Online Appendix for Borrowing Stigma and Lender of Last Resort Policies

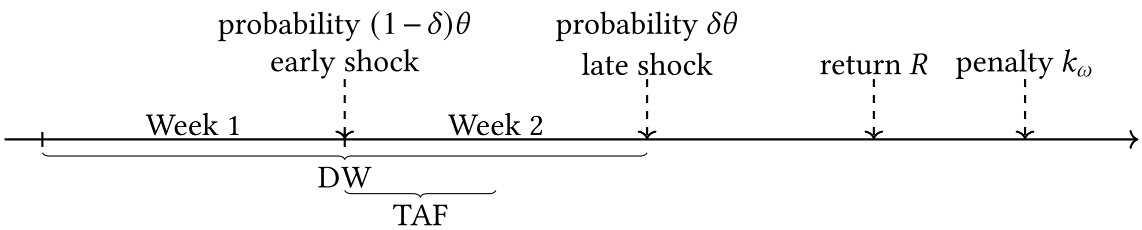
I. A Model without the Delay of Funds

This appendix shows that the separation of weaker banks to DW and stronger banks to TAF continues to hold without the delayed release of funds (Proposition 1 below). It demonstrates that the competitive nature of the auction and the delayed release of funds from the auction can drive the separation of banks' borrowing behavior in borrowing from different facilities. In the language of the model below, Proposition 1 below holds when $\delta = 1$ and/or $c = 0$.

A. Model

We introduce a two-period, n-bank model. The timeline of the model is as follows. Each bank is endowed with an illiquid asset that pays off after the second week. Before the asset pays off, a liquidity shock may hit a bank with a probability that is privately known by the bank; the shock may arrive in the first week or the second week. Before the shock, each bank can borrow from DW and TAF. Borrowing banks may incur a penalty if detected of borrowing. Figure B1 sketches the timing and sequence of events, which we will describe in detail next.

FIGURE B1
Timeline of the model



Technology, Preferences, Shocks. All parties are risk neutral and do not discount future cash flows. At the beginning of the first week, each bank has one unit of long-term, illiquid assets that will mature at the end of the second week. The asset generates cash flows R upon maturity but nothing if liquidated early. Shortly before the end of the second week, each bank may be hit with a liquidity shock. The size of the shock is normalized as one unit. Let $1-\theta_i \in [0,1]$ be the probability that the liquidity shock hits bank i, where θ_i follows the independent and identically distributed cdf F and associated pdf f on the support $[0,1]$. We assume that θ_i is private information and only known by bank i itself. Without loss of generality, we drop the subscript i subsequently.

A loan in the first week will help the bank defray the liquidity shock and therefore brings net benefits $(1-\theta)R$ at the cost of interest rate r. Finally, to capture the idea that earlier liquidity may be more valuable, we assume that the liquidity shock may arrive in the first week with probability $1-\delta$ and in the second week with probability δ, conditional on the shock arriving. To capture the same idea, there can be an additive delayed cost of $c \geq 0$, which can be interpreted as the cost incurred when banks sell illiquid assets at fire-sale prices in order to satisfy immediate liquidity needs. To summarize, a type-θ bank's payoff is $\pi_1(\theta, r) = (1-\theta)R - r$ if it borrows in week 1, and is $\pi_2(\theta, r) = \delta(1-\theta)R - r - c$ if it borrows in week 2.

Borrowing. A bank can borrow from DW or TAF. DW offers loans at a fixed interest rate r_D. TAF allocates pre-announced m units of liquidity through an auction. In the auction, banks who decide to participate simultaneously submit their sealed bids. Bid β_i specifies the maximum interest rate bank i is willing to pay. The bid needs to be higher than the reserve interest rate r_A. After receiving all the bids, the auctioneer ranks them from the highest to the lowest. All winners pay the same interest rate while losers do not pay anything. If there are fewer bids than the units of liquidity provided, each bidder receives a loan and pays r_A. If there are more bidders than the total offering liquidity, each of the m highest bidders receives one unit of liquidity by paying the highest *losing* bid. In this case, the highest losing bid is also called the stop-out rate s, which is the clearing price at which aggregate demand in the auction matches the aggregate supply. Let $w(\theta, \beta)$ denote the (equilibrium) probability that bank θ can win the auction by bidding β. We will focus on symmetric strategies in bidding and as a result can write $w(\theta, \beta(\theta))$ as $w(\theta)$ without loss of generality.

Stigma. Denote the probability of being detected of borrowing from DW, borrowing from TAF, and the probability of verifying that a bank has not borrowed to be p_D, p_A, and p_N, respectively. Let G_D, G_A, and G_N be the type distributions of the banks that have borrowed from DW, from TAF, and have not borrowed, respectively. We capture the notion of stigma in a parsimonious way. Specifically, we assume that after all the borrowings are accomplished, the banks that have successfully borrowed may be detected independently, after which a penalty will be imposed. This penalty can be understood as a cost in bank's deteriorated reputation, a cost in a reduced chance to find counterparties, or a cost from a heightened chance of runs and increasing withdrawals by creditors. Let the stigma cost be $k(\theta, G_\omega)$, where $\omega \in \{D, A, N\}$. The stigma cost is naturally assumed to be higher when the borrowing banks are worse. Formally, $k(\theta, G) > k(\theta, G')$

if G is strictly first-order stochastically dominated by G'. In the baseline model, we eliminate the dependence of stigma cost on a bank's private type and instead assume that it only depends on the borrowing facility $\omega \in \{D, A, N\}$. In other words, $k(\theta, G_\omega) = k(G_\omega) \equiv k_\omega$. For simplicity, we normalize k_N to be 0.

Equilibrium. In summary, the setting is summarized by the return R, probability δ of late shock, type distribution F of banks, discount rate r_D in DW, number m of units of liquidity auctioned, minimum bid r_A in TAF, and the penalty function $k(G)$ attached to different belief distributions of bank's type. A type-θ bank's strategy can be succinctly described by $\sigma(\theta) = (\sigma_D(\theta), (\sigma_A(\theta), \beta(\theta)))$, where $\sigma_\omega(\theta)$ is the probability of participating in $\omega \in \{D, A\}$ and $\beta(\theta)$ is its bid if it participates in the auction. Given strategies σ, beliefs about the financial situation can be inferred by the Bayes' Rule. In this case, we say aggregate strategies $\sigma(\cdot)$ generate posterior belief system $G = (G_A, G_D, G_N)$. Note that we have restricted each bank's strategy to be symmetric so that $\sigma(\cdot)$ only depends on θ. Strategies σ^* and beliefs G^* form an equilibrium if (i) each type-θ bank's strategy $\sigma^*(\theta)$ maximizes its expected payoff given belief system G^*, and (ii) the belief system G^* is consistent with banks' aggregate strategies σ^*. Clearly, the best (i.e., type-1) bank has no intention to borrow at all, because it would only pay a price and stigma cost but has no benefit from borrowing. We assume that the borrowing benefit of the worst (i.e., type-0) bank is so high that it has a strict incentive to borrow even given the most pessimistic belief about the banks who borrow: $\delta R - r_D - k(G) > 0$ when $G(\theta) = 1$ for all $\theta > 0$.

