The Fed's New Discount Window and Interbank Borrowing

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Abstract

The Federal Reserve's new primary credit facility offers guilt-free overnight loans to commercial banks at a rate of 100 basis points over the target federal funds rate. If utilized freely by the market, the facility places an upper bound on the rates at which financial institutions lend to one another overnight, reducing the volatility of the daily effective federal funds rate. Conceivably, however, banks may continue to perceive a stigma from borrowing from the Fed, and thus borrow *less* than what one might expect, potentially reducing the facilities effectiveness at reducing interest rate volatility. By contrast, routine use of the facility might decrease a bank's incentive to participate actively in the interbank market. Thus, the mere availability of primary credit may lead to its use being *more* than what would be expected based on the historical characteristics of the interbank market. We develop a model demonstrating these two alternative market reactions to the new credit facility. A comparison of data from before and after recent changes to the discount window suggests continued reluctance to borrow from the Fed.

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1. Introduction

Modern central banks implement monetary policy primarily by setting a target for some short-term rate of interest that is consistent with its ultimate objective of price stability. Because central banks pursue their goals operationally by periodically intervening in financial markets to affect the level of bank reserves, overnight rates of interest on loans between financial institutions are typically chosen as a central bank's intermediate target. Excessive volatility in interbank rates, if viewed by market participants as an inability of the central bank to achieve its intermediate goals, is potentially damaging to the central bank's reputation and its ability to stabilize market expectations.

To address their common concern over interbank interest rate volatility, central banks in industrialized countries have used a variety of tools to reduce interest rate volatility (Laurens (1994)). Since short-term interest rate volatility is largely determined by volatility in reserve demand, interest rate stability was historically achieved through high statutory reserve requirements that provided a predictable demand for reserves. Over the past two decades, however, largely due to pressure from the banking industry that argued that reserve requirements place it at a competitive disadvantage relative to unregulated financial intermediaries, reserve requirements have been reduced or eliminated in industrialized countries. Therefore, attention has once again focussed on the volatility of short-term interest rates and the implications of this volatility for achieving the goals of monetary policy.[1]

One approach that central banks have taken in response to lower (non-zero) reserve requirements has been to operate under a regime of lagged reserve accounting.[2] Under such

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[1] In the US, this has been a popular theme in both the popular press and academic research. See, for example, Clouse and Elmendorf (1997), Naroff (1997), and VanHoose and Humphrey (1998).

[2] The Federal Reserve returned to such a system effective July 30, 1998.

accounting practices, institutions know how much they must hold in reserves in advance of the period over which the reserves must be held. Such a system reduces volatility in interbank interest rates that would otherwise be caused by banks having to make large and rapid adjustments to their reserves (through interbank transactions) due to late and unexpected changes in reservable liabilities.[3]

A more direct method that some central banks use to limit interbank interest rate volatility is to provide credit to market participants directly through so-called standing facilities. Importantly, the use of such a facility is not supposed to be accompanied by additional central bank or supervisory scrutiny that accompanies borrowing from a central bank in its lender-of-last-resort capacity (e.g. in an emergency). Thus, standing facilities attempt to offer commercial banks a guilt-free alternative to borrowing in traditional interbank markets.

Until recently, the Federal Reserve did not operate a standing facility. Loans made through the discount window were offered at below-market rates, necessitating intense supervisory scrutiny and moral suasion to limit the market's use of such loans. In recent years, the fraction of required reserves that were borrowed from the Fed's discount window fell dramatically (see Figure 1). Peristiani (1998) argues that this may be due to market participants refraining from requesting discount loans because of the perception that it would send a negative signal to the Fed, bank supervisors, and eventually the market at large. In response to the perception that banks were unwilling to borrowing from the discount window, the Federal Reserve drastically changed its discount window policy and began the operation of a standing facility (see Madigan

[3] Whether lagged reserve accounting reduces interest rate volatility remains an open question. Lasser (1992) finds that when the Fed abandoned lagged reserve accounting in favor of contemporaneous reserve accounting (CRA), interest rate volatility rose only for a short time period before returning to the earlier lower levels. In fact, Lasser (1992) argues that the Fed's reason for going towards CRA was to "allow the Fed to conduct a more effective monetary policy." The 1998 return to LRA in the US was motivated by the belief that "it has become increasingly

and Nelson (2002)). This facility offers banks in good financial condition “primary credit” from the central bank at 100 basis points above the FOMC’s target federal funds rate. “Secondary credit” would be offered at a slightly higher rate. This policy became effective January 9, 2003. Like other central bank standing facilities, the above market price of funds serves as a rationing mechanism that dramatically reduces the need for much, if any, supervisory review of the potential borrower. Thus, as designed, use of the new primary credit facility should not necessarily imply anything negative about an infrequent borrower, and therefore, banks should be willing to make occasional use of the facility if market conditions warrant. As a result, the mere existence of the new facility might be expected to truncate the cross-transaction distribution of interest rates at 100 basis points over the target funds rate.[4]

