Signaling Concerns, Discount Window Borrowing and
Competing Liquidity Facilities

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Abstract

The financial crisis started in mid 2007 constitutes the most recent challenge for the discount window facility (DW). At the onset of the crisis, the Federal Reserve saw little demand for primary credit through its discount window, even after lowering the discount rate from 100bp to 50bp above the federal funds target. Alternative liquidity facilities, such as the Federal Home Loan Bank system (FHLB) and the Term Auction Credit Facility (TAF), took the early lead and were the dominant sources of liquidity during the crisis.

This paper studies the role of the DW in the presence of competing liquidity facilities with market determined interest rates. There is stigma attached to borrowing at the DW. Stigma costs are assumed to be fixed costs and therefore banks borrow at the DW only when the fed funds market is severely tight. When the fed funds market is "mildly" tight supply adjusts to meet demand solely via the provision of new funds by alternative facilities. A more attractive discount window (lower discount rate or lower signaling costs) results in higher total discount window borrowing and a higher fraction of banks borrowing from the facility. It is also accessed in more states of the world.

I propose an empirical approach based on cross-district data to test for the stigma hypothesis. Variations in Federal Reserve district characteristics (e.g. number and size distribution of depository institutions) serve as a proxy for variations in (unobservable) signaling costs to test their effect on borrowing at the DW facility.

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1 Introduction

The discount window (DW) constitutes the longest standing liquidity provision facility by the US government. Its goal is to function as a safety valve in relieving pressures in reserve markets and therefore relieve liquidity strains in depository institutions and the banking system as a whole. However, depository institutions have expressed their concern that banking supervisors, other banks, and investors might see borrowing as a sign of financial weakness. According to a Fed report, "such stigma deterred some institutions from using adjustment credit when doing so would have been appropriate." Starting in the mid and late 1980s, banks showed a growing reluctance to borrow at the discount window (Pearce 1993, Peristiani 1998, Dow 2001). Discount window borrowing declined dramatically and the close relationship between borrowing and the spread between the federal funds rate and the discount rate (the so-called "borrowing function") effectively disappeared.

In 2003, the discount window was redesigned in an attempt to reduce market stigma and costly regulatory monitoring, which were believed to hinder borrowing at the facility (Madigan and Nelson 2002). Adjustment credit, the previous version of the facility, was characterized by a below-market discount rate and a requirement that depository institutions borrow only to meet short term needs after exhausting all available sources of funds. The new version, in particular the Primary Credit program, was designed to more closely resemble a Lombard facility. The Primary Credit program provides funds to financially sound depository institutions at an above-market rate but with very little administration and no restrictions on the use of the proceeds.

There is no consensus on whether the redesign of the facility achieved its goal. Empirical studies yield contradicting conclusions depending on the time horizon considered. Furine 2001 and 2003 study the experience with the Special Lending Facility\(^1\) (SLF) and the results of the first three months of the redesigned discount window facility. He concludes that despite the removal of administrative costs, depository institutions remained hesitant to borrow from the Fed because stigma could not be eliminated completely.

Allowing for a three year time lapse of the new regime, Artuc and Demiralp 2007 find different results. The authors analyze daily borrowings behavior before

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\(^1\) A facility similar in design to the new discount window program temporarily established by the Fed to ensure adequate liquidity provision around Y2K.
and after the establishment of the new facility. They estimate implicit costs of borrowing using the fixed cost model proposed by Clouse and Dow 1998. They find that stigma substantially decreased and the borrowing function (i.e. the sensitivity of total DW borrowing to the spread between the fed funds and the discount rate) became operational again.

The financial crisis started in mid 2007 constitutes the most recent challenge for the DW facility. At the onset of the crisis, the Federal Reserve received little demand for primary credit through its discount window, even after lowering the discount rate from 100 basis points to 50 basis points above the federal funds target. Economic analysts interpreted this as evidence of how signaling concerns still hinder borrowing at the DW facility. Ashcraft, Bech and Frame 2008 (ABF 08) propose an alternative explanation: the presence of an alternative lower cost government sponsored liquidity facility. The authors document the important role played by alternative liquidity facilities, like the Federal Home Loan Bank (FHLB) and the Term Auction Credit Facility (TAF).

The Federal Home Loan Bank (FHLB) System is a government-sponsored liquidity facility consisting of 12 cooperatively owned wholesale banks which function as a general source of liquidity for its member financial institutions. Liquidity is provided through advances (over-collateralized loans) to members. In order to raise funding, the FHLB system issues debt instruments (bonds and discount notes). Obligations consolidate borrowing needs of all institutions into joint securities offerings which are sold in capital markets. Members share the funds raised by the sale of securities and share the obligation to repay. Being a government sponsored enterprise, the perception in financial markets is that of an implicit Federal government guarantee. Overnight advances are priced to compete with the federal funds rate.

The Term Auction Credit Facility (TAF), introduced on December 12, 2007, complements the DW in providing liquidity to sound depository institutions. The facilities are close substitutes in many respects. Both offer funding to the same set of eligible institutions, against the same collateral, and using identical haircut calculations. However, the interest rate for the TAF is determined competitively through an auction as opposed to the posted discount rate for the DW.\(^2\) The sup-

\(^2\)For each TAF auction, the Federal Reserve announces an amount to be allocated. Eligible financial institutions may submit a bid (subject to a maximum amount) consisting of at most two rate-quantity pairs. Bids are accepted starting with the highest rate submitted until the announced offering amount has been allocated or until the minimum bid rate is reached. The lowest accepted interest is the "stop-out rate", and is paid by all participants with awarded bids. There are also
ply of liquidity at market rates, determined by competitive auctions, attempts to circumvent the stigma associated with the DW.

