**Overcoming Discount Window Stigma**

**An Experimental Investigation**

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**Abstract**

A core function of central banks is to act as a “lender of last resort” to the banking system. In the U.S., the Federal Reserve relies on the Discount Window (DW) to fulfill this task. Historically, however, the DW has not been an effective liquidity backstop because its usage is stigmatized. Although DW stigma is a serious impediment to the mission of central banks, little is known about the issue. This paper reports on an experiment aimed at testing ways to overcome DW stigma. We find that, whereas lowering the DW cost and making DW borrowing harder to detect are ineffective, regular random DW borrowing can mitigate stigma.

Keywords: Lender of last Resort, Central Bank, Discount Window, Stigma, Laboratory Experiment

JEL codes: E58 G01 C92

“*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.*” Fed Chairman Bernanke (2009)

“*The discount window is the Fed’s main tool for distributing money to the banking system in emergencies when bank-to-bank lending is not functioning, which is precisely the situation that prevailed in late 2007. But because banks were very reluctant to use the window, that key tool was broken.”* Fed Governor Duke (2010*)*

“[Banks] *deliberately did not ask for the liquidity they needed for fear of damaging their reputation—the “stigma” problem… I do not think we were conscious of this before the crisis started and I do not think central banks have a convincing answer to it… This is, I think, still a challenge in how to manage the process of central bank provision of liquidity support. This is one of the big intellectual issues that has not been fully resolved.*” Bank of England Governor King (2016a)

# 1. Introduction

This paper is concerned with “Discount Window” (DW) stigma, a reluctance to access the central bank backstop lending facility even for benign reasons out of concerns that it could be interpreted as a sign of financial weakness if detected. As explained below, DW stigma is a threat to financial stability and an impediment to the mission of central banks. However, little is known about DW stigma in large part because of the absence of data. The object of this paper is to understand better the driver of DW stigma and to explore how the problem could be mitigated. To do so, we run a laboratory experiment to generate data under different environments. To the best of our knowledge, this is the first paper to use experimental methods to study DW stigma and more generally the provision of emergency liquidity.

In principle, solvent but illiquid banks should obtain funding from private counterparties with excess liquidity in the interbank market. Various frictions, however, can impair the interbank market. In particular, asymmetric information can prevent lenders from distinguishing illiquid from insolvent borrowers, especially when markets are stressed.[[2]](#footnote-2) As a result, solvent banks can fail to secure private funding, in which case they have to resort to costly alternatives (e.g. “fire sales” of assets, borrowing at prohibitively high rates) to meet their liquidity obligations (Winters 2012). As illustrated by the rapid demise of *Northern Rock* in 2007, these actions can trigger a bank run, insolvency and ultimately, the failure of an illiquid yet ex-ante solvent bank (Shin 2009). The inability to fund privately illiquid institutions can also have negative externalities and social costs. In particular, spillovers from fire sales can result in insolvency cascades (Brunnermeier 2009, Shleifer and Vishny 2011,).[[3]](#footnote-3) As illustrated in the aftermath of the 2008 *Lehman Brothers*’ failure, exposure to a failing bank can easily lead to contagion in a highly interconnected financial system (Caballero and Simsek 2013). Ultimately, adverse selection in the interbank market can start or deepen a liquidity crisis, which may lead to a contraction in economic activity.[[4]](#footnote-4)

To address market failures in the interbank market and prevent the negative externalities they can generate, central banks typically assume “Lender of last Resort” (LoLR) responsibilities. The objective of the LoLR is to avoid unnecessary and socially costly failures by providing liquidity support when private alternatives are not available or prohibitively expensive.[[5]](#footnote-5) In the U.S., the Federal Reserve (the Fed) has been operating as a LoLR through its “Discount Window” for more than a century.[[6]](#footnote-6) As further explained in Appendix 1, the DW is a standing facility (i.e. open every business day) that provides sound depository institutions backup overnight funding against a broad range of collateral at a premium above the target rate. Because it aims to address any liquidity problems before they have systemic consequences, the DW is the Fed’s first line of defense against a liquidity crisis. Historically, however, the DW has been little used, even when banks faced acute liquidity shortages. Most notably, the DW was scarcely accessed at the onset of the 2008 financial crisis despite several policy measures enacted to encourage DW borrowing (see Appendix 1). As illustrated by Chairman Bernanke’s quote above, this lack of DW borrowing is generally attributed to DW stigma under which even solvent banks that cannot meet their funding needs in private markets for benign reasons refrain from accessing the DW out of concern that, if observed, they might be perceived as insolvent.

DW stigma is a first order concern for central banks because it can affect two of their core responsibilities: acting as a LoLR and implementing monetary policy. A central bank can only fulfill its LoLR obligations if financial institutions are willing to access the DW. As illustrated by Governor Duke’s quote above, stigma inhibited DW borrowing in the second half of 2007, which prevented the Fed from containing the emerging crisis.[[7]](#footnote-7) In normal times, DW stigma can also impair the implementation of monetary policy. Since 2008, the Fed has been using a “corridor system” to ensure that market rates are close to its target.[[8]](#footnote-8) The floor of the corridor is the interest paid on excess reserves, and the ceiling is the DW rate (Keister 2012). In principle, banks have no incentives to borrow above the ceiling or lend below the floor. When stigma drives banks to borrow on the interbank market above the DW rate, however, the ceiling becomes “leaky” and the Fed loses its ability to control market rates fluctuations (Kahn 2010). It is well documented that stigma was a major concern in the design of the policy responses during the latest financial crisis (Geithner 2014, Fischer 2016).[[9]](#footnote-9) Since then, DW stigma has been identified as a significant threat to financial stability (Winters 2012, Domanski and Sushko 2014, Duke 2016). As a result, some central banks have recently revised their DW policies with the explicit objective of mitigating stigma (e.g. the BoE in 2015), while others are contemplating possible reforms.[[10]](#footnote-10)

Despite its relevance, DW stigma is not a well-understood phenomenon, as illustrated by Governor King’s quote above.[[11]](#footnote-11) Only a few theoretical models have been developed in which stigma emerges in equilibrium (Ennis and Weinberg 2013, La’O 2014, Gorton and Ordonez 2016, Ennis 2017, Che, Choe and Rhee 2018) and empirical evidence has been scarce (Armantier et al. 2015). The major challenge is the lack of data: If financial institutions avoid the DW regardless of the environment, then analysts do not have data to study the phenomenon. In this context, experimental methods offer a unique opportunity to generate data in a controlled environment so as to better understand and mitigate DW stigma.

To study DW stigma in the lab, we develop a coordination game with adverse selection. As explained in Section 2, there are two types of players, banks and investors. The bank receives a solvency shock and an end-of-day liquidity shock that are private information. The bank can address its liquidity shock either at the DW or with a fire sale of assets. DW borrowing is less costly than the alternative, but it may be detected by the investor who must decide whether or not to fund the bank. Because liquidity is informative about solvency, the investor may decide not to fund a detected bank. This may produce DW stigma, as the bank may prefer to pay the higher cost of a fire sale to remain undetected and improve its chances of being funded. An original feature of the model is that, consistent with practitioners’ beliefs (Moore 2017), the detection probability decreases with the number of DW borrowers. This creates a coordination problem for banks and two pure strategy equilibria: a stigma-free equilibrium under which every illiquid bank borrows at the DW and a stigma equilibrium under which the DW is never accessed.

In addition to a control treatment, we conduct three treatments aimed at evaluating policies that have been proposed to mitigate DW stigma. The first treatment explores how lowering the cost of the DW impacts DW borrowing. Starting with Bagehot (1873), the appropriate price of emergency lending has long been debated: Making the DW too affordable creates moral hazard, while highly penal rates stigmatize the DW by making it attractive only to the most distressed banks. In principle, lowering the DW rate should promote DW borrowing and thus reduce stigma. This measure was recommended by Winters (2012) to the BoE to overcome stigma and it was actually implemented by the Fed in August 2007 to encourage DW borrowing at the onset of the crisis (see Appendix 1).

The second treatment tests the efficacy of regular random borrowing, a measure proposed by Winters (2012) to reduce DW stigma at the BoE: “*The Bank should further consider concrete action to reduce any remaining reluctance of banks to use the DW. The best way to accomplish this would be to regularize its use so that crisis usage is less visible and, hence, less stigmatized…. Drawings would be required in large enough size so that usage in the event of a significant* ***‘****genuine****’*** *need by a bank would be less likely to be noticed*.” Thus, the idea is to make DW borrowing both unremarkable and uninformative by having banks access the DW regularly.

The third treatment evaluates the effect of changing the DW probability of detection. Clearly, there cannot be DW stigma unless there is a chance that DW borrowing is detected. Although the Fed does not disclose the borrowers’ identities in real time, concerns have been expressed recently over proposed changes in disclosure policies that could make DW identification easier and thereby exacerbate stigma (Bernanke 2015a, Calomiris et al. 2017).[[12]](#footnote-12)

The results from the control treatment show that subjects coordinate systematically on the stigma equilibrium. Thus, we are able to make DW stigma, a phenomenon rarely observed but widely believed to occur in the field, emerge in the lab. We also find that DW stigma is not reduced significantly by cutting the cost of DW borrowing or by making DW borrowing harder to detect. In contrast, random borrowing solves the stigma problem in our experiment as it helps subjects learn to coordinate on the stigma-free equilibrium.

The paper is structured as follows. The model is introduced in Section 2. The experiment is described in Section 3. The results of the experiment are reported in Section 4. An econometric analysis sheds light on the drivers of DW stigma in Section 5. Finally, Section 6 concludes.

# 2. The Model

To capture the essence of emergency lending and DW stigma, we develop a coordination game with adverse selection. The model is rich enough to produce DW stigma in equilibrium, but simple enough to implement in the lab. Unlike (e.g.) Ennis and Weinberg (2013), we take a partial equilibrium perspective and do not model the interbank market for funds.

### The setting

There are two populations of players, banks and investors, each of size . A bank is matched randomly with an investor. The players move sequentially. The bank moves in period 1, the investor in period 2. Players are risk neutral and do not discount the future. We focus on pure strategies.

The bank can be solvent or insolvent, liquid or illiquid. The bank at the end of period 2 is worth if solvent or 0 if insolvent. If the bank is illiquid, then it must come up with 1 unit of liquidity in period 1.[[13]](#footnote-13) There is asymmetric information about the bank’s type: It is known to the bank at the beginning of the game, but it is revealed to the investor only at the end of the game. To simplify, we assume that all insolvent banks are illiquid.[[14]](#footnote-14) Thus, there are three types of banks: solvent-liquid with probability , solvent-illiquid with probability and insolvent-illiquid with probability . While a bank’s type is private, these probabilities are common knowledge.

In period 1, an illiquid bank chooses between borrowing 1 unit of liquidity at the DW at a cost or incurring a loss . Note that we are making four assumptions. First, a bank’s liquidity status is measured at the end of the day and is net of what can be obtained in the interbank market. Second, consistent with Ennis and Weinberg (2013), a solvent bank may need to borrow at the DW because frictions can impair the interbank market. Third, the central bank is unable to distinguish solvent-illiquid from insolvent-illiquid banks, and thus lends to any bank at the DW. In practice, the Fed should not lend to insolvent banks, but solvency screening is difficult, especially in times of crises (Freixas et al. 2004). Here, we assume it is impossible, consistent with Ennis and Weinberg (2013).[[15]](#footnote-15) Fourth, consistent with Ennis and Weinberg (2013), the cost of the alternative is higher than the DW rate as it captures both monetary (e.g. losses from fire sales) and non-monetary (e.g. loss of reputation) elements.

