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Abstract

A core responsibility of a central bank is to ensure financial stability by acting as the "lender of last resort" through its Discount Window. The Discount Window, however, has not been effective because its usage is stigmatized. In this paper, we study experimentally how such stigma can be cured. We find that, once a Discount Window facility is stigmatized, removing stigma is difficult. This result is consistent with the Federal Reserve's experiences which have been unsuccessful at removing the stigma associated with its Discount Window.

JEL classification: E58, G01, C92
Key words: lender of last resort, discount window, stigma, laboratory experiment

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"*Why should not we have, maybe on some kind of random basis, a mandatory use of the Discount Window, so that we can start erasing that stigma? I am going to put forward legislation that would require some usage and how we do that on an episodic basis.*" Senator Mark Warner, December 6, 2023.

1. Introduction

One of the core responsibilities of central banks is to act as "lender of last resort" to the financial system. In the U.S., the Federal Reserve (the Fed) has been operating as a lender of last resort through its "Discount Window" (DW) for more than a century.[1] Because its aims to address liquidity problems before they have systemic consequences, the DW is the Fed's first line of defense against financial crises. Historically, however, the DW has been plagued by stigma, the banks' reluctance to use the DW even for benign reasons, out of concerns that it could be interpreted as a sign of financial weakness.[2] In this paper, we build on Armantier and Holt (2020) (A&H hereafter) to study experimentally how a stigmatized DW can be cured.

In principle, solvent but illiquid banks should obtain funding from private counterparties in the interbank market. Asymmetric information, however, can prevent lenders from distinguishing illiquid from insolvent borrowers, especially when markets are stressed. As a result, even solvent institutions can fail to secure funding on the interbank market, in which case they have to resort to costly alternatives such as fire sales of assets, borrowing at high rates through different channels or failing to (re)pay a counterparty. As illustrated by the rapid demise of Northern Rock in 2007 in the U.K. or Silicon Valley Bank in 2023 in the U.S, these actions can trigger a bank run and the failure of an illiquid yet (arguably) ex-ante solvent institution (Shin 2009, Metrick 2024). The inability to secure private funding can also have negative externalities and social costs. In particular, spillovers from fire sales can result in insolvency cascades as illustrated by the aftermath of the 2008 failure of Lehman Brothers (Shleifer and Vishny 2011, Caballero and Simsek 2013).

To address market failures in the interbank market and prevent the negative externalities they

[1] See Gorton and Metrick (2013) or Bordo (2014) for comprehensive historical reviews of the Fed's DW operations.
[2] Stigma is not confined to the Fed's DW. In particular, Winters (2012) and Fulmer (2022) document how stigma limited the effectiveness of the Bank of England emergency liquidity facility during the 2008 financial crisis.

can generate, central banks typically act as lender of last resort. The objective is to avoid unnecessary and socially costly failures by providing liquidity support when private alternatives are not available or are prohibitively expensive. Historically, however, DW usage has been scant, even when banks faced acute liquidity shortages. This was the case in the early stages of the 2007 financial crisis and at the onset of the banking turmoil of March 2023.[3] This lack of DW borrowing is often attributed to stigma. The argument goes as follows: Banks that cannot meet their funding needs in private markets for benign reasons refrain from borrowing at the DW out of concern that, if detected, they might be perceived as insolvent by market participants.[4] DW stigma is a first order concern for central banks because they can only fulfill their emergency lending obligations if financial institutions are willing to access the DW. In particular, stigma was a major concern in the design of the international policy response to the 2008 crisis (Geithner 2014, Winters 2012). Several central banks have reformed their DW over the years with the explicit objective of mitigating stigma (e.g. the Fed in 2003, the Bank of England in 2015), and stigma was an important consideration in the design of new backstop facilities such as the 2007 Term Auction Facility (Armantier et al. 2008) or the 2021 Standing Repo Facility (Andolfatto and Ihrig 2019).

The aftermath of the 2023 banking turmoil in the U.S. saw renewed interest in reforming the Fed's DW.[5] The rapid collapse of Silicon Valley Bank made it clear that modern bank runs can unfold in a matter of hours (through social media and online banking), instead of days or weeks as in the past.[6] To prevent these runs, banks need the ability to access emergency funding as least as fast as depositors can withdraw cash. Policy makers believe that the DW should be uniquely positioned to provide ready access to liquidity (Barr 2023, Hsu 2024).[7] To achieve this objective, several reforms have been proposed, from streamlining DW operations (Logan 2023, Scott 2024),

[3] See Armantier et al. (2015), McLaughlin (2023, 2024), Metrick (2024), or Armantier and Cipriani (2024).
[4] "*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). There is a second form of stigma whereby banks may be concerned that DW borrowing sends a negative signal to the Fed, which acts both as a lender of last resort and a regulator. Following most of the literature, we focus on DW stigma with respect to market participants.
[5] See the 12/6/2023 Senate Banking Committee hearing "Annual Oversight of Wall Street Firms," or the 02/15/2024 Congressional hearing "Lender of last resort: Issues with the Fed Discount Window and emergency lending."
[6] Silicon Valley Bank experienced an outflow of $42 billion (or 25% of deposits) in a single day. During the run on Washington Mutual in 2008, the outflow of $19 billion (or 10% of deposits) took 16 days (see Rose 2023).
[7] In particular, the Federal Home Loan Banks system, a common source of funding for troubled banks, noted in a recent report that it is "*not designed or equipped to take on the function of the lender of last resort*" (FHLB 2024).

to requiring that banks have enough collateral pre-positioned at the DW to cover any meaningful run on their assets (McLaughlin 2023, G30 2024, Hsu 2024). Further, recognizing that stigma must be mitigated, regulators have considered imposing a mandate for banks to access the DW regularly (Logan 2023, Barr 2023, Hsu 2024, Mester 2024). This would not only ensure banks' operational readiness when emergency funding is needed,[8] but, as illustrated by Senator Warner's quote above, it should also mitigate stigma by making DW borrowing unremarkable and uninformative.[9]

This mandate, originally proposed by Winters (2012) for the Bank of England's DW, finds partial support in A&H. To study experimentally how stigma may be prevented, A&H developed a coordination game with adverse selection that can produce two pure strategy equilibria, with and without stigma. They find that while lowering the cost of DW borrowing and making DW borrowing harder to detect are ineffective, requiring banks to borrow at the DW at random times can prevent stigma. These results, however, do not imply that random borrowing can cure pre-existing stigma. In A&H's *between-subjects* experiment, the entire game is played under a *single* DW policy and the DW does not initially suffer from stigma. Namely, the proportion of banks willing to borrow from the DW in the first round of A&H's experiments is around 50%, far from the 0% a fully stigmatized DW would produce.

In this paper, we build on A&H and conduct a series of *within-subject* experiments with *two* consecutive DW policy treatments. In the first part of the experiment, the policy is such that the DW becomes severely stigmatized. Then a "cure" policy is introduced in the second part. Under the cure, stigma is no longer an equilibrium, so theory predicts that behavior should shift to the unique stigma-free equilibrium. We consider three cures, the same required random borrowing

[8] A compounding factor in the banking turmoil of 2023 was the lack of operational readiness to tap the DW in a timely manner. Before they failed, Silicon Valley Bank had limited collateral pledged at the DW and it had not tested its ability to borrow at the DW in more than a year, while Signature Bank had no collateral posted at the DW and did not conduct a test transaction in more than 5 years (Metrick 2024).

[9] For instance, the President of the Federal Reserve Bank of Cleveland stated "*Currently, the Reserve Banks are encouraging eligible financial institutions to ensure that they…have tested their ability to use the discount window in a timely way should the need arise. Testing at this time is not mandatory, but I support requiring such testing*" Mester (2024). Similarly, the President of the Federal Reserve Bank of Dallas stated "*an expectation that depository institutions establish and periodically test access to the discount window could help make individual firms and the financial system more resilient. ... Also, if all depository institutions regularly tested their discount window access, the traditional stigmas associated with borrowing from the Fed would be further reduced*" Logan (2023). See also "US prepare rule forcing banks to tap the Fed Discount Window," Bloomberg, January 18, 2024, or "JP Morgan see Discount Window proposal as attempt to end stigma," Bloomberg, January 22, 2024.

policy that prevented the formation of stigma in A&H; a high random borrowing policy where we double the frequency with which banks are required to borrow at the DW; and a free DW policy under which the cost of DW borrowing is set at zero, in which case DW borrowing is not only an equilibrium but it is also a dominant strategy.

We find that, although all three cure treatments significantly promote DW borrowing, there is no evidence that they fully cure DW stigma. In the random borrowing experiment, the proportion of banks that borrow at the DW in the last three rounds does not exceed 50% as compared to more than 75% under the same policy in A&H (where the DW is not initially stigmatized). A higher frequency of required borrowing produces a statistically significant increase in DW borrowing, but it still does not cure stigma fully. Finally, under the extreme scenario of a free DW under which DW borrowing is a dominant strategy, less than 70% of banks borrow at the DW in the last three rounds of the experiment. As discussed in the conclusion, these results reflect the Fed's multiple and mostly unsuccessful attempts to break the stigma attached to its DW.

This paper contributes to the growing literature concerned with DW operations and stigma. Recent studies on liquidity provision through the DW include Ackon and Ennis (2017), Ennis and Klee (2023), and Beyhaghi and Gerlach (2023). Empirical evidence of stigma associated with backstop facilities like the DW has been provided by Peristiani (1998), Furfine (2001), Armantier et al. (2015), Anbil (2018), Vossmeyer (2019), Anbil and Vossmeyer (2019), Beyhaghi and Gerlach (2023), and Armantier and Cipriani (2024). Formal models of emergency lending with stigma have been proposed by Ennis and Weinberg (2013), La'O (2014), Ennis (2019), Gorton and Ordonez (2020), Hu and Zhang (2023), and Che et al. (2023). To the best of our knowledge, A&H and the present paper are the only studies that focus on anti-stigma policies.

Our paper also adds to the vast literature that uses laboratory experiments to design new markets and testbed policies (see e.g. Roth 2016, Hakimov and Kübler 2021, and Chen et al. 2021 for reviews).[10] It is also belongs to the recent but rapidly expanding experimental literature in

[10] Smith (1994) argues that two (of seven) reasons for conducting experiments is to "*evaluate policy proposals"* and to "*provide a testing ground for institutional design*." Falk and Heckman (2009) observe that the comparative advantage of experimental methods when designing new markets and policies are the cost effectiveness of generating data and the ability to create exogenous variation, thereby enabling causal identification. In particular, lab experiments have proved particularly useful for understanding phenomena which (like stigma) are hard to observe in the field, such as the *winner's curse* (e.g. Kagel 2003) or unethical behavior (e.g. Attanasi et al. 2019). Recent evidence suggests that

banking and finance (see e.g. Dufwenberg 2015, Kiss et al. 2022, and Davis and Korenok 2023).[11] Recent experiments closely related to our paper use experimental methods to study bank behavior (e.g. Bosch-Rosa 2018, Duffy et al. 2019, or Davis et al. 2020) and central bank policies (e.g. Kostyshyna et al. 2022, Cox et al. 2023, or Camera 2024).