B. Equilibrium Characterization

We now solve for the equilibrium when both DW and TAF are available. We first describe a bank's bidding strategy in TAF, followed by its incentives in choosing between DW and TAF. Our result shows that relatively stronger banks have more incentives to bid in TAF rather than borrow immediately from DW, which is the key force behind the separation of types in equilibrium.

Let's start by describing a bank's bid in the auction. In general, a bank's bidding strategy depends on its plan after losing in the auction: It can either borrow from DW in the second period or not to borrow at all. Clearly in this case, the incentive to borrow declines with a bank's financial strength.

Lemma 1. *Only banks $\theta \le \theta_2$ will borrow from DW in the second week if they have not borrowed.*

Proof of Lemma 1. The payoff of not borrowing is $u_N(\theta) = 0$, and the payoff of borrowing from DW in the second week is $u_2(\theta) = \delta(1-\theta)R - r_D - k_D - c$. Bank θ borrows from DW in week 2 if and only if $u_2(\theta) \ge u_N(\theta)$, which is rearranged as $\theta \le 1 - (r_D + k_D + c)/(\delta R) \equiv \theta_2$. □

Let $\beta^D(\theta)$ be a type-θ bank's bid if it plans to borrow from DW after losing the auction. Let $\beta^N(\theta)$ be its bid if it doesn't plan to borrow after losing the auction. Given that a bank's bid does not (directly) affect its payment conditional on winning the auction, a bank bid its own willingness to pay (WTP), as follows.

Lemma 2. *Bank θ who borrows from DW after losing in the auction bids*

$$\beta^D(\theta) = r_D + k_D - k_A. \tag{1}$$

Bank θ who does not borrow from DW after losing in the auction bids

$$\beta^{N}(\theta) = \delta(1-\theta)R - k_A. \tag{2}$$

Proof of Lemma 2. In the auction, the winning bank pays the highest bid among the losers. Therefore, its own bid does not affect its equilibrium payment but only its chance of winning the auction. Therefore, it is its dominant strategy to bid its own willingness to pay. Bank θ's willingness to pay $\beta(\theta)$ satisfies $\delta(1-\theta)R - \beta(\theta) - k_A - c = \max\{\delta(1-\theta)R - r_D - k_D - c, 0\}$. If $\delta(1-\theta)R - r_D - k_D \geq 0$ so that the losing bank will go to DW, $\beta(\theta) = r_D + k_D - k_A$. Otherwise, $\beta(\theta) = \delta(1-\theta)R - k_A - c$. □

Note that $\beta^{D}(\theta)$ does not depend on θ. In other words, any bank who plans to go to DW bids up to the same amount, which equals the sum of r_D, the discount rate, and $k_D - k_A$, the net stigma cost of DW relative to TAF. Intuitively, these banks will always borrow in equilibrium, from either DW or TAF. Therefore, since DW charges the same rate to all borrowers and the stigma cost is also homogeneous across all borrowers from the same facility, their willingnesses to pay are also the same. On the other hand, $\beta^{N}(\theta)$, however, does depend on θ. Among these banks, weaker ones have higher willingnesses to pay because they have stronger demand for liquidity but will not borrow if they lose in TAF.

Proposition 1 is our main result. It describes the incentive to borrow from DW1 against participating in the auction. In particular, it shows the skimming property that stronger banks are more willing to wait for TAF.

Proposition 1. *Let $u_1(\theta)$ be bank θ's expected equilibrium payoff if it borrows from DW in period 1,* *and* $u_A(\theta)$ *its expected payoff if it bids in the auction. In any equilibrium,* $u_1(\theta) - u_A(\theta)$ *is decreasing in* θ.

Proof of Proposition 1. The benefit of borrowing in week 1's DW is $u_1(\theta) = (1-\theta)R - r_D - k_D$. Let $\tau \in [0,1]$ be the highest losing bank and $H(\tau)$ its distribution. First consider $u_A(\theta)$ for $\theta < \theta_2$. If $\tau < \theta_2$, bank θ's payoff from winning the auction is $\delta(1-\theta)R - \beta^D(\theta) - k_A - c$, which simplifies to $\delta(1-\theta)R - r_D - k_D - c$. If it loses, it turns to DW and receives the same payoff. If $\tau \geq \theta_2$, bank $\theta < \theta_2$ wins the auction for sure and receives payoff $\delta(1-\theta)R - \beta^N(\tau) - k_A - c$, which simplifies to $\delta(\tau-\theta)R$. Therefore, $u_A(\theta) = \delta(1-\theta)R - (r_D + k_D + c)H(\theta_2) - \int_{\theta_2}^{1}[\delta(1-\tau)R]dH(\tau)$ if $\theta < \theta_2$. Next, consider $u_A(\theta)$ for $\theta \geq \theta_2$. In this case, bank θ receives $\delta(\tau-\theta)R - c$ if it wins in the auction. Therefore, $u_A(\theta) = \int_{\theta}^{1}[\delta(\tau-\theta)R - c]\,dH(\tau)$ if $\theta \geq \theta_2$. Taking the difference, we have

$$u_1(\theta) - u_A(\theta) = \begin{cases} (1-\delta)(1-\theta)R - H(\theta_2)c - \int_{\theta_2}^{1}[\delta(1-\tau)R + r_D + k_D]dH(\tau) & \text{if } \theta < \theta_2 \\ (1-\theta)R - r_D - k_D - \int_{\theta}^{1}[\delta(\tau-\theta)R + c]dH(\tau) & \text{if } \theta \geq \theta_2. \end{cases}$$

Clearly, $u_1(\theta) - u_A(\theta)$ is continuous and decreasing at the rate of $(1-\delta)R$ when $\theta < \theta_2$. When $\theta > \theta_2$, $\frac{d(u_1(\theta) - u_A(\theta))}{d\theta} = [-1 + \delta(1 - H(\theta))]R < 0$. □