Figure (1) shows total liquidity provision during the last crisis by the Term Auction Credit facility, the Discount Window facility, and the Federal Home Loan Bank system. During the first four months of the crisis, the FHLB system was the dominant source of government sponsored liquidity. It was not until December 2007 that the Federal Reserve began to lend significant amounts, as a result of the introduction of the Term Auction Facility (TAF). The FHLB remained an important source of liquidity through 2008. In addition, several other liquidity facilities were introduced during the crisis, including the Primary Dealer Credit Facility (PDCF) and the Term Securities Lending Facility (TSLF). Quoting ABF 08: "While the FHLB System was the lowest-cost source of secured term funding for U.S. depository institutions during fall 2007, the new liquidity facilities created by the Fed in Dec. 2007 complemented FHLB advances by extending "stigma free" term dollar credit to non-FHLB members including foreign institutions." Armantier, Ghusels, Sarkar and Shrader 2010 document that during the summer of 2008 banks preferred to pay, on average, at least 34bp more to borrow from the Fed’s Term Auction Facility than from the discount window.

The Federal Reserve implemented a number of important changes to the primary program after the financial crisis emerged. On August 17, 2007, the penalty spread was reduced from 100 bp to 50bp, with maturities extended up-to 30 days. On March 16, 2008, the spread was further reduced to 25bp and maturities extended up-to 90 days. However, borrowing at the DW remained insignificant until late March 2008.

In this paper, I study the role of the discount window in the presence of competing liquidity facilities with market determined interest rates, such as the FHLB system or the Term Auction Facility (TAF). A bank’s reserve position is subject to individual and aggregate shocks. Banks that face a deficiency must borrow at the market determined interest rate or at the discount window. Accessing the DW involves a direct cost (the posted discount rate) and an indirect cost, since it may raise concern in the market about the institution’s financial condition (a signaling differences in maturity, availability frequency, prepayment options and borrowing limits.

3The FHLB time series is constructed subtracting the value of advances in January 2007.

4In spite of the fact that in the second quarter of 2008, the borrowing costs and advance rates for the FHLB increased as a result of the association of this government sponsored facility with Fannie Mae and Freddie Mac.
Figure 1: Crisis liquidity provision per facility.
cost). I assume a key distinction: signaling costs are attached to the discount window but not to alternative liquidity sources. Signaling costs are fixed costs as in Clouse and Dow 1998 (CD 98) and Artuc and Demiralp 2007 (AD 07). The presence of fixed costs explains instances of extremely high fed funds rate and heterogeneous behavior across banks with respect to the discount window.

The total supply of federal funds is given by banks with excess reserves which choose to lend in the fed funds market, and by the provision of funds by an alternative liquidity facility. Because the discount window is subject to fixed costs, some banks borrow at the DW only when the fed funds market is severely tight (as a consequence of large negative aggregate shocks). When the fed funds market is "mildly" tight (as a result of negative but not too large aggregate shocks), supply adjusts to meet demand solely via the provision of new funds by an alternative facility. No bank borrows at the discount window.

As opposed to AD 07, the presence of an alternative liquidity facility makes the aggregate supply of funds elastic with respect to the interest rate. As a result, given the aggregate shock, changes in signaling costs and the discount rate affect both equilibrium prices and quantities. A more attractive facility (lower discount rate or lower signaling costs) results in more total discount window borrowing and a higher fraction of banks borrowing at the facility. Also, a more attractive facility is accessed in more states of the world.

The model offers an alternative interpretation of two findings made by Reddy and Shaffer 2007. The authors find that the DW redesign did not significantly change the average level of aggregate overnight DW borrowing. They interpret this as the higher direct cost of borrowing (above-market interest rate) offsetting the lower indirect costs (reduced stigma and administration costs). They also find that the pricing of overnight FHLB system loans did not respond to the systemic change in the discount rate, concluding that the FHLBs do not view the DW as a primary competitor in overnight lending. However, these findings are consistent with a period of mildly tight fed funds markets in which the discount window is not systematically used (e.g. borrowing due to technical reasons), and the discount rate and signaling costs have no effect on the equilibrium interest rate. It should be noted that the authors' sample (from January 10, 2003 to January 1, 2005) included only two instances when the intra-day maximum fed funds rate exceeded the discount rate.

I propose an empirical approach to test for the stigma hypothesis. The empirical
approach is based on exploiting differences across Federal Reserve districts. Signaling costs are unobservable, so we cannot directly test the hypothesis that signaling costs affect discount window borrowing. However, district characteristics (e.g. number and size distribution of institutions, variance of shocks, etc.) may function as a proxy for variations in signaling costs to test their effect on borrowing at the facility.

Individual bank discount window borrowing is strictly confidential. Primary credit data is published only aggregated across Federal Reserve districts or across several liquidity facilities. The signaling concern is that market participants may combine this information with bidding behavior in the federal funds market to infer the identity of institutions borrowing at the discount window. Consider, for example, cross-district variation in the number of eligible institutions for primary credit. All things equal, it should be harder to identify a borrowing bank in a district with more eligible institutions because banks may "hide in the bushes" more easily. A higher number of eligible institutions may be used as a proxy for lower signaling costs. Under the identifying assumptions that fixed costs represent signaling costs and the number of institutions proxies variations in signaling costs across districts, we may test the predictions of the model. All else equal, districts with more institutions should experience a higher fraction of banks accessing the facility and higher district average DW borrowing.

The relationship between DW borrowing and the spread between the fed funds rate and the discount rate should indicate the presence of fixed costs. If borrowing at the government facility had no indirect costs attached, then the discount rate should function as an upper bound on the fed funds rate and no discount window borrowing is expected when the fed funds rate falls below the bound. A fixed cost attached to DW borrowing explains those occasions when the fed funds rate rises above the discount rate. I study the evolution of the relationship between DW borrowing and the spread since 2003. I divide the sample into three sub-periods: pre-crisis, first phase of the crisis, and last phase of the crisis through recovery.

Despite the differences in scale (given the arrival and deepening of the financial crisis), the pattern is similar in the first two sub-periods. When the fed funds rate falls below the discount rate, discount borrowing is low. When the spread is positive, borrowing increases in the spread. The figures are consistent with the revival of the borrowing function proposed by Artuc and Demiralp 2007. The figures suggest the presence of fixed costs attached to DW borrowing. The last sub-period shows a positive relationship between DW borrowing and the spread. I observe a new, salient
feature in the last phase: there are large amounts of borrowing at negative spreads. This phenomenon may be explained by banks, with sound credit quality, scaling back their lending to other banks (e.g. due to increased uncertainty in counterparty risk) in times of financial turmoil. As a result some institutions may have limited access to those funds and are forced to borrow from government facilities.