In period 2, the investor decides whether or not to take a stake in the bank. To simplify, we say that the investor either funds or does not fund the bank. When the investor does not fund the bank, the bank effectively ceases to operate. In this case, the investor gets an outside option and the bank gets 0 in period 2. If the investor funds the bank, then the investor gets 0 if the bank is insolvent or is the banks is solvent, while the bank gets a profit from operating in period 2.[[16]](#footnote-16)

In principle, DW borrowing should remain anonymous, in which case there cannot be DW stigma (Ennis and Weinberg 2013, Gorton and Ordonez 2016).[[17]](#footnote-17) In practice however, public identification has occurred in real-time on occasions and various detection channels have been mentioned.[[18]](#footnote-18) Further, practitioners argue that real-time detection is more difficult when more banks borrow at the DW simultaneously (Moore 2017, Anbil 2018). To capture this “safety in numbers” effect we assume that , the probability that the investor detects the bank’s DW borrowing between the two periods when a total of banks borrow at the DW in period 1, is decreasing in : . As we shall see, the endogenous nature of the detection probability introduces a coordination component for the banks.

Observing the bank going to the DW enables the investor to update its beliefs about the bank’s solvency before making a funding decision. Indeed, DW detection implies that the bank is illiquid and illiquid banks are by construction more likely to be insolvent. Thus, there is an indirect cost to DW borrowing for the banks: if detected, the investor may decide not to fund the bank because of the increased solvency concern.

### Restrictions on the parameters

We impose the following restrictions on the model’s parameters:

* *R1* :
* *R2* : , where and

*R1* guarantees that i) DW borrowing is not strictly dominated (), ii) it is profitable for a bank to operate in period 2 even after incurring the higher illiquidity cost (), and iii) it is socially inefficient to fund an insolvent bank ().[[19]](#footnote-19) Because is the probability that a bank is solvent conditional on being illiquid, the first inequality in *R2* implies that the investor should not fund a bank that is known to be illiquid (). Because is the unconditional probability that a bank is solvent, the second inequality in *R2* implies that it is beneficial for the investor to fund a random bank. Thus, *R2* provides a potential role for the DW as a screening device for investors. Indeed, if DW detection reveals that the bank is illiquid (and therefore more likely to be insolvent), then the investor can decide to fund only non-detected banks.[[20]](#footnote-20)

### Equilibrium

Let us define two pairs of strategy profiles, the stigma strategy= {*No bank borrows at the DW; Investors fund only banks not seen borrowing at the DW*}, and the no-stigma strategy = {*Illiquid banks borrow at the DW; Investors fund only banks not seen borrowing at the DW*}. Consider first the case of a fixed detection probability .

**Proposition 1**: When the unique equilibrium is , otherwise the unique equilibrium is .

**Proof**: see Appendix 2.

As illustrated below, Proposition 1 states that there is a threshold probability. When the probability of detection is lower than this threshold, then it is a best response for illiquid banks to use the DW, and when is higher than , illiquid banks are better off not using the DW. In particular, in the extreme case where , DW borrowing cannot be detected and there cannot be stigma. Conversely, when , DW borrowing is systematically detected and stigma is inevitable. Thus, as increases, the equilibrium switches from the no-stigma strategy to the stigma strategy . This result is consistent with the position of policy makers who argue that making DW borrowing easier to identify publicly can generate stigma.[[21]](#footnote-21)

***NoSt***: {*Illiquid borrow; Fund only non-detected banks*} ***St***: {*No one Borrows; Fund only non-detected banks*}

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We now return to the case of an endogenous probability of detection . We denote the threshold such that and the expected number of illiquid banks .

**Corollary 1**: If , then there are two equilibria, and .Otherwise, is the unique equilibrium when and is the unique equilibrium when .

**Proof**: see Appendix 2.

Intuitively, Corollary 1 states that if a critical mass of illiquid banks, such (with ), borrow at the DW, then the detection probability becomes sufficiently low (i.e. ) to make DW borrowing a best response for any illiquid bank. Thus, banks coordinate on DW borrowing in that case and is an equilibrium. Conversely, if a critical massof DW borrowers is not reached (i.e. ), then the detection probability is too high (i.e. ) to make DW borrowing a best response for an illiquid bank. Thus, banks coordinate on not borrowing at the DW in that case and is an equilibrium.

In the remainder of the paper, we assume that which let us focus on the most interesting case with multiple equilibria. The objective is then to understand what factors drive banks to coordinate on one equilibrium or the other. Of particular interest is , the only policy variable which is under the control of the LoLR. Because is decreasing in and is decreasing in , we have . Thus, increasing the DW cost makes coordination on the stigma-free equilibrium more difficult in the sense that a larger critical mass of DW borrowers is required to make a best response. In the extreme, setting would necessarily create stigma (since and any positive detection probability would support stigma in that case), while setting would not necessarily eliminate stigma (since in that case).

### Total Surplus

Following Ennis and Weinberg (2013), we define total surplus for each bank/investor pair as the sum of the bank’s and investor’s expected profits.[[22]](#footnote-22) We consider two benchmarks. Under the upper benchmark every illiquid bank borrows at the DW (thereby incurring the low illiquidity cost ) and the investors fund solvent banks only.[[23]](#footnote-23) Total surplus in that case is:

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Under the lower benchmark there is no DW in which case the investors lend to every bank and illiquid banks incur the higher illiquidity cost . Total surplus in that case is:

It is easy to verify that under *R1*.

Because no one borrows at the DW under ,total surplus is equal to the lower benchmark without DW (). Under , total surplus is:

,

where is the expected detection probability under . We have:

Observe that since under *R1*. Further, under *R2*. Thus, . Similarly, it is easy to show that . Therefore, we have the following ranking with respect to total surplus: In other words, total surplus is higher when the DW is stigma-free.

To summarize the theoretical results so far, when , there are two equilibria, one bad equilibrium (i.e. with lower total surplus) with DW stigma in which no bank borrows at the DW, and one good, stigma-free equilibrium in which every illiquid bank (solvent or not) borrows at the DW. Further, coordination on the stigma-free equilibrium should be easier when the cost of the DW is low and when the detection probability is low.

### Model Extension: Random DW borrowing

We now assume that, before a bank learns its type, it faces a probability of being selected, in which case it has to borrow at the DW in period 1. The illiquid banks that have not been selected must then decide in period 1 whether or not to borrow voluntarily at the DW. Thus, we now have two kinds of DW borrowers: voluntary borrowers (that are necessarily illiquid) and involuntary borrowers (that may be of any type, i.e. liquid or illiquid, solvent or insolvent).

To simplify, we assume that all DW borrowers (i.e. voluntary and involuntary) borrow 1 unit of liquidity at a cost . Further, voluntary and involuntary borrowers are indistinguishable from the perspective of the investor and they face the same endogenous detection probability , where and are the number of banks that borrow at the DW voluntarily and involuntarily, respectively.[[24]](#footnote-24) Let us define the threshold probability and the strategy profile = {Illiquid banks borrow at the DW; Investors fund every bank}.

**Proposition 2**: is no longer an equilibrium when *.* The unique equilibrium is when , and otherwise.

**Proof**: see Appendix 2.

The first part of proposition 2 states that introducing a chance (even a small chance) of random borrowing eliminates DW stigma as a possible equilibrium. The intuition behind this result is straightforward: Assume that no bank voluntarily borrows at the DW. In that case, the only banks that can be detected are involuntary borrowers. Then, the investor is willing to fund every detected bank under *R2*, because involuntary borrowers are selected randomly from the pool of all banks. As a result, illiquid banks would now be funded regardless of whether or not they are detected. Therefore, they have a strict incentive to deviate and borrow voluntarily at the DW in period 1 because it is cheaper than the alternative. So, cannot be an equilibrium.

The second part of proposition 2 states that all illiquid banks borrow at the DW in equilibrium. The equilibrium behavior of investors now depends on how many solvent banks are added to the pool of DW borrowers by the random selection. If is sufficiently large (i.e. ), then enough solvent banks are added to make it beneficial for the investor to fund a detected bank.

Finally, we compare , total surplus under the random borrowing equilibrium, with and , total surplus under and in the absence of random borrowing. It is easy to show that , while when is small enough. In other words, random borrowing produces higher surplus than a stigmatized DW. The intuition behind this result is the following: Under random borrowing, illiquid banks (which now coordinate on the good equilibrium) experience gains, while liquid banks (which now occasionally incur the illiquidity cost ) experience losses. The balance between gains and losses is positive as long as , the probability of being randomly selected, remains low.

# 3. The Experiment

The between subjects experiment consists of four treatments. A treatment has 6 sessions, each with 12 subjects (6 banks and 6 investors) and 25 rounds. Roles are fixed and pairs are randomly formed in each round. Pilot experiments were done at the University of Virginia and the experiment was conducted at the Toulouse School of Economics. The instructions (see Appendix 3) and decisions pages were displayed using the web-based Veconlab interface. Each session lasted about 90 minutes. Earnings averaged around 17€, plus a show-up payment of 5€.

The average participant in the experiment was 22 years old. Most subjects were man (58%) and 70% studied Economics or Social Sciences. We measured risk attitudes using the Bomb Risk Elicitation Task (BRET) of Crosetto and Filippin (2013). The average BRET score, measured on a 100 points scale with 50 indicating risk neutrality, was 47 thereby indicating slight risk aversion.

### The Control Treatment

Subjects in the control treatment play the game described in Section 2 with the following parameters.[[25]](#footnote-25) The probabilities for the bank’s types are , and . Thus, the unconditional probability that a bank is solvent is , while the probability that a bank is solvent conditional on being illiquid is only . The value of the bank when solvent is and the investor’s outside option is . It is easy to verify that *R2* is satisfied (i.e. ). The cost of the DW is set to be half as large as the cost of the alternative, with and Setting the bank’s profit to guarantees that *R1* is satisfied (i.e. ).

The endogenous probabilities of detection are set to , , and for . With banks and a probability to be liquid of , the average number of illiquid banks in each round is . The threshold probability is , so that . Thus, the condition from Corollary 1, i.e. , is satisfied and both and are equilibria.

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| --- | --- | --- | --- | --- | --- | --- |
| **Table 1: Profits and Total Surplus in Each Treatment** | | | | | | |
| Treatment |  | | Illiquid Bank’s Profit | Liquid Bank’s Profit | Investor’s Profit | Total Surplus |
| Control | Expectation under |  | 14.8 | 50 | 69.2 | 101.6 |
|  | 10 | 50 | 66.7 | 96.7 |
| Observed in Experiment† | | 1.7 (2.0) | 43.1 (2.9) | 63.5 (7.9) | 85.1 (12.3) |
| Low DW Cost | Expectation under |  | 24.8 | 50 | 69.2 | 106.6 |
|  | 10 | 50 | 66.7 | 96.7 |
| Observed in Experiment | | 6.4 (6.5) | 40.0 (4.6) | 61.9 (4.9) | 84.7 (8.2) |
| Random Borrowing | Expectation under | | 16.4 | 44.1 | 68.7 | 99.0 |
| Average in Experiment† | | 14.1\*\* (2.9) | 36.7 (4.0) | 61.9 (5.1) | 86.9 (5.0) |
| Low Detection Probability | Expectation under |  | 17.1 | 50 | 68.8 | 102.3 |
|  | 10 | 50 | 66.7 | 96.7 |
| Observed in Experiment† | | 2.7 (6.1) | 40.9 (2.0) | 61.4 (2.8) | 82.6 (6.6) |

†Treatment average calculated over the last 10 rounds of each session. Numbers in parenthesis refer to the standard devia-tion of session averages. \*\* indicates a treatment effect that is significant at the 5% level compared to the control treatment.