In this paper, we develop a model of a bank’s decision to borrow from a central bank standing facility. The model emphasizes two aspects that affect the bank’s decision to borrow in addition to the stated interest rate of the facility. First, we suggest that despite the assertions of the central bank, banks may remain reluctant to borrow. That this might hold true is suggested by the results of Furfine (2001). He demonstrates that when the Fed implemented a temporary Special Lending Facility (SLF) surrounding Y2K and combined this implementation with written assurances that the Fed would not look unfavorably upon a bank that borrows from the SLF, banks were still very reluctant to borrow. This conclusion was reached after observing that banks were willing to pay higher interest rates in the federal funds market rather than the rate offered on the SLF.

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difficult to estimate the quantity of balances that depositories must hold at the Reserve Banks …” (Federal Reserve (1998)). It remains to be tested whether interest rate volatility has fallen since LRA was reinstated in the US.

[4] These overnight loans from the Fed require collateral, so the relevant cost of collateral must be added to the stated interest rate charge.

Second, the model in the paper also suggests how the introduction of a standing facility may actually lead to greater borrowing from the central bank than would be warranted by interbank interest rates alone. Specifically, if the interest rates on central bank standing facilities are set too close to rates that occasionally occur in the market, interbank market participants may have less of an incentive to actively seek the best possible market outcome.[5] Thus, the interbank market may not allocate funds as well as it would in the absence of the standing facility competitor. One result of this would be that standing facilities might witness more activity than would be warranted solely on the characteristics of the interbank market.

A simple example illustrates these two alternative possibilities. Suppose participants in an interbank market without access to standing facilities offer overnight loans uniformly over the range 4.0% to 6.0%. This implies that 25% of the interbank market transacts between 5.5% and 6.0%. Suppose that a standing facility is then introduced offering to lend funds at 5.5%. Ex ante, one would expect 25% of the interbank market to move to the standing facility. However, the model developed in this paper suggests two reasons why the observed borrowing from the central bank may be more or less than 25% of the market. First, borrowing from the central bank might carry a stigma, suggesting that less than 25% of the market might move to the Fed. Second, the mere existence of the standing facility may change the behavior of market participants. In particular, banks may have a lesser incentive to participate actively in the interbank market due to the certainty of transacting at the standing facility. As a result, one might find that more than 25% of the market ultimately uses the standing facility.

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[5] Since market rates, i.e. those measured by the daily effective federal funds rate, rarely rise to 100 basis points over target, one might believe that individual federal funds transactions also only rarely rise to this level. However, variation in average rates does not consider variation in transaction rates across banks on any given day. For instance, Furfine's (2002) analysis of federal funds borrowers from the first half of 1998 documents that average interest rates paid varied by 70 basis points across banks. Cross-bank variation in rates on any given day, therefore,

The remainder of the paper is organized as follows. Section 2 documents that policymaker interest in limiting financial market volatility is much broader and has a longer history than the question of the role of standing facilities. A model of transaction interest rate determination is developed in Section 3. Section 4 describes the model's implications. Section 5 provides some institutional details of the interbank market in the United States and describes the data used in this paper. Section 6 conducts tests of the implications of the model. Section 7 concludes.

2. Related literature

The notion that the act of requiring something may create unintended incentive effects that reduce, if not eliminate, the expected benefits of the requirement has been the focus of extensive economic analysis. A classic example of such work is Peltzman's (1975) study of the relationship between automobile safety requirements and motor vehicle deaths. He finds that regulations to improve automobile safety were associated with offsetting changes to driver behavior. As a result, a decline in the deaths of drivers accompanied an increase in pedestrian deaths and a greater incidence of motor vehicle accidents. Viscusi (1983) argues that child-resistant packaging on aspirin bottles may have contributed to increased "parental irresponsibility," consistent with the finding that safety packaging requirements could not be shown to contribute to a decline in accidental child overdoses.