The paper is structured as follows: the model is summarized in section 2. The design of each experiment is described in section 3, and experiment results are reported in section 4. In section 5, an econometric analysis shed light on why the cures are ineffective. Finally, section 6 concludes.

2. The Model

The box below summarizes the basic structure of the coordination game proposed by A&H to capture the essence of emergency lending and DW stigma. A summary of the model's parameters is also provided in Table 1. There are two populations of players, banks and investors, each of size N. 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. 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 every insolvent bank is illiquid. Thus, there are three types of banks: solvent-liquid with probability P_{SL}, solvent-illiquid with probability P_{SL} and insolvent-illiquid with probability P_{SL}. The banks' types are randomly determined and private, but the probability structure $\{P_{SL}, P_{SL}, P_{SL}\}$ is common knowledge. If the bank is illiquid, then it must borrow one unit of liquidity in period 1 either at the DW at a cost dw, or from an alternative source at a cost $c > dw$.[12]

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treatment effects from such lab experiments are robust and generally carry over to professionals in the field (see e.g. Fréchette 2016, Snowberg and Yariv 2021, or DellaVigna and Pope 2022). Nevertheless, we need to be cognizant of external validity concerns. In particular, while this paper provides original insights on how DW stigma may be cured, it should only be considered a partial step toward a complete understanding of the issue.

[11] See also the September 2023 special issue of the *Journal of Banking and Finance* on laboratory experiments.

[12] In the model, the DW lends to any bank. In practice, however, the DW should not lend to insolvent banks, but solvency screening is difficult, especially in times of crises (Freixas et al. 2004). To simplify, we assume that screening is impossible, consistent with Ennis and Weinberg (2013) and A&H.

The Structure of the Game

Period 1: Each of N banks receives a private type, solvent-liquid, solvent-illiquid or insolvent-illiquid with known probability P_{SL}, P_{SL}, and P_{SL}, respectively. Each bank may be required to borrow at the DW (at cost dw) with probability $\alpha \geq 0$. Illiquid banks not selected must borrow at the DW (at cost dw) or from another source (at cost $c > dw$). Each of the n DW borrowers can be detected with probability $\theta(n)$.

Period 2: The investor first learns whether their matched bank was detected at the DW. Then, the investor decides whether to fund the bank. If the investor funds the bank, then the bank earns k, and the investor earns either V if the bank is solvent or 0 if the bank is insolvent. If the investor does not fund the bank, then the investor earns v and the bank earns 0.

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. An investor who funds the bank earns V if the bank turns out to be solvent or 0 if the bank is insolvent. An investor who does not fund the bank earns v from an outside option, with $v < V$. The bank's operating revenue in period 1 is k. In period 2, the bank's revenue is either k if it is funded by the investor or 0 otherwise as it effectively ceases to operate.

At the beginning of period 2, the bank's DW borrowing may be detected by the investor with a probability $\theta(n)$ where n is the total number of banks that borrow at the DW. We assume that $\theta'(n) < 0$ to capture the idea that real-time detection is more difficult when more banks borrow at the DW simultaneously (Bernanke 2009, Anbil 2018). DW detection is informative for the investor because it means the bank needed emergency liquidity, which is more likely for insolvent banks. Thus, there is an indirect cost of DW borrowing for the bank: If detected, the investor may decide not to fund the bank because of the increased solvency concern.[13]

We denote the stigma strategy $\boldsymbol{St}$ = {*No bank borrows at the DW*; *Investors fund only non-detected banks*}, and the no-stigma strategy $\boldsymbol{NoSt}$ = {*Illiquid banks borrow at the DW*; *Investors fund only non-detected banks*}. A&H show that that $\boldsymbol{NoSt}$ and $\boldsymbol{St}$ are the two equilibria when the

[13] Consistent with Ennis and Weinberg (2013) and A&H, we assume that the private borrowing alternative to the DW is unobservable to the investor in the model. Further, in the model the investor should fund a random bank but not a bank that needs emergency liquidity. Finally, note that the endogenous nature of the detection probability introduces a coordination component to the game consistent with the broader stigma theory (Bénabou and Tirole 2006).

threshold number of borrowers $n_0 = \theta^{-1}\big((c - dw)/k\big)$ is between 1 and $(1 - P_{SL})N$, the expected number of illiquid banks. Otherwise, ***NoSt*** is the unique equilibrium when $n_0 < 1$, and ***St*** is the unique equilibrium when $n_0 > (1 - P_{SL})N$.

A&H also consider an extension with random borrowing. Before a bank learns its type in period 1, it faces a probability α of being selected to borrow at the DW. The illiquid banks not selected must then decide whether to borrow voluntarily at the DW. Thus, there are now two kinds of DW borrowers: voluntary borrowers (who are necessarily illiquid) and involuntary borrowers (who can be of any type). To simplify, voluntary and involuntary DW borrowers are assumed to be indistinguishable. They all borrow one unit of liquidity at a cost *dw* and face the same detection probability $\theta(n)$ where n is the total number of banks that borrow at the DW either voluntarily or involuntarily. In that case, A&H show that ***St*** is no longer an equilibrium and that ***NoSt*** is the unique equilibrium when the random borrowing probability α satisfies $0 < \alpha < \big(v - \underline{P}V\big)/\big(V(p - \underline{P})\big)$, where p and $\underline{P}$ are the probability that a bank is solvent, and the probability that a bank is solvent conditional on being illiquid, respectively. Hence, introducing a chance (even a small chance) of random borrowing eliminates DW stigma as a possible equilibrium.[14]

3. The Design of the Experiments

We conduct three within-subjects experiments. Each experiment has two treatments, a *Stigma treatment* in the first 15 rounds, followed by a *Cure treatment* in the last 15 rounds. As explained below, the Stigma treatment is the same across the three experiments, while different stigma cures are considered in each experiment. An experiment has 6 sessions, each with 12 subjects (6 banks and 6 investors). Roles are fixed throughout an experiment whereas bank-investor pairs are formed randomly in each round. Following A&H, the experiments are conducted with the "strategy method" under which subjects make decisions for all possible contingencies simultaneously.[15] The

[14] 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 detected banks, 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 because it is less costly than the alternative. Thus, ***St*** cannot be an equilibrium.

[15] Before learning its type, the bank selects whether or not to borrow at the DW if solvent-illiquid and if insolvent-illiquid. Before learning whether the bank was detected at the DW, the investor makes a funding decision if the bank is detected and if the bank is not detected. After decisions are made, uncertainty (about the bank's type and DW

experiments were conducted at the Economics Science Institute at Chapman University. The instructions (see Appendix 1) and decision pages were displayed using the web-based Veconlab interface. Each session lasted about 70 minutes. Earnings averaged around $26, with a minimum of $17.5 and a maximum of $37.4, plus a show-up payment of $7.

The stigma treatment.

The objective of the first 15 rounds is to stigmatize the DW. To do so, we replicate A&H's control treatment that produced significant stigma. Namely, subjects in the first 15 rounds of each experiment play the game with endogenous detection probabilities and no random borrowing, using the parameters shown in Table 1. It is easy to verify that $(c - dw)/k = 0.4$, which is between $\theta(2)$ and $\theta(3)$. So, the threshold number of DW borrowers $n_0 = \theta^{-1}\big((c - dw)/k\big)$ in the Stigma treatment is such that $2 < n_0 < 3 = (1 \quad P_{SL})N$. Hence, both ***NoSt*** and ***St*** are equilibria in the first 15 rounds of each experiment.

Table 1: Experiment Parameters

Parameters common to all treatments

# of banks and # of investors	N	6	DW detection probability with		
Solvent-Liquid probability	P_{SL}	1/2	1 DW borrower	$\theta(1)$	3/4
Solvent-Illiquid probability	P_{SL}	1/6	2 DW borrowers	$\theta(2)$	1/2
Insolvent-Illiquid probability	P_{SL}	1/3	3 DW borrowers or more	$\theta(3)$	1/4
Bank's per period revenue	k	50	Bank's value when solvent	V	100
Alternative funding cost	c	40	Investor's outside option payoff	v	50

Differences across treatments

		Stigma (first 15 rounds)	Random Borrowing	High Random Borrowing	Free DW
DW Cost	dw	20	20	20	0
Random Borrowing Probability	α	0	1/6	1/3	0
Expected detection probability as a function of the number of *voluntary* DW Borrowers	1	3/4	1/2	1/4	3/4
	2	1/2	1/4		1/2
	≥ 3	1/4			1/4
Equilibrium		***St*** and ***NoSt***	***NoSt***	***NoSt***	***NoSt***

The stigma cure treatments

A stigma cure is introduced in the final 15 rounds of each experiment. We consider two cures that

detection) is resolved and payoffs are calculated using the subjects' contingent choices. Compared to the direct-response method (under which the game is played sequentially), the strategy method produces more data because a subject's full strategy profile is elicited instead of a single choice. This is particularly relevant here because half of the banks are solvent on average and therefore would end-up making no decision under the direct-response method. See Fréchette and Schotter 2015 for a discussion of the pros and cons of using the strategy method.

have been suggested after the 2023 banking turmoil: required random borrowing and cheaper DW lending. As we shall see, unlike the game played in the first 15 rounds which has two equilibria, the game played in these cure treatments has a unique stigma-free equilibrium.

We consider two treatments with required random borrowing, the *Random Borrowing* treatment and the *High Random Borrowing* treatment. The Random Borrowing treatment is a replication of one of the treatments in A&H, which was found to help subjects converge to the stigma-free equilibrium when launching a new DW facility which is not already stigmatized. As indicated in Table 1, where treatment differences are summarized, the Random Borrowing treatment is identical to the Stigma treatment with one exception: In each of rounds 16 to 30, each bank faces a 1/6 chance of being required 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 $dw = 20$ and they face the same endogenous probability of detection as in the first 15 rounds. However, because there is one involuntary DW borrower on average in each round, the expected detection probability is now 1/2 (respectively, 1/4) when one (respectively, two or more) illiquid bank borrows at the DW voluntarily. Note also that the required random borrowing probability of $\alpha = 1/6$ is below the threshold $\left(v - \underline{P}V\right)/\left(V(p - \underline{P})\right) = 0.5$, so that $\boldsymbol{NoSt}$ becomes the only equilibrium.