We report in Table 1 equilibrium expected profits and total surplus under our parameter selections. In the control treatment, coordination on the stigma-free equilibrium instead of leaves liquid banks unaffected, it benefits investors slightly and it increases illiquid banks expected profits by about 50%. Nevertheless, observe that it is a best response for a bank to borrow at the DW only when there are at least two other DW borrowers (i.e. ). Thus, despite substantial financial incentives, subjects may find it difficult to coordinate on in the control treatment.

### The Low DW Cost treatment

As indicated in Table 2, the *Low DW Cost* treatment has the same parameter values as the control treatment except for the DW rate which is reduced by half, from 20 to 10. Because the threshold probability is , we now have . Thus, it is a best response for a bank to borrow at the DW if there is at least one other DW borrower. Further, as indicated in Table 1, illiquid banks’ incentives to coordinate on increases from 14.8 in the control treatment to 24.8 in the low DW cost treatment. Hence, coordination on should be easier than in the control treatment.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Table 2: Parameters in Each Treatment** | | | | | |
|  | Detection probability when  banks borrow voluntarily at DW | | | DW Cost | Random Borrowing Probability |
| Treatment |  |  |  |
| Control | 0.75 | 0.50 | 0.25 | 20 | 0 |
| Low DW Cost | 0.75 | 0.50 | 0.25 | 10 | 0 |
| Random Borrowing | 0.50 | 0.25 | 0.25 | 20 | 1/6 |
| Low Detection | 0.50 | 0.25 | 0.25 | 20 | 0 |

### The Random Borrowing treatment

The *Random Borrowing* treatment has the same parameter values as the control treatment. The difference is that in each round, 1 out of the 6 banks is picked at random and has to borrow at the DW regardless of its type (i.e. liquid or illiquid, solvent or insolvent). Voluntary and involuntary DW borrowers incur the same cost , they cannot be distinguished by investors and they face the same endogenous probability of detection as in the control treatment. However, because there is always one involuntary borrower in each round, the detection probabilities actually faced by the voluntary borrowers are now 0.5 and 0.25 when and , respectively (see Table 2). Note also that the random borrowing probability is below the threshold from Proposition 2, so that is the only equilibrium in this treatment. We can see in Table 1 that compared to the stigma equilibrium in the control treatment, random borrowing benefits investors and illiquid banks, while it is detrimental to liquid banks. In aggregate, however, random borrowing is beneficial as it increases total expected surplus by 2.4% compared to .

### The Low Detection treatment

The *Low Detection* treatment has the same parameter values as the control treatment except that the endogenous detection probabilities are now set at , and for , as shown in Table 2. Thus, the detection probabilities in the Low Detection treatment are the same as the one faced by voluntary borrowers in the random borrowing treatment.

### Predictions

Based on the results from the theory section and the parameters selected for the experiment, we can make the following predictions to be tested in the experiment.

* ***P1***: In every treatment investors fund only banks not detected at the DW.
* ***P2***: Banks are more likely to coordinate on the no-stigma equilibrium in the low DW cost and low detection treatments than in the control treatment.
* ***P3***: Banks coordinate on the no-stigma equilibrium in the random borrowing treatment.

### Additional design features common to all treatments

The experiment is conducted under the strategy method. In each round, before learning its type, the bank is asked to decide whether or not to borrow at the DW for both contingencies: if solvent-illiquid and if insolvent-illiquid. Similarly, before learning whether the bank was seen borrowing at the DW, the investor is asked to make a funding decision for both contingencies: if the bank is detected at the DW and if the bank is not detected. After decisions are made by both players, uncertainty (about the bank’s type and DW detection) is resolved and payoffs are calculated using the subjects’ conditional choices. The main reason for using the strategy method is to collect more data. This is especially relevant in this experiment because half of the banks are solvent (on average) in each round and therefore make no decision.

To promote learning, we provide private and public feedback between rounds. In particular, subjects are given all of the information necessary to understand their payoffs. Specifically, each bank is told its type, whether it was detected, and the investor’s funding decision. The investor is told whether the bank was detected at the DW and the value of the asset (if the investor ended up funding the bank). In addition, summary measures about the other players are provided: Every subject is told the proportion of banks that chose to borrow at the DW when solvent-illiquid and when insolvent-illiquid, as well as the proportion of investors that chose to fund a bank detected and not detected at the DW.

Finally, subjects are given experimental instructions with economic context, with terms like “bank,” “investor,” “insolvent,” and “illiquid.” However, we did not refer to the “discount window” because we were concerned it would not be intuitive. Instead, subjects are told they can borrow from “the central bank in its role as the lender-of-last-resort” (see Appendix 3).[[26]](#footnote-26)

# 4. Experiment Results

### The control treatment

Figure 1 shows the banks’ and investors’ behaviors in the control treatment. The left panel displays the percentage of investors (averaged across the 6 sessions) that choose to fund banks detected and not detected at the DW in each round. The right panel displays the percentage of banks that choose to borrow at the DW when solvent-illiquid and when insolvent-illiquid. Horizontal lines also indicate predicted equilibrium behavior in each panel. Figures that display session level choices in each treatment can be found in Appendix 4.

**Figure 1: Control Treatment**\*

\*Average across 6 sessions

Starting with the left panel, note that most investors (81% in round 1) realize immediately that they should fund a bank not detected at the DW. Investors also learn at a rapid pace not to fund a bank detected at the DW: While 53% of investors fund a detected bank in round 1, only 17% still do so in round 10. Over the last 10 rounds, investors overwhelmingly stigmatize DW borrowers as only 4% of detected banks are funded. Overall, investors’ choices in the control treatment become consistent with equilibrium behavior, which provides support for prediction ***P1***.

Turning now to the right panel of Figure 1, observe first that, consistent with theory (since they have the same payoff function), illiquid banks behave essentially in the same way throughout the experiment when they are solvent or insolvent. Note also that a majority (60%) of banks chooses to borrow at the DW in round 1 when illiquid. Further, there is some evidence that banks initially try to coordinate on the good equilibrium. Indeed, the proportion of DW borrowers increases over the first three rounds. This effort, however, is short lived and quickly unravels. Over the last 10 rounds, stigma is prevalent as only 20% of illiquid banks are willing to borrow at the DW. Thus, the banks’ choices at the end of the control treatment are generally consistent with the DW stigma equilibrium. Figure 1.1 of Appendix 4 reveals that this behavior is systematic as coordination on the stigma strategy is observed in all 6 sessions we conducted.

To sum up, behavior in the control treatment is generally consistent with theory. Further, banks’ behavior converges toward the stigma strategy in every session we conducted. Thus, we have been able to replicate in the lab DW stigma, a behavior widely believed to occur, but rarely observed in the field. This, in itself, may be considered an interesting result. Next, we look at factors that may shift banks from the bad equilibrium to the good, stigma-free equilibrium.

### The low DW cost treatment

Figure 2 indicates that, by and large, behavior in the low DW cost treatment is consistent with behavior in the control treatment. Similar to the control treatment, investors realize almost immediately that they should fund a bank not detected at the DW, and they quickly learn to stigmatize DW borrowers (i.e. not to fund detected banks). In fact, we are unable to find a statistical difference in the investors’ decisions between the control and the low DW cost treatment at usual significance levels.[[27]](#footnote-27) Thus, investors’ behavior is again generally consistent with theory, which provides additional support for ***P1***.

**Figure 2: Low DW Cost Treatment**\*

\*Average across 6 sessions

Similar to the control treatment, the majority of banks borrow at the DW in early rounds (64% in round 1), but DW borrowing then declines and stigma becomes prevalent. Average DW borrowing over the last 10 rounds, however, is higher (albeit not significantly) in the low DW cost treatment (32%) than in the control treatment (20%). As indicated on Figure 2.1 of Appendix 4, this difference is driven by a single session, session 5 of the low DW cost treatment, in which subjects were actually able to coordinate on the no-stigma strategy. Without session 5, DW borrowing over the last 10 rounds of the low DW cost treatment drops to 22%, in line with the control treatment average of 20%. Therefore, we find no clear evidence to support prediction ***P2***.

To sum up, a 50% cut in the cost of the DW enabled coordination on the stigma-free equilibrium in 1 of the 6 sessions conducted. Overall, however, reducing the DW cost fails to solve the stigma problem: Ultimately, most subjects in the low DW cost treatment decide not to borrow at the DW. Again, this result is interesting as it echoes the Fed’s experience. On August 17, 2007 the Fed took a number of measures to encourage DW borrowing (see Appendix 1 for details). Among them, the DW “penalty” spread over the target rate was reduced by 50%, from 100 basis points to 50, thereby reducing the DW rate from 5.75% to 5.25%. Similar to our experimental results, this policy change was ineffective, as access to the DW increased little in the second half of 2007.

### The random borrowing treatment

We now turn to Figure 3 where behavior in the random borrowing treatment is displayed. As in the previous two treatments, investors fund banks not detected at the DW. In fact, the funding behavior of investors who face a non-detected bank cannot be distinguished statistically across the three treatments at usual significance levels. In contrast, funding behavior toward banks detected at the DW is statistically different (at the 5% level) in the random borrowing treatment. While investors learn not to fund a detected bank in the other two treatments, we can see in the left panel of Figure 3 that the funding trend is slightly upward in the random borrowing treatment. Nevertheless, the majority of investors still stigmatize DW borrowers (the 50% threshold is not crossed in any round). This treatment effect may be explained by the fact that random borrowing adds solvent-liquid banks to the pool of detected banks, which makes the investors’ funding decisions less obvious. Over the last 10 rounds of the control treatment, the expected profit of an investor who funds a detected bank is 29.8 if he funds a detected bank which is clearly dominated by the investor’s outside option of 50. In contrast, an investor’s expected profit when funding a detected bank in the last 10 rounds of the random borrowing treatment is 44.5, which is closer to his outside option of 50.

**Figure 3: Random Borrowing Treatment**\*

\*Average across 6 sessions

Turning now to banks’ behavior, we can see in the right panel of Figure 3 a clear and highly significant (at the 1% level) treatment effect. In contrast with the other two treatments, banks learn to access the DW voluntarily in the random borrowing treatment. In fact, Figure 3.1 of Appendix 4 reveals that banks systematically learn to coordinate on the stigma-free equilibrium in all 6 sessions of the random treatment. Thus, we find evidence that subjects converge toward the unique stigma-free equilibrium in the random treatment, thereby providing support for prediction ***P3***.

### The low detection treatment

The results in the low detection treatment are summarized in Figure 4. Overall, the same dynamics of play emerge in the low detection and control treatments. Despite some differences in early rounds, investors learn to fund only non-detected banks in both treatments. Further, after an early attempt at coordinating on the good equilibrium, most banks end up settling on the DW stigma strategy. In fact, we are unable to find a significant difference (at usual significance levels) between choices over the last 10 rounds in the control and low detection treatments for banks and investors.