Other studies that highlight the potential adverse incentive effects of required policies have been conducted in financial economics. For example, many studies have analyzed the impact of policies aimed at reducing market volatility, primarily in equity markets. One illustration of such a policy is the series of circuit breakers implemented following the 1987 stock market crash, which attempt to limit large price swings by closing the New York Stock Exchange after it has

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could reasonably be expected to be much wider, making it likely that certain banks may face market rates of more moved by a certain amount.[6] However, Subrahmanyam (1994) argues that circuit breakers may actually exacerbate volatility since traders may trade sub-optimally in order to guarantee themselves the ability to transact before a market-wide closure.[7] Another policy that aims to reduce financial market volatility that can generate unintended consequences is a margin requirement. By requiring investors to post collateral when borrowing to finance security investments, margin requirements were designed by policymakers to limit volatility by curbing credit-financed speculation that was believed to be a root cause of market instability. However, Hardouvelis et. al. (1997) argue that although margin requirements may be stabilizing during market upswings, they may actually be volatility-enhancing during a downturn as investors must sell stock to cover margin calls in a declining market. Studying the time series relationship between margin requirements and stock price volatility, Hardouvelis et. al. find empirical support for this asymmetric relationship between margin requirements and market volatility.[8]

Thus, policies that limit the degree to which market prices can move may have unintended consequences that undermine some of the policy's benefits. As mentioned in the introduction, the focus of this paper will be on one of these policies, namely central bank standing facilities. Much like a circuit breaker, standing facilities attempt to limit price (interest rate) movements by eliminating those movements that lie outside some predefined region. In the next two sections of

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than 100 basis points over the Fed's target.

[6] Many other changes to policies aimed at limiting market volatility followed the 1987 crash. For a useful summary, see Harris (1998).

[7] An alternative viewpoint is provided by Kodres and O'Brien (1994). They develop a framework in which limits on the price movement of securities (i.e. circuit breakers) can be pareto improving when they successfully insure investors against implementation risk, i.e. the risk arising from delays and imperfect price information typical of extremely volatile markets.

[8] Kupiec (1998) reviews the academic evidence on the link between margin requirements and stock market volatility and concludes that there is no strict link between the level of margin requirements and volatility.

the paper, we look theoretically at the interaction of an interbank market and a central bank that offers standing facilities.

3. Model

This section develops a simple search model of an interbank market. Consider a bank that needs to borrow a fixed amount. Its objective is to pay the lowest interest rate possible for its loan. There exists an interbank market in which the bank can participate. For simplicity, it is assumed that the existing environment allows the bank to obtain, at zero cost, one loan offer from a counterparty. We define this first interest rate offer as i_1. This initial rate might be the one available from a bank's regular correspondent or counterparty. It might also represent the prevailing quote from an overnight money broker.

In response to receiving this first offer, the bank has three options: accept the offer, decline the offer and find another offer from the market, or borrow from the central bank at a fixed standing facility rate of i_{CB}. Banks borrowing from the central bank are further assumed to incur a non-price stigma cost s. If the bank chooses neither to accept i_1 nor borrow from the central bank, it must solicit another offer from the market at a cost to the bank of c. In its simplest interpretation, c can represent the search costs of finding another suitable counterparty. The decision to invest c can also be viewed from a longer-term perspective. For example, the cost might represent the costs of establishing a wider network of counterparty relationships or the costs of installing sophisticated cash management software that would allow a bank to learn its borrowing needs earlier in the day when the market may be more liquid. Should the bank decide to seek an additional market offer, i_2, it must then accept either market offer or borrow from the central bank.

The key choice the bank faces is whether or not to seek a second market offer. This decision logically depends on the tradeoff between the costs of searching and the benefits of a potential improvement in borrowing terms.[9] To analyze this choice more formally, we assume that a bank's initial offer, i_1, is drawn from a fixed and known distribution with cumulative distribution function $F(.)$. Should the bank make an investment of c and elicit a second market offer, it is assumed that the bank increases its chances of receiving a better rate. Mathematically, after investing c, the bank's second offer, i_2, is drawn from a fixed and known distribution with cumulative distribution $G(.)$ where $F(x) \leq G(x)\,\forall x$.[10] That is, bank investment improves the underlying distribution of a bank's offer rates. Both $F(.)$ and $G(.)$ are assumed to be continuous and monotonically increasing.

Economically, the functions $F(.)$ and $G(.)$ represent the distribution of offers that a bank can hope to receive in the interbank market. For example, one might think that a bank with a relatively stable risk profile and an established relationship would have a fairly narrow window of expected initial offer rates i_1. Bad draws from the distribution might nevertheless occur. For example, a bank may experience an unexpected outflow late in the business day when it can no longer arrange a loan from one of its normal counterparties. Similarly, a bank's typical

[9] As the model presented is static, the fixed cost c can be interpreted as a cost per unit of borrowing. In a dynamic version of the model, the fixed cost c would be balanced against the present discounted value of future benefits arising from the ability to get improved terms. While adding some analytical complexity, the intuition delivered by the model remains the same. Thus, the simpler exposition is presented.

