08)	(0.07)
Pledged collateral increased	0.47***	0.20	0.19
	(0.09)	(0.12)	(0.12)
Bank bid at previous auction	-0.81***	-0.67***	-0.51***
	(0.12)	(0.15)	(0.16)
Awarded funds at previous auction	0.09	0.12	0.28
	(0.14)	(0.18)	(0.18)
Bid above DW at previous auction	2.20***	1.18***	0.88***
	(0.12)	(0.16)	(0.17)
Fed funds standard deviation	0.019***	0.006	-0.002
	(0.002)	(0.004)	(0.005)
LIBOR-OIS spread	0.006**	0.007**	0.008**
	(0.002)	(0.003)	(0.004)
Fed funds target rate		0.008***	0.011***
		(0.003)	(0.003)
After DW penalty change		4.29***	4.37***
		(0.52)	(0.57)
Days in last week bank took DW loan			-0.65***
			(0.14)
Banks taking DW loans week before			0.03***
			(0.005)
Constant	-0.70**	-5.33***	-6.46***
	(0.31)	(1.12)	(1.22)
Observations	1505	1505	1505
Number of Unique Entities	178	178	178
Log Likelihood	-638.6	-436.3	-411.9
Panel Variance, σ_ν	0.355	1.031	0.894

Table 4: Estimation with Effective Stigma Premium: 28-day, Fully Subscribed Auctions

Dependent variable is the difference between a bank's TAF bid rate and the DW primary credit rate, if that bank bid above the DW primary credit rate. If the bank submitted two bids, only the higher of the two bids is considered. The regressors are defined in the Appendix. The sample includes all bank-auction pairs where the TAF bid rate was above the DW primary credit rate at 28-day, fully subscribed TAF auctions. Heteroskedasticity robust standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

Linear Regression: Dependent Variable is Effective Stigma Premium Lower bound (Basis Points)
28-day, Fully Subscribed TAF Auctions

	(1)	(2)	(3)
VARIABLES	Baseline	Policy Change	DW Participation
Log of assets	-5.25**	-5.18**	-4.96**
	(2.06)	(2.03)	(2.02)
Log of pledged collateral	3.88**	3.78**	3.51**
	(1.84)	(1.79)	(1.77)
Pledged collateral increased	5.53**	4.38*	4.39*
	(2.53)	(2.55)	(2.53)
Bank bid at previous auction	-4.23	-2.14	-0.62
	(3.15)	(3.21)	(3.12)
Awarded funds at previous auction	2.07	2.35	3.89
	(3.71)	(3.70)	(3.77)
Bid above DW at previous auction	10.69***	6.33**	4.17
	(2.31)	(2.66)	(2.86)
Fed funds standard deviation	-0.06	-0.06	-0.05
	(0.07)	(0.07)	(0.07)
LIBOR-OIS spread	0.30***	0.50***	0.61***
	(0.06)	(0.07)	(0.08)
After Lehman bankruptcy	100.82***	83.72***	67.95***
	(12.68)	(13.32)	(14.14)
Fed funds target rate		-0.22**	-0.18**
		(0.09)	(0.09)
After DW penalty change		-24.53	-15.94
		(19.86)	(18.24)
Days in last week bank took DW loan			-11.88*
			(6.26)
Banks taking DW loans week before			0.22***
			(0.07)
Constant	28.89**	90.81**	58.53
	(14.60)	(40.28)	(38.45)
Observations	840	840	840
Number of Unique Entities	137	137	137
R-squared Overall	0.463	0.467	0.474
σ_ϵ	30.64	30.49	30.31
Panel Standard Deviation, σ_ν	25.13	25.28	25.32