**Figure 4: Low Detection Treatment**\*

\*Average across 6 sessions

These results provide some insights into how random borrowing helped overcome DW stigma. There are two possible hypotheses to explain why subjects were able to coordinate on the stigma-free equilibrium: a lower detection probability and involuntary DW experience. Under the *detection* hypothesis, banks find it easier to coordinate on DW borrowing because the endogenous detection probabilities are lower for voluntary borrowers. Under the *experience* hypothesis, a bank learns the value of borrowing at the DW from having to do so involuntarily. Because the detection probabilities for voluntary borrowers are the same as in the random borrowing treatment, the low detection treatment allows us to disentangle the two hypotheses by muting the *experience* effect. Because behavior converged toward the stigma equilibrium in the low detection treatment, we find no support for the *detection* hypothesis. Instead, it appears that it is the experience banks acquire when they have to borrow involuntarily at the DW that helps drives behavior toward the no-stigma equilibrium in the random borrowing treatment.

We conclude with a brief comparison of profits and surplus across treatments. As shown in Table 1, the average profits recorded in the last 10 rounds of each treatment are well below the theoretic benchmarks. In the last 10 rounds of the control and random borrowing treatments, total surplus was 85.1 and 86.9, respectively. Thus, random borrowing produced higher total surplus and the magnitude of the increase is consistent with theory (+2.1% in the experiment versus +2.4% under equilibrium behavior). The effect, however, is too small to be significant at usual significance levels. We can also see in Table 1 that the average profits of illiquid banks over the last 10 rounds were significantly higher (at the 5% level) in the random borrowing treatment. This treatment effect is consistent with theory, because illiquid banks should benefit the most from random borrowing.

Summing up the results from this section, we were able to generate DW stigma in the control treatment. In contrast with lowering the DW cost and lowering the probability of detection, which were ineffective at overcoming stigma, random borrowing helped subjects coordinate on the stigma-free equilibrium.

# 5. Regressions analysis

This section uses econometric methods to study the dynamics of play in the experiment and identify the factors that drive coordination toward one equilibrium or the other.

## 5.1 Banks’ Behavior

To study a bank’s simultaneous decisions to borrow at the DW *if solvent-illiquid* and *if insolvent-illiquid*, we estimate a panel seemingly unrelated bivariate Probit model of the form:

(1)

where and are the latent variables corresponding to bank *i*’s decisions to borrow at the DW in round *t* if solvent-illiquid and if insolvent-illiquid, respectively;[[28]](#footnote-28) , and are dummy variables equal to 1 when subject *i* participated in the low DW cost, random borrowing and low detection treatment, respectively; and capture the private and public feedback given to subject *i* at the end of the previous round; are individual characteristics and (, ) follows a bivariate normal distribution with correlation . Table 3 reports the marginal effects estimated by full information maximum likelihood for three different specifications.

Specification 1: The first specification focuses on treatment effects. The regression results confirm the absence of a treatment effect on banks’ behavior in the low DW cost and low detection treatments (rows 1 and 3). In contrast, we find the propensity to borrow at the DW to be significantly and substantially higher (in excess of 30%) in the random borrowing treatment (row 2). Finally, a bank’s decisions to borrow at the DW if solvent-illiquid and if insolvent-illiquid are positively and highly correlated (row 26). This result is consistent with theory (since illiquid banks have the same payoff function regardless of solvency) and it confirms that our econometric approach, in which the two decisions are modeled jointly, is appropriate.

Specification 2: We now augment the model by controlling for private and public feedback. First, note that the dummy variable for the random borrowing treatment becomes insignificant (row 2). The treatment effect we identified with specification 1 therefore does not result from a systematic difference in behavior. Instead, it appears that, using the feedback provided after each round, banks in the random borrowing treatment learn to adjust their behavior differently than in the control treatment. Not surprisingly, we find that banks’ behavior exhibit a strong inertia effect (rows 4 and 5): A bank that chooses to borrow at the DW if solvent-illiquid (respectively, if insolvent-illiquid) is 57% (respectively, 56%) more likely to do so again in the next round.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 3: Panel Seemingly Unrelated Bivariate Probit for Banks’ DW Decisions** | | | | | | | | | | |
|  | | | Specification 1  The Bank Borrows at DW in *t* if illiquid- | | | Specification 2  The Bank Borrows at DW in *t* if illiquid- | | Specification 3  The Bank Borrows at DW in *t* if illiquid- | | |
| Insolvent | Solvent | | Insolvent | Solvent | Insolvent | Solvent | |
| 1 | Low DW Cost Treatment | | 0.108  (0.065) | 0.010  (0.067) | | 0.071  (0.049) | -0.014  (0.048) | 0.067  (0.051) | -0.014  (0.050) | |
| 2 | Random Borrowing Treatment | | 0.350\*\*\*  (0.059) | 0.318\*\*\*  (0.065) | | 0.080  (0.051) | 0.063  (0.054) | 0.077  (0.052) | 0.053  (0.055) | |
| 3 | Low Detection Treatment | | 0.050  (0.061) | 0.063  (0.073) | | 0.053  (0.069) | -0.041  (0.070) | 0.012  (0.067) | -0.078  (0.069) | |
| 4 | Bank Chose to Borrow at DW in *t-1*  if Insolvent-Illiquid | | \_\_ | \_\_ | | 0.563\*\*\*  (0.043) | \_\_ | 0.536\*\*\*  (0.044) | \_\_ | |
| 5 | Bank Chose to Borrow at DW in *t-1*  if Solvent-illiquid | | \_\_ | \_\_ | | \_\_ | 0.572\*\*\*  (0.036) | \_\_ | 0.556\*\*\*  (0.036) | |
| 6 | Bank Actually Borrowed at DW in *t-1*  \* Detected | | \_\_ | \_\_ | | -0.341\*\*\*  (0.092) | -0.282\*\*\*  (0.077) | -0.349\*\*\*  (0.093) | -0.309\*\*\*  (0.082) | |
| 7 | Bank Actually Borrowed at DW in *t-1*  \* Detected \* Not Funded | | \_\_ | \_\_ | | -0.080  (0.090) | -0.049  (0.084) | -0.084  (0.091) | -0.045  (0.085) | |
| 8 | Bank Actually Borrowed at DW in *t-1*  \* Not Detected | | \_\_ | \_\_ | | 0.136\*\*  (0.057) | 0.137\*\*  (0.056) | 0.119\*\*  (0.060) | 0.108\*  (0.058) | |
| 9 | Bank Actually Borrowed at DW in *t-1*  \* Not Detected \* Not Funded | | \_\_ | \_\_ | | -0.013  (0.079) | 0.058  (0.078) | -0.022  (0.079) | 0.062  (0.080) | |
| 10 | Bank was Undetectable in *t-1* (i.e. Liquid or did not borrow at DW) \* Not funded | | \_\_ | \_\_ | | 0.033  (0.031) | 0.048  (0.032) | 0.029  (0.031) | 0.045  (0.033) | |
| 11 | Bank was Forced to borrow at DW in *t-1*  \* Detected | | \_\_ | \_\_ | | -0.138  (0.134) | -0.126  (0.123) | -0.140  (0.137) | -0.131  (0.124) | |
| 12 | Bank was Forced to borrow at DW in *t-1*  \* Detected \* Not Funded | | \_\_ | \_\_ | | -0.035  (0.164) | -0.231  (0.147) | -0.015  (0.166) | -0.216  (0.148) | |
| 13 | Bank was Forced to borrow at DW in *t-1*  \* Not Detected | | \_\_ | \_\_ | | 0.353\*\*\*  (0.074) | 0.357\*\*\*  (0.081) | 0.370\*\*\*  (0.077) | 0.372\*\*\*  (0.090) | |
| 14 | Bank was Forced to borrow at DW in *t-1*  \* Not Detected \* Not Funded | | \_\_ | \_\_ | | -0.021  (0.168) | -0.059  (0.183) | -0.018  (0.164) | -0.092  (0.206) | |
| 15 | Bank was Solvent-Illiquid in *t-1* | | \_\_ | \_\_ | | -0.003  (0.035) | -0.058  (0.036) | -0.001  (0.036) | -0.049  (0.037) | |
| 16 | Bank was Insolvent-Illiquid in *t-1* | | \_\_ | \_\_ | | -0.062  (0.037) | -0.010  (0.026) | -0.061\*  (0.036) | -0.001  (0.027) | |
| 17 | Probability of Detection in *t-1* | | \_\_ | \_\_ | | -0.057  (0.061) | -0.025  (0.061) | -0.075  (0.062) | -0.046  (0.061) | |
| 18 | Percentage of Banks that Chose to  Borrow at DW if Solvent-Illiquid in *t-1* | | \_\_ | \_\_ | | 0.004  (0.064) | 0.369\*\*\*  (0.074) | -0.063  (0.065) | 0.308\*\*\*  (0.080) | |
| 19 | Percentage of Banks that Chose to  Borrow at DW if Insolvent-Illiquid in *t-1* | | \_\_ | \_\_ | | 0.300\*\*\*  (0.072) | -0.046  (0.061) | 0.351\*\*\*  (0.076) | -0.020  (0.067) | |
| 20 | Percentage of Investors that Chose to  Invest in Bank not Detected at DW in *t-1* | | \_\_ | \_\_ | | -0.052  (0.076) | -0.105  (0.075) | -0.046  (0.078) | -0.075  (0.078) | |
| 21 | Percentage of Investors that Chose to  Invest in Bank Detected at DW in *t-1* | | \_\_ | \_\_ | | 0.203\*\*\*  (0.067) | 0.270\*\*  (0.086) | 0.218\*\*\*  (0.067) | 0.327\*\*\*  (0.085) | |
| 22 | Initial Condition (Percentage of Banks  that Borrow at DW in round 1) | | \_\_ | \_\_ | | -0.177  (0.233) | 0.153  (0.219) | -0.097  (0.213) | 0.210  (0.218) | |
| 23 | Risk Attitude Measure (BRET) | | \_\_ | \_\_ | | \_\_ | \_\_ | 0.005\*\*\*  (0.001) | 0.006\*\*\*  (0.002) | |
| 24 | Female | | \_\_ | \_\_ | | \_\_ | \_\_ | 0.004  (0.037) | -0.026  (0.040) | |
| 25 | Age | | \_\_ | \_\_ | | \_\_ | \_\_ | 0.005  (0.007) | -0.007  (0.007) | |
| 26 |  | | 0.484\*\*\*  (0.051) | | | 0.266\*\*\*  (0.053) | | 0.252\*\*\*  (0.054) | | |
| 27 | Log Likelihood | N | -4,505.2 | | 3,600 | -2,981.2 | 3,456 | -2,916.7 | | 3,456 |

Marginal effects (evaluated at means) are reported. Standard errors (in parenthesis) are clustered at the individual level. Specification 3 also controls for the subject field of studies (economics, social science, hard science, literature or others). The estimates (not reported) reveal no significant effect.

The subject of reference in Specification 3 is a man who studied economics. He participated in the control treatment as a bank. In the previous round, he was undetectable at the DW (i.e. he was either liquid or did not borrow at the DW) and he was funded by the investor.

Rows 6 to 16 focus on the impact of private feedback. We find that banks react strongly to DW detection (row 6): After being detected, a bank is roughly 30% less likely to borrow again at the DW in the next round. Conversely, going to the DW without being detected makes a bank significantly more likely to return to the DW (row 8). The magnitude (as well as significance) of this effect, however, is substantially smaller than DW detection (roughly 14% versus 30%). Interestingly, whether or not the bank is funded by the investor does not seem to influence significantly the bank’s subsequent behavior (rows 7, 9 and 10). In other words, it is DW detection (despite having no financial implication), rather than its consequence on funding that seems to drive the banks subsequent behavior.