[10] This assumption is without loss of generality. It was assumed that investment improves outcomes in a probabilistic sense to be consistent with intuition. The results of the model hold even if the distribution of second offers is worse than that of the first offer, as long as there is some probability that the second offer will be better than the first.

counterparty may experience a sudden demand for liquidity itself and may not easily lend funds as it typically would do.[11]

Given the above assumptions regarding the operation of a representative borrower in the overnight interbank market, it is possible to examine the choice of whether a bank finds it worthwhile to make the investment c in return for a second offer from the interbank market. Suppose a bank chooses not to seek a second offer. This choice costs either i_1 (when $i_1 \le i_{CB} + s$) or $i_{CB} + s$ (when $i_1 > i_{CB} + s$). Alternatively, if the bank seeks a second offer, it will pay a total cost of $c + \min(i_1, i_2)$ or $c + \min(i_{CB} + s, i_2)$ when i_1 is less than or greater than $i_{CB} + s$, respectively.

Suppose $i_1 \le i_{CB} + s$. With probability $G(i_1)$, the second offer will be lower than the first and conditional on this being the case, the expected offer rate can be written

$$E(i_2 \mid i_2 < i_1) = \frac{\int_{-\infty}^{i_1} i_2 dG(i_2)}{G(i_1)} \tag{1}$$

With probability $1 - G(i_1)$, the original offer will be lower and the bank will simply pay i_1. The bank will choose to seek a second offer whenever

$$i_1 > c + E\left(\min(i_1, i_2)\right) \tag{2}$$

$$i_1 > c + G(i_1)\frac{\int_{-\infty}^{i_1} i_2 dG(i_2)}{G(i_1)} + (1 - G(i_1))i_1 \tag{3}$$

$$c < i_1 G(i_1) - \int_{-\infty}^{i_1} i_2 dG(i_2) \tag{4}$$

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[11] Systemwide reasons may also cause a change in the underlying distribution functions $F(.)$ and $G(.)$. For instance, the Fed may have supplied too few reserves to the banking system suggesting that the entire market will be

It is straightforward to check that the right-hand side of (4) is increasing in i_1. Consistent with intuition, this says that the higher the offered interest rate i_1, the more likely that the inequality in (4) will hold and the bank will seek a second offer. One can similarly show that for a given value of c there will exist a value for i_1, which we denote by $i^*(c, G(.))$, at which (4) will hold with equality. For all $i_1 > i^*(c, G(.))$, the bank will choose to seek a second offer. In what follows, we will focus on the important role of search costs, and thus we will write $i^*(c, G(.))$ as simply $i^*(c)$. Note that $i^{*\prime}(c) > 0$, meaning that as search costs become larger, the interest rate at which banks begin to seek a second offer rises. Similarly, one can define the search cost level $c^*(i_1)$ to be the level of search costs *below* which banks will wish to obtain a second offer given a first offer of i_1.

Analogous to the derivation above, when $i_1 > i_{CB} + s$, the bank will choose to seek a second offer whenever condition (5) holds.

$$c < (i_{CB} + s)G(i_{CB} + s) - \int_{-\infty}^{i_{CB}+s} i_2 dG(i_2) \tag{5}$$

Thus, whenever $i^*(c) \leq i_{CB} + s$, the bank's decision to seek a second offer is unrelated to the presence of the standing facility. Intuitively, this is because search costs are low enough so that banks try again in the interbank market even if their first interest rate offer is lower than the total cost of borrowing from the standing facility. By contrast, if search costs are sufficiently high such that $i^*(c) > i_{CB} + s$, the presence of the standing facility eliminates a bank's incentive to ever seek a second offer. This is because observations of $i_1 \geq i_{CB} + s$ are treated as if $i_1 = i_{CB} + s$, and at this level of interest, banks choose not to seek another offer.

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paying higher rates for overnight funds.

4. Implications

The model of Section 3 documented that the presence of a standing facility will only affect bank behavior when $i^*(c) > i_{CB} + s$. To derive further implications of this result, it is useful to distinguish between offered rates of interest (heretofore called i_1 and i_2) and *accepted* rates of interest. An accepted rate of interest is the rate that the bank ultimately chooses to pay. That is, the accepted rate can be equal to i_1, i_2, or $i_{CB} + s$. Defining i_A as the accepted rate, it is straightforward to calculate the probability that $i_A \geq \bar{i}$, where $\bar{i}$ is an arbitrary rate of interest.