The structure of this paper is as follows: section 2 introduces the model of the discount window facility with competing liquidity sources and solves for the equilibrium; section 3 compares predictions of the model to Artuc and Demiralp 2007 and reinterprets the findings by Reddy and Shaffer 2007; section 4 proposes an empirical approach to test for the stigma hypothesis; section 5 studies the evolution of the relationship between DW borrowing and the spread since 2003; section 6 concludes. All proofs are included in the appendix.

2 The model

I borrow the basic setting from Clouse and Dow 1998 (CD 98) and Artuc and Demiralp 2007 (AD 07). In this setting a bank’s reserve position is subject to individual and aggregate shocks. Banks that face deficiencies are forced to borrow at the federal funds market or the discount window. Accessing the liquidity facility involves both a variable and a fixed cost.

The bank’s reserve position is realized at the beginning of the period and is given by $a + u + v$; where $a$ is a constant, $u$ is a shock common to all banks, and $v$ is a bank specific shock. Aggregate and individual shocks are assumed to be independent symmetric shocks with bounds $[-k, k]$. I assume $0 < a < k$.

If a bank has positive reserves ($a + u + v > 0$) it may either lend the reserves at the fed funds market (at the fed funds rate $i$), or hold on to the reserves receiving a marginal benefit $\gamma$. If the bank is deficient in reserves ($a + u + v < 0$), it may borrow at the fed funds rate $i$, or access the discount window at discount rate $i_{dw}$. The latter involves stigma costs modelled as a fixed cost $P$. I assume $\gamma < i_{dw}$ throughout the paper.

There is a continuum of banks; the individual shock $v$ indexes the distribution of banks. Following CD 98 and AD 07, I assume that banks borrowing at the discount window may not re-lend funds to other banks. Otherwise, given the presence of fixed costs, there would be an incentive for only one bank to borrow at the discount
The total supply of federal funds has two sources: (1) some banks with excess reserves choose to lend in the fed funds market; (2) there exists an extra source of federal funds which increases in the interest rate \( i \) when the interest rate rises above the marginal benefit \( \gamma \). The extra source of liquidity is given by the function \( Ah(i - \gamma) \) for \( i \geq \gamma \); with \( h(0) = 0 \) and \( h'(.) > 0 \). This extra source of funds is the key departure from CD 98 and AD 07, because it makes the total federal funds supply an elastic function of the federal funds rate. For a given spread of the fed funds rate over the banks’ marginal benefit \( i - \gamma \), the extra funds going into the market increase with \( A \). Note that the model encompasses CD 98 and AD 07, which correspond to \( A = 0 \).

The extra source of funds represents a competing and complementary liquidity facility, which allocates funds to the fed funds market when market gets tighten, similar to the Federal Home Loan Bank system (FHLB) or the Term Auction Facility (TAF). This facility includes market determined interest rates and is not subject to stigma concerns.

### 2.1 Equilibrium

In this section I characterize the equilibrium of the model. Given the continuum of banks and that \( E(v) = 0 \), the aggregate reserve position is \( a + u \). For each value of the aggregate shock \( u \), the equilibrium interest rate \( i^* \) must be such that demand meets supply.

If the aggregate reserve position is positive, \( a + u > 0 \), then total positive reserve positions are greater than total negative reserve positions. Therefore, given that supply is greater than demand, the federal funds rate is brought down to the marginal value of reserves, \( i = \gamma \). Note that because \( \gamma < i^{dw} \), there is no bank borrowing at the discount window. There is no borrowing at the alternative liquidity facility either.

If \( a + u \leq 0 \), fewer funds can be lent than are demanded. As such, the fed funds rate rises above \( \gamma \) (I refer to this situation as a tight market). Consequently, extra funds enter the market (increasing supply) and some banks may choose to borrow at the discount window (reducing demand).

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5However, it should be noted that after the modification of the Discount Window facility in 2003, Primary Credit lending imposes no restrictions on the use of the borrowed funds.
I characterize supply and demand in turn. To simplify notation, I define the state variable \( x = -a - u \). High values of \( x \) correspond to large negative aggregate shocks. The federal funds supply is given by

\[
S(x, i) = S(x) + \tilde{S}(i)
\]

where \( \tilde{S} \) refers to the supply of funds by banks with excess reserves\(^6\),

\[
\tilde{S}(x) = \int_x^k (v - x) \, dF(v)
\]

and \( \tilde{S} \) refers to the extra source of funds

\[
\tilde{S}(i) = \begin{cases} 
0 & \text{if } i \leq \gamma \\
Ah(i - \gamma) & \text{if } i > \gamma
\end{cases}
\]

Banks in need of funds lie in the interval \(-k < v < x\). Within this interval, some borrow at the fed funds market and some may go to the discount window. Given the fixed costs, a bank prefers to either borrow entirely in the market or at the discount window. The total cost of market borrowing for a bank with shock \( v \) is given by \(-i(v - x)\). The total cost of borrowing at the discount window is given by \( P - i_{dw}(v - x) \). When \( i < \frac{P}{k+x} + i_{dw} \), even the bank with the worse shock prefers borrowing at the market to borrowing at discount window. Therefore, demand is given by the function

\[
D(x, i) = \begin{cases} 
\tilde{D}(x) = -\int_{-k}^{x} (v - x) \, dF(v) & \text{if } \gamma < i < \frac{P}{k+x} + i_{dw} \\
-\int_{x-\frac{P}{i_{dw}}}^{x} (v - x) \, dF(v) & \text{if } i \geq \frac{P}{k+x} + i_{dw}
\end{cases}
\]

As shocks get worse, there are three effects affecting demand. First, some banks shift from supplying to borrowing fed funds. Given that the marginal bank does not demand nor supply funds, the effect of a marginal worsening in the shock \( x \) is negligible. Second, each bank that continues to borrow at the fed funds market will demand more funds, increasing demand. Finally, provided that the market is tight (\( x > 0 \)) and that the interest rates are sufficiently high (\( i \geq i_{dw} + \frac{P}{x+k} \)), some banks exit the fed funds market to borrow at the discount window. This effect reduces demand for fed funds. I assume that the second effect dominates the latter.