Rows 11 to 14 measure the impact of random borrowing. A bank is more likely to borrow voluntarily at the DW when it was previously selected to borrow and not detected at the DW (row 13). This appears to be a major driver of behavior as it increases significantly and substantially (by 35%) the probability that the bank returns voluntarily to the DW in the next round. This result provides additional support for the *experience* hypothesis discussed in the previous section, whereby subjects learn from involuntary borrowing to return to the DW voluntarily. In contrast, we find no evidence that the bank’s type in the previous round (i.e. solvent or insolvent, liquid or illiquid) have a significant impact on subsequent behavior (rows 15 and 16).

Next, consider the impact of public feedback in rows 17 to 22. A bank’s probability of being detected at the DW in the previous round does not appear to influence banks’ behavior (row 17). This result provides further evidence against the *detection* hypothesis discussed in the previous section. Indeed, it appears that coordination on the no-stigma equilibrium in the random borrowing treatment was not driven by the reduction in the detection probability for voluntary borrowers.

Rows 18 and 19 indicate a clear imitation effect: The more banks go to the DW when solvent-illiquid (respectively, insolvent-illiquid), the more a subject is likely to do the same in the next round. This result is consistent with an effort to coordinate on the part of banks. Interestingly, while the investors’ funding decisions when a bank is not detected appears to have no influence on a bank’s behavior (row 20), a bank’s willingness to borrow at the DW is positively correlated with the number of investors who chose to fund detected banks in the previous round (row 21). Finally, we do not find a session effect in the sense that banks’ choices in the first round of a session cannot explain subsequent behavior (row 22). As a result, we find no evidence that banks are more likely to converge toward the stigma (respectively, no stigma) equilibrium in sessions where most banks did not borrow (respectively borrowed) at the DW in round 1.

Specification 3: The last specification controls for individual characteristics: risk attitude, gender, age and field of studies.[[29]](#footnote-29) First, observe that the results from specification 2 are robust as the sign and magnitude of the parameters remain essentially unchanged. The only individual characteristic with explanatory power is the measure of risk attitude (row 23): a subject with a higher BRET score (reflecting less risk aversion) of one standard deviation (i.e. 13.5 points) is roughly 8% more likely to borrow at the DW. The magnitude of the effect is modest but the direction is consistent with intuition as borrowing from the DW is riskier because it involves a risk of detection.

Summing up: The econometric estimations in Table 3 provide evidence of banks’ coordination. They also suggest that the failure to coordinate on the stigma-free equilibrium in the control and low DW cost treatments can be explained in large part by DW detection which drives behavior away from DW borrowing (row 6). In contrast, the econometric analysis confirms that having to experience DW borrowing without negative consequences (i.e. being selected and not being detected) help banks learn to coordinate on the good equilibrium in the random borrowing treatment. Finally, somewhat surprisingly, both being funded and the probability of DW detection do not have significant impacts on banks’ behavior.

## 5.2 Investors’ Behavior

To study an investor’s behavior, we estimate the joint panel model in equation (1) where and are now the latent variables corresponding to investor *i*’s decisions to fund a bank in round *t* *if detected* and *if not detected* at the DW, respectively. The estimated marginal effects for the same three specifications as in the previous section are reported in Table 3.

Specification 1: The results from specification 1 confirm the absence of any treatment effect on funding decisions for banks not seen at the DW. In contrast, the propensity to fund a detected bank is significantly higher in the random borrowing treatment (row 2). As discussed earlier, this result is not necessarily surprising because random borrowing adds solvent banks to the pool of detected banks. Finally, we find a negative and significant correlation in an investor’s decisions to fund a bank when it is detected and not detected at the DW (row 18), thereby providing additional support for our joint econometric model.

Specification 2: Next, we add controls for private and public feedback. First, observe the absence of any treatment effect. Thus, similar to the banks’ regressions, the treatment effect we identified with specification 1 can be explained by investors’ adjustments based on the feedback they receive. Similar to the banks’ behavior, we also find the investors’ behavior to exhibit inertia (rows 4 and 5): An investor who funds a bank detected (respectively, not detected) at the DW is 30% (respectively, 22%) more likely to do so again in the next round.

Rows 6 to 9 relate to the impact of private feedback. We find that investors react negatively after being matched with an insolvent bank (rows 7 and 9). Namely, when an investor funds a detected (respectively, undetected) bank which turns out to be insolvent, the investor is 27% (respectively, 35%) less likely to do so again in the next round. Further, funding detected banks that turn out to be solvent promotes future funding of detected banks (row 6). This result explains why investors are more prone to fund detected banks in the random borrowing treatment (see Figure 3). Indeed, the random selection process makes it more likely that detected banks are solvent.

The impact of public feedback is shown in rows 10 to 14. Similar to the banks, we find that the detection probability in the previous round has no significant influence on the investors’ behavior (row 10). However, unlike banks (who have a clear incentive to coordinate), we do not find an imitation effect for investors (rows 13 and 14). The only impact of public feedback on investors’ behavior is from the percentage of illiquid banks that chose to borrow at the DW when solvent (row 11). Namely, investors tend to fund detected banks when they are more likely to be solvent.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table 4: Panel Seemingly Unrelated Bivariate Probit for Investors’ Funding Decisions** | | | | | | | | |
|  | | | Specification 1  The Investor fund the Bank in *t* if the bank is | | Specification 2  The Investor fund the Bank in *t* if the bank is | | Specification 3  The Investor fund the Bank in *t* if the bank | |
| Seen  at DW | Not Seen  at DW | Seen  at DW | Not Seen  at DW | Seen  at DW | Not Seen  at DW |
| 1 | Low DW Cost Treatment | | 0.029  (0.036) | 0.001  (0.028) | 0.020  (0.030) | 0.004  (0.026) | 0.022  (0.033) | 0.008  (0.024) |
| 2 | Random Borrowing Treatment | | 0.204\*\*\*  (0.053) | -0.026  (0.032) | 0.063  (0.039) | 0.012  (0.030) | 0.040  (0.039) | 0.008  (0.029) |
| 3 | Low Detection Treatment | | 0.068  (0.043) | -0.056  (0.034) | 0.036  (0.033) | -0.048  (0.032) | 0.026  (0.034) | -0.035  (0.030) |
| 4 | Investor Chose to Fund a Bank in *t-1*  Seen Borrowing at the DW | | \_\_ | \_\_ | 0.299\*\*\*  (0.034) | \_\_ | 0.278\*\*\*  (0.031) | \_\_ |
| 5 | Investor Chose to Fund a Bank in *t-1*  Not Seen Borrowing at the DW | | \_\_ | \_\_ | \_\_ | 0.217\*\*\*  (0.042) | \_\_ | 0.214\*\*\*  (0.042) |
| 6 | The Investor Actually Funded in *t-1*  a Detected \* Solvent Bank | | \_\_ | \_\_ | 0.202\*\*  (0.066) | -0.024  (0.064) | 0.193\*\*  (0.066) | -0.029  (0.065) |
| 7 | The Investor Actually Funded in *t-1*  a Detected \* Insolvent Bank | | \_\_ | \_\_ | -0.267\*\*\*  (0.067) | -0.075  (0.054) | -0.268\*\*\*  (0.064) | -0.071  (0.053) |
| 8 | The Investor Actually Funded in *t-1*  a Non-detected \* Solvent Bank | | \_\_ | \_\_ | 0.027  (0.020) | 0.029  (0.036) | 0.020  (0.020) | 0.027  (0.036) |
| 9 | The Investor Actually Funded in *t-1*  a Non-detected \* Insolvent Bank | | \_\_ | \_\_ | 0.008  (0.025) | -0.349\*\*\*  (0.040) | 0.001  (0.025) | -0.351\*\*\*  (0.041) |
| 10 | Probability of Detection in *t-1* | | \_\_ | \_\_ | -0.054  (0.036) | 0.042  (0.030) | -0.054  (0.035) | 0.041  (0.031) |
| 11 | Percentage of Banks that Chose to Borrow at DW if Solvent-illiquid in *t-1* | | \_\_ | \_\_ | 0.138\*\*  (0.045) | -0.055  (0.035) | 0.172\*\*\*  (0.041) | -0.041  (0.036) |
| 12 | Percentage of Banks that Chose to Borrow at DW if Insolvent-illiquid in *t-1* | | \_\_ | \_\_ | 0.042  (0.045) | -0.001  (0.044) | 0.016  (0.045) | -0.013  (0.043) |
| 13 | Percentage of Investors that Chose to  Invest in Bank not Detected at DW in *t-1* | | \_\_ | \_\_ | 0.018  (0.048) | 0.075  (0.045) | 0.026  (0.048) | 0.069  (0.046) |
| 14 | Percentage of Investors that Chose to  Invest in Bank Detected at DW in *t-1* | | \_\_ | \_\_ | 0.072  (0.063) | -0.050  (0.047) | 0.089  (0.060) | -0.062  (0.043) |
| 15 | Risk Attitude Measure (BRET) | | \_\_ | \_\_ | \_\_ | \_\_ | 0.003\*\*  (0.001) | 0.001  (0.001) |
| 16 | Female | | \_\_ | \_\_ | \_\_ | \_\_ | -0.011  (0.024) | 0.022  (0.022) |
| 17 | Age | | \_\_ | \_\_ | \_\_ | \_\_ | -0.007  (0.006) | 0.003  (0.004) |
| 18 |  | | -0.052\*\*\*  (0.018) | | -0.045\*\*\*  (0.016) | | -0.062\*\*\*  (0.016) | |
| 19 | Log Likelihood | N | -3,623.5 | 3,600 | -2,668.4 | 3,456 | -2,633.1 | 3,456 |

Marginal effects (evaluated at means) are reported. Standard errors (in parenthesis) are clustered at the individual level. Specification 3 also controls for the subject field of studies (i.e. economics, social science, hard science, literature or others). The estimates (not reported) reveal no significant effect.

The subject of reference in Specification 3 is a man who studied economics. He participated in the control treatment as an investor and he did not fund a bank in the previous round.

Specification 3: We conclude by adding controls for individual characteristics. The results are similar to those for the banks’ in Table 3. First, we find that the results from specification 2 are robust as the sign and magnitude of the parameters remain essentially unchanged. Second, the only individual characteristic with explanatory power is the measure of risk attitude (row 15). Interestingly, risk attitude only affects the investor behavior when the bank is detected at the DW: an investor with a higher BRET score (reflecting less risk aversion) of one standard deviation (i.e. 13.5 points) is roughly 4% more likely to fund a detected bank. This result may be explained by the fact that the solvency risk is higher for detected banks.[[30]](#footnote-30)

Summing up: The econometric estimations in Table 4 suggest that investors respond mostly to private and public feedback about banks (in)solvency (rows 6, 7, 9 and 11). Similar to banks, investors do not seem influenced by the probability of DW detection. However, unlike banks, we find no evidence that investors try to coordinate.

# 6. Conclusion

DW stigma is a serious problem that can impede two of the core responsibilities of central banks: acting as an lender of last resort and implementing monetary policy. Yet, little is known about DW stigma in large part because of the absence of data. In this paper, we propose a coordination game with adverse selection that possesses two equilibria, with and without DW stigma, and we use experimental methods to generate data and test policies aimed at overcoming DW stigma.

Consistent with behavior believed to occur in the field, stigma prevails in the control treatment. Lowering the cost of the DW is found to have little effect on stigma. This is consistent with anecdotal evidence: In August 2007, the Fed’s was unable to stimulate DW borrowing by cutting the DW rate. Similarly, lowering the detection probability fails to address DW stigma in the experiment. This result challenges the view that stigma concerns can be attenuated by making DW borrowing relatively more opaque. Finally, consistent with theory, behavior converges to the stigma-free strategy under random borrowing. This result provides support to Winters (2012) who recommended regular DW borrowing to the Bank of England, arguing that it would overcome stigma by making DW access both unremarkable and uninformative.