Intuitively, auction introduces uncertainty in terms of whether a bidding bank is able to borrow and if so at what price. Specifically, it introduces one mechanism that enables a bank to borrow at a low rate, lower than its own willingness to pay, at the cost of potentially failing to borrow (for banks $\theta \in [\theta_2, 1]$) or delaying to borrow (for banks $\theta \in [0, \theta_2]$). This cost of not borrowing (or delayed borrowing) is lower for stronger banks because their borrowing benefits are lower. Therefore, they are more inclined to participate in the auction and take advantage of the opportunity to borrow when rates are sufficiently low. In this case, auction is able to separate borrowers into two groups, the so-called "single-crossing" condition. Mathematically, a bank $\theta \in [0, \theta_2]$ will always borrow even if it chooses to participate in TAF: it will turn to DW in week 2 in the event of losing in TAF, in which case the cost of delay is $(1-\delta)(1-\theta)R$, decreasing in θ. Bank $\theta \in [\theta_2, 1]$ no longer borrows if it loses in the auction, with the cost of failing to borrowing being $(1-\theta)R$.

Our result on separation does not depend on the assumption that delaying cost is bigger for weaker banks; that is, the result continues to hold when $c = 0$ and/or $\delta = 1$. We would like to emphasize that not any mechanism that offers a trade-off between probability of winning and price paid can separate borrower. To see this, note that a bank's overall payoff has three components that vary with θ. First, a stronger bank has lower borrowing benefits. Second, in equilibrium, a stronger bank is less likely to win in the auction. However, conditional on winning in the auction, it pays less in expectation. When a bank bids optimally, it is indifferent between raising the bid to increase the winning probability and paying more conditional on winning. Therefore, the last two effects exactly cancel out. As a result, the overall effect is simply the decreasing benefits of borrowing times the probability of winning in the auction: $-R[1-H(\theta)]$. Next, let us consider a mechanism $(w(\theta), b(\theta))$ where $w(\theta)$ is the probability of receiving one unit of liquidity and $b(\theta)$ is the price paid. Let $u_\omega(\theta)$ be bank θ's payoff in this mechanism.

$$u_1(\theta) - u_M(\theta) = w(\theta)[b(\theta) + k_\omega + c - r_D - k_D] + [1 - w(\theta)][(1-\theta)R - r_D - k_D].$$

By taking derivatives with respect to θ, we can see clearly that the overall effect is ambiguous.

Given Proposition 1, in any equilibrium, weaker banks choose to borrow from DW in week 1, and stronger banks bid in the auction. Among the banks who lose in the auction, relatively stronger ones (if any) will still go to the auction.

Theorem 1. *There exists an equilibrium. Equilibrium borrowing decision is characterized by three thresholds, θ_1, θ_2, and θ_A: (i) Banks $\theta \in [0,\theta_1]$ borrow directly from week 1's DW; (ii) Banks $\theta \in (\theta_1,\theta_A]$ participate in the auction; (iii) Banks $\theta \in [\theta_2,\theta_A]$ borrow in week 2's auction if they lose in the auction; and (iv) Banks $\theta \in (\theta_A,1]$ do not borrow at all.*

Proof of Theorem 1. Denote the three thresholds by θ_1, θ_2, and θ_A. Let $u_\omega(\theta|\theta_1,\theta_2,\theta_A)$, $\omega \in \{1,2,A\}$, denote bank θ's expected payoff of participating in mechanism ω. The three equilibrium thresholds are determined by three conditions: $u_1(\theta_D|\theta_1,\theta_2,\theta_A) = u_A(\theta_D|\theta_1,\theta_2,\theta_A)$, $u_2(\theta_2|\theta_1,\theta_2,\theta_A) = 0$, and $u_A(\theta_A|\theta_1,\theta_2,\theta_A) = 0$.

Let $h_m^n(x) \equiv \binom{n}{m} x^m (1-x)^{n-m}$. Define three correspondences:

$$\phi_1(\theta_1,\theta_2,\theta_A) = \left\{\theta : u_1(\theta|\theta_1,\theta_2,\theta_A) - \max\{u_A(\theta|\theta_1,\theta_2,\theta_A), u_N(\theta|\theta_1,\theta_2,\theta_A)\} \geq 0\right\} \cup \{0\},$$

$$\phi_2(\theta_1,\theta_2,\theta_A) = \left\{\theta : u_2(\theta|\theta_1,\theta_2,\theta_A) - u_N(\theta|\theta_1,\theta_2,\theta_A) \geq 0\right\} \cup \{0\},$$

and

$$\phi_A(\theta_1,\theta_2,\theta_A) = \left\{\theta : u_A(\theta|\theta_1,\theta_2,\theta_A) - u_N(\theta|\theta_1,\theta_2,\theta_A) \geq 0\right\} \cup \{0\}.$$

Economically, if it is believed that (i) $[0,\theta_1]$ is the set of banks willing to borrow from DW 1, (ii) $[0,\theta_A]$ is the set of banks willing to bid if it has not borrowed from discount window 1, and (iii) $[0,\theta_2]$ is the set of banks willing to borrow from DW 2 if it has not borrowed after auction, then optimally, (i) $\phi_1(\theta_1,\theta_2,\theta_A)$ is the set of banks willing to borrow from DW 1, (ii) $\phi_A(\theta_1,\theta_2,\theta_A)$ is the set of banks willing to bid in the auction if it has not borrowed from discount window 1, and (iii) $\phi_A(\theta_1, \theta_2, \theta_A)$ is the set of banks willing to borrow from DW 2 if it has not borrowed after auction. We have an equilibrium if the belief is consistent with the optimal action: $[0, \theta_1] = \phi_1(\theta_1, \theta_2, \theta_A)$, $[0, \theta_2] = \phi_2(\theta_1, \theta_2, \theta_A)$, and $[0, \theta_A] = \phi_A(\theta_1, \theta_2, \theta_A)$; or more simply, if $(\theta_1, \theta_2, \theta_A) \in \phi(\theta_1, \theta_2, \theta_A) \equiv (\phi_1(\theta_1, \theta_2, \theta_A), \phi_2(\theta_1, \theta_2, \theta_A), \phi_A(\theta_1, \theta_2, \theta_A))$. Hence, to prove the existence of an equilibrium, it suffices to show that the correspondence $\phi \equiv (\phi_1, \phi_2, \phi_A)$ has a fixed point. Each of the three correspondences is well-defined on $X \equiv [0,1]^3 \cap \{(\theta_1, \theta_2, \theta_A) : \theta_1 \leq \theta_A\}$, a non-empty, compact, and convex subset of the Euclidean space $\mathbb{R}^3$, and is upperhemicontinuous with the property that $\phi_\omega(x)$ for each $\omega \in \{1, 2, A\}$ is non-empty, closed, and convex for all $x \in X$. By Kakutani's fixed point theorem, $\phi : X \rightarrow 2^X$ has a fixed point $x \in X$. □