\(^6\)Actually, \( S(x) \in \int_0^x (v - x) \, dF(v) \) if \( i = \gamma \) and \( S(x) = 0 \) if \( i < \gamma \).
Therefore, demand weakly increases when the market is tighter.

**Condition 1** Assume for $x > 0$ and $i \geq i_{dw} + \frac{P}{x+k}$

$$F(x) - F\left(x - \frac{P}{i - i_{dw}}\right) \geq \frac{P}{i - i_{dw}} f \left(x - \frac{P}{i - i_{dw}}\right)$$

In a tight market ($x > 0$) there are fewer funds to be lent than are demanded, which puts upward pressure on interest rates (that rise above $\gamma$). Given fixed costs, no bank exits the fed funds market to borrow at the discount window unless the interest rate is high enough $\left(i \geq \frac{P}{x+k} + i_{dw}\right)$. Thus, there exists a region in which supply adjusts to meet demand solely via the provision of new funds entering the market $\tilde{S}(i) > 0$.

Potentially, a large inflow of funds from alternative sources could keep the interest rate sufficiently low, deterring banks from borrowing at the discount window for any shock $x$. Throughout this paper, I assume that the alternative source of funds $\tilde{S}(i)$ allows for borrowing at the discount window given certain values of $x$. This condition requires an upper bound on $A$.

**Condition 2** Assume that $Ah \left(i_{dw} + \frac{P}{2k-a} - \gamma\right) < k - a$.

As a result, a tight market ($x > 0$) requires that we distinguish two regions. In the first region, when the shock is not too large, demand for fed funds is met by banks with excess reserves and by funds from an alternative liquidity source. The interest rate rises above $\gamma$ but not enough for banks to borrow at the discount window. I refer to this region as Region 1. If the market tightens enough, in spite of the provision of funds from the alternative liquidity source, the interest rate becomes high enough inducing some banks to borrow at the discount window facility. This is the case whenever the aggregate shock is large enough $x > \bar{x}$, where $\bar{x}$ solves

$$\bar{x} = \tilde{S} \left(\frac{P}{k+\bar{x}} + i_{dw}\right) = Ah \left(\frac{P}{k+\bar{x}} + i_{dw} - \gamma\right)$$

Given condition 2, there exists a unique value $\bar{x}$ that satisfies this expression. The region without discount window borrowing expands with the signaling cost $P$, the discount rate $i_{dw}$ and the parameter $A$. The region shrinks with the cost of funds $\gamma$. Next, I analyze equilibrium determination in Region 1 ($x \in [0, \bar{x}]$) and Region 2 ($x > \bar{x}$).

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7 This condition is satisfied for the uniform distribution which is used in CD 98 and AD 07.
Proposition 1 \( \bar{x} \) is increasing in \( P, i^{dw} \) and \( A \), and decreasing in \( \gamma \).

2.1.1 Region 1: \( x \in [0, \bar{x}] \)

When the fed funds market is mildly tight \( (x \in [0, \bar{x}]) \) there is no discount window borrowing. In this case, the equilibrium interest rate \( i^* (x) \) is given by

\[
\tilde{S} (i^*) = \tilde{D} (x) - \tilde{S} (x)
\]

or equivalently

\[
Ah (i^* - \gamma) = x
\]

The equilibrium interest rate \( i^* (x) \) is increases with shock \( x \) and satisfies \( \gamma < i^* (x) \leq \frac{P}{k+x} + i^{dw} \).

2.1.2 Region 2: \( x > \bar{x} \)

When the fed funds market tightens severely \( (x > \bar{x}) \), some banks exit the market to borrow at the discount window. The equilibrium interest rate \( i^* (x) \) satisfies

\[
\tilde{S} (x) + \tilde{S} (i^*) = - \int_{x-\frac{P}{i^{dw}}}^{x} (v - x) \, dF (v)
\]

or equivalently

\[
Ah (i^* - \gamma) = - \int_{x-\frac{P}{i^{dw}}}^{x} (v - x) \, dF (v)
\]

In this region, the equilibrium interest rate satisfies \( i^* (x) > \frac{P}{k+x} + i^{dw} \). The mass of banks exiting to the discount window lies in the interval \( [-k, x - \frac{P}{i^{dw}}] \), with total discount window borrowing given by

\[
DW^* (x) = - \int_{-k}^{x-\frac{P}{i^{dw}}} (v - x) \, dF (v)
\]

As aggregate conditions worsen the supply of bank funds decreases and, given condition 1, demand for funds weakly increases. As a result, the equilibrium interest rate \( i^* (x) \) and equilibrium discount window borrowing \( DW^* (x) \) are both increasing in \( x \) and therefore, positively related in region 2. The mass of banks borrowing at
the discount window $F \left( x - \frac{P}{i^w + i^{dw}} \right)$ also increases with shock $x$.

Note that at $\bar{x}$, the equilibrium interest is sufficiently high for banks with the worst individual shocks to consider borrowing at the discount window. That is, at the threshold between the two regions, $i^* (\bar{x}) = \frac{P}{k+\bar{x}} + i^{dw}$ and $\bar{x} - \frac{P}{i^* (\bar{x}) - i^{dw}} = -k$.

Figure (2) illustrates equilibrium prices and quantities when shocks are uniformly distributed and the extra source of funds is linear $\tilde{S} (i) = A (i - \gamma)$ for $i \geq \gamma$.