A&H found that the experience acquired from involuntary DW borrowing is one of the main factors that helps banks overcome DW stigma. In particular, after a bank is randomly selected to borrow and not detected, it is 35% more likely to return to the DW voluntarily in the next round. Consistent with this result, A&H found that making the required borrowing experience more frequent accelerates convergence toward the stigma-free equilibrium. So, could frequent involuntary borrowing be more effective at curing an *already stigmatized* DW? To test this hypothesis, we conduct a High Random Borrowing treatment in which the probability of required DW borrowing is doubled to $\alpha = 1/3$. In that case, there are two involuntary DW borrowers on average in each round, and the expected detection probability is 1/4 when one or more illiquid bank borrows at the DW voluntarily.

In the aftermath of the 2023 banking turmoil, some observers suggested that the pricing of the

DW should become more competitive so as to mitigate stigma (McLaughlin 2023, G30 2024).[16] While such a policy has often been discussed in the past, A&H found that lowering the cost of the DW was not effective in their experiment. Nevertheless, we consider here an extreme scenario, the Free DW treatment, which is identical to the Stigma treatment except that the cost of the DW is now set to 0 in rounds 16-30. Under this scenario ***NoSt*** is not only the unique equilibrium, but DW borrowing becomes a dominant strategy for a bank. Indeed, the profit of an illiquid bank (whether solvent or insolvent) in period 2 when it does not borrow at the DW is $-c + k$, whereas the bank's expected profit if it borrows at the DW becomes $(1 - \theta(n))k$. With c = 40 and k =50, the bank is better off borrowing at the DW even under the highest detection probability $\theta(1)$=3/4. This is the main difference from the A&H treatments in which the DW cost was positive and both ***St*** and ***NoSt*** were equilibria.

Predictions

The previous analysis suggests the following predictions:

- ***P1***: In the first 15 rounds of every treatment, subjects coordinate on ***St***, the stigma equilibrium.
- ***P2***: In the last 15 rounds of every treatment, subjects coordinate on ***NoSt***, the unique (stigma-free) equilibrium.
- ***P3***: Behavior converges to ***NoSt*** at a faster rate in the High Random Borrowing treatment than in the Random Borrowing treatment.
- ***P4***: In the Free DW treatment behavior switches immediately to the dominant strategy ***NoSt***.

4. The Results from the Experiments

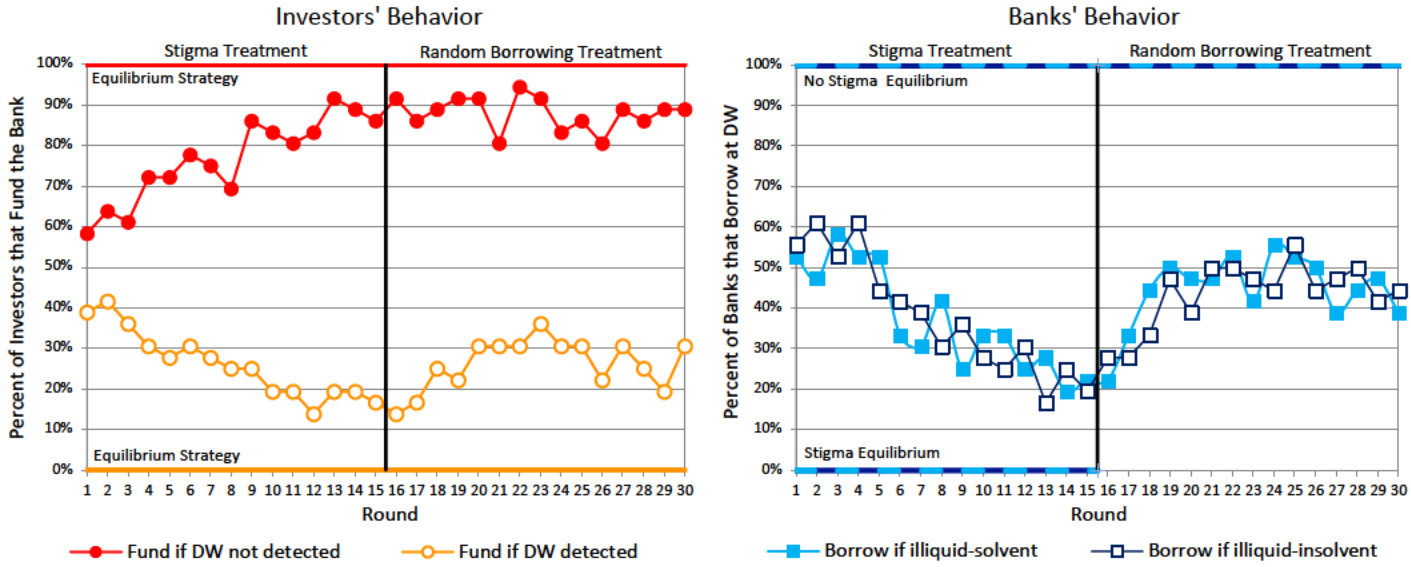
4.1 The Random Borrowing Experiment

Figure 1 shows the banks' and investors' decisions in the Random Borrowing experiment. The left panel displays the percentage of investors in each round that fund banks detected (hollow dots) and not detected (full dots) at the DW across the 6 sessions. The right panel displays the percentage of banks that borrow at the DW when insolvent-illiquid (hollow squares) and when solvent-illiquid (full squares). In each panel, horizontal lines indicate predicted equilibrium behavior, while a

[16] "*To make the Discount Window more attractive, the government is considering ways to make it cheaper for borrowers*" see "US prepare rule forcing banks to tap the Fed Discount Window," Bloomberg, January 18, 2024.

vertical line separates the Stigma treatment (first 15 rounds) from the Random Borrowing treatment (last 15 rounds). Figures A1 to A3 in the appendix show choices at the session level.

Figure 1: The Random Borrowing Experiment



Notes The Figure shows the share of investors who fund banks (left panel) and the share of banks who borrow at the DW (right panel) in each round averaged across the 6 sessions. The first 15 rounds of the experiment are conducted under the Stigma treatment, the last 15 rounds under the Random Borrowing treatment.

Table 2: Treatment Effects in the Random Borrowing Experiment (averages in first and last three rounds of each treatment)

	Stigma Treatment		Random Borrowing	
	Rounds 1-3	Rounds 13-15	Rounds 16-18	Rounds 28-30
Share of investors who fund a non-detected bank	0.611* (0.238)	0.889 (0.035)	0.889 (0.099)	0.880 (0.082)
Share of investors who fund a detected bank	0.389* (0.153)	0.185 (0.152)	0.185 (0.125)	0.250 (0.156)
Share of banks who borrow at the DW when illiquid	0.546*** (0.164)	0.218 (0.032)	0.315** (0.153)	0.444*** (0.072)

Notes The table shows the share of investors who fund banks and the share of banks who borrow at the DW in the first and last three rounds of each treatment. The first 15 rounds of the experiment are conducted under the Stigma treatment, the last 15 rounds under the Random Borrowing treatment. The table shows averages and standard deviations (in parentheses) across the 6 sessions. We use a paired permutation test to compare choices at the end of the Stigma treatment (rounds 13-15 in column 2) with choices at the beginning of the Stigma treatment (rounds 1-3 in column 1), as well as at the beginning (rounds 16-18 in column 3) and end (rounds 28-30 in column 4) of the Random Borrowing treatment. The superscripts ***, **, and * indicate that the null hypothesis of equal means is rejected at the 1%, 5%, and 10% significance levels.

Table 2 displays averages in the first and last three rounds of each treatment. We establish statistical significance of treatment effects with a series of 2-tail paired permutation tests (Good 2000), an exact non-parametric test, that compare subjects' decisions at the end of the Stigma treatment (rounds 13-15) with their decisions at the beginning of the Stigma treatment (rounds 1-3), at the beginning of the Random Borrowing treatment (rounds 16-18), and at the end of the

Random Borrowing treatment (rounds 28-30). As shown in Table A1 in the appendix, tests based on the first and last five (instead of three) rounds of each treatment produce similar conclusions.

4.1.1 The stigma treatment

We start with the Stigma treatment in the first 15 rounds. The left panel of Figure 1 shows that investors rapidly learn to fund banks not detected at the DW and to stigmatize (i.e. not fund) banks detected at the DW. As indicated in Table 2, the investors' funding behavior is significantly different (albeit only at the 10%) in the first and last 3 rounds of the Stigma treatment.

Turning now to the right panel of Figure 1, observe first that, consistent with theory (since they have the same payoff function), illiquid banks make essentially the same decisions throughout the experiment, regardless of whether they are solvent or insolvent. To simplify, we therefore combine both types of illiquid banks when we test for treatment effects in Table 2.[17] The right panel of Figure 1 shows that a majority of banks initially borrow at the DW at the start of the experiment, but their choices quickly trend toward the stigma equilibrium. Specifically, the proportion of illiquid banks that borrow at the DW drops from 55% in the first three rounds, to 22% in the last three rounds of the Stigma treatment, a difference significant at the 1% level (see Table 2).

To sum up, although behavior does not fully converge to the stigma-equilibrium (under which no bank borrows at the DW), it is clear that the treatment was successful in the sense that the DW becomes severely stigmatized by round 15. Hence, we find evidence supporting prediction ***P1***. As we shall see, the other two experiments strongly supports prediction ***P1*** as well. These results therefore replicate A&H's findings, as shown in Figure A4 in the appendix where we reproduce the results from A&H's control treatment. They also confirm that DW stigma, a behavior believed to be prevalent in the field but rarely observed, can emerge in the lab.

4.1.2 The random borrowing treatment

Does the introduction of random borrowing in round 16 cure DW stigma? To answer this question we turn to the results in the last 15 rounds of the experiment. Investors' behavior in the left panel of Figure 1 is little changed after the stigma cure is introduced. This result is confirmed in Table

[17] As indicated, in Table A2 in the appendix similar treatment effects emerge when we separate illiquid-solvent and illiquid-insolvent banks.

2, which does not reveal the presence of a statistically significant treatment effect between the last three rounds of the Stigma treatment, and either the first or last three rounds of the Random Borrowing treatment. Nevertheless, there is a noticeable uptick in the proportion of investors that fund a detected bank in the last 15 rounds (see Figure 1). As shown in the left panel of Figure A5 in the appendix, A&H observe a similar pattern in their random borrowing treatment. They show that it is due to the random borrowing process: Because solvent-liquid banks are added to the pool of banks detected at the DW, the investors' incentive not to fund a detected bank becomes weaker.