Consider first the case where the policy rate of the standing facility does not affect bank behavior. That is, $i^*(c) \leq i_{CB} + s$. In this case, the probability of the bank accepting a rate $i_A \geq \bar{i}$ is simply the probability that $i_1 \geq \bar{i}$ and i_1 is accepted plus the probability that i_1 is at first rejected and that the best available offer remains higher than $\bar{i}$ (e.g. $Min(i_1, i_2) \geq \bar{i}$). This relationship is given in (6).

$$\Pr(i_A \geq \bar{i}) = \Pr(\bar{i} \leq i_1 \leq i^*(c)) + \Pr(i_1 \geq i^*(c), Min(i_1, i_2) \geq \bar{i}) \tag{6}$$

Equation (6) can be simplified depending on the level of $\bar{i}$. For instance, when $\bar{i} \leq i^*(c)$, the second term in the right-hand side of (6), e.g. the probability that i_1 is rejected and that $Min(i_1, i_2) \geq \bar{i}$, is simply the probability that the first offer is rejected and the second offer is accepted at a rate above $\bar{i}$. Because the offers are independent, this probability is simply equal to $\Pr(i_1 \geq i^*(c))\Pr(i_2 \geq \bar{i})$. By contrast, whenever $\bar{i} > i^*(c)$, then the first term on the right-hand side of (6) is equal to zero. Intuitively, first offers above $i^*(c)$ will never be accepted. Further, the second term is simply equal to the probability that both offers are greater than $\bar{i}$. Again, because of the independence of the offers, this is simply equal to $\Pr(i_1 \geq \bar{i})\Pr(i_2 \geq \bar{i})$. Finally, accepted offers can never be higher than the standing facility rate plus the assumed stigma cost

$i_{CB}+s$. Overall, therefore, when the standing facility rate does not influence bank behavior, the probability of $i_A \geq \bar{i}$ can be summarized by (7).

$$\Pr(i_A \geq \bar{i}) = \begin{cases} \Pr(\bar{i} \leq i_1 \leq i^*(c)) + \Pr(i_1 \geq i^*(c))\Pr(i_2 \geq \bar{i}) & \forall \bar{i} \leq i^*(c) \\ \Pr(i_1 \geq \bar{i})\Pr(i_2 \geq \bar{i}) & \forall i^*(c) \leq \bar{i} < i_{CB}+s \\ \Pr(i_1 \geq i_{CB}+s)\Pr(i_2 \geq i_{CB}+s) & \bar{i} = i_{CB}+s \\ 0 & \bar{i} > i_{CB}+s \end{cases} \tag{7}$$

The second case to consider is where $i^*(c) > i_{CB}+s$. Recall that in this case, search costs are so high that a bank will never seek a second offer. Therefore, the distribution of accepted offers equals the distribution of first offers, except that accepted offers are never greater than $i_{CB}+s$. Thus, when the standing facility rate does influence bank behavior, accepted interest rates have the simpler probability distribution given by (8).

$$\Pr(i_A \geq \bar{i}) = \begin{cases} \Pr(i_1 \geq \bar{i}) & \forall \bar{i} \leq i_{CB}+s \\ \Pr(i_1 \geq i_{CB}+s) & \bar{i} = i_{CB}+s \\ 0 & \bar{i} > i_{CB}+s \end{cases} \tag{8}$$

Determining whether (7) or (8) describes the distribution of accepted rates is thus equivalent to determining whether $i^*(c) < i_{CB}+s$ or $i^*(c) > i_{CB}+s$. Mathematically, one can see that in the limit as $i_{CB} \to \infty$ or $c \to 0$, equation (7) will necessarily become the relevant distribution function of accepted offers. In other words, a very high rate charged at the standing facility for a given search cost c will necessarily be higher than $i^*(c)$ and thus banks will choose to search as if there was no standing facility. Likewise, for any positive level of the standing facility rate i_{CB}, a sufficiently low level of search costs would also lead to a bank engaging in search as if there was no standing facility.

As we will ultimately be making an empirical comparison between a market both with and without a standing facility, it is helpful to state what the distribution of accepted rates would look like in the absence of such a central banking facility. We view an interbank market with no standing facility as equivalent to a market with a standing facility with a standing facility rate $i_{CB} = \infty$. Taking the limit of (7) as $i_{CB} \to \infty$ gives

$$\Pr(i_A \geq \bar{i}) = \begin{cases} \Pr(\bar{i} \leq i_1 \leq i^*(c)) + \Pr(i_1 \geq i^*(c)) \Pr(i_2 \geq \bar{i}) & \bar{i} \leq i^*(c) \\ \Pr(i_1 \geq \bar{i}) \Pr(i_2 \geq \bar{i}) & i^*(c) \leq \bar{i} \end{cases} \tag{9}$$

5. Institutional details and data

The Fed announces a target rate for federal funds. However, as a practical matter, achieving this target is accomplished by regular interventions in the reserves market in an effort to have the volume-weighted *average* rate on federal funds transactions (a.k.a. the effective federal funds rate) be close to the target rate *over some horizon*, typically one reserve maintenance period. In other words, the Fed does not have much of a concern with small deviations of the effective rate from target and has even less concern with the fact that individual federal funds transactions may take place at an interest rate far from the target rate. In particular, the federal funds market exhibits cross-bank variation in interest rates paid for funds. In this paper, we exploit the fact that rates paid for federal funds do vary across banks to determine whether the distribution of rates paid by banks seems to have changed since the introduction of the Fed's new standing facility.