### 3 Comparative Statics

In this section, I analyze and relate the model results to other relevant papers that study the new discount window facility established in January 2003. Consider
the discount window model proposed by Artuc and Demiralp 2007. The authors’ framework yields counterintuitive results due to the inelastic federal funds supply built in the model. Under such conditions, given the aggregate shock \( x \), the signaling cost \( P \), the discount rate \( i^{dw} \) (provided that \( i^{dw} > \gamma \)) and the marginal benefit \( \gamma \) (provided \( i^{dw} > \gamma \)) have no effect on the mass of banks accessing the DW, the total amount borrowed at DW, nor on the states of the world in which the DW is used. Also, the marginal benefit \( \gamma \) (identified as the target rate by the authors in their empirical estimation) has no effect on the equilibrium interest rate when the market is tight.

In AD 07, aggregate shock \( x \) entirely determines the supply of funds in the fed funds markets. In equilibrium, total demand must equal total supply. Therefore, total demand at the fed funds market is also entirely determined by the shock \( x \). For a given \( x \), variations in \( P, i^{dw} \) or \( \gamma \) are accommodated solely by the equilibrium interest rate; there are no quantity effects.

After the introduction of an alternative liquidity facility, the federal funds total supply is no longer inelastic, so variations in \( P, i^{dw} \), and \( \gamma \) have both price and quantity effects. A more attractive facility (lower \( i^{dw} \) or \( P \)) results, for each \( x > \bar{x} \), in more total discount window borrowing and a higher fraction of banks borrowing at the facility. Also, a more attractive facility is accessed in more states of the world (lower \( x \)).

When the opportunity cost of funds \( \gamma \) increases\(^8\), liquidity provision by the alternative liquidity facility is reduced (for each value of the interest rate) and banks with excess reserves require higher payments to lend at the fed funds market. As a result, a higher value of \( \gamma \) reduces supply and increases equilibrium interest rates. Because some banks borrow at the DW, the effect on the fed funds rate is lower in region 2. The following propositions summarize the comparative statics of the model.

**Proposition 2** If \( A, P > 0 \), for each value of the shock \( x \), the federal funds rate \( i^*(x) \) is

- **decreasing in** \( A \), **increasing in** \( \gamma \) and independent of \( i^{dw}, P \) in Region 1: \( x \in [0, \bar{x}] \).
- **decreasing in** \( A \), **increasing in** \( \gamma, i^{dw}, P \) in Region 2: \( x > \bar{x} \)

\(^8\)I continue to assume \( \gamma < i^{dw} \).
Proposition 3 If $A, P > 0$, for each value of the shock $x$, the provision of funds by the alternative liquidity facility $Ah(i^*(x) - \gamma)$ is

- independent of $A, \gamma, i^{dw}, P$ in Region 1: $x \in [0, \bar{x}]$.
- decreasing in $\gamma$ and increasing in $A, i^{dw}, P$ in Region 2: $x > \bar{x}$

Proposition 4 If $A, P > 0$, for each value of the shock $x$, total discount window borrowing $DW^*(x)$ and the fractions of banks accessing the facility are

- zero in Region 1: $x \in [0, \bar{x}]$.
- increasing in $\gamma$ and decreasing in $A, i^{dw}, P$ in Region 2: $x > \bar{x}$

The model in AD 07 also predicts that the sensitivity of DW borrowing to the fed funds rate $\frac{\partial DW^*}{\partial i^*}(x)$ is decreasing in the fixed cost of accessing the facility $P$. With the introduction of the extra source of liquidity, the relationship is no longer straightforward. Consider the case in which the shocks are uniformly distributed $(u, v \sim U[-k, k])$ and the additional source of funds is linear $\tilde{S}(i) = A(i - \gamma)$. In this case, the sensitivity of DW borrowing to the fed funds rate $\frac{\partial DW^*}{\partial i^*}(x)$ is decreasing in the fixed cost of accessing the facility $P$ provided that $A$ is not too large.

The model in this paper suggests an alternative interpretation of the empirical findings by Reddy and Shaffer 2007, who study the effects of the re-design of the discount window facility. The authors find that "the new program did not significantly change the average level of aggregate overnight DW borrowing (...) consistent with a roughly equal offset between the higher direct cost of borrowing and lower indirect costs under the new policy." In terms of the model, the authors interpret modifications to the facility as an increase in the discount rate $\uparrow i^{dw}$ and a decrease in the non-price cost $\downarrow P$. These forces push DW borrowing in opposite directions in Region 2. However, an alternative interpretation may characterize the period following the modification of the facility as having mild aggregate shocks that lead to no systematic borrowing at the discount window (Region 1). The observed borrowing may have occurred due to technical reasons. In this region, the discount

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9 The actual condition is given by that $4k(i^*(x) - i^{dw})^3 A < 1$.
10 E.g., technical difficulties with the Fedwire payment system or the realization of unexpected transactions late in the day, that may not leave sufficient time to find a suitable counterparty in the fed funds market.
rate $i^{dw}$ and the fixed cost $P$ have no effect on equilibrium interest rates. It should be noted that in the authors’ sample (from January 10, 2003 to January 1, 2005) the intra-day maximum fed funds rate exceeded the discount rate $i^{dw}$ only twice.

This alternative story would modify the authors’ conclusion that "several simple tests indicated that the pricing of overnight Federal Home Loan Banks system loans did not respond to the systemic change in the discount rate, suggesting that the FHLBs do not view the DW as a primary competitor for their lending overnight". We may think of the FHLB system as an alternative liquidity facility. Even though changes in $i^{dw}$ and $P$ have no effect on equilibrium interest rates $i^*$ in Region 1, the alternative liquidity facility and the DW facility may still compete.

4 Empirical test proposal

Many economists have argued that the "stigma" attached to borrowing at the Discount Window explains banks’ reluctance to use the facility. The argument is straightforward from a theoretical point of view, but empirical evidence supporting the hypothesis remains elusive. Empirical research regarding discount window borrowing has been limited because individual bank discount window borrowing is strictly confidential. Primary credit data is published only aggregated across Federal Reserve districts or across several liquidity facilities (i.e. primary, secondary and seasonal credit and other liquidity programs). The signaling concern is that market participants may combine this information with the bidding behavior in the federal funds market to infer the identity of borrowing institutions.