An econometric analysis provides additional insights into the drivers of DW stigma. In particular, we find that the failure to coordinate on the stigma-free equilibrium in three of the four treatments can be explained to a large extent by DW detection. That is, banks tend not to return to the DW after being detected. Further, the estimation results show that random borrowing operates through two complementary channels. First, consistent with the hypothesis that random borrowing makes DW access both unremarkable and uninformative, investors are more likely to fund banks detected at the DW than in the other treatments. Second, banks seem to learn the value of DW borrowing after having to do so involuntarily. That is, banks tend to return to the DW voluntarily after being randomly selected to borrow and not detected.

Implementing regular random DW borrowing would raise several practical challenges, but none seems insurmountable. In particular, although the Fed cannot currently require banks to access the DW, it could do so by revising its DW eligibility rules: To have the ability to access the DW when liquidity support is needed, banks would have to commit to regular borrowing.[[31]](#footnote-31) Note also that the cost of regular DW borrowing would be relatively modest for banks. In particular, observe that the opportunity cost of a $100 million overnight DW loan (a large loan by historical standards) at a 50 basis points spread is around a $1,000.[[32]](#footnote-32) It should also be noted that a well-functioning (i.e. stigma free) LoLR program is of value to the financial system and banks should be willing to pay for the service. The cost of this service is currently the DW rate, but it could also include the cost of random borrowing. A reasonable balance could be achieved by lowering the DW rate or by discounting the DW rate for regular (i.e. involuntary) DW borrowing. Additional practical issues that would need to be addressed concern the frequency of regular borrowing (e.g. once or twice a year for major banks), the amount banks would be asked to borrow (it could be a function of the bank’s size), the timing of random borrowing (e.g. a bank could be given a week notice),[[33]](#footnote-33) and the disclosure policy (banks would not be allowed to disclose random borrowing in real time).

It should be noted that the premise for our analysis is that the LoLR responsibilities are assigned to the DW. Our objective was then to explore adjustments to the DW that can address stigma concerns. In other words, we focused on solutions that could be implemented in the relatively short term and without major disruptions. Of course, this should not prevent a more general discussion about DW alternatives and optimal LoLR mechanisms. Such possible alternatives include transforming the DW into a fee-based contingent liquidity facility (Nelson 2017), the “pawnbroker” approach of King (2016b), open market type auctions (Selgin 2017), and regular liquidity auctions (similar to the Term Auction Facility used by the Fed between 2007 and 2010, or the long-term repo auctions used by the BoE since 2012). Such alternatives, however, may be more difficult to put in place. Further, as argued by e.g. Hauser (2014), some of these approaches are not perfect substitute for the DW and may be best described as “lender of next to last resort.”[[34]](#footnote-34) Thus, there may still be a need for a stigma-free DW-like bilateral standing facility where a bank can address any idiosyncratic liquidity shock in real time before it festers into a solvency or a systemic problem.

Fixing the DW may not seem like a pressing problem in the current high reserves environment in which the need for liquidity support is unlikely. However, DW stigma could become relevant again when the size of the Fed’s balance sheet returns to historical standards. As argued by Bernanke (2015b), one does not modify the fire code once the fire has started. In other words, it may be prudent to think about how to address DW stigma ex-ante in normal times, rather than wait until the onset of the next financial crisis to do so. The value of implementing regular random DW borrowing in normal times finds additional support in Bernanke (2016) who argues that the stigma problem was less severe in the Eurozone during the 2008 financial crisis in part because European banks routinely engaged with the central bank in normal times.

We conclude by noting that understanding and mitigating stigma is relevant beyond the DW. In particular, stigma is also a major concern for government bailouts (Che et al. 2018, Anbil 2018) and IMF programs (Ito 2012, Reinhart and Trebesch 2016).[[35]](#footnote-35) In each case, eligible distressed firms or countries refrain from seeking the help they need for fear that it may signal weakness and inhibit future borrowing. Other forms of economic stigma (related e.g. to long-term unemployment or bankruptcy) and social stigma (related to mental health or weight issues) have also been studied.[[36]](#footnote-36) One case of particular interest, is a form of welfare stigma (Moffitt 1983) called “free lunch stigma.” To promote health and academic performance, low-income children in most U.S. public schools are eligible to receive free or reduced-price lunch. Many of them do no to take part in the program and prefer to forego lunch because of the stigma associated with letting classmates know they are poor enough to qualify.[[37]](#footnote-37)

Interestingly, some of the policies that have been enacted to overcome stigma in the situations just described share the same fundamental principle with the random borrowing approach we propose: have non-concerned parties take part in the program as a way to dilute any negative signal from participation. In particular, when the Troubled Asset Relief Program (TARP) was launched in 2008, the nine largest U.S. banks were compelled to accept capital injections to promote take up from smaller banks and prevent “TARP stigma.”[[38]](#footnote-38) Similarly, several school districts have recently decided to adopt “universal free lunch” policies under which lunch is provided for free to all students, regardless of income. Two studies suggest that these programs improve academic performance (Schwartz and Rothbart 2018) and students’ behavior (Altindag et al. 2018).

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# Appendix 1 : Institutional Background

This section provides a brief historical perspective on the DW and the provision of emergency liquidity by the Fed, emphasizing the issue of stigma. For additional details see Gorton and Metrick (2013), Carlson and Rose (2017) or www.frbdiscountwindow.org.

The DW was established through legislation passed by congress in 1913. At the time, the money supply was adjusted by controlling the rate at which banks could borrow from the DW. Starting in the late 1920s, the Fed gradually switched to “open market operations” (the buying and selling of government securities in the open market) to conduct monetary policy. The DW then became the Fed’s primary tool to provide emergency credit to depository institutions in its role of “lender of last resort.” Over the past 50 years, the objective of the DW has been to relieve liquidity strains for individual depository institutions and for the banking system as a whole by providing a reliable backup source of funding.

All depository institutions that maintain a reserves account at the Fed (currently in excess of 2,500 institutions) are entitled to borrow at the DW. These include any FDIC-insured bank, savings or mutual bank, insured credit union, and U.S. branch and agency of a foreign bank. DW loans are extended on an overnight basis, with a few historical exceptions.

In contrast with the interbank market for Federal funds, DW loans are fully collateralized. Before they can borrow at the DW, eligible institutions must first pledge assets as collateral. A broad range of marketable and non-marketable assets are accepted as DW collateral. The assets most commonly pledged include U.S. Treasuries, agencies and government-sponsored enterprises obligations, corporate and municipal bonds, asset-backed securities, commercial, industrial, or agricultural loans, consumer loans, as well as residential and commercial real estate loans. The assets pledged by a bank as collateral are assigned a lendable value (i.e. a fair market value estimate adjusted by a haircut) against which the institution can borrow.

Until 2010, DW borrowing was fully anonymous. Neither the amounts borrowed by individual institutions nor their identities were ever disclosed. The only information made public was the weekly aggregate amount borrowed in each Federal Reserve District. In accordance with the provisions of the Dodd-Frank Act, the Federal Reserve changed its DW disclosure practices. Starting on July 21, 2010 the identity of the borrower, the amount borrowed and the collateral pledged in connection with a DW loan are all disclosed publicly after a two years lag.

The question of stigma has been a lingering issue throughout the history of the DW and led to fundamental reforms in 2003. Prior to 2003, banks in distress could borrow from the DW at a rate below the Fed’s target rate. Because of the subsidized rate, the Fed was concerned about “opportunistic” DW borrowing. Accordingly, before accessing the DW, a bank had to satisfy the Fed that it had exhausted private sources of funding and that it had a genuine business need for the funds. Hence, if market participants learned that a bank had accessed the DW, then they could conclude that the bank had limited sources of funding. These concerns may have deterred banks from accessing the DW even if they had an urgent need for funds. The *old* DW regime therefore created a perception of stigma

To address stigma concerns, the Fed fundamentally changed its DW policy on January 9, 2003. In Regulation A, the Fed classified DW loans into primary credit, secondary credit and seasonal credit. Financially strong and well-capitalized banks can borrow under the primary credit program at a penalty rate above the target fed funds rate (rather than a subsidized rate under the *old* DW regime). Other banks use the secondary credit program and pay a rate higher than the primary credit rate. Finally, seasonal credit is for relatively small banks with seasonal fluctuations in reserves. By far, the most common form of DW borrowing is through the primary credit program. Our focus is exclusively on the primary credit facility. Further, whenever we refer to the DW, we mean the DW primary credit facility.

The *new* DW is a “no questions asked” facility for primary credit. Namely, the Fed no longer establishes a bank’s funding needs, sources and usage. Instead, primary credit for overnight maturity is allocated with minimal administrative burden. Hence, borrowing from the *new* DW need not be motivated by pressing funding needs or signal financial weakness.

Despite these changes, DW borrowing remained sparse after 2003 and perceptions of stigma resurfaced at the onset of the 2007 financial crisis. By the mid 2007, financial institutions were perceived to face serious liquidity shortages for term funding (Hilton and McAndrews 2011). The DW however, remained scarcely visited. To stimulate DW borrowing, the Fed reduced the DW spread over the target rate from 100 basis points to 50 basis points on August 17, 2007 and increased the term of DW financing from overnight to as long as 30 days. In addition, the Fed issued statements that DW borrowing would be viewed as a sign of strength and not a sign of weakness (Hilton and McAndrews 2011). Finally, the Fed encouraged the four biggest U.S. banks to take a leadership role and set an example by borrowing $500 million each at the DW on August 17, 2007. These policy changes, however, generated little DW borrowing in the second half of 2007. Stigma was believed to be the main contributing factor to the persistent reluctance in accessing the DW.

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 TAF was designed as an alternative to the DW to provide term funding with a primary objective of eliminating any perception of stigma attached to borrowing from the DW. A total of 60 TAF auctions were conducted every two weeks between December 17, 2007 and March 8, 2010 when the TAF program was terminated. Funding was offered against the same terms at the DW and at the TAF (i.e. same maturity, collateral, haircut calculations, eligibility and disclosures rules). However, having banks approach the Fed collectively at TAF (rather than individually) and obtaining funds at a competitive rate after a three day delay (rather than immediately at a premium set by the Fed) were expected to solve the coordination problem and mitigate stigma concerns. In contrast to the DW, the TAF was an immediate success in terms of amounts bid and allocated, thereby providing evidence that less, if any, stigma was attached to TAF borrowing (see Armantier et al. 2015).

While the aggregate amount borrowed at the DW reached record highs during the 2008 financial crisis (in particular after the failure of Bear Stearns and Lehman Brothers), Ackon and Ennis (2018) document that DW access has been low since 2010 relative to the pre-crisis period. This result may be explained in part by the abundance of liquidity in the financial system during this period that has made liquidity support unnecessary. However, the decrease in DW borrowing may also reflect increased stigma. In particular, financial institutions have reported that the new disclosure requirement under the 2010 Dodd-Frank Act would make even more reluctant to borrow at the DW.

# Appendix 2 : Proofs of Propositions

## Proof of Proposition 1

The restrictions on the model’s parameters are:

* *R1* :
* *R2* : , where and

The two pairs of strategies are:

= {No bank borrows at the DW;

Investors fund only banks not seen borrowing at the DW}

= {Illiquid banks borrow at the DW;

Investors fund only banks not seen borrowing at the DW}

We consider the case of a fixed detection probability .