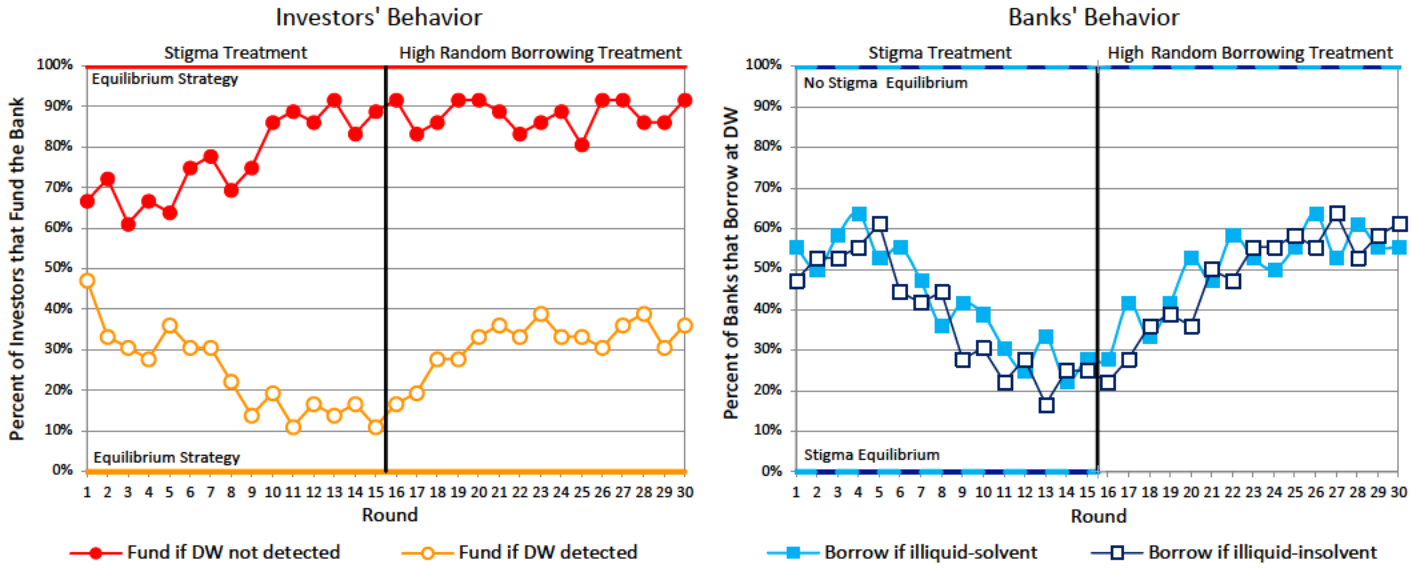
In contrast to the investors' behavior, there is a clear and immediate treatment effect for banks in the right panel of Figure 1. The proportion of illiquid banks that borrow voluntarily at the DW window increases from 22% in the last three rounds of the Stigma treatment, to 32% immediately after random borrowing is introduced (rounds 16-18), a difference significant at the 5% level, and to 44% in the last three rounds of the experiment, a difference significant at the 1% level (see Table 2). However, despite the marked increase in voluntary DW borrowing, there is no indication that random borrowing cures stigma. DW borrowing does not exceed 50% in any of the last five rounds of the experiment (see Figure 1), with no clear tendency to increase. This pattern is far from the 100% required under the no-stigma equilibrium, and well below the 75% to 80% in the last 10 rounds of A&H's Random Borrowing treatments (see Figures A5 and A6 in the appendix).

To sum up, whereas random borrowing helps prevent stigma in A&H's experiment (i.e. help subjects coordinate on the stigma-free equilibrium when a new DW is launched), and although it significantly promotes DW borrowing in this experiment, it does not fully cure a severely stigmatized DW. Therefore, we find no evidence to support prediction ***P2***.

4.2 The High Random Borrowing Experiment

A&H found that banks learn to borrow voluntarily at the DW from the experience they garner when they are required to borrow. Would making involuntary borrowing more frequent help bank converge toward the stigma-free equilibrium? To answer this question we now turn to the High Random Borrowing treatment in which the probability of being asked to borrow at the DW is doubled from 1/6 to 1/3. The results are presented in Figure 2 and Table 3.

Figure 2: The High Random Borrowing Experiment



Notes The Figure shows the share of investors who fund banks (left panel) and the share of banks who borrow at the DW (right panel) in each round averaged across the 6 sessions. The first 15 rounds of the experiment are conducted under the Stigma treatment, the last 15 rounds under the High Random Borrowing treatment.

Table 3: Treatment Effects in the High Random Borrowing Experiment (averages in first and last three rounds of each treatment)

	Stigma Treatment		High Random Borrowing	
	Rounds 1-3	Rounds 13-15	Rounds 16-18	Rounds 28-30
Share of investors who fund a non-detected bank	0.667* (0.127)	0.880 (0.108)	0.870 (0.097)	0.880 (0.042)
Share of investors who fund a detected bank	0.370** (0.097)	0.139 (0.110)	0.213 (0.096)	0.352* (0.103)
Share of banks who borrow at the DW when illiquid	0.528*** (0.093)	0.250 (0.030)	0.315*** (0.038)	0.574*** (0.067)

Notes The table shows the share of investors who fund banks and the share of banks who borrow at the DW in the first and last three rounds of each treatment. The first 15 rounds of the experiment are conducted under the Stigma treatment, the last 15 rounds under the High Random Borrowing treatment. The table shows averages and standard deviations (in parentheses) across the 6 sessions. We use a paired permutation test to compare choices at the end of the Stigma treatment (rounds 13-15 in column 2) with choices at the beginning of the Stigma treatment (rounds 1-3 in column 1), as well as at the beginning (rounds 16-18 in column 3) and end (rounds 28-30 in column 4) of the High Random Borrowing treatment. The superscripts ***, **, and * indicate that the null hypothesis of equal means is rejected at the 1%, 5%, and 10% significance levels.

Observe first in Figure 2 that the Stigma treatment is again successful at stigmatizing the DW in the first 15 rounds of the experiment. In particular, the proportion of illiquid banks that borrow at the DW is more than halved between the first and the last three rounds of the Stigma treatment, from 53% to 25%, a difference significant at the 1% level (see Table 2). This therefore provides additional support to prediction ***P1***. Note also that, as expected, there is no statistical difference between subjects' choices in the Stigma treatment of the first and second experiments (compare

the first 15 rounds in Figures 1 and 2).[18]

Next consider the High Random Borrowing treatment in the last 15 rounds. Starting with investors in the left panel of Figure 2, we can see that funding a non-detected bank remains unaffected, whereas funding a detected bank becomes more prevalent after high random borrowing is introduced. Table 3 shows that the proportion of investors who fund a detected bank grows from 14% in the last three rounds of the Stigma treatment, to 35% in the last three rounds of the High Random Borrowing treatment. The difference, however, is only significant at the 10% level. As mentioned earlier, this result reflects the higher share of liquid banks that are added to the pool of detected banks by random borrowing, which investors find profitable to fund.

The right panel of Figure 2 shows that banks' decisions change substantially after round 15. The proportion of illiquid banks that borrow at the DW grows from 25% in the last three rounds of the Stigma treatment, to 31% and 57% in the first and last three rounds of the High Random Borrowing treatment, respectively (see Table 3). Both of these differences are statistically significant at the 1% level. A comparison of Tables 2 and 3 indicates that the treatment effect is stronger in the High Random Borrowing treatment than in the Random Borrowing treatment. While the proportion of banks borrowing in rounds 16 to 18 are statistically indistinguishable across the two experiments (31% and 32%, respectively), the proportion of banks that borrow in the last three rounds is significantly different (at the 5% level) in the High Random Borrowing treatment (57%) than in the Random Borrowing treatment (44%). Nevertheless, there is still no evidence that behavior is converging toward the stigma-free equilibrium in the High Random Borrowing treatment. The proportion of DW borrowers never exceeds 64% and the trend in the last rounds of the experiment seems relatively flat.

Hence, we only find partial support for prediction ***P3***: An increase in the frequency of required random borrowing promotes voluntary DW borrowing, but it does not cure stigma fully.

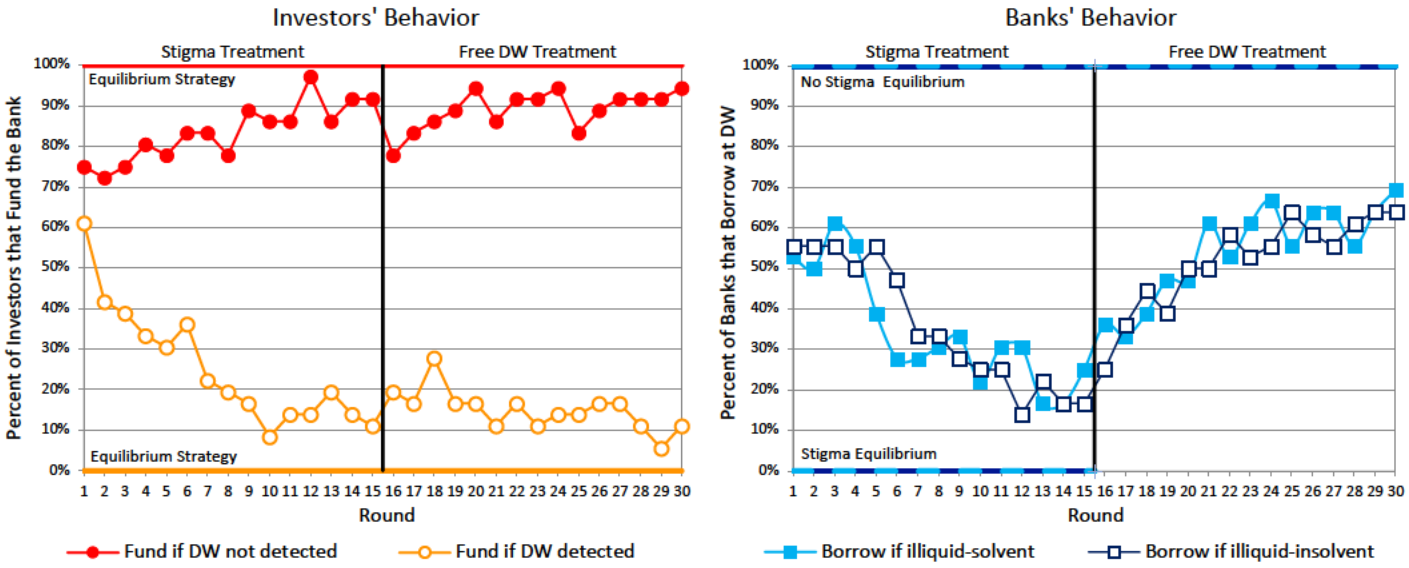
[18] We establish statistical significance of differences between experiments with a 2-tail permutation test of differences in means. For instance, when we compare the last three rounds of the Stigma treatment in the Random Borrowing and in the High Random Borrowing experiments, we find no statistical difference in the proportion of investors who fund a detected bank (P-value=55.1%), and in the proportion of investors who fund a bank not detected (P-value=92.8%).