II. Empirical Implications

A main prediction of our theory is that the banks that borrowed more from DW over time were fundamentally weaker than the banks that borrowed more from TAF. In this section, to examine this hypothesis, we use data from various sources, including banks' regulatory reporting and subsequent failure. Throughout this section, all analysis is conducted at the bank holding company (BHC) level, so our sample is restricted to large banks. Although under Section 23A of the Federal Reserve Act, it is illegal for a member bank to channel funds borrowed from LOLR to other affiliates within the same BHC, temporary exemptions of Section 23A were granted in late 2007 (Bernanke (2015)). Therefore, by conducting our analysis at the BHC level, we implicitly assume an efficient internal capital market within a BHC, which is consistent with the evidence in Cetorelli and Goldberg (2012) and Ben-David, Palvia, and Spatt (2017).

A. Descriptive Statistics of DW and TAF Borrowing

Let us start by describing the BHCs' borrowing behaviors from DW and TAF. The main dataset we use is obtained through Bloomberg and includes 407 institutions that borrowed from the Fed between August 1, 2007 and April 30, 2010. These data were released by the Fed on March 31, 2011, under a court order, after Bloomberg filed a lawsuit against the Fed.[1] The data contain information on each institution's daily outstanding balance of its borrowing from DW, TAF, and five other related programs. We will merge this dataset with the banks' regulatory database to study how financial conditions affected the BHCs' borrowing decisions.

Since the Bloomberg dataset was collected by scraping over 29,000 pages of PDF files released from the Fed, data processing could be compromised. To evaluate the data's quality, we calculate the aggregate weekly outstanding balance in DW and TAF programs from the Bloomberg dataset and compare these numbers with the official ones released by Board of Governors of the Federal Reserve System (2019). Figure 1 shows the comparison. Clearly, the Bloomberg data managed to capture the vast majority of borrowing in both DW and TAF.

Table B1 provides the summary statistics of the BHCs' borrowing behavior during the crisis. Approximately 73 percent of borrowing institutions (313 out of 407) are banks, together with diversified financial services (mostly asset management firms), insurance companies, savings and loans, and other financial service firms. Foreign banks that borrowed through their U.S. subsidiaries were also included. Banks' choices of borrowing facilities were heterogeneous: 260 borrowing

[1] For details, see Torres (2011). In May 2008, Bloomberg News reporter Mark Pittman filed a FOIA request with the Fed, requesting data about details of DW lending and collateral. Unsurprisingly, it was stonewalled by the Fed. In November 2008, Bloomberg LP's Bloomberg News filed a lawsuit challenging the Fed, with the Fox News Network later filing a similar lawsuit. Other news organizations also showed support by filing legal briefs. In March 2011, the US Supreme Court ruled that the Fed must release information on DW loans in response to the lawsuits. Later that month, the Fed released the data, in the form of 894 PDF files with more than 29,000 pages on two CD-ROMS. Bloomberg News later published an exhaustive analysis that included the detailed data.

institutions tapped both facilities, 18 used only TAF, and 86 used only DW. Borrowing frequencies in both programs exhibit large skewness. While the median bank tapped DW twice, the Alaska USA Federal Credit Union used it 242 times. Similarly, for the 60 TAF auctions, while the median bank borrowed only three times, Mitsubishi UFJ Financial Group borrowed 28 times. On average, TAF lent more liquidity ($3,174 million) than DW ($1,529 million) to an average bank, consistent with the evidence in Figure 1 that TAF was more successful in providing liquidity. However, the Dexia Group—the BHC that borrowed the most from DW—borrowed approximately $190 billion over the 3-year period, far exceeding $100 billion from the largest borrower in TAF (Bank of America Corporation). This evidence suggests that DW banks were in need of larger amount of liquidity than TAF banks.

B. Evidence from Banks' Fundamentals

1. Domestic Banks

We link the Bloomberg data to FR Y-9C reports, the Consolidated Financial Statements for Holding Companies. The Y-9C reports collect financial-statement data from BHCs on a quarterly basis, which are then published in the Federal Reserve Bulletin. All domestic BHCs are required to submit these reports within 40 or 45 calendar days following the end of a quarter. While this merge allows us to use proxies for banks' financial condition, it excludes all foreign banks from the borrowing sample, which took out about 60% of total TAF loans (Benmelech (2012)). Among the 289 U.S.-based banks that borrowed from either DW or TAF, we managed to merge Y-9C reports to 135 of them. These banks account for 42.2% of all American banks' loans from DW, and 81.8% from TAF. Given the reasons for missing matches, our subsequent analysis essentially compare the relatively healthier subsample among DW-borrowing banks with (almost) the whole sample among U.S. TAF-borrowing banks.[2] Therefore, the later results that DW-borrowing banks are on average weaker than TAF-borrowing banks would go through if we could have found all the matches for DW-borrowing banks.

Did bank fundamentals predict LOLR borrowing decisions? To explore how the BHCs' financial condition affects their borrowing from DW and TAF, we estimate the following specification:

$$\frac{DW_{it}}{DW_{it}+TAF_{it}} = \alpha + \beta_1 \cdot x_{it} + \Gamma \cdot [\text{Size}_{it}, ROA_{it}] + \gamma_i + Q_t + \varepsilon_{it}, \tag{3}$$

where DW_{it} and TAF_{it} are bank i's average daily outstanding balance from DW and TAF in quarter t. The left-hand side of equation (3) therefore measures the use of DW relative to TAF. On the right-hand side, x_{it} is one of the proxies for BHC i's financial condition in quarter t, including its core deposit to assets ratio, book leverage, tier-1 capital to risk-weighted asset ratio (T1RWA), unused commitment to assets, and short-term wholesale funding to assets. These variables are defined following Ellul and Yerramilli (2013) and Erel, Nadauld and Stulz (2014). In all regressions, γ_i is the bank fixed effect to take into account time-invariant conditions in the bank's fundamentals, and Q_t is the quarter fixed effect to incorporate variations in aggregate economic conditions.