Furfine 2001/03 and Armantier, Ghulsels, Sarkar and Shrader 2010 (AHSS 10 hereafter) are notable exceptions. Furfine 2001 documents that whenever market interest rates rose noticeably, borrowing in the federal funds markets at 150 or more basis points above target dwarfed lending at a facility similar in design to the new DW that charged 150bp over the fed funds target. Furfine 2003 finds that borrowing at the new DW was significantly lower than predicted using interbank borrowing behavior past data. Even at less attractive interest rates, the volume of fed funds borrowing was several times larger than DW borrowing. AHSS 10 find that during the summer of 2008 banks preferred to pay on average at least 34bp more to borrow

\footnote{The pre-2003 version of the facility published adjustment credit data at a district level (see Mitchell and Pearce 91).}
\footnote{The Special Lending Facility (SLF) was a temporary facility that operated between October 1, 1999 and April 7, 2000.}
from the Fed’s Term Auction Facility than from the discount window.

Given the DW’s economic importance, it is crucial to obtain rigorous and robust evidence for the existence of stigma. The non-disclosure policy by the Fed has been challenged recently by various news organizations. During the last year, Bloomberg News and Fox News have brought lawsuits against the Federal Reserve because it refuses to provide discount window documentation under the Freedom of Information Act. In March 2010, the federal appeals court ruled that the Fed must disclose documents related to individual borrowing from DW. However, in May 2010, Fed representatives asked the federal appeals court to reconsider the ruling because "banks would be less likely to use the DW (...) if they know their use would be made public", that is "the disclosure of the identity of financial institutions (...) will severely undermine the board’s ability to implement lending programs critical to the economy (...)".

In this section, I propose an empirical approach to test for stigma. The empirical approach is based on exploiting differences across districts\textsuperscript{13}. According to the model, signaling costs affect discount window borrowing. Signaling costs are unobservable so the hypothesis cannot be tested directly. However, district characteristics (e.g. number and size distribution of institutions, variance of shocks, etc.) affect the ability of market participants to identify institutions borrowing at the DW. Therefore, we may use district characteristics as a proxy for variations in signaling costs in order to test how these affect borrowing at the facility.

Consider, for example, cross district variation in the number of eligible institutions for primary credit. All else equal, it should be harder to identify a borrowing bank in a district with more eligible institutions because banks can "hide in the bushes" more easily. Higher numbers of eligible institutions may proxy for lower signaling costs. Under the identifying assumptions that fixed costs represent signaling costs and that number of institutions proxies for variations in signaling costs across districts, we may test the model’s predictions. According to the model, we should expect the following in districts with more institutions:

- the fraction of banks and the probability that a bank will access the DW is higher,
- district average DW borrowing is higher,

\textsuperscript{13}Data disaggregated at a district level is currently confidential. However, it represents a useful middle-step to obtain solid evidence for stigma without the disclosure of individual bank borrowing data.
the sensitivity of average DW borrowing to the fed funds rate \( \frac{\partial DW_t}{\partial s_t} \) is higher (under certain conditions, see section 3)

We may also use heterogeneity in bank size as a proxy for signaling costs. In order to conduct the test, I consider a variation of the specification proposed by Artuc and Demiralp. The authors use daily data to estimate pre and post 2003:

\[
DW_t = \alpha_0 + \alpha_1 s_t + \hat{\alpha}_2 X_t + \varepsilon_t
\]

where \( DW_t \) denotes daily aggregate primary credit at the Federal level, \( s_t \) is the spread between the fed funds rate and the discount rate, and \( X_t \) is a vector of other controls. They find that, after the modifications of the DW facility in 2003, the borrowing function is again effective, i.e. their estimate for \( \alpha_1 \) is positive and significant.

To test the stigma hypothesis, I extend the time series specification into a panel. Let \( DW_{it} \) be discount window borrowing in district \( i \) at date \( t \). To proxy for signaling costs, I use the number of institutions per district (\( NUM_{it} \)) and the within district depository institution size variance (\( \sigma_i \)). I control for total depository institutions assets in each district and use the same vector of controls as in Artuc and Demiralp \( X_{it} \). The specification to estimate is given by

\[
DW_{it} = \alpha_0 + \alpha_1 NUM_{it} + \beta_2 \sigma_{it} + \beta_3 \text{SIZE}_{it} + \beta_4 s_{it} + \beta_5 (s_{it} \times NUM_{it}) + \beta_6 (s_{it} \times \sigma_{it}) + \hat{\beta}_7 X_{it} + \varepsilon_{it}
\]

The model, subject to the identifying assumptions stated above, predicts positive coefficients for \( \beta_1 \) and \( \beta_2 \). Empirical estimation would allow to identify if the borrowing function is still effective at the district level (\( \beta_4 > 0 \)) or if it is a result of aggregation across districts. Finally, subject to certain conditions (see section 3), the model predicts positive coefficients for the interaction terms (\( \beta_5 \) and \( \beta_6 \))

\footnote{The vector of controls \( X_{it} \) includes: the spread between the intra-day maximum fed funds rate and the fed funds target when higher than 1 bp, the spread between the fed funds rate at the close of the day and the fed funds target, the spread between the fed funds rate and the fed funds target on the previous day, the log of required operating balances, a dummy for the last day of the maintenance period, a dummy for special pressure days, a dummy for Fedwire extension days, the intraday fed funds volatility and a time trend.}
5 Evolution of the borrowing function

In this section, I study the evolution of the relationship between DW borrowing and the spread between the fed funds rate and the discount rate since 2003. This relationship should indicate the presence of fixed costs.

The discount window facility is designed to place an upper bound on the rates at which institutions lend to one another overnight, reducing the volatility of the overnight interest rate, which is typically the rate targeted by the central bank. If borrowing at the government facility is not associated with any indirect costs, then the discount rate should work as an upper bound on the fed funds rate and no discount window borrowing is expected when the fed funds rate falls below the bound.