4.3 The Free Discount Window Experiment

We now consider a scenario with a free DW under which DW borrowing is not only an equilibrium, but it is also a dominant strategy. Can such an extreme intervention cure stigma? Before we answer the question, observe in Figure 3 and Table 4 that behavior in the first 15 rounds of the Free DW experiment is very similar (and in fact statistically indistinguishable) to behavior in the other two experiments (Figures 1 and 2, Tables 2 and 3). Hence, the Stigma treatment again successfully stigmatized the DW consistent with prediction ***P1***.

The left panel of Figure 3 shows that making the DW free does not affect the investors' funding decisions. Table 4 confirms that there is no statistical difference between the funding decisions made in the last three rounds of the Stigma treatment, and the first and last three rounds of the Free DW treatment. Note also that the proportion of investors who fund a detected bank is at its lowest toward the end of the experiment. This is in contrast with the other two experiments with random borrowing in which there was an uptick in this measure in later rounds. In fact, there is a statistically significant difference between the proportion of investors who fund detected banks in the last three rounds of the Free DW treatment compared to the Random Borrowing treatment (at the 5% level) and compared to the High Random Borrowing treatment (at the 1% level). This result supports the hypothesis that random borrowing promotes the funding of banks detected at the DW.

Figure 3: The Free DW Experiment



Notes The Figure shows the share of investors who fund banks (left panel) and the share of banks who borrow at the DW (right panel) in each round averaged across the 6 sessions. The first 15 rounds of the experiment are conducted under the Stigma treatment, the last 15 rounds under the Free DW treatment.

Table 4: Treatment Effects in the Free DW Experiment
(averages in first and last three rounds of each treatment)

	Stigma Treatment		Free DW	
	Rounds 1-3	Rounds 13-15	Rounds 16-18	Rounds 28-30
Share of investors who fund a non-detected bank	0.741* (0.103)	0.898 (0.074)	0.824 (0.096)	0.926 (0.084)
Share of investors who fund a detected bank	0.472*** (0.130)	0.148 (0.057)	0.213 (0.155)	0.093 (0.067)
Share of banks who borrow at the DW when illiquid	0.551*** (0.117)	0.190 (0.067)	0.356*** (0.081)	0.630*** (0.124)

Notes The table shows the share of investors who fund banks and the share of banks who borrow at the DW in the first and last three rounds of each treatment. The first 15 rounds of the experiment are conducted under the Stigma treatment, the last 15 rounds under the Free DW treatment. The table shows averages and standard deviations (in parentheses) across the 6 sessions. We use a paired permutation test to compare choices at the end of the Stigma treatment (rounds 13-15 in column 2) with choices at the beginning of the Stigma treatment (rounds 1-3 in column 1), as well as at the beginning (rounds 16-18 in column 3) and end (rounds 28-30 in column 4) of the Free DW treatment. The superscripts ***, **, and * indicate that the null hypothesis of equal means is rejected at the 1%, 5%, and 10% significance levels.

The right panel of Figure 3 shows that DW borrowing increases at a relatively steady pace once the DW becomes free in round 16. The proportion of illiquid banks that borrow at the DW increases from 19% in the last three rounds of the Stigma treatment to 36% and 63% in the first and last three rounds of the Free DW treatment, with both differences significant at the 1% level (see Table 4). The treatment effect is strongest in the Free DW treatment: 63% of banks borrow at the DW in the last three rounds compared to 44% and 57% in the Random Borrowing and High Random Borrowing treatments, respectively. The difference, however, is only statistically significant for the Random Borrowing treatment (at the 5% level). Nevertheless, despite being a dominant strategy, not every bank borrows at the DW. Further, with less than two thirds of banks going to the DW after 15 rounds of free DW, behavior is still not close to the stigma-free equilibrium. The borrowing trend, however, remains positive throughout the treatment, and it is conceivable that banks would ultimately end up coordinating fully on the no-stigma strategy.

To sum up, we do not find strong support for prediction ***P4***. While DW borrowing steadily increases when the cost of the DW is reduced to zero, banks' decisions do not immediately shift to the dominant strategy of DW borrowing.

5. Why are the DW Stigma Cures Ineffective?

This section uses econometric methods to shed light on why the stigma cures were unable to shift behavior fully toward the no-stigma equilibrium. 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:

$$Y^*_{i,t,1} = \alpha_0 + \alpha_1 Rand_i + \alpha_2 HRand_i + \alpha_3 FreeD_i + \alpha_4 X_{i,t-1} + \alpha_5 Z_{t-1} + \varepsilon_{i,t,1}$$
$$Y^*_{i,t,2} = \beta_0 + \beta_1 Rand_i + \beta_2 HRand_i + \beta_3 FreeD_i + \beta_4 X_{i,t-1} + \beta_5 Z_{t-1} + \varepsilon_{i,t,2} \qquad (1)$$

where $Y^*_{i,t,1}$ and $Y^*_{i,t,2}$ are latent variables corresponding to bank i's decisions to borrow at the DW in round t if solvent-illiquid and if insolvent-illiquid, respectively;[19] $Rand_i$, $HRand_i$ and $FreeD_i$ are dummy variables equal to 1 when subject i participated in the Random Borrowing, High Random Borrowing and Free DW experiment, respectively; $X_{i,t-1}$ and Z_{t-1} capture the private and public feedback subject i receives at the end of the previous round; finally, the pair $\{\varepsilon_{i,t,1}, \varepsilon_{i,t,2}\}$ follows a bivariate normal distribution with correlation ρ. Table 5 reports the marginal effects estimated by full information maximum likelihood for three different specifications.

Specification 1 in Table 5 focuses on treatment effects. The results confirm that the three cures are effective in the sense that DW borrowing increases significantly between the first and last 15 rounds of each experiment. Note also that a bank's decisions to borrow at the DW if solvent-illiquid and if insolvent-illiquid are positively and highly correlated (row 20). This is consistent with theory (since every illiquid bank has the same payoff function) and it confirms that the two decisions should not be modelled separately, thereby supporting our joint econometric model.

Specification 2 controls for the private and public feedback given to subjects between rounds. First, note that the dummy variables are no longer significant for the two treatments with random borrowing (rows 1 and 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 between rounds, banks in the two random borrowing treatments *learn* to behave differently than in the Stigma treatment.

Not surprisingly, we find that banks' behavior exhibits strong inertia (rows 4 and 5). A bank that chooses to borrow at the DW if insolvent-illiquid (respectively, if solvent-illiquid) is 46% (respectively, 45%) more likely to do so again in the next round.

[19] Recall that we observe the DW decision under both contingencies for each bank because we use the strategy method.

Table 5: 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-		**A&H's Experiment** The Bank Borrows at DW in *t* if illiquid-	
		Insolvent	Solvent	Insolvent	Solvent	Insolvent	Solvent
1	Random Borrowing Treatment	0.060* (0.038)	0.063* (0.039)	0.043 (0.033)	0.036 (0.029)	0.078 (0.052)	0.065 (0.054)
2	High Random Borrowing Treatment	0.106*** (0.040)	0.119*** (0.045)	0.029 (0.040)	0.024 (0.041)	—	—
3	Free DW Treatment	0.146*** (0.041)	0.165*** (0.044)	0.137*** (0.037)	0.152*** (0.036)	—	—
4	Bank Chose to Borrow at DW in *t-1* if Insolvent-Illiquid	—	—	0.463*** (0.026)	—	0.578*** (0.042)	—
5	Bank Chose to Borrow at DW in *t-1* if Solvent-illiquid	—	—	—	0.453*** (0.030)	—	0.578*** (0.037)
6	Bank Actually Borrowed at DW in *t-1* * Detected	—	—	-0.251*** (0.074)	-0.257*** (0.092)	-0.385*** (0.087)	-0.293*** (0.077)
7	Bank Actually Borrowed at DW in *t-1* * Detected * Not Funded	—	—	-0.036 (0.082)	-0.038 (0.090)	-0.079 (0.091)	-0.052 (0.086)
8	Bank Actually Borrowed at DW in *t-1* * Not Detected	—	—	0.088** (0.041)	0.089** (0.038)	0.099** (0.049)	0.120** (0.049)
9	Bank Actually Borrowed at DW in *t-1* * Not Detected * Not Funded	—	—	0.041 (0.101)	-0.030 (0.079)	-0.011 (0.081)	0.061 (0.078)
10	Bank was Undetectable in *t-1* (i.e. Liquid or did not borrow at DW) * Not funded	—	—	0.022 (0.034)	-0.015 (0.031)	0.033 (0.031)	0.049 (0.033)
11	Bank was Forced to borrow at DW in *t-1* * Detected	—	—	-0.082 (0.140)	-0.081 (0.179)	-0.159 (0.134)	-0.135 (0.125)
12	Bank was Forced to borrow at DW in *t-1* * Detected * Not Funded	—	—	0.073 (0.142)	0.124 (0.171)	-0.044 (0.165)	-0.225 (0.148)
13	Bank was Forced to borrow at DW in *t-1* * Not Detected	—	—	0.119* (0.063)	0.145* (0.089)	0.346*** (0.073)	0.354*** (0.080)
14	Bank was Forced to borrow at DW in *t-1* * Not Detected * Not Funded	—	—	0.072 (0.126)	0.146 (0.152)	-0.021 (0.170)	0.048 (0.179)
15	Probability of Detection in *t-1*	—	—	-0.067 (0.057)	-0.063 (0.050)	-0.061 (0.061)	-0.022 (0.061)
16	Percentage of Banks that Chose to Borrow at DW if Solvent-Illiquid in *t-1*	—	—	0.076 (0.054)	0.137** (0.055)	-0.010 (0.063)	0.376*** (0.074)
17	Percentage of Banks that Chose to Borrow at DW if Insolvent-Illiquid in *t-1*	—	—	0.142** (0.056)	0.074 (0.062)	0.300*** (0.071)	-0.045 (0.061)
18	Percentage of Investors that Chose to Invest in Bank not Detected at DW in *t-1*	—	—	0.014 (0.069)	-0.024 (0.070)	-0.051 (0.077)	-0.104 (0.075)
19	Percentage of Investors that Chose to Invest in Bank Detected at DW in *t-1*	—	—	0.245*** (0.061)	0.237*** (0.068)	0.210*** (0.068)	0.261** (0.075)
20	ρ	0.410*** (0.035)		0.264*** (0.038)		0.259*** (0.053)	
21	Log Likelihood / N	-4,265.1	3,240	-3,331.7	3,132	-2,988.6	3,456

Marginal effects (evaluated at means) are reported. Standard errors (in parenthesis) are clustered at the individual level. The last two columns report regression results using data from the experiment conducted by Armantier and Holt (2020).