The null hypothesis being tested is whether the amount of borrowing of primary credit from the Fed is equal to the volume that one would have predicted in advance, given the historical (pre-facility) empirical distribution of cross-bank interest rates paid. For instance, if stigma and search costs were low, one would expect the amount of borrowing at the Fed's new facility to be equal to the amount of borrowing that had previously been done in the federal funds market at 100 or more basis points over the target rate. Further, one would not expect to see any federal funds market transactions occurring at 100 or more basis points over the target rate. If stigma costs are high relative to search costs, however, one might expect to see less borrowing at the Fed's facility and also federal funds market transactions occurring at rates at 100 or more basis points over target. By contrast, if search costs are high relative to stigma costs, one might find more volume at the facility than you would have predicted based on the pre-facility empirical distribution of interest rates paid in the market.

To examine which of these possibilities more accurately represents the US federal funds market, we require data on interbank market transactions both before and after the policy change. In particular, we require information regarding the distribution of interest rates on individual interbank market transactions. These data were constructed from payment flow information. To be precise, federal funds transactions are settled over Fedwire, the real-time gross settlement system owned and operated by the Federal Reserve. For this study, a record of every Fedwire funds transfer was collected between January 9, 2002 and March 31, 2002 (Period 1) and also between January 9, 2003 and March 31, 2003 (Period 2). Using identical days in the two years helps to mitigate any seasonal patterns to interbank lending that may be present. These funds transfers were then searched for those related to the federal funds market. For instance, if Bank A agrees to lend \$10 million to Bank B on a Tuesday at an interest rate of 5.50%, the Fedwire transaction data will contain a payment from Bank A to Bank B for \$10 million on Tuesday and also a payment from Bank B to Bank A for \$10,001,527.78 on Wednesday. Based on anecdotal evidence presented by Stigum (1990), payments whose amounts were greater than \$1 million, ended in five zeros, and had a payment the following business day in the opposite direction in an amount that could reasonably be construed as the initial payment plus interest were identified as federal funds transactions.[12] Once the underlying transaction data have been uncovered, calculating the value transacted over certain interest rate ranges is straightforward. For Period 2, we also utilize data from the Federal Reserve's H.3 release on the dollar volume of lending done at the Fed's primary credit facility, augmented by similar confidential data collected by the Fed at a daily frequency.

6. Empirical tests

The empirical question is whether or not the use of the primary credit facility has been used more or less than what one would predict, given the characteristics of the interbank market. For each day during Period 1, we calculate the fraction q_{1t} of the interbank market that takes place on day *t* of Period 1 at 100 or more basis points above the target federal funds rate, which during Period 1 was 1.75%. In the absence of stigma and search costs, we should expect this same fraction of the market to simply move to the primary credit facility during Period 2. We can similarly calculate q_{2t} as the total amount of primary credit borrowed divided by the total volume of interbank loans on day *t* during Period 2. Thus, our first null hypothesis is that the distribution of q_{1t} is the same as the distribution of q_{2t}. Intuitively, this corresponds to the "25% of the market" example given in the introduction.

Summary statistics for q_{1t} and q_{2t}, shown in Table 1, indicate that borrowing at the primary credit facility seems far lower than could have been expected. As Table 1 indicates, the mean fraction of the interbank market that borrowed at or above 100 basis points above target during Period 1 is slightly less than one percent. This fraction, however, is 140 times larger than the average fraction of the market that borrowed from the primary credit facility in Period 2. On

[12] Because we are particularly interested in finding transactions somewhat far from the Fed's target rate, we allow

one day during Period 1, over 2.1% of the interbank market trading at 100 or more basis points above target. The largest single day of borrowing from the primary credit facility during Period 2 amounted to less than eight hundredths of a percent of total market volume.

Although the simple sample statistics indicate that the borrowing at the primary credit facility has been lower than what we might have expected given the distribution of interest rates paid in the market during Period 1, we test this formally by calculating both Kolmogorov-Smirnov and Wilcoxon rank statistics.[13] The Kolmogorov-Smirnov statistic tests the null hypotheses that q_{1t} comes from a smaller or larger distribution than q_{2t}. The Wilcoxon statistic tests the null hypothesis that both q_{1t} and q_{2t} were drawn from the same distribution. These results are shown in Table 2. As should be no surprise after seeing Table 1, the results presented in Table 2 indicate overwhelmingly that the fraction of the interbank market that has borrowed from the primary credit facility is lower than the fraction of the interbank market that would seem to benefit from doing so.