[2]There are several reasons behind the missing matches. First, many borrowers were credit unions or savings and loans holding companies that did not file Y-9C reports. For example, US Central Federal Credit Union took out $39,101 million in loans from the two facilities. Another example is Washington Mutual Inc. Even though it had an RSSD 2550581, it was an S&L holding company instead of a BHC. Therefore, it was regulated by the Office of Thrift Supervision and did not file a Y-9C report. Second, there are certain thresholds for reporting Y-9C. For example, banks with assets below $1 billion did not have to report. Finally, there were several mergers and acquisitions during the crisis period. For example, Wachovia borrowed $34,460 million from DW from 2007 Q3 to 2008 Q4, with the majority ($29,000 million) borrowed in 2008 Q4. However, Wachovia was acquired by Wells Fargo in 2008 Q4, and thus did not file a Y-9C report that quarter.

We include bank size and return to assets (ROA) as additional controls. Note that we use the *contemporaneous* measurement of banks' financial condition, for two reasons. First, the results are qualitatively unchanged if we control for lagged measurements $x_{i,t-1}$. Second, since these risk measurements were not available until at least 30 days after the quarter ended, we interpret the contemporaneous risk measurements as the part of banks' fundamentals that are not entirely observed by the public yet.

Table B2 reports the results if the above-mentioned bank fundamental measurements are included one by one; we use robust standard errors in all the regressions. Columns titles indicate the measurement used for bank fundamentals. Column (1) and (2) show that once a bank's core deposits to assets ratio goes up by 1%, the same bank borrows relatively 1% less from DW. The results are economically and statistically significant and also not driven by either time-varying aggregate conditions or the bank's time-invariant variables. Clearly, banks with more stable funding tried to avoid borrowing from DW. Column (3), (4), (5) and (6) confirm similar results if we measure a bank's fundamental through its capital adequacy. Banks with higher book leverage and lower tier-1 capital to risk-weighted assets tend to borrow more from DW. Moreover, Ivashina and Scharfstein (2010) show that borrowers heavily drew down their credit lines during the crisis, implying that banks with more unused loan commitments were more vulnerable and therefore had more urgent liquidity demand. Column (7) and (8) show that indeed, these banks tend to borrow relatively more from DW. Finally, it is widely acknowledged that the 2008 crisis was a run by short-term wholesale creditors (Shin (2009)). Our results in Column (9) and (10) show that banks relied more on short-term wholesale funding also borrowed relatively more from DW as well. Table B3 reports the regression results when we simultaneously control for all these bank fundamental measurements.[3] Clearly, book leverage and tier-1 capital ratio still stand out as important predictors on a bank's relative use of DW.[4]

Did LOLR borrowing decisions predict future bank fundamentals? Did DW and TAF loans capture potentially unobservable risks in banks' fundamentals? In particular, did these loans predict changes in banks' fundamentals? To answer this question, we estimate the following specification:

$$x_{i,t+1} = \alpha + \beta_1 \cdot x_{it} + \beta_2 \cdot \frac{DW_{it}}{DW_{it} + TAF_{it}} + \Gamma \cdot [\text{Size}_{it}, ROA_{it}] + \gamma_i + Q_t + \varepsilon_{it}, \tag{4}$$

where $x_{i,t+1}$ is one of the previous proxies for BHC i's financial condition in quarter $t+1$. We control for the one-quarter lagged financial condition, size, ROA, as well as bank and quarter fixed effects.

Table B4 reports the results. Across all columns, the results show that the relative borrowing from DW could have additional predictive power regarding a bank's core deposits, book leverage, tier-1 capital ratio, unused loan commitment, and reliance on short-term whole sale funding in the next quarter. In particular, if a bank borrows relatively more from DW, all these measurements will imply that the bank becomes less healthy in the next quarter. In other words, the relative borrowing from DW can predict deterioration in a bank's future financial condition, controlling for the relevant financial condition this quarter. Therefore, a bank's reliance on DW captures

[3] Since tier-1 capital ratio and book leverage are highly correlated (correlation≈ -0.7), we don't control for both in the same regression.

[4] We have run additional robustness checks. In particular, the results are largely unchanged if 1) we only use the subsample before 2008 Q3; 2) if we eliminate banks that exclusively borrow from DW throughout the crisis; 3) if we use the lagged bank fundamental measurement x. Moreover, note that we have used the share of outstanding balance from DW as the left-hand-side variable. The results also stay unchanged if instead we use the share of new borrowing loans from DW.

certain financial condition that is not publicly observable.

The results also have strong economic significance. For example, if a bank switches from 0% to 100% DW borrowing (which is not rare in the sample), its book leverage increases by 0.2%–0.3% after controlling for either the quarter-specific fixed effects or the bank-specific fixed effects. Meanwhile, the unconditional standard deviation of the book leverage is merely 0.01% in our sample. Similarly, the standard deviation of core deposits over assets is 0.06%, whereas a bank that switched from 0% to 100% DW borrowing would reduce its core deposits to assets ratio by somewhere between 0.4% and 1.4%. In terms of the remaining proxies for financial strength, T1RWA has a standard deviation of 0.02%, unused commitment/assets 0.05%, and STWF/Assets 0.04%. All of them are small relative to the magnitude reported in Table B4.

2. International Evidence

Specification (3) suffers from potential endogeneity issues. In particular, it does not control unobserved time-varying bank fundamental conditions. To address concerns about these omitted variables, we further employ a difference in differences (DID) approach and explore the international aspects of borrowing banks. In October 2008, leaders from the G7 countries met and established a plan of actions that aimed to stabilize financial markets, restore the flow of credit, and support global economic growth. Following the meeting, all of the G7 countries except Japan immediately announced to launch credit guarantee programs that effectively reduced the liquidity risk faced by domestic financial institutions (Yale Program on Financial Stability (2019)). Later on, many other countries also undertook similar credit guarantee programs to combat the potential crisis.[5] The operation dates of country-specific policies were staggered, however, as

[5] The details of these programs are available at https://newbagehot.yale.edu/find/all/credit-guarantee.

these policies could be largely driven by political obstacles through bargaining and renegotiation.[6] The staggered structure offers us an ideal setup to study the difference in these countries' banks' decisions to borrow from LOLR in the US.[7] Specifically, we compare the decisions to borrow from DW and TAF by banks from different countries before and after their country-specific credit guarantee programs. In particular, we focus on the auction held on October 20, 2008 and examine whether implementing (and also announcing) a credit guarantee program prior to that date affects banks' decisions to borrow from DW or TAF. The following equation is estimated a biweekly basis using data from 2008 Q3:

$$\frac{DW_{iw}}{DW_{iw}+TAF_{iw}} = \alpha + T_i + \lambda_w + \delta \cdot (T_i \times \lambda_w) + \varepsilon_{iw}, \tag{5}$$

where DW_{iw} and TAF_{iw} are bank i's outstanding balance from DW and TAF in the w's bi-week, respectively. In the specification, T_i is a dummy variable for the treated group, which takes a value of 1 if the country's operation (announcement) date happens before October 20, 2008. The control group therefore includes countries with policies implemented (announced) after October 20, 2008, as well as countries that did not announce any policy. λ_w is the time trend, which equals one after October 20, 2008. We are mainly interested in the coefficient δ before the interaction term, which estimates the DID effect.