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 25% 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 the significance)

of this effect, however, is substantially smaller than DW detection (roughly 9% versus 25%). Hence, banks react more strongly to negative than to positive feedback. The subjects' failure to coordinate on the stigma-free equilibrium in the experiment can therefore be explained in large part by DW detection which drives behavior away from DW borrowing. 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 rather than its financial consequence that seems to drive the banks subsequent behavior.

Rows 11 to 14 measure the impact of random borrowing. Only two parameters are significant (albeit at the 10% level). Namely, we find that a bank is more likely to borrow voluntarily at the DW when in the previous round it was selected to borrow at the DW and not detected (row 13).

Finally, consider the impact of public feedback in rows 15 to 22. The DW actual detection probability in the previous round does not appear to influence banks' behavior (row 15). Rows 16 and 17 reveal a significant imitation effect: The more banks go to the DW when solvent-illiquid (respectively, insolvent-illiquid), the more likely a subject is to do the same in the next round. This result is consistent with an effort to coordinate among banks. Interestingly, while the investors' funding decisions for detected banks appear to have no influence on a bank's behavior (row 18), 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 19).

The last two columns of Table 5 report the results of the regression estimated with the data collected in A&H's experiment. Observe first that the results are remarkably similar to those in specification 2. In particular, the same parameters are statistically significant. The magnitude of the effects, however, are smaller in the present experiment. In particular, the two main channels through which subjects learned to coordinate on the stigma-free equilibrium in A&H (involuntary DW experience and imitation) are significantly more muted here. Having to experience DW borrowing involuntarily without negative consequences (i.e. being selected and not being detected) increased the probability to borrow at the DW in the next round by 35% in A&H, versus only 12% to 15% in this experiment (row 13). Similarly, a 10% increase in the share of banks that go to the DW increases the probability to borrow at the DW in the next round by 3% to 4% in A&H, versus only 1.4% in this experiment (rows 16 and 17). These differences are significant at the 1% level. Hence, it appears that once subjects have coordinated on the stigma strategy, they are less

responsive to the feedback they receive and less willing to adjust their behavior.

Interestingly, A&H found a similar, albeit opposite, form of inertia after convergence. A&H had subjects play the Random Borrowing treatment for 20 rounds followed by the Stigma treatment for 10 rounds. As shown on Figure A6 in the appendix, behavior converged to the no-stigma equilibria within 20 rounds, but the DW did not become stigmatized after random borrowing was removed. Instead, banks continued to coordinate on the no-stigma equilibrium.

To sum up, the econometric analysis provides insights on why the cures do not break DW stigma. Although the drivers of behavior are the same as in A&H, subjects in the present experiment are generally less responsive to the environment. In particular, the channels that helped banks learn to coordinate on the no-stigma equilibrium in A&H become significantly more muted once behavior has converged to the stigma equilibrium.

5. Conclusion

DW stigma is a major challenge to central banks' lender of last resort responsibilities. After the 2023 banking turmoil, U.S. regulators proposed various reforms to remove stigma at the Fed's DW, including a mandate for banks to borrow at the DW regularly. This proposal finds partial support in A&H who found that required random borrowing can prevent the formation of stigma when a new (i.e. *not yet stigmatized*) DW facility is introduced. In this paper, we tested experimentally whether two interventions, random borrowing and a free DW, can cure the stigma attached to an *already stigmatized* DW.

Our results show that both types of interventions significantly promote DW borrowing. However, we find no evidence that they cure DW stigma fully. In particular, in the last rounds of our Random Borrowing (respectively, High Random Borrowing) treatment, the proportion of banks that borrow at the DW do not exceed one-half (respectively, two-thirds) and the borrowing trend is flat in the last rounds of the experiment. Similarly, setting the cost of the DW to zero, an extreme scenario under which DW borrowing is not only the equilibrium but it is also a dominant strategy, also fails to cure stigma fully. An econometric analysis reveals that once the DW becomes stigmatized, inertia sets in and subjects' behavior become less responsive to the feedback they

receive. These results, combined with the results in A&H, suggest that required random borrowing can be considered a preventive, but not a curative intervention to treat DW stigma.

Our results are reminiscent of the long literature on coordination failure in games with pareto-ranked equilibria such as the *weakest-link or stag-hunt* game. Various interventions (e.g. communication, financial incentives, punishment) have been shown to improve coordination in these game, but they typically fail to help behavior converge fully to the first-best equilibrium (for recent contributions see e.g. Jacquemet et al. 2018, and Le Lec et al. 2023). Further, using a within-subject design similar to ours, Brandts and Cooper (2006) find the impact of these coordination-inducing interventions to be weaker when subjects first experience an extensive period of coordination failure. This is consistent with our finding that required random borrowing is less effective when subjects first experience a stigmatized DW.

Our results also echo the Fed's experience. Over the years, DW policies have been modified on multiple occasions with the explicit objective of promoting DW borrowing and mitigating stigma.[20] To this day, none of these reforms seem to have been satisfactory (McLaughlin 2024). Our results suggest that indeed, curing pre-existing DW stigma is difficult. In particular, we find that the latest reform proposed, mandating regular DW borrowing, is unlikely to be effective.[21] In fact, finding that even extreme interventions, such as making the DW free, may not be sufficient to fully cure stigma raises the question of whether there is any hope of removing the stigma already attached to the Fed's DW. DW stigma has clearly become deeply engrained among practitioners and it may be impossible to change that norm.[22] Two approaches could be envisioned instead.

[20] This was the case in 2003 when the Fed fundamentally changed the DW policy by introducing a penal rate (i.e. a rate with a spread over the Federal Open Market Committee's target rate), a tiered credit program with advantageous terms for strong and well-capitalized institutions (the primary credit program), and a "no question asked" lending approach. DW policies were also amended in 2007 at the onset of the global financial crisis when the penalty spread was cut in half, from 100 to 50 basis points (bps), and the loans' term was temporarily extended from overnight to 30, and then 90 days. Finally, on March 15, 2020, at the onset of the COVID-19 pandemic, the Fed suspended the penalty spread, cut the primary credit rate 150bps to 0.25% (the lowest DW rate ever), extended the term of DW loans back to 90 days, publicly encouraged DW borrowing and made its weekly disclosure policy more opaque. For details see e.g. Carlson and Rose (2017), Ennis and Price (2020), or McLaughlin (2023, 2024).

[21] Although it may not cure stigma, required borrowing may have value. In particular, we have shown that it promotes DW borrowing. Further, it would ensure that banks are operationally ready to tap the DW should the need arise.

[22] Bankers often quip that any borrowing at the DW would be followed by two phone calls, one from the regulator asking if everything is ok, and one from their boss asking them to clear their desk.

First, new (i.e. not yet stigmatized) temporary emergency facilities could be introduced when liquidity markets become severely strained. These temporary facilities could be designed specifically to address the source of the problem at hand. This is in essence what the Fed has done in recent years when it introduced the Term Auction Facility at the onset of the Global Financial Crisis in December 2007, or the Bank Term Funding Program in March 2023. This approach, however, may not be fully satisfactory. Indeed, although such *temporary* facilities could fix nascent liquidity crises, they would not prevent them. Only a *permanent* facility like the DW could do so. This leads us to the second approach.

Second, instead of trying to fix the DW, new permanent backstop facilities could be designed to be stigma-proof. One possible example is the Standing Repo Facility introduced by the Fed in 2021, where primary dealers and banks can obtain overnight liquidity. This facility was designed specifically to mitigate stigma concerns. In particular, it accepts only high quality collateral (Treasuries and agency securities) and its rate is determined competitively by auction. Although it has been little used, interest in the facility as a possible complement to the DW has grown in the aftermath of the 2023 banking turmoil.[23] In fact, our results suggest that if the Fed intends to protect the Standing Repo Facility against the formation of stigma, it should consider required random borrowing for this facility, not for the DW.

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Appendix 1 : Instructions in Stigma Treatment

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**

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**. A bank's type is 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.

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

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.

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**.

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:
1. **Sell some of its own assets** at a cost of **40**, or
2. **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.