One possible explanation to the low level of borrowing from the primary credit facility is that during Period 2, the range of interest rates paid in the federal funds market was much smaller than the range paid during Period 1. A narrower range of interest rates would suggest less of a benefit from borrowing directly from the Fed and would not have been accounted for in the univariate results discussed above. Table 1 also indicates summary statistics on data from the federal funds brokers that is published each day by the Federal Reserve Bank of New York.

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interest rates to range from a low rate of 0.5% to a high of 250 basis points above the target rate.

[13] The Kolmogorov-Smirnov test uses the maximum distance between two cumulative distribution functions as the test statistic D. Details of tests of this type are given in Conover (1999). The Wilcoxon ranksum test first orders all observations, regardless of which distribution the observation was drawn from. Then, each observation is ranked and then summed separately for each distribution. The test statistic is based upon the difference between the actual sum and the expected sum of the ranks of all the observations. Details are given in Wilcoxon (1945). The results from the Wilcoxon test are equivalent to those from a Mann-Whitney test described in Mann and Whitney (1947).

According to these data, the market did seem to have a wider range of interest rates during Period 1. The mean standard deviation of interest rates paid in the brokered market was 13 basis points in Period 1 but only 4 basis points in Period 2. This difference in mean, however, may be overstated because of the occurrence of a very large and outlying value for this variable during Period 1. A more informative comparison is the difference in the median standard deviation. During the first period, the median standard deviation of interest rates was 6 basis points but only 3 basis points in Period 2. Thus, by this measure, the dispersion of interest rates was twice as wide during the first period. Table 1 also reports summary statistics on the highest rate reported by the brokers during the two periods. These data, too, indicate a wider range of interest rates paid during Period 1.

We then try to determine whether or not the lower dispersion of rates paid in the market can explain the low borrowing from the primary credit facility. Using data from Period 1, we fit a series of regression models to estimate the fraction of the market that trades at 100 or more basis points above target. The dependent variable is q_{1t}. In some specifications, we include a lagged dependent variable. We consider the broker-reported standard deviation of interest rates and the spread between the broker-reported high rate and the target rate as independent variables. These two variables are expected to be correlated with higher fractions of market activity conducted at higher rates. In some specifications, we include volatility measures from other financial markets to investigate whether federal funds rate volatility may be related to financial market volatility more generally. We proxy for market volatility by using absolute values of the daily return on the S&P 500 stock index and the daily yield change on the 10-year Treasury note.[14]

The results from these regression equations are shown in Table 3. The coefficients reported generally have the expected signs. In particular, the spread between the broker-reported highest rate in the market and the target funds rate enters with a positive sign. Higher standard deviations of interest rates paid are also generally correlated with higher fractions of the market transacted at 100 or more basis points over target. However, the coefficient on the standard deviation does not enter significantly when measures of market volatility enter the regression, although these variables are jointly significant at standard significance levels. Also, movements in the broker-reported average rate (effective federal funds rate) do not seem to have additional significant explanatory power.

Using the estimated coefficients, we then create predicted values $\hat{q}_{2t}$ of the fraction of the market that should be expected transact over this range of interest rates using data from Period 2. These predicted shares are then compared to the actual shares q_{2t} and additional equality of distribution tests are conducted. The final row of Table 3 reports analogous findings to those reported in Table 2. Specifically, even after controlling for differences in market conditions between Period 1 and Period 2, we overwhelmingly reject the null hypothesis that the quantity of borrowing from the primary credit facility is what would be expected given the variation in interest rates in the market in favor of the alternative that primary credit usage is abnormally low.

The results of the above analysis suggests that borrowing from the primary credit facility has been lower than one might have expected given the distribution of interest rates paid in the

[14] In regression results not reported, we have additionally considered calendar-related variables such as month-end and quarter-ends, reserve settlement days, and days before and after holidays. Coefficients on these additional variables were never statistically significantly different from zero.

federal funds market. A further indication of this fact can be found in the third row of Table 1, which reports the fraction of the federal funds market that either borrows from the primary credit facility or borrows in the funds market at 100 or more basis points over target. A comparison of the second and third lines of Table 1 indicates that an average of more than 57 times more activity occurs in the federal funds market at rates equal to or higher than the rate offered by the primary credit facility. Within the context of the model, this can be explained by a stigma that is attached to central bank borrowing that is not present in the interbank market.

7. Conclusion

This paper develops a model of a bank's decision to borrow from a central bank's standing facility. This model incorporates that (a) there may be a stigma attached to borrowing from the central bank instead of the interbank market and (b) the mere presence of a standing facility may inhibit a bank's incentive to solicit attractive market offers. These two effects have opposite predictions regarding the likelihood that a bank will borrow from the central bank. We then conduct an empirical comparison of the federal funds market during periods with and without a standing facility. After controlling for other differences between the two periods, we find that borrowing from the Fed's new primary credit facility is far lower than could have been expected given the cross-sectional variation in interest rates paid in the federal funds market. Further, the amount of borrowing from the Fed is dwarfed by the amount of interbank borrowing at less attractive rates of interest. Thus, it would seem that a strong reluctance to borrow from the Fed remains.