We plot the the dependent variable $\frac{DW_{iw}}{DW_{iw}+TAF_{iw}}$ in Figure B3. The two dashed vertical lines mark the two TAF auctions held on October 6 and October 20. Clearly, there was a sharp decline by the treatment group on the relative usage of DW. Prior to Oct 6 and post Oct 20, 2008, the two

[6] Table B5 lists announcement and operation dates.

[7] Buch, Koch, and Koetter (2018) show that access to TAF eased German banks financial stress.

groups have parallel trend in terms of the relative borrowing from DW and TAF.[8] A t-test on the difference in the growth rate of the dependent variable across the two groups shows the t statistic is only 0.1070 prior to October 6. By contrast, the same t-test during the post-treatment period has a t-statistic 1.7839. Table B6 presents the results to specification (5). Column (1) shows that after the policy shock, banks from treated countries, i.e., those countries with credit guarantee programs started before October 20, 2008 borrow about 11% less from DW. Note that these banks originally borrowed more from DW, compared with banks from the control groups. Column (2) conducts the same analysis, but using the announcement date of the credit guarantee program as the quasi-experiment. The results stay largely unchanged. Note that we do not further explore countries whose policies were implemented between the auctions held on Oct 20 and Nov 3, because only very few banks fall into the treatment group in this case.[9]

C. Evidence from Bank Failure

Next, we study whether banks that borrowed more from DW were also more likely to fail subsequently. To do so, we manually collect data on whether a bank failed, was acquired, or got nationalized by the government by December 31, 2011. Our results are robust to the choice of this ending date. In the borrowing sample, 36 financial institutions failed by December 31, 2011. Of these, 11 failed in 2008, eight in 2009, seven in 2010, and 10 in 2011. We study whether banks that borrowed more from DW were more likely to fail from the following linear-probability specification.

[8]Note that the treatment group experiences a small upward jump in the week of Sep 23. This jump is statistically insignificant and possibly driven by the collapse of Lehman (15) and AIG (Sep 16).

[9]Indeed, Table B5 shows only Austria, Germany, The Netherlands, Portugal, and Sweden fall into this treatment group. Among banks from these countries, only a total of eight banks were borrowing from both DW and TAF during the crisis.

$$(6) \qquad \mathbb{1}\{\text{bank } i \text{ fails in } t\} = \alpha + \beta_1 \cdot \frac{DW_{it}}{DW_{it} + TAF_{it}} + \gamma_i + Q_t + \varepsilon_{it},$$

where $\mathbb{1}\{\text{bank } i \text{ fails in } \tau\}$ is an indicator function on whether bank i failed in quarter t, and $\frac{DW_{it}}{DW_{it}+TAF_{it}}$ is the fraction of DW outstanding balance. We will also run the unconditional regression where the left-hand side variable is whether the bank failed during the crisis, and the right-hand side includes the aggregate borrowing during the entire sample period (2007Q3 to 2010Q2).

Table B7 reports the results. Column (1) shows that compared with a bank that only borrowed from TAF, a bank that solely borrowed from DW was more likely to fail within the same quarter by an additional probability of 1.1%. Column (2) confirms the result if we control for aggregate conditions by adding quarter fixed effects. Column (3) controls for bank fixed effects, where the result is no longer statistically significant. Finally, column(4) shows that if a bank borrows more from DW during the entire sample period, the chance that is fails during the crisis increases by 12.8%. Therefore, the borrowing from DW relative to TAF is associated with more bank failure, so that there are systematic differences between DW-borrowing banks and TAF-borrowing banks.

FIGURE B2
Comparison of Bloomberg Data and Fed Data

This figure plots the total weakly borrowing amount from DW (left panel) and from TAF (right panel), aggregated from the Bloomberg data (red solid line) and reported from the Fed (blue dashed).

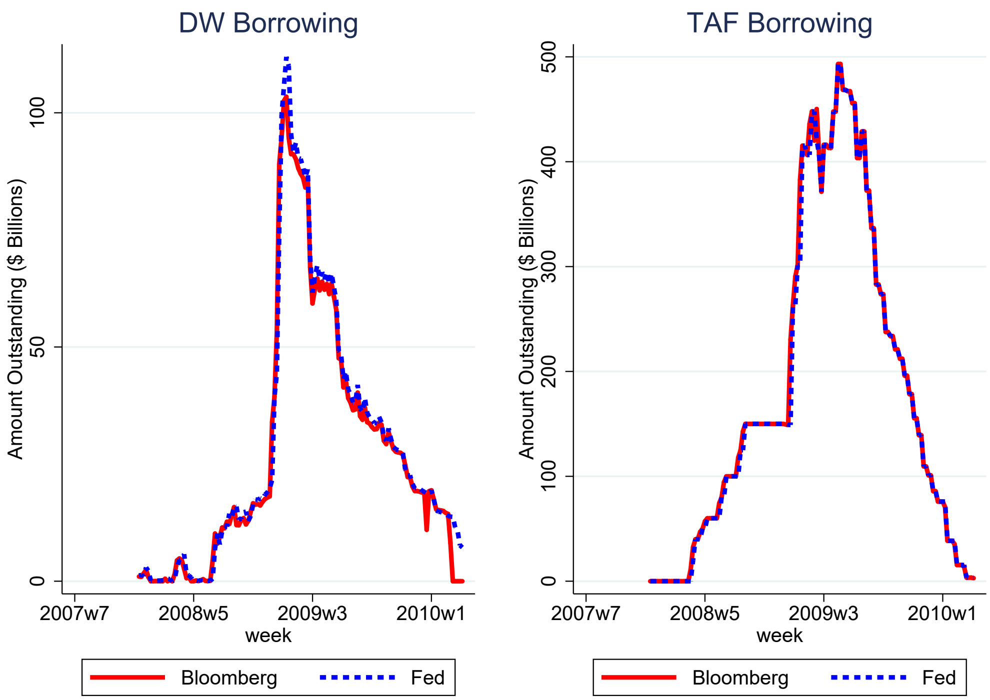


FIGURE B3
Share of DW Borrowing in 2008 Q3 and Q4

This figure plots the average of the variable $\frac{DW_{iw}}{DW_{iw}+TAF_{iw}}$ across different groups, where DW_{iw} and TAF_{iw} are bank i's outstanding balance from DW and TAF in the two week indexed by w, respectively. The red solid line shows the average across all banks in the treated groups, i.e., banks from countries whose credit guarantee programs operating before October 20, 2008. The blue dashed line shows the average across all the banks in the remaining countries, i.e., the control group. The two dashed vertical lines mark the two subsequent TAF auctions held on October 6 and October 20.