Table 5: Potential Cost of Bidding Above DW Rate

Panel A: Potential cost is the amount of interest that a bank risked paying in excess of the DW when submitting a TAF bid above the DW rate. Potential cost is calculated as the dollar value of a bank's bid amount times the spread between the bid rate and the DW rate times the term of the loan divided by 360. *Total per Auction* is the sum of individual bank potential costs, averaged over the 21 auctions in the sample. *Average Per Bank per Auction* is the average potential cost at each auction for each bank. *Bid Above Cost/Interest Paid* is the total value paid above the DW rate divided by the total interest these banks would have paid if charged interest at their bid rates. **Panel B:** Realized cost is the amount of interest that a bank paid in excess of the DW when the TAF stop out rate was above the DW rate. Realized cost is calculated as the dollar value of funds awarded at the TAF times the spread between the stop out rate and the DW rate times the term of the loan divided by 360. *Total per Auction* is the sum of individual bank actual costs, averaged over the 21 auctions in the sample. *Average Per Bank per Auction* is the average actual cost at each auction for each bank. *Bid Above Cost/Interest Paid* is the total value paid above the DW rate divided by the total interest these banks paid on interest for their TAF loans. The full sample is all 28-day fully subscribed auctions, the summer of 2008 is the subset of these auctions from March 24, 2008 through September 8, 2008, and Lehman is the single auction on September 22, 2008.

A: Potential Cost

	Full Sample	Summer 2008	Lehman
Total per Auction (millions USD)	17.8	15.9	164.4
Average Per Bank per Auction (millions USD)	0.43	0.26	2.05
Bid Above Cost/Interest Paid	12.3 %	12.4 %	46.5 %

B: Realized Cost

	Full Sample	Summer 2008	Lehman
Total Cost per Auction (millions USD)	6.7	5.5	74.7
Average Per Bank per Auction (millions USD)	0.25	0.10	2.41
Bid Above Cost/Interest Paid	9.1 %	5.6 %	40.0 %

Table 6: Changes in Borrowing Rate After DW and TAF Visits: First Difference Test

Column 1 shows the impact on borrowing rates of banks' DW visits. The dependent variable is the percent change in overnight fed funds borrowing rate for each bank that participated in the fed funds market. *DW Visit* is the estimated difference in the dependent variable between banks that did and did not go to the DW on the indicated day where date t is a bank's actual DW visit day. **Column 2** shows the impact on borrowing rates of banks' TAF visits. The dependent variable is the percent change in overnight fed funds borrowing rate for each bank that participated in the fed funds market *and* did not borrow from the DW over the entire sample. *TAF Visit* is the estimated difference in the dependent variable between banks that did and did not go to the TAF on the indicated day where date t is a bank's actual TAF visit day. The sample is from January 3, 2007 and February 1, 2010. Estimates are calculated using OLS with block bootstrapping within bank clusters. Bootstrapped standard errors are in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)
Time of Visit	DW Visit	TAF Visit
t-2	-0.68	1.20
	(0.55)	(1.27)
t-1	0.60	-1.07
	(0.71)	(1.25)
t	3.27***	2.58
	(0.812)	(1.57)
t+1	-0.65	0.08
	(0.88)	(1.14)
t+2	-0.33	-0.43
	(0.53)	(2.95)
constant	-0.45***	-0.39***
	(0.02)	(0.04)
R-squared	0.000	0.001
N	103,673	33,173
Number of Unique Entities	553	351
Entity Fixed Effects	Yes	Yes

Table 7: Changes in Borrowing Rate After DW and TAF Visits: Matched Sample Test

Banks are matched by asset size, with each DW or TAF visitor assigned a unique match for the full sample. The matched bank is required to borrow in the fed funds market on at least 40 % of the days during which the DW or TAF visiting bank borrowed. **Column 1:** Impact of DW visit is calculated as the difference in percent change in overnight fed funds borrowing rate between a bank that visits the DW and a matched bank that does not. **Column 2:** Impact of TAF visit is calculated as the difference in percent change in overnight fed funds borrowing rate between a bank that visits the TAF and a matched bank that does not. Date t is a bank's actual DW or TAF visit day. The sample is January 3, 2007 to February 1, 2010. Observations per test are at least the number given, with some samples larger than others due to an unbalanced panel. Standard errors are in parentheses, *** p<0.01, ** p<0.05, * p<0.1.

	(1)	(2)
Time of Visit	DW Visit	TAF Visit
t-2	0.91	-0.85
	(1.13)	(0.74)
t-1	0.68	1.13
	(0.96)	(0.79)
t	2.03**	-0.35
	(0.95)	(0.75)
t+1	2.32***	-0.33
	(0.98)	(0.66)
t+2	0.51	-0.38
	(0.78)	(0.78)
Observations per test	657	1,149