A fixed cost (e.g. stigma costs) associated with borrowing at the facility explains instances when the fed funds rate rises above the discount rate. Fixed costs might also explain heterogeneous behavior across banks towards the discount window. Still, we expect no discount window borrowing when the fed funds rate is below or slightly above (Region 1 in terms of the model) the discount rate. In practice, some noise is expected because not all depository institutions are eligible for DW borrowing at each moment in time, and discount window borrowing may be triggered by non-systematic reasons (e.g. technical difficulties in the "Fedwire" system).

I focus on the relationship between DW borrowing and the spread between the intra-day maximum fed funds rate and the discount rate. Wednesday’s primary credit at the federal level provided by the Fed Board and interest rate data provided by the NY Fed is used in the construction of the figures. I divide the sample in three sub-periods: pre-crisis, first phase of the crisis, and last phase of the crisis through recovery.

Figures (3) and (4) depict the relationship between borrowing and the spread from January 15, 2003 until August 15, 2007 and from August 22, 2007 until October 8, 2008 respectively. Despite the differences in scale (possibly due to the arrival and deepening of the financial crisis), the pattern is the same in both figures. When the fed funds rate falls below the discount rate, discount borrowing is low. When the spread is positive, borrowing at the facility increases with the spread. The figures are consistent with the revival of the borrowing function proposed by Artuc and Demiralp 2007. The figures suggest the presence of fixed costs attached to DW borrowing.
The last period, corresponding to October 15, 2008 until April 7, 2010 is shown in Figure 5. DW borrowing still shows a positive relationship with the spread. However, the large amount of borrowing at negative spreads (when the discount rate is above the federal funds rate) is the salient feature of the figure. This piece of evidence cannot be explained by the model in this paper as it stands. A possible explanation may be that in times of financial turmoil, banks with sound credit scale back their lending to other banks (e.g. due to increased uncertainty in counterparty risk). As a result, some institutions may have limited access to those funds and be forced to borrow from government facilities.

In terms of the model, we may think that a fraction of the banks with very negative reserve positions \((a + u + v < b < 0)\) must borrow directly at the discount window (e.g. because banks with positive reserve positions do not want to transact with them). As aggregate shocks worsen, more banks are forced to exit the fed funds market. These banks borrow at the facility even if the spread is negative. Also, worse aggregate shocks reduce the supply of funds and (under certain assumptions) increase the demand for funds, putting upward pressure on the interest rate. These results explain the positive correlation between the interest rate and positive discount window borrowing at negative spreads.
Figure 4: Initial phase of the crisis.

Figure 5: Last phase of the crisis and recovery.
6 Conclusion

The discount window is designed to function as a safety valve, relieving pressure on reserves markets, liquidity strains on depository institutions, and the banking system as a whole. In 2003, the facility was redesigned to reduce market stigma and costly regulatory monitoring, which many believe hindered borrowing at the facility (Madigan and Nelson 2002). The new version, in particular the Primary Credit program, provides funds to financially sound depository institutions at an above market rate but with very little administration and no restrictions on the use of the proceeds.

There is no consensus on whether the redesign of the facility has achieved its goal. Empirical studies yield different conclusions depending on the time period considered. The financial crisis started in mid 2007 constitutes the most recent challenge for the facility. At the onset of the crisis, the Federal Reserve saw little demand for primary credit through its discount window, even after lowering the discount rate from 100 basis points to 50 basis points above the federal funds target. Many economic analysts interpreted this as evidence of how signaling concerns still hinder borrowing at the facility. Alternative liquidity facilities like the Federal Home Loan Bank (FHLB) and the Term Auction Credit Facility (TAF) took the early lead and were the dominant sources of liquidity.

This paper proposes a model of the DW facility that incorporates both the notion of stigma and competing liquidity facilities with market determined interest rates. Within the paper, stigma costs are assumed to be fixed costs. Therefore, banks borrow at the DW only when the fed funds market is severely tight. When the fed funds market is "mildly" tight supply adjusts to meet demand solely via the provision of new funds by the alternative facilities. A more attractive discount window (lower discount rate or lower signaling costs) results in higher total discount window borrowing and a higher fraction of banks borrowing at the facility. It is also accessed in more states of the world.

This paper proposes an empirical approach based on cross-district data to test for stigma. Variations in Federal Reserve district characteristics (e.g. number and size distribution of depository institutions) are used as a proxy for variations in (unobservable) signaling costs to test their effect on borrowing at the DW facility. Districts with more institutions should yield a higher fraction of banks accessing the facility and higher DW district average borrowing. The data needed to perform such
test is currently confidential\textsuperscript{15}. The release of information aggregated at a district level represents a major step in the pursuit of rigorous and robust evidence for the existence of stigma.

On the theoretical side, the reasons why accessing the DW may send a worse signal than borrowing above the discount rate on the market are still not fully understood. Ennis and Weinberg (2009) suggest that borrowing at the DW may be observed by participants other than the credit market who may interpret borrowing at the facility as a negative signal. However, it is hard to justify why alternative government liquidity facilities like the TAF are not subject to the same scrutiny. Theoretical efforts should focus on understanding the consequences in terms of stigma of posted-rates versus market-determined-rates liquidity facilities.

References


\textsuperscript{15}The period of response to my Freedom of Information Act request (No. 2010100287) submitted in April 2010 has been extended twice and the answer is still pending.


7 Appendix

7.1 Existence of $\bar{x}$

Given condition 2, there exists a value $\bar{x} > 0$ such that

$$S(\bar{x}, \frac{P}{k+\bar{x}} + i^dw) = \bar{D}(\bar{x}).$$

Proof: Let $\Phi(x) = \bar{S}(x) - \bar{D}(x) + \bar{S}\left(\frac{P}{k+x} + i^dw\right)$, then

$$\Phi(x) = \bar{S}\left(\frac{P}{k} + i^dw\right) > 0$$

$$\Phi'(x) = \bar{S}'(x) - \bar{D}'(x) - \bar{S}'\left(\frac{P}{k+x} + i^dw\right) \frac{P}{(k+x)^2} < 0$$

Also, condition 2 may be written as

$$\bar{S}(k-a) + \bar{S}\left(\frac{i^dw + \frac{P}{2k-a}}{k}\right) < \bar{D}(x) = k-a),$$

and therefore, $\Phi(x = k-a) < 0$. As $\Phi(x)$ is continuous, there exists a value $\bar{x} > 0$ such that

$$S\left(\bar{x}, \frac{P}{k+\bar{x}} + i^dw\right) = \bar{D}(\bar{x}).$$

7.2 Comparative statics

Restrict attention to $x > \bar{x}$.