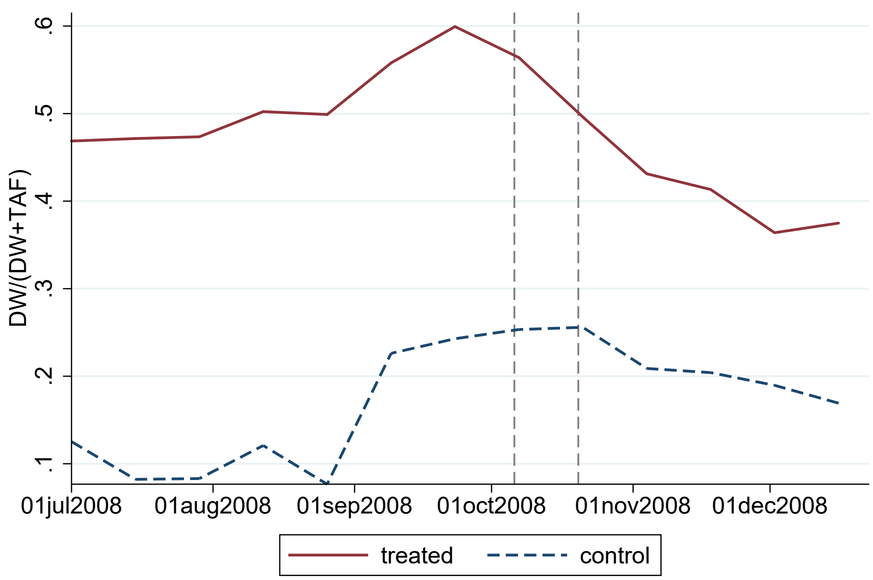


TABLE B1
Summary Statistics of Bloomberg Data

This table reports the summary statistics of borrowers in the Bloomberg data. The data cover institutions that borrowed from the Fed between August 1, 2007 and April 30, 2010. These data were released by the Fed on March 31, 2011 and subsequently collected by Bloomberg.

	N	Mean	Max	Min	SD	10^{th}	50^{th}	90^{th}
Borrowers	407							
Banks	313							
Diversified Financial Services	24							
Insurance Companies	12							
Savings and Loans	30							
Market Cap on 8/1/07 (MM)		28525	399089	11	49876.8	107	7331	81813
Foreign Banks	92							
DW-only banks	18							
TAF-only banks	86							
borrow both	260							
Total DW events		12	242	0	28.7	0	2	35
Total TAF events		5	28	0	5.1	0	3	13
Total DW amount (MM)		1529	190155	0	10393.8	0	20	1809
Total TAF amount (MM)		3174	100167	0	10727.5	0	58	7250
Number of days in debt to Fed		323	814	28	196.8	85	306	606

TABLE B2

LOLR Borrowing and Univariate Bank Fundamentals

This table reports OLS and fixed-effect regression results in specification (3), where we put univariate proxy for financial health. The sample contains all BHCs (bank holding companies) that have borrowed in the Bloomberg sample and filed FR Y-9C reports. The columns differ in the measurement of financial strength: (1) and (2) use core deposits over assets; (3) and (4) use book leverage; (5) and (6) use T1RWA, (7) and (8) use unused commitment to assets, (9) and (10) use short-term wholesale funding to assets. All the regressions control for bank size and ROA. Standard errors in the parentheses are robust standard errors.

	Core Deposits/Assets		Book Lev		Tier-1 Capital/RWA		Unused Commit/Assets		STWF/Assets	
	1	2	3	4	5	6	7	8	9	10
x	-0.098	-1.105***	2.111***	4.179***	-1.982***	-4.736***	0.066	2.730***	0.227	0.889**
	(0.116)	(0.363)	(0.650)	(1.277)	(0.676)	(0.970)	(0.245)	(0.565)	(0.189)	(0.347)
ROA	0.443	17.959***	2.653	20.599***	2.740	17.195***	0.355	13.573***	0.298	18.121***
	(3.387)	(4.287)	(3.437)	(4.225)	(3.467)	(4.220)	(3.437)	(4.613)	(3.377)	(4.308)
log(Size)	-0.045***	-0.752***	-0.037***	-0.770***	-0.042***	-0.668***	-0.045***	-0.508***	-0.041***	-0.775***
	(0.008)	(0.160)	(0.007)	(0.160)	(0.007)	(0.159)	(0.008)	(0.172)	(0.007)	(0.160)
Constant	1.050***	12.665***	-1.039*	8.573***	1.170***	11.271***	0.997***	7.816***	0.897***	12.254***
	(0.167)	(2.517)	(0.622)	(2.725)	(0.136)	(2.485)	(0.118)	(2.745)	(0.121)	(2.516)
Fixed Effects	Quarter	BHC	Quarter	BHC	Quarter	BHC	Quarter	BHC	Quarter	BHC
N	731	731	731	731	731	731	674	674	731	731
R^2	0.19	0.53	0.20	0.53	0.19	0.54	0.19	0.54	0.19	0.53

TABLE B3
LOLR Borrowing and Multivariate Bank Fundamentals

This table reports OLS and fixed-effect regression results in the specification (3), where we include multiple proxies for financial health. Due to collinearity, we do not simultaneously include book leverage and T1RWA. The sample contains all BHCs (bank holding companies) that have borrowed in the Bloomberg sample and filed FR Y-9C reports. All the regressions control for bank size and ROA. Standard errors in the parentheses are robust standard errors.