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Table 1: Summary statistics

This table reports summary statistics for various measures of interbank market activity. Period 1 consists of 56 trading days from January 9, 2002 through March 29, 2002. Period 2 consists of 56 trading days from January 9, 2003 through January 31, 2003.

Variable	Mean	Standard Deviation	Minimum	Median	Maximum
Fraction of market trading at or above target+100 during Period 1.	.0097635	.0040487	.0011751	.0095214	.0218257
Fraction of market borrowing primary credit during Period 2.	.0000697	.0001421	0	.0000206	.0007724
Fraction of market trading at or above target+100 or borrowing primary credit during Period 2.	.0040602	.002413	.0003974	.0037616	.010511
Brokered reported daily standard deviation of interest rates paid in the funds market during Period 1.	0.13	0.32	0.03	0.06	1.77
Brokered reported daily standard deviation of interest rates paid in the funds market during Period 2.	0.04	0.02	0.02	0.03	0.11
Brokered reported daily highest rate paid in the funds market less the target rate during Period 1.	0.33	0.87	0	0.13	6.25
Brokered reported daily highest rate paid in the funds market less the target rate during Period 2.	0.16	0.14	0	0.13	0.75

Table 2: Tests for Equality of Distribution

This table reports test statistics for univariate comparisons of the fraction of the interbank market transacting at or above 100 basis points over target during Period 1 with the fraction of the interbank market transacting at the primary credit facility during Period 2. Period 1 consists of 56 trading days from January 9, 2002 through March 29, 2002. Period 2 consists of 56 trading days from January 9, 2003 through January 31, 2003.

Null hypothesis	Kolmogorov-Smirnov equality of distributions	Wilcoxon rank-sum tests
Fraction of market trading at or above target+100 during Period 1 is **greater** than fraction of market borrowing primary credit during Period 2.	D=0.000 p-value 1.000	
Fraction of market trading at or above target+100 during Period 1 is **less** than fraction of market borrowing primary credit during Period 2.	D=1.000 p-value 0.000	
Fraction of market trading at or above target+100 during Period 1 is **the same as** the fraction of market borrowing primary credit during Period 2.		Z=-9.125 p-value 0.000

Table 3: Regression models

This table reports coefficient estimates (and robust standard errors) for various regression specifications. The dependent variable in all specifications is the fraction q_{1t}, which measures the fraction of the interbank market that transacted at rates 100 or more basis points above the target funds rate of 1.75% during Period 1.

	1	2	3	4	5	6
Lagged dependent variable	0.285	0.276	0.283			
	(0.116)*	(0.120)*	(0.107)*			
Broker-reported high rate less target rate	0.001	0.001	0.001	0.002	0.002	0.002
	(0.000)**	(0.000)**	(0.000)**	(0.000)**	(0.000)**	(0.000)**
Broker-reported standard deviation	0.001	0.001	0.001	0.002	0.001	0.001
	(0.001)*	(0.001)*	(0.001)	(0.001)**	(0.001)*	(0.001)
Broker-reported average rate less target rate	-0.006		-0.008	-0.004		-0.006
	(0.010)		(0.011)	(0.010)		(0.011)
Abs. val. of the return on the S&P 500			0.097			0.106
			(0.060)			(0.065)
Abs. val. of the 10-year T-note yield change			0.012			0.012
			(0.014)			(0.015)
Constant	0.006	0.006	0.005	0.009	0.009	0.008
	(0.001)**	(0.001)**	(0.001)**	(0.001)**	(0.001)**	(0.001)**
Observations	55	55	55	56	56	56
R-squared	0.22	0.21	0.26	0.14	0.14	0.19
Robust standard errors in parentheses						
* significant at 5%; ** significant at 1%						
K-S test statistic comparing distribution of predicted values with actual primary credit borrowing	D=1.000 p-value 0.000	D=1.000 p-value 0.000	D=1.000 p-value 0.000	D=1.000 p-value 0.000	D=1.000 p-value 0.000	D=1.000 p-value 0.000
Wilcoxon test statistic comparing distribution of predicted values with actual primary credit borrowing	Z=-9.083 p-value 0.000	Z=-9.083 p-value 0.000	Z=-9.083 p-value 0.000	Z=-9.125 p-value 0.000	Z=-9.129 p-value 0.000	Z=-9.125 p-value 0.000

Figure 1: Borrowing from the discount window

This figure plots the ratio of borrowed reserves to required reserves since January 1959. Source: Federal Reserve H.3.