**Proposition 1**: When the unique equilibrium is , otherwise the unique equilibrium is .

**Proof**: First, observe that there cannot be a separating equilibrium in which one type of illiquid bank borrows at the DW while the other type does not. Indeed, the two types of illiquid banks (i.e. solvent and insolvent) have the same payoff function. Thus, if it is strictly better for a solvent-illiquid bank to borrow at the DW, then an insolvent-illiquid bank has an incentive to mimic this strategy and behave as if solvent-illiquid.

Consider the case where no bank borrows at the DW. In that case, the investor cannot update its beliefs between the two periods. An investor expected profit is (where is the unconditional probability that a bank is solvent) if he funds the bank and otherwise. Because under *R2*, the investor funds the bank. The profit of an illiquid bank (whether solvent or insolvent) is then . Does a bank have an incentive to deviate and borrow at the DW? It depends on the strategy of the investor if it were to detect a bank borrowing at the DW. If the investor funds a detected bank, then an illiquid bank has a strict incentive to deviate, as this would yield a higher profit () even when the bank is detected at the DW. If instead the investor does not fund a detected bank, then a bank expected profit when it deviates and borrows at the DW becomes . The bank has no incentive to deviate when or equivalently when .Thus, the strategy profile **St** is an equilibrium only when is large enough, i.e. .

Consider now the case where every illiquid bank borrows at the DW. In that case, an investor can update its beliefs between the two periods when it faces a detected bank. In particular, because all illiquid banks borrow at the DW, the probability that a bank is solvent conditional on being detected is the same as the probability that a bank is solvent conditional on being illiquid:. Under *R2*, , so an investor does not fund a detected bank. In contrast an investor funds a non-detected bank. Indeed, because all insolvent banks are illiquid and borrow at the DW, the probability that a bank is solvent conditional on not being detected is higher than the unconditional probability . Under *R2*, , so an investor funds a non-detected bank. The expected profit of illiquid banks in that case is . If an illiquid bank deviates and does not go to the DW, then it gets a profit of . An illiquid bank has no incentive to deviate when , or equivalently when . Thus, the strategy profile **NoST** is an equilibrium only when is small enough, i.e. .

## Proof of Corollary 1

The endogenous probability of detection is , with , the threshold is such that , and is the expected number of illiquid banks.

**Corollary 1**: If , then there are two equilibria, and **.** Otherwise, is the unique equilibrium when and is the unique equilibrium when .

**Proof**: When we have for all . Thus, a single DW borrower is sufficient to make the detection probability lower than the threshold . According to Proposition 1, with such low probability of detection the best response of any illiquid bank is to borrow at the DW regardless of the number of DW borrowers, and the unique equilibrium is .

When we have for any . Thus, more than the expected number of illiquid banks would be required to access the DW simultaneously for the detection probability to become lower than the threshold . In that case, an illiquid bank should expect the detection probability to be too high (i.e. higher than ) to make it a best response to borrow at the DW. The unique equilibrium is therefore in that case.

Finally, consider the case If there is a critical mass of DW borrowers such that , then the best response for an illiquid bank is to borrow at the DW. Indeed, doing so would make the detection probability lower that the threshold (i.e. ). Thus is an equilibrium. Conversely, if there are too few DW borrowers, to make the detection probability low enough (i.e. ), then the best response for an illiquid bank is not to borrow at the DW. Thus, is also an equilibrium.

## Proof of Proposition 2

With probability a bank has to borrow at the DW in period 1 regardless of type. Voluntary and involuntary DW borrowers pay , they are indistinguishable, and they face the same endogenous detection probability , where and are the number of banks that borrow at the DW voluntarily and involuntarily, respectively. We denote and ={Illiquid banks borrow at the DW; Investors fund every bank}. Recall that we focus on the case .

**Proposition 2**: is no longer an equilibrium *.* The unique equilibrium is when , and otherwise.

**Proof**: First, observe that the two types of illiquid banks (i.e. solvent and insolvent) still have the same payoff function. Therefore, there cannot be a separating equilibrium in which one type of illiquid bank voluntarily borrows at the DW while the other type does not.

Consider the case where no bank voluntarily borrows at the DW. In that case, the investor cannot update its beliefs between the two periods. Indeed, if a bank is detected, then the investor knows that this DW borrowing was involuntary and therefore the investor does not receive any information about the bank’s type. In that case, the investor funds every bank, i.e. detected and not detected, because under *R2*. The profit of a non-selected illiquid bank (whether solvent or insolvent) is then . Because the investor also funds detected banks, a non-selected illiquid bank has an incentive to deviate and borrow at the DW. Indeed, doing so would yield a higher profit () even when the bank is detected. Thus, the strategy profile can no longer be an equilibrium.

Consider now the case where every non-selected illiquid bank voluntarily borrows at the DW. In that case, an investor can update its beliefs when it faces a detected bank. In particular, because all illiquid banks borrow at the DW, the probability that a bank is solvent conditional on being detected is where is the unconditional probability that a bank is solvent and is the probability that a bank is solvent conditional on being illiquid. Observe that .

We now assume that . In that case, and an investor has no incentives to fund a detected bank. In contrast, an investor funds a bank not seen borrowing at the DW. Indeed, because all insolvent banks are illiquid and borrow at the DW, the probability that a bank is solvent conditional on not being detected is higher than the unconditional probability . Under *R2*, , so an investor funds a non-detected ban. The expected profit of a non-selected illiquid bank is . If an illiquid bank deviates and does not go to the DW, then it gets a profit of . An illiquid bank has no incentive to deviate when , or equivalently when or when which is satisfied since we assume . Thus, the strategy profile is an equilibrium when .

Finally, consider now the case where every non-selected illiquid bank voluntarily borrows at the DW and . In that case, and an investor funds every bank, i.e. detected and non-detected. Then, because it is funded even when detected, a non-selected illiquid bank has a strict incentive to borrow at the DW. Thus, is an equilibrium in that case.

# Appendix 3 : Instructions

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**Instructions Page 1 of 5**

**Roles**: There are two types of participants in this experiment: **Banks** and **Investors.**

**Your Role:** Throughout the experiment, you will be a (**Bank** or **Investor**).

**Rounds:** The experiment will consist of **25 rounds**. Each round has **2 periods**.

**Matching:** In each round, a **Bank** and an **Investor** are paired together at random.

**Decisions:** The **Bank** makes a decision in **period 1**, and the **Investor** makes a decision in **period 2**

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**Instructions Page 2 of 5**

**Bank Characteristics**:

A **Bank** can be **“Solvent”** or **“Insolvent”**. A bank that is insolvent will fail at the end of period 2, at which point it is worth **0** to the **Investor**. In contrast, a solvent bank is worth **100** to the **Investor** at end of period 2.

A **Bank** can also be **“Liquid”** or **“Illiquid”**. An illiquid bank must make a payment at the end of period 1. As explained next, an illiquid bank must incur a cost to secure funds to make this payment. In contrast, a liquid bank does not have any payment to make.

**Probabilities for Bank Types**:

Solvent banks may either be liquid or illiquid. In contrast, all insolvent banks will be illiquid. Therefore, there are three types of banks: **solvent-liquid**, **solvent-illiquid** and **insolvent-illiquid**. Banks types are determined randomly. In each round, there is a

**1 in 2 chance (50%)** that a **Bank** is **solvent and liquid**

**1 in 6 chance (17%)** that a **Bank** is **solvent and illiquid**

**1 in 3 chance (33%)** that a **Bank** is **insolvent and illiquid**

Observe that an illiquid bank is more likely to be insolvent than a liquid bank. In fact, a liquid bank is guaranteed to be solvent, but an illiquid bank has a 2 in 3 chance **(66%)** of being insolvent.

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**Instructions Page 3 of 5**

**Period 1**

Because it operates in period 1, a **Bank** receives an income of **50** regardless of its type, that is, whether it is **liquid** or **illiquid**, **solvent** or **insolvent**.

An **illiquid Bank**, however, must incur a cost to make the required payment. The illiquid bank can either

1. **Sell some of its own assets** at a cost of **40**, or
2. **Obtain emergency credit** from the Central Bank operating as the **“Lender of Last Resort**,” at a cost of **20**

**Confidentiality of Asset Sales:** The **Investor** cannot observe whether a **Bank** sells its own assets. So, when a **Bank** chooses to sell its own assets, the **Investor** cannot infer that the **Bank** is illiquid.

**Lender of Last Resort Detection:** If the **Bank** borrows from the Lender of Last Resort, then there is a chance that this action is observed by the **Investor**, in which case the **Investor** knows the **Bank** is illiquid. If only one bank borrows from the Lender of Last Resort, then there is a **75% chance** that this borrowing will be observed by the **Investor**, but there is only a **50% chance** of detection if 2 banks borrow, and only a **25% chance** of detection if 3 or more banks borrow.

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**Instructions Page 4 of 5**

**Period 2**

At the beginning of Period 2, the **Investor** is told whether or not the **Bank** was observed borrowing from the Lender of Last Resort. If the **Bank** was observed borrowing from the Lender of Last Resort, then that means that the **Bank** is **illiquid**. If the **Bank** was not seen borrowing from the Lender of Last Resort, then that means that the **Bank** **may or may not be illiquid**.

The **Investor** is not told whether the **Bank** is **solvent** or **insolvent**, but recall that an **illiquid Bank is more likely to be insolvent**.

Then the **Investor** must decide whether to invest or not to invest in the bank.

When the **Investor DOES INVEST** in the bank,

The **Investor** receives either **0** if the **Bank** is **insolvent** or **100** if the **Bank** is **solvent**.

The **Bank** can operate in Period 2 and receives **50**, **whether or not it is solvent**.

When the **Investor DOES NOT INVEST** in the bank,

The **Investor** receives an outside option payment of **50**.

The **Bank** cannot operate in Period 2, and therefore receives **0**.

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**Instructions Page 5 of 5**

There will be **25 rounds** and each round has **2 periods**.

You will be a **Bank**/**Investor** in all rounds.

Each round begins with a new random pairing of **Banks** and **Investors**.

There is a

**1 in 2 chance (50%)** that a **Bank** is **solvent-liquid**

**1 in 6 chance (17%)** that a **Bank** is **solvent-illiquid**

**1 in 3 chance (33%)** that a **Bank** is **insolvent and illiquid**

**Period 1:** **Banks** receive an income of **50** in each round, but an **illiquid bank** must either:

**Sell some of its own assets** at a cost of **40**, or

**Borrow from the Lender of Last Resort** at a cost of **20**.

**Note:** If 1 **Bank** borrows from the Lender of Last Resort, then there is a **75% chance** that the **Investor** will find out that the **Bank** is illiquid before having to make an investment decision. If 2 banks are borrowing from the Lender of Last Resort, this chance of detection falls to **50%**, and the chance of detection is only **25%** if 3 or more banks are borrowing. In contrast, if an illiquid **Bank** sells some of its own assets to raise funds, this action will not be observed by the **Investor**.

**Period 2:** The **Investor** first learns whether or not the **Bank** was observed borrowing from the Lender of Last Resort. Then the **Investor** decides whether or not to invest in the bank.

When the **Investor DOES INVEST** in the bank,

The **Investor** receives either **0** if the bank is **insolvent** or **100** if the bank is **solvent**.

The **Bank** can operate in period 2 and receives **50** **whether it is solvent or not**.

When the **Investor DOES NOT INVEST** in the bank,

The **Investor** receives **50**.

The **Bank** receives **0** in period 2, **whether it is solvent or not**.