Appendix 2 : Additional Figures and Tables

Figure A1 : Random Borrowing Experiment

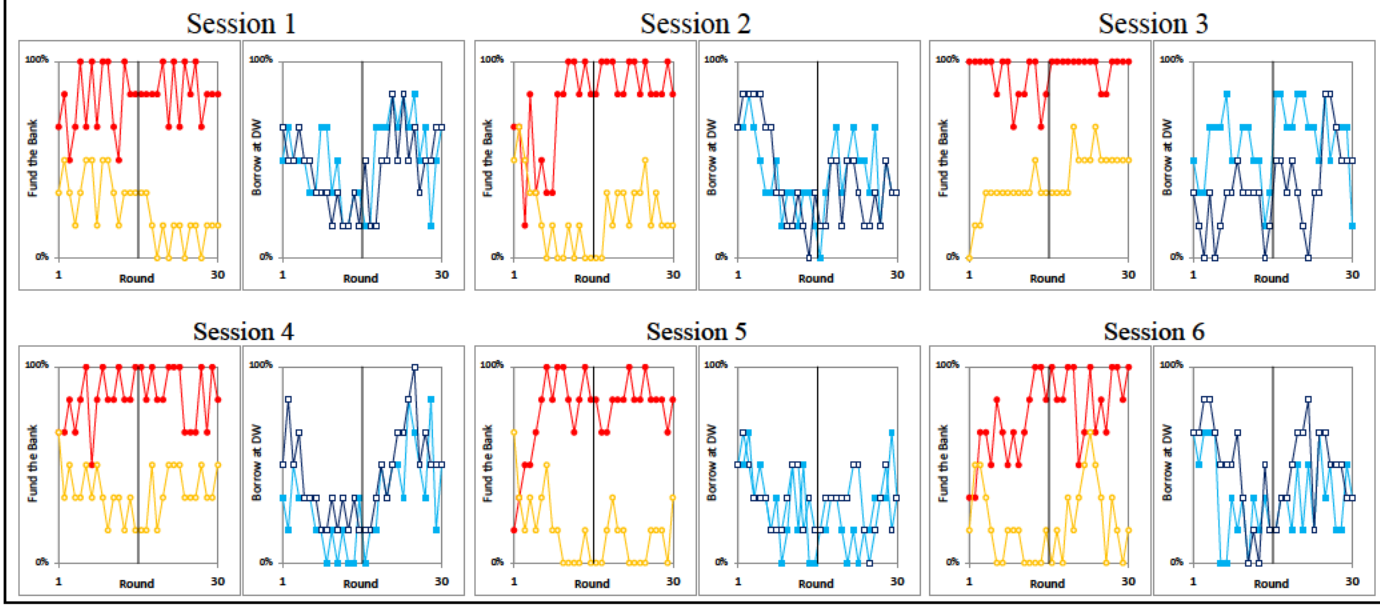


Figure A2 : High Random Borrowing Experiment

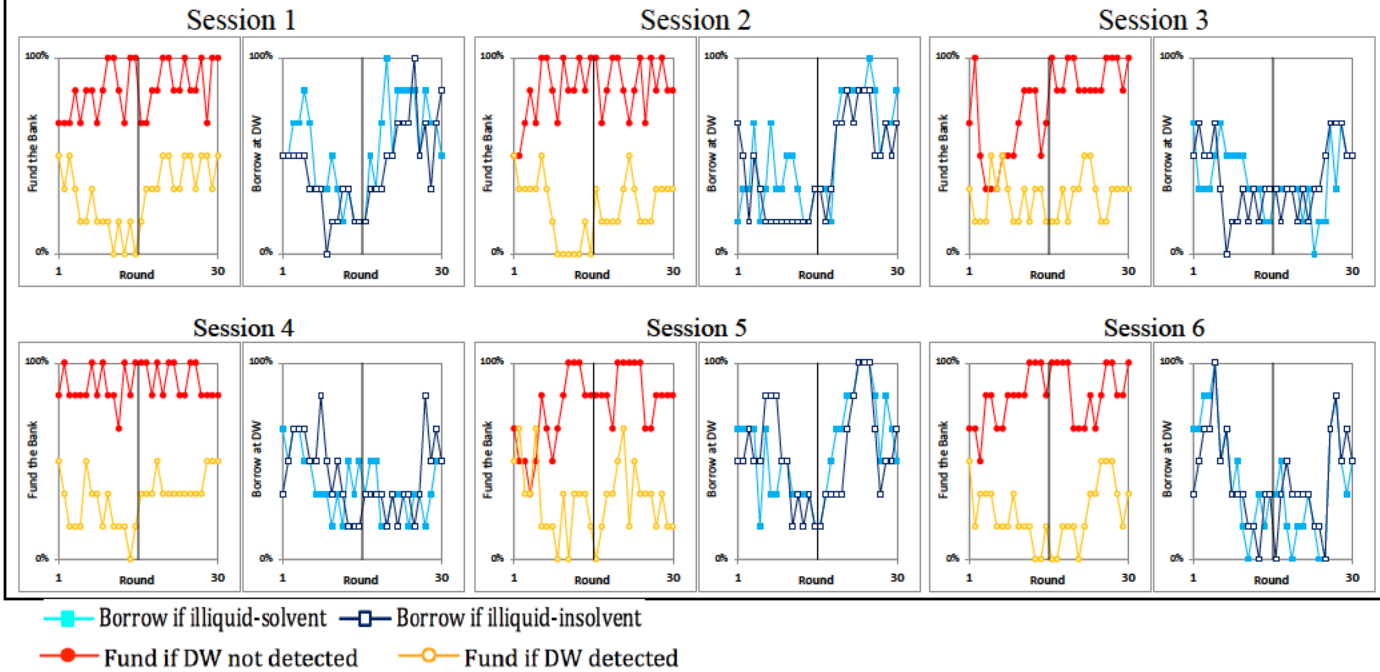


Figure A3 : Free Discount Window Experiment

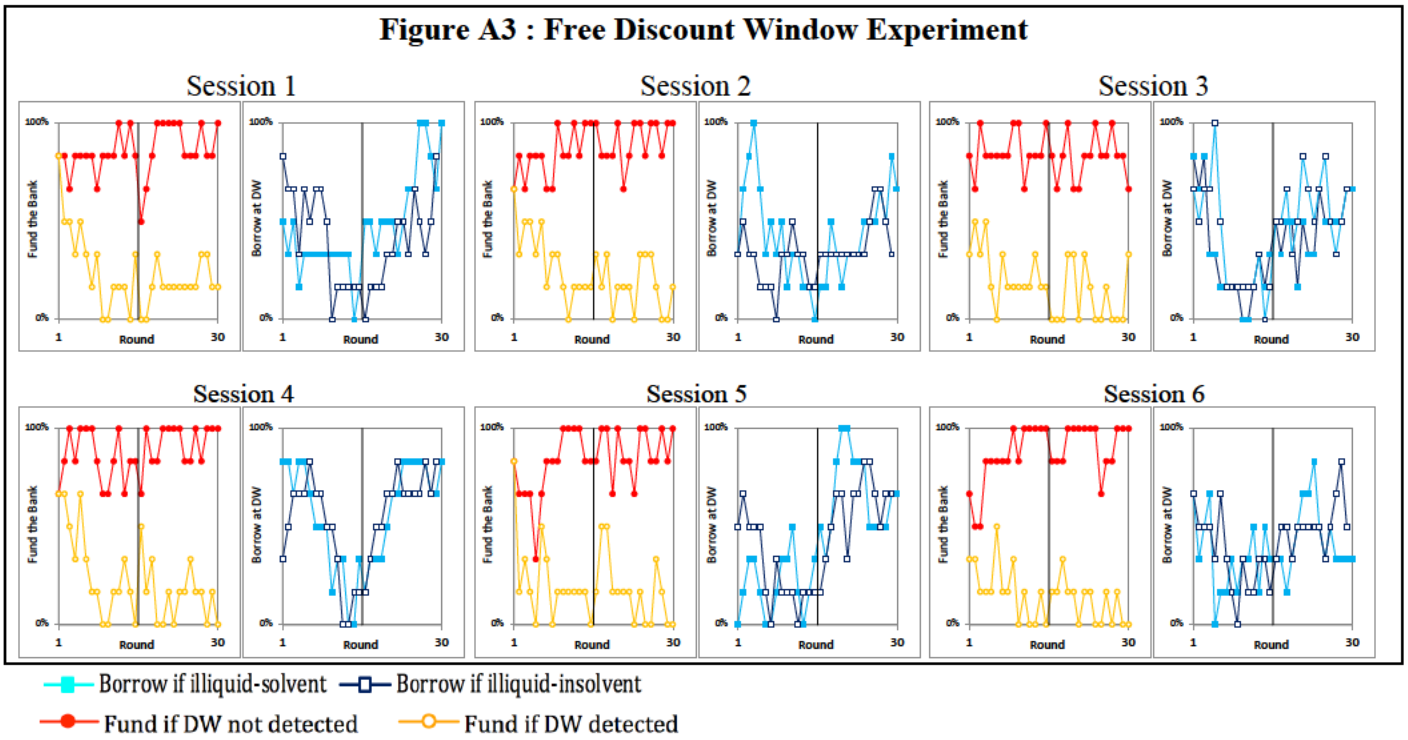
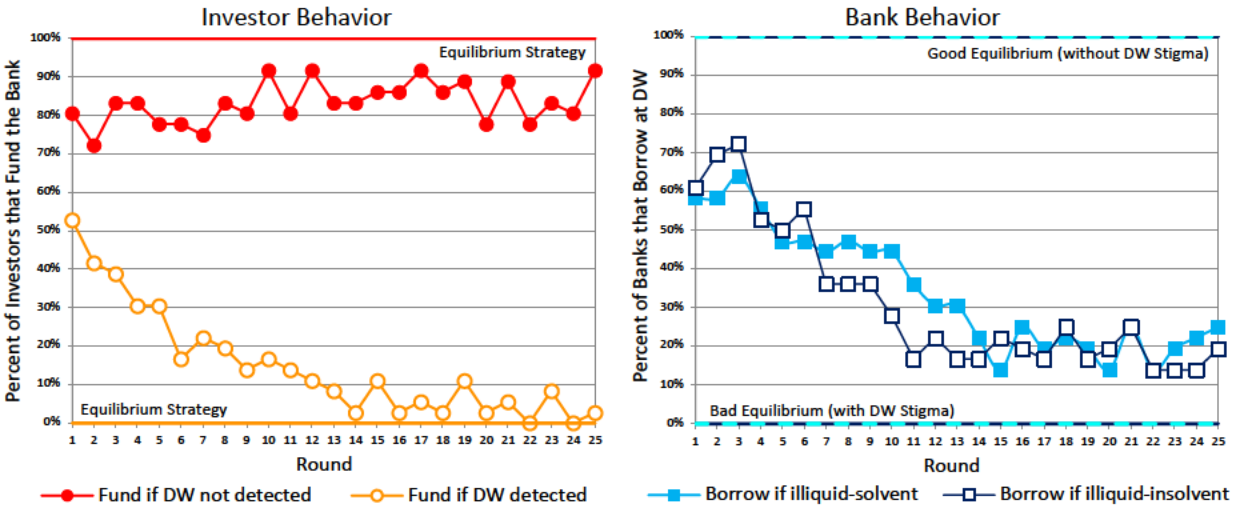
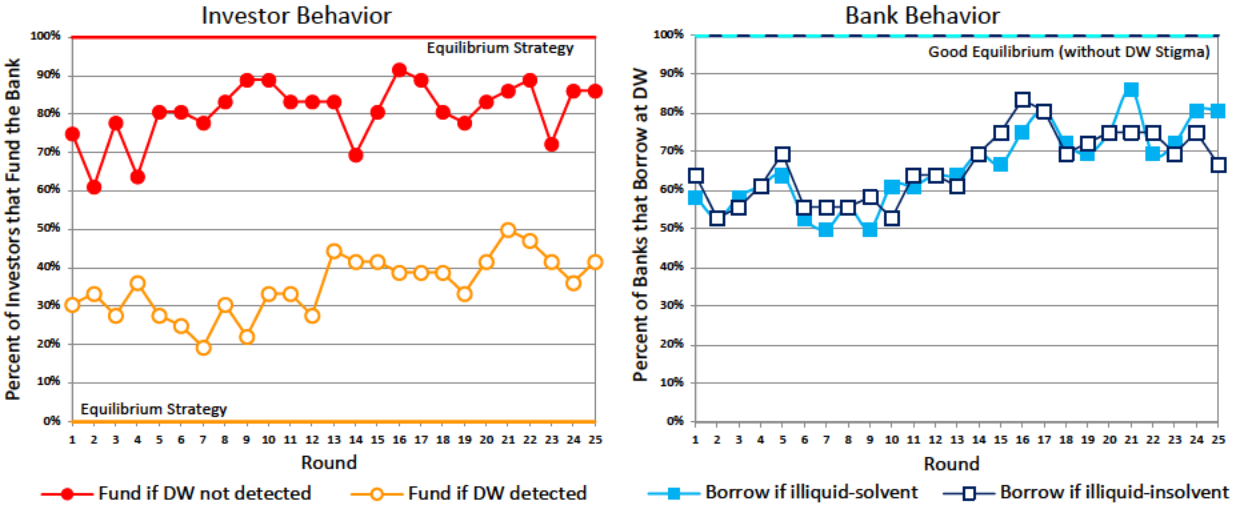