- **Interest rate**

  $i^*(x)$ satisfies

  $$\int_{x-\frac{P}{i^*-i^dw}}^{k} (v-x) dF(v) + \bar{S}(i^*) = 0$$

  And

  $$\frac{\partial i^*}{\partial x} = \frac{F(k) - F\left(x - \frac{P}{i^*-i^dw}\right) - \frac{P}{i^*-i^dw} f\left(x - \frac{P}{i^*-i^dw}\right)}{\bar{S}(i^*)' + \frac{P^2}{(i^*-i^dw)^2} f\left(x - \frac{P}{i^*-i^dw}\right)}$$

  which is positive given condition 1.

  Also,

  $$\frac{\partial i^*}{\partial P} = \frac{1}{(i^*-i^dw)^2} f\left(x - \frac{P}{i^*-i^dw}\right) + \frac{i^dw}{P} i^* \bar{S}(i^*)' > 0$$

- **Discount window borrowing**

  $DW^*(x)$ is given by
\[ DW^* (x) = - \int_{-k}^{x} \frac{P}{i^* (x) - i^{dw}} (v - x) dF (v) \]

\[
\frac{\partial DW^*}{\partial x} = \frac{P}{i^* (x) - i^{dw}} f \left( x - \frac{P}{i^* (x) - i^{dw}} \right) \left[ 1 + \frac{P}{(i^* (x) - i^{dw})^2} \frac{\partial i^*}{\partial x} \right]
+ F \left( x - \frac{P}{i^* (x) - i^{dw}} \right) - F (-k)
\]

Given that \( \frac{\partial i^*}{\partial x} > 0 \), we get \( \frac{\partial DW^*}{\partial x} > 0 \).

Let \( b^* (x) = x - \frac{P}{i^* - i^{dw}} \), banks with \( v \) in \([-k, b^* (x)]\) borrow at the discount window and

\[
\frac{\partial b^*}{\partial P} = - \left[ \frac{i^* - i^{dw} - P \frac{\partial i^*}{\partial P}}{(i^* - i^{dw})^2} \right]
\]

The numerator is given by

\[
i^* - i^{dw} - P \frac{\partial i^*}{\partial P} = \left( i^* - i^{dw} \right) \left[ 1 - \frac{P}{(i^* - i^{dw})^2} f \left( x - \frac{P}{i^* - i^{dw}} \right) \right] + \frac{i^* - i^{dw}}{P} \tilde{S} (i^*)' > 0
\]

And therefore the higher the fixed cost \( P \), the fewer banks go to the DW \( \frac{\partial b^*}{\partial P} < 0 \).

Using the result, we conclude total discount window borrowing (for a given \( x \)) is decreasing in \( P \).

\[
\frac{\partial DW^*}{\partial P} = -(b^* - x) f (b^*) \frac{\partial b^*}{\partial P} < 0
\]

### 7.3 Uniform example

Assume that individual shocks are uniformly distributed \( v \sim U [-k, k] \) and \( \tilde{S} (i^*) \) is linear \( Ah (i - \gamma) = A (i - \gamma) \). In this case,

\[
\frac{\partial i^*}{\partial x} \left. \frac{1}{2k \tilde{S} (i^*)'} + \frac{1}{(i^* - i^{dw})^2} \frac{k - x}{2k} \right)
\]
\[
\frac{\partial DW^*}{\partial x} = \frac{1}{2k} \left[ \frac{P^2}{(i^*(x) - i^{dw})^3} \frac{\partial i^*}{\partial x} + x + k \right]
\]

\[
\frac{\partial i^*}{\partial P} = \frac{P}{(i^*-i^{dw})^2} \frac{1}{2k} + \tilde{S}(i^*)'
\]

Then:
\[
\frac{\partial DW^*}{\partial i^*} = \frac{\partial DW^*}{\partial x} = \frac{x + k}{k - x} \tilde{S}(i^*)' + \frac{1}{k - x} \left( i^* - i^{dw} \right)^3
\]

Compute:
\[
\frac{\partial \left[ \frac{\partial DW^*}{\partial P} \right]}{\partial i^*} = \frac{x + k}{k - x} \tilde{S}(i^*)'' \frac{\partial i^*}{\partial P} + \frac{2}{k - x} \left( i^* - i^{dw} \right)^3
\]

\[
- \frac{3}{2k} \frac{1}{k - x} \left( i^* - i^{dw} \right)^6 \frac{P^3}{(i^*-i^{dw})^3} \frac{1}{2k} + \tilde{S}(i^*)'
\]

If \( \tilde{S}(i^*)' = A = 0 \) we obtain the result in AD 07: the sensitivity of DW borrowing to the fed funds rate is decreasing in \( P \).

\[
\frac{\partial \left[ \frac{\partial DW^*}{\partial P} \right]}{\partial P} = - \frac{1}{k - x} \left( i^* - i^{dw} \right)^3 < 0
\]

If \( \tilde{S}(i^*)' = A \) then

\[
\frac{\partial \left[ \frac{\partial DW^*}{\partial P} \right]}{\partial P} = - \frac{1}{k - x} + \frac{4k}{k - x} \frac{(i^*-i^{dw})^3}{P^2} A
\]

\[
+ \frac{(i^*-i^{dw})^6}{P^3} \frac{1}{2k} A
\]

The sensitivity of DW borrowing to the fed funds rate is decreasing in \( P \) provided that \( 4k \frac{(i^*-i^{dw})^3}{P^2} A < 1 \).