**Special Earnings Announcement:** The computer will keep track of your total earnings for all rounds. Your cash earnings will be **5%** of your total earnings at the end of the experiment.

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**V*e***con Lab - August 23, 2018

# Appendix 4 : Session level Figures

**Figure 1.1 : Control Treatment**

Session 1 Session 2 Session 3

Session 4 Session 5 Session 6

**Figure 2.1 : Low DW Cost Treatment**

Session 1 Session 2 Session 3

Session 4 Session 5 Session 6

**Figure 3.1 : Random Borrowing Treatment**

Session 1 Session 2 Session 3

Session 4 Session 5 Session 6

**Figure 4.1 : Low Detection Treatment**

Session 1 Session 2 Session 3

Session 4 Session 5 Session 6

1. \*The first author would like to thank the Toulouse School of Economics where part of this research was conducted. We are especially thankful to Stephane Cezera for his help running the experiments at TSE, as well as Laura Young and Maria Winchell for research assistance. We would like to thank seminar participants at TSE, EIEF, Universita degli Studi di Milano, Lille 3, GATE, and LUISS. We also thank participants at the EWEBE conference in Bertinoro, ESA conferences in Vienna and Richmond, Experimental Finance conference in Nice, ASFE conference in Nice, the 8th theoretical and Macroeconomic workshop in Stony Brook, IMEBESS in Florence, and JIMF in Rabat. [↑](#footnote-ref-1)
2. In practice, solvency and liquidity are related (one can lead to the other), and distinguishing between the two can be difficult, especially during a financial crisis. Other frictions that may impair the interbank market include search costs (Ennis and Weinberg 2013), coordination failures (Occhino 2016), as well as operational problems, which can be idiosyncratic (e.g. counterparty failures) or systemic (e.g. the 9/11 terrorist attack). [↑](#footnote-ref-2)
3. There is also an ex-ante effect under which banks hoard on liquidity to absorb tail liquidity risks, thereby reducing the loans they extend to the real economy (Winters 2012, Gale and Yorulmazer 2013). [↑](#footnote-ref-3)
4. It is now well recognized that the 2007 financial crisis was characterized by such disruptions to the interbank market for short-term funding (Bernanke 2009, Winters 2012, Geithner 2014). [↑](#footnote-ref-4)
5. There is an extensive literature on the LoLR. Questions that have attracted particular attention include the relative benefits (prevent a crisis, address negative externalities) and costs (default risk, moral hazard) of a LoLR, whether the LoLR should be public or private, and the price at which emergency lending should be provided. For reviews see Freixas, Parigi and Rochet (2004), Rochet and Vives (2004), Gorton and Metrick (2013), or Ennis (2016). [↑](#footnote-ref-5)
6. See Gorton and Metrick (2013) or Bordo (2014) for comprehensive historical reviews of the Fed’s DW operations. [↑](#footnote-ref-6)
7. Winters (2012) also documents how stigma limited the effectiveness of the Bank of England (BoE) emergency liquidity facility during the 2007 financial crisis and resulted in substantial costs to the financial system. [↑](#footnote-ref-7)
8. Many central banks, e.g. the BoE, the Bank of Japan and the European Central Bank, also rely on a corridor system. [↑](#footnote-ref-8)
9. See also the minutes from the December 6, 2007 Federal Open Market Committee. [↑](#footnote-ref-9)
10. See the July and November 2016 minutes from the Federal Open Market Committee. [↑](#footnote-ref-10)
11. “Understanding stigma, and potential ways to mitigate it, seems like an under-researched area.” Potter (2016). [↑](#footnote-ref-11)
12. As explained in Appendix 1, DW borrowing used to be fully anonymous until the Dodd-Frank Act of 2010 required the Fed to reveal the identity of DW borrowers. However, recognizing the possible adverse consequences of real-time disclosure, a two year lag was imposed. The 2015 Warren-Vitter “Bailout Prevention” bill recommended disclosing emergency loans to congress within a week, prompting concerns about information leakage and real time identification. [↑](#footnote-ref-12)
13. In practice, a bank may become illiquid when a set of depositors suddenly withdraw their deposits or when a counterparty fails to send a payment in time. For an example of the latter see “*Barclays admits borrowing hundreds of millions at Bank’s emergency rate*,” The Guardian, Aug 30, 2007. [↑](#footnote-ref-13)
14. This assumption is not necessary. All we need is for the illiquidity probability to be higher for insolvent banks. [↑](#footnote-ref-14)
15. This assumption is not necessary. Insolvent banks could be granted DW access with a positive probability. This probability, however, cannot be too small as there cannot be DW stigma when the central bank can screen solvent banks (nearly) perfectly. In that case, the opposite of stigma would occur: banks would have an incentive to borrow at the DW and make it public to show market participants they received a “certificate of solvency” from the central bank. [↑](#footnote-ref-15)
16. An equivalent interpretation of the model (adopted by Tirole 2012 and Ennis 2017) is that the bank can embark on a risky project for which it needs funding. If the investor funds the project, then the investor gets either 0 or , and the bank gets . Otherwise, the investor gets an outside option and the bank gets . Note also that, to simplify, we assume that illiquid banks have the same payoff function when solvent and insolvent. The model can be generalized by assuming that a funded bank has some “skin in game” and benefits from the success of the risky project. In that case, it is easy to show that the equilibria discussed next are unaffected, but that a separating equilibrium under which only insolvent-illiquid banks borrow at the DW may emerge under specific parameter values. [↑](#footnote-ref-16)
17. As explained in Appendix 1, the DW was fully anonymous between 1913-2010. Further, the banks’ clearinghouse that preceded the Fed as a (private) LoLR also operated under secrecy. [↑](#footnote-ref-17)
18. During the 2007 financial crisis, the press reported that Deutsche Bank had accessed the DW (“Fed fails to calm money markets,” *The Financial Times*, August 20, 2007). Similarly, Barclays’ use of the BoE’s DW was immediately reported (“Barclays admits borrowing hundreds of millions at Bank’s emergency rate,” *The Guardian*, August 30, 2007). Finally, a BBC leak that Northern Rock borrowed from the BoE was instrumental in the bank’s demise (Shin 2009). Beyond media coverage, two identification channels are often mentioned. First, DW borrowers may be identified from the Fed’s weekly public report of aggregate DW borrowings by district (Duke 2010). Second, analysts, bankers and investors may be able to make educated guesses about possible DW borrowers based on market activity (“Banks Face Borrowing Stigma,” *The Wall Street Journal*, April 1, 2011. [↑](#footnote-ref-18)
19. Under *R1*, the total surplus when an insolvent bank is not funded (in which case the bank gets and the investor ) is larger than the total surplus when an insolvent bank is funded (in which case the bank gets and the investor 0) [↑](#footnote-ref-19)
20. The second inequality in *R2* also implies that the market is not frozen in period 2 in the absence of the DW, because the investor is willing to fund a random bank. This is in contrast with Tirole (2012) and Che et al. (2018) who a government intervention aimed at jumpstarting a market that is otherwise frozen (i.e. no bank gets funded). The DW, however, is a *permanent* facility and its primary role is not to jumpstart markets. Finally, it is easy to show that there cannot be stigma in equilibrium if we relax *R2* and assume that absent a DW the market is frozen. Indeed, if there is stigma and no one borrows at the DW in period 1, then the market remains frozen and no bank gets funded in period 2, in which case illiquid banks have an incentive to deviate in period 1 and pay the lower cost . [↑](#footnote-ref-20)
21. In the 2009 lawsuit filed by Bloomberg News to obtain DW data, Fed’s officials argued that revealing the identity of DW borrowers would stigmatize banks and impede the Fed’s ability to respond to future crises (Madigan 2009). [↑](#footnote-ref-21)
22. A comprehensive welfare analysis is more difficult as it requires defining the social costs of DW lending (which uses public funds), of its the alternatives (e.g. fire sales create negative externalities), and of DW stigma (which prevents the central bank from effectively acting as the LoLR and implementing monetary policy). [↑](#footnote-ref-22)
23. Alternatively, we could consider that DW loans are extended only to solvent banks. Note however, that DW loans are fully collateralized with a haircut. Thus failure to repay a DW loan should have limited to no cost to the public. [↑](#footnote-ref-23)
24. The assumption that, when detected, voluntary and involuntary DW borrowers are indistinguishable is not necessary. The investor could distinguish voluntary and involuntary borrowers with a small probability. [↑](#footnote-ref-24)
25. There is one difference between the experiment and the game described in Section 2. To avoid banks’ losses, and to make payoffs comparable across subjects, every bank receives a lump-sum *k* in each round described to subjects as the bank’s profit from operating in period 1. The lump-sum is irrelevant in the model and does not affect equilibrium calculations. The experimental results presented in the remainder do not take the lump-sum into consideration. [↑](#footnote-ref-25)
26. We recognize that there are pros and cons in using the strategy method, providing feed-back and introducing context in the experiment. Note, however, that these design features are common to all treatments. [↑](#footnote-ref-26)
27. Treatment effects are determined by running 2-tail permutation tests of differences in medians using the session averages over the last 10 rounds of the relevant treatments. [↑](#footnote-ref-27)
28. Recall that because we use the strategy method, we observe a bank’s decisions to borrow at the DW both if insolvent-illiquid and if solvent-illiquid. [↑](#footnote-ref-28)
29. The fields of studies are economics, social science, hard science, literature and other. To save space, the estimates (which are all insignificant) are not reported. [↑](#footnote-ref-29)
30. For instance, in the control treatment, the probability of being solvent is 66% (close to the 2/3 theoretical probability), while the probability of being solvent conditional on being detected is only 30%. [↑](#footnote-ref-30)
31. As explained in Appendix 1, a bank’s eligibility for primary credit at the DW is already contingent on a number of factors (about e.g. financial health, collateral). The Fed could modify Regulation A to add a new rule: To be eligible for primary credit, a bank would have to commit to borrowing a certain amount during the year. [↑](#footnote-ref-31)
32. Only 0.1% of the DW loans extended between 2010 and 2015 exceeded $100 million (Ackon and Ennis 2018). Since 2007 the spread between the DW and the interest rate paid on reserves by the Fed has been 50 basis points. [↑](#footnote-ref-32)
33. Since the 2003 DW reform, funds borrowed at the DW can be lent on the interbank market. Thus, even if banks do not need liquidity when they are asked to borrow at the DW, they could always lend it on the interbank market. Alternatively, the funds could be safely stored at the Fed to earn interest on reserves. [↑](#footnote-ref-33)
34. As explained by Tucker (2009), recognizing that liquidity shocks can occur between auctions, the BOE decided to combine periodic liquidity auctions with a DW facility available on a continuous basis. [↑](#footnote-ref-34)
35. In 2017 the IMF stated: “A key objective of the lending reform is to reduce the perceived stigma of borrowing from the IMF” (<https://www.imf.org/external/np/exr/faq/facfaqs.htm#q11>). See also “Move to Repay Aid Helps Bank of America Shed Stigma,” The New York Times, December 3, 2009 for a discussion of stigma attached to the Troubled Asset Relief Program. [↑](#footnote-ref-35)
36. See e.g. Vishwanath (1989), Athreya (2004) or Knaak et al. (2017) [↑](#footnote-ref-36)
37. Schwartz and Rothbart (2018) report that 2/3rd of the students eligible for free lunch do not take part in the program. [↑](#footnote-ref-37)
38. “I warned the bankers that if they all didn’t accept the capital, TARP would be stigmatized” Geithner (2014). [↑](#footnote-ref-38)