Figure A4: Control Treatment in Armantier and Holt (2020)



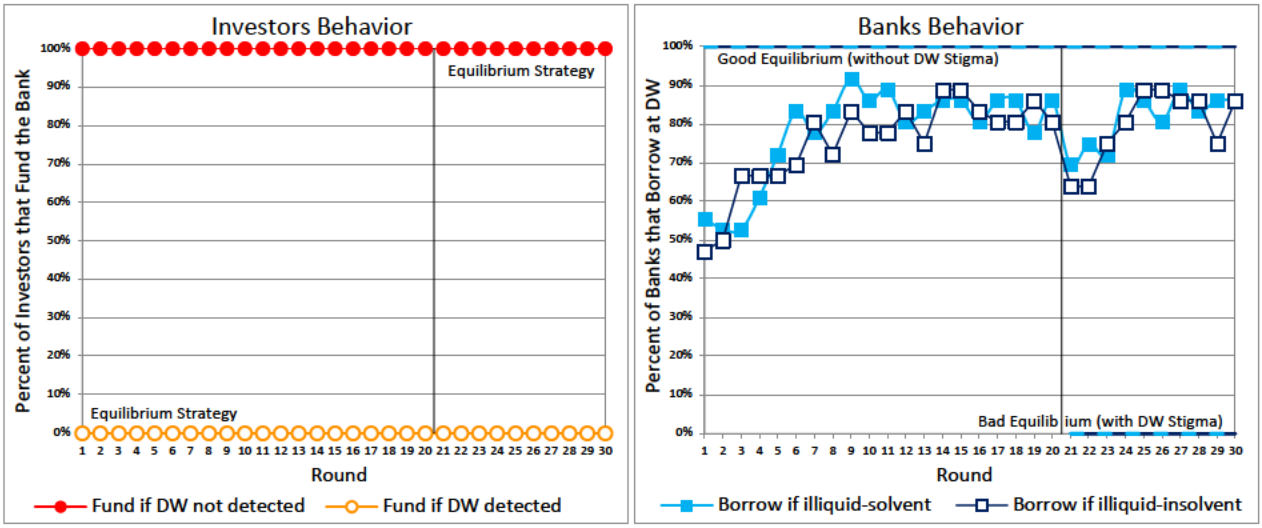
Notes The Figure shows the share of investors who fund banks (left panel) and the share of banks who borrow at the DW (right panel) in each round averaged across the 6 sessions. The 25 rounds of the experiment were conducted under the Stigma treatment.

Figure A5: Random Borrowing Treatment in Armantier and Holt (2020)



Notes The Figure shows the share of investors who fund banks (left panel) and the share of banks who borrow at the DW (right panel) in each round averaged across the 6 sessions. The 25 rounds of the experiment were conducted under the Random Borrowing treatment.

Figure A6: Automaton Investors and Temporary Random Borrowing Treatment in Armantier and Holt (2020)



Notes The Figure shows the share of investors who fund banks (left panel) and the share of banks who borrow at the DW (right panel) in each round averaged across the 6 sessions. The first 20 rounds of the experiment were conducted under the Random Borrowing treatment. The last 20 rounds of the experiment were conducted under the Stigma treatment. Investors were replace by automata that played the equilibrium strategy (i.e. fund a bank not detected at the DW and do not fund a bank detected at the DW).

Table A1: Treatment Effects Based on the First and Last Five Rounds of Each Treatment

Random Borrowing Experiment				
	Stigma Treatment		Random Borrowing	
	Rounds 1-5	Rounds 11-15	Rounds 16-20	Rounds 26-30
Share of investors who fund a non-detected bank	0.656* (0.209)	0.861 (0.057)	0.900 (0.079)	0.867 (0.060)
Share of investors who fund a detected bank	0.350* (0.094)	0.178 (0.150)	0.217 (0.103)	0.256 (0.156)
Share of banks who borrow at DW when illiquid-solvent	0.528*** (0.118)	0.256 (0.111)	0.394** (0.203)	0.439*** (0.074)
Share of banks who borrow at DW when illiquid-insolvent	0.550** (0.224)	0.233 (0.056)	0.350** (0.059)	0.456** (0.120)
High Random Borrowing Experiment				
	Stigma Treatment		Random Borrowing	
	Rounds 1-5	Rounds 11-15	Rounds 16-20	Rounds 26-30
Share of investors who fund a non-detected bank	0.661** (0.127)	0.878 (0.075)	0.889 (0.058)	0.894 (0.057)
Share of investors who fund a detected bank	0.350** (0.086)	0.139 (0.093)	0.250 (0.096)	0.344** (0.081)
Share of banks who borrow at DW when illiquid-solvent	0.561*** (0.163)	0.278 (0.058)	0.394* (0.112)	0.578** (0.120)
Share of banks who borrow at DW when illiquid-insolvent	0.539*** (0.068)	0.233 (0.030)	0.322** (0.058)	0.583*** (0.035)
Free DW Experiment				
	Stigma Treatment		Random Borrowing	
	Rounds 1-5	Rounds 11-15	Rounds 16-20	Rounds 26-30
Share of investors who fund a non-detected bank	0.761* (0.093)	0.906 (0.065)	0.861 (0.049)	0.917 (0.051)
Share of investors who fund a detected bank	0.411*** (0.133)	0.144 (0.046)	0.194 (0.061)	0.122 (0.058)
Share of banks who borrow at DW when illiquid-solvent	0.517** (0.224)	0.239 (0.065)	0.406** (0.131)	0.633** (0.184)
Share of banks who borrow at DW when illiquid-insolvent	0.544*** (0.126)	0.189 (0.066)	0.389** (0.122)	0.606*** (0.083)

Notes The table shows the share of investors who fund banks and the share of banks who borrow at the DW in the first and last five rounds of each treatment. The first 15 rounds of the experiment are conducted under the Stigma treatment, the last 15 rounds under the Random Borrowing treatment (top panel), the High Random Borrowing treatment (middle panel) and the Free DW treatment (bottom panel). The table shows averages and standard deviations (in parentheses) across the 6 sessions. We use a paired permutation test to compare choices at the end of the Stigma treatment (rounds 11-15 in column 2) with choices at the beginning of the Stigma treatment (rounds 1-5 in column 1), as well as at the beginning (rounds 16-20 in column 3) and end (rounds 26-30 in column 4) of the second treatment. The superscripts ***, **, and * indicate that the null hypothesis of equal means is rejected at the 1%, 5%, and 10% significance levels.

Table A2: Treatment Effects Based on the First and Last Three Rounds of Each Treatment

Random Borrowing Experiment				
	Stigma Treatment		Random Borrowing	
	Rounds 1-3	Rounds 13-15	Rounds 16-18	Rounds 28-30
Share of investors who fund a non-detected bank	0.611* (0.238)	0.889 (0.035)	0.889 (0.099)	0.880 (0.082)
Share of investors who fund a detected bank	0.389* (0.153)	0.185 (0.152)	0.185 (0.125)	0.250 (0.156)
Share of banks who borrow at DW when illiquid-solvent	0.528*** (0.144)	0.231 (0.082)	0.333* (0.230)	0.435*** (0.065)
Share of banks who borrow at DW when illiquid-insolvent	0.565** (0.215)	0.204 (0.029)	0.296** (0.076)	0.454*** (0.102)
High Random Borrowing Experiment				
	Stigma Treatment		Random Borrowing	
	Rounds 1-3	Rounds 13-15	Rounds 16-18	Rounds 28-30
Share of investors who fund a non-detected bank	0.667* (0.127)	0.880 (0.108)	0.870 (0.097)	0.880 (0.042)
Share of investors who fund a detected bank	0.370** (0.097)	0.139 (0.110)	0.213 (0.096)	0.352* (0.103)
Share of banks who borrow at DW when illiquid-solvent	0.546*** (0.163)	0.278 (0.086)	0.343** (0.055)	0.574** (0.115)
Share of banks who borrow at DW when illiquid-insolvent	0.509*** (0.042)	0.222 (0.035)	0.287** (0.023)	0.574*** (0.029)
Free DW Experiment				
	Stigma Treatment		Random Borrowing	
	Rounds 1-3	Rounds 13-15	Rounds 16-18	Rounds 28-30
Share of investors who fund a non-detected bank	0.741* (0.103)	0.898 (0.074)	0.824 (0.096)	0.926 (0.084)
Share of investors who fund a detected bank	0.472*** (0.130)	0.148 (0.057)	0.213 (0.155)	0.093 (0.067)
Share of banks who borrow at DW when illiquid-solvent	0.546** (0.232)	0.194 (0.091)	0.361** (0.091)	0.630** (0.167)
Share of banks who borrow at DW when illiquid-insolvent	0.556*** (0.111)	0.185 (0.057)	0.352** (0.148)	0.630*** (0.120)

Notes The table shows the share of investors who fund banks and the share of banks who borrow at the DW in the first and last three rounds of each treatment. The first 15 rounds of the experiment are conducted under the Stigma treatment, the last 15 rounds under the Random Borrowing treatment (top panel), the High Random Borrowing treatment (middle panel) and the Free DW treatment (bottom panel). The table shows averages and standard deviations (in parentheses) across the 6 sessions. We use a paired permutation test to compare choices at the end of the Stigma treatment (rounds 13-15 in column 2) with choices at the beginning of the Stigma treatment (rounds 1-3 in column 1), as well as at the beginning (rounds 16-18 in column 3) and end (rounds 28-30 in column 4) of the second treatment. The superscripts ***, **, and * indicate that the null hypothesis of equal means is rejected at the 1%, 5%, and 10% significance levels.