	1	2	3	4
Core Deposits/Assets	-0.107	-1.325**	-0.013	-1.404***
	(0.155)	(0.533)	(0.155)	(0.536)
Tier 1 Capital/Risk-Weighted Assets	-2.212***	-4.246***		
	(0.740)	(1.150)		
Book Leverage			2.005***	4.751***
			(0.714)	(1.449)
Unused Commitments/assets	0.117	2.087***	0.181	2.651***
	(0.267)	(0.587)	(0.268)	(0.581)
Short-Term Wholesale Fund/Assets	0.158	-0.683	0.107	-0.663
	(0.234)	(0.520)	(0.235)	(0.525)
ROA	3.256	12.300***	2.593	14.004***
	(3.549)	(4.558)	(3.511)	(4.591)
log(Size)	-0.051***	-0.473***	-0.043***	-0.521***
	(0.011)	(0.171)	(0.011)	(0.171)
Constant	1.331***	8.660***	-0.893	4.590
	(0.252)	(2.717)	(0.720)	(2.988)
Fixed Effects	Quarter	BHC	Quarter	BHC
N	674	674	674	674
R^2	0.20	0.55	0.20	0.55

TABLE B4
LOLR Borrowing and Future Bank Fundamentals

This table reports OLS and fixed-effect regression results in specification (4), where we put into proxies for future financial health one by one. The sample contains all BHCs (bank holding companies) that have borrowed in the Bloomberg sample and filed FR Y-9C reports. The columns differ in the measurement of financial strength: (1) and (2) use core deposits over assets; (3) and (4) use book leverage; (5) and (6) use T1RWA, (7) and (8) use unused commitment to assets, (9) and (10) use short-term wholesale funding to assets. All the regressions control for bank size and ROA. Standard errors in the parentheses are robust standard errors.

	Core deposits/assets		Book Lev		Tier-1 Capital/RWA		Unused commit/assets		STWF/assets	
	1	2	3	4	5	6	7	8	9	10
DW/(DW+TAF)	-0.004	-0.014***	0.002***	0.003**	-0.003**	-0.003**	0.001	0.004**	0.008***	0.012***
	(0.003)	(0.004)	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)	(0.004)
x_{it}	0.984***	0.716***	0.950***	0.626***	0.905***	0.670***	0.960***	0.658***	0.913***	0.692***
	(0.009)	(0.033)	(0.016)	(0.035)	(0.019)	(0.032)	(0.012)	(0.030)	(0.015)	(0.031)
log(Size)	0.000	0.061***	-0.000**	-0.010**	0.000	0.013**	0.001***	0.002	-0.001	-0.040***
	(0.001)	(0.015)	(0.000)	(0.004)	(0.000)	(0.005)	(0.000)	(0.009)	(0.001)	(0.015)
ROA	0.080	-0.713*	-0.250***	-0.040	0.204**	-0.225	0.353**	1.019***	0.490*	1.154***
	(0.260)	(0.390)	(0.085)	(0.116)	(0.097)	(0.137)	(0.178)	(0.242)	(0.266)	(0.394)
Constant	0.012	-0.804***	0.051***	0.503***	0.007*	-0.162**	-0.019***	0.018	0.023**	0.677***
	(0.013)	(0.229)	(0.015)	(0.074)	(0.004)	(0.081)	(0.006)	(0.143)	(0.010)	(0.230)
Fixed Effects	Quarter	BHC	Quarter	BHC	Quarter	BHC	Quarter	BHC	Quarter	BHC
N	726	726	726	726	726	726	597	597	726	726
R^2	0.96	0.97	0.85	0.89	0.81	0.86	0.94	0.96	0.85	0.89

TABLE B5
Announcement and Operation Dates of Credit Guarantee Programs

This table lists the announcement and operational dates of all the credit guarantee programs carried out by G7 countries and others that followed. The data are collected by Yale Program on Financial Stability (2019).

Country	Announcement Date	Operational Date
Australia	10/12/2008	11/28/2008
Austria	10/27/2008	10/27/2008
Belgium	10/15/2008	10/15/2008
UK	10/8/2008	10/13/2008
Canada	10/23/2008	2/25/2009
Denmark	10/10/2008	10/11/2008
France	10/12/2008	10/17/2008
Germany	10/13/2008	10/27/2008
Ireland	11/20/2009	12/9/2009
Italy	10/13/2008	12/4/2008
Netherlands	10/13/2008	10/23/2008
Portugal	10/12/2008	10/29/2008
South Korea	10/19/2008	10/20/2008
Spain	10/13/2008	11/21/2008
Sweden	10/20/2008	10/29/2008
US	10/14/2008	10/14/2008

TABLE B6
Credit Guarantee Programs and LOLR Borrowing

This table reports DID regression results in the specification (5). The sample contains all international BHCs (bank holding companies) that have borrowed in the Bloomberg sample between July 1, 2008 and Dec 31, 2008. All borrowings are aggregated at the bi-weekly frequency. The treament group includes BHCs from countries whose credit guarantee program happens before October 20, 2008. The control group includes countries with programs after October 20, 2008, as well as countries that did not announce any policy. Column (1) uses the operational dates for the credit guarantee programs at the cutoff, whereas column (2) uses announcement dates. Table B5 lists announcement and operation dates, collected by Yale Program on Financial Stability (2019). Standard errors in the parentheses are robust standard errors.

	Operational Dates	Announcement Dates
Treated × after 10/20/2008	-0.112***	-0.172***
	(0.043)	(0.050)
Treated countries	0.364***	0.373***
	(0.032)	(0.035)
After 10/20/2008	0.029	0.095**
	(0.034)	(0.044)
Constant	0.150***	0.104***
	(0.025)	(0.030)
Observations	1844	1844
Adjusted R^2	0.076	0.042

TABLE B7
LOLR Borrowing and Bank Failure

Column (1)-(3) report the regression results in the specification (6) with and without BHC/quarter fixed effects. In Column (4), we report the results from the unconditional version of (6), where the dependent variable is whether a bank fails by the end of 2011, and the variable DW_{it} and TAF_{it} are respectively replaced by the aggregate borrowing DW and TAF between 2007Q3 and 2010Q2. The sample contains all U.S.-based and international BHCs (bank holding companies) that have borrowed in the Bloomberg sample between 2007Q3 and 2010Q2. We manually collect data on whether a bank failed, was acquired, or got nationalized by the government by December 31, 2011. Standard errors in the parentheses are robust standard errors.

	Fail this quarter			Fail during Crisis
DW/(DW+TAF)	0.011***	0.009**	0.006	0.128**
	(0.004)	(0.004)	(0.005)	(0.064)
Constant	0.002	0.002	0.003	0.070***
	(0.002)	(0.002)	(0.002)	(0.016)
Fixed Effects	No	Quarter	BHC	No
N	2025	2025	2025	364
R^2	0.00	0.01	0.19	0.02