8-10-2010

Provision of Liquidity through the Primary Credit Facility during the Financial Crisis: A Structural Analysis

Erhan Artuc

Selva Demiralp

Erhan Artuç and Selva Demiralp

Provision of Liquidity through the Primary Credit Facility during the Financial Crisis: A Structural Analysis

1. Introduction

In response to the liquidity crisis that began in August 2007, central banks designed a variety of tools for supplying liquidity to financial institutions. The Federal Reserve introduced several programs, such as the Term Auction Facility, the Term Securities Lending Facility, and the Primary Dealer Credit Facility, while enhancing its open market operations and discount window. This paper focuses on the financial market effects of changes to the discount window borrowing facility. Specifically, we investigate whether the changes represent a fundamental shift in the way the Federal Reserve traditionally provided liquidity through the primary credit facility as well as whether the Fed would be well served to retain these changes to its borrowing facility indefinitely.

In January 2003, the Federal Reserve revised its discount window lending program. The revision was designed to improve the operation of the facility, which had experienced declines in usage. Before 2003, borrowing from the Fed took place at a rate below the market rate, known as the discount rate. Fed officials applied a non-price funds-rationing mechanism by asking potential borrowers detailed questions about their financial well-being before lending funds. This administrative process deterred depository institutions from using the discount window because borrowing from the Fed was perceived as a signal of financial weakness by market participants.[1]

The revised discount window borrowing facility was designed to eliminate the reluctance to borrow from the Fed by including a new "no-questions-asked" policy for eligible borrowers. However, despite Fed assurance that the new facility would eliminate all administrative costs of borrowing, some argued that the stigma could not be eliminated completely (see, for example, Furfine [2001, 2003]). However, Artuç and Demiralp (2010) recently showed that the stigma of borrowing declined substantially in the post-2003 period, following the easing of the Fed's administrative policy and restrictions.

In this paper, we assess the effects of changes to the primary credit facility since August 2007 by performing out-of-sample simulations based on a model developed by Artuç and Demiralp (2010). Our results are highly consistent with the predictions of our 2008 study—that is, the revised discount window is effective and plays an essential role in moderating volatility in the federal funds market.

[1] See, for example, Goodfriend (1983), Pearce (1993), Dutkowsky (1993), Peristiani (1998), Clouse and Dow (1999), Furfine (2003), Dow (2001), and Darrat et al. (2004).

Erhan Artuç is an assistant professor of economics and Selva Demiralp an associate professor of economics at Koç University, Turkey.
Correspondence: eartuc@ku.edu.tr

The authors thank Seth Carpenter, Refet Gürkaynak, Carolyn Wilkins, and conference participants for comments. Financial support for this paper was provided by the Scientific and Technological Research Council of Turkey (TUBITAK). Demiralp's research was also funded by the Turkish Academy of Sciences (TUBA). The views expressed are those of the authors and do not necessarily reflect the position of the Federal Reserve Bank of New York or the Federal Reserve System.

2. Recent Changes to the Primary Credit Facility

The primary credit facility, as revised by the Federal Reserve in 2003, offered credit to financially sound banks at a rate 100 basis points above the Federal Open Market Committee's target federal funds rate (the primary credit rate). Primary credit was made available to depository institutions at an above-market rate but with very few administrative restrictions and no limits on the use of proceeds (see Madigan and Nelson [2002]). Because the interest rate charged on primary credit was above the market price of funds, it replaced the rationing mechanism for obtaining funds from the central bank and eliminated the need for administrative review by the Federal Reserve.

Amid the onset of the liquidity crisis in August 2007, the Federal Reserve lowered the spread between the primary credit rate and the target funds rate from 100 basis points to 50 basis points and extended the maximum term of loans to thirty days. In March 2008, the Fed once again narrowed the spread, this time to 25 basis points, and extended the loan term to ninety days. The moves were motivated by the desire to make discount window credit more accessible to depository institutions.

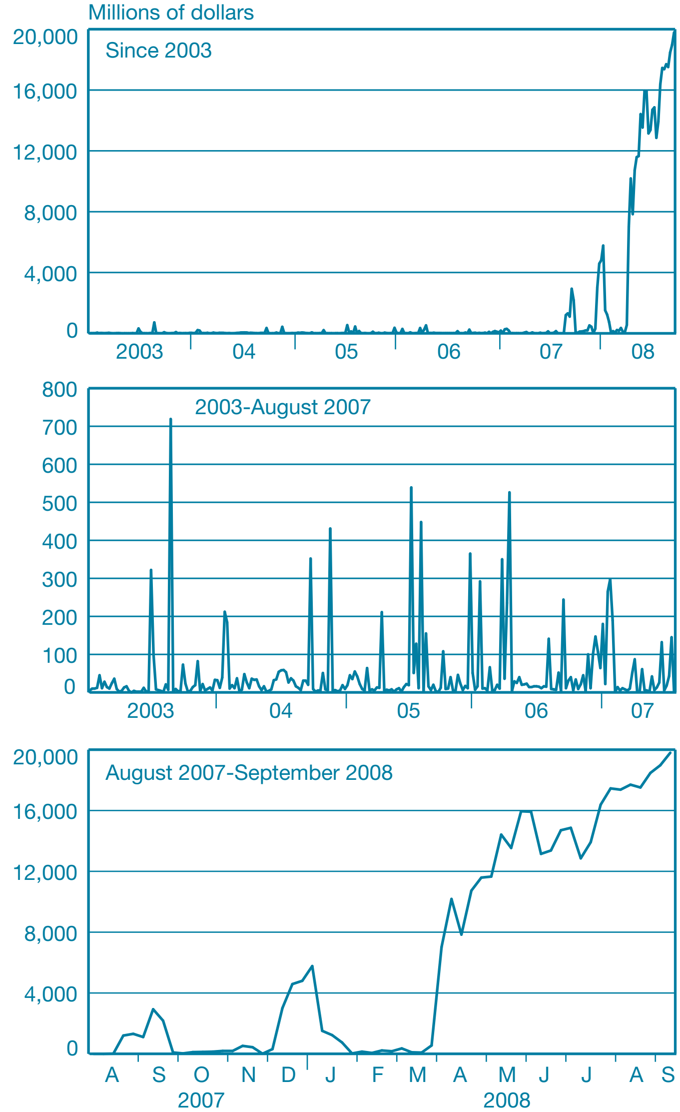
The Federal Reserve's actions led to an increase in the volume of discount window borrowing during the crisis (Chart 1). The upper panel of the chart shows total primary credit outstanding since the establishment of the revised facility in 2003. The middle and lower panels, which split the sample at August 2007, illustrate the enormous rise in borrowing that occurred.

While the massive increase in the volume of borrowing supports the argument that the stigma of borrowing had been eliminated, one should be cautious when interpreting this result. Chart 2, which plots the highest traded funds rate against the primary credit rate, shows that despite the expansion in borrowing, some trades in the funds market took place at rates above the primary credit rate. What is reassuring about these findings, however, is their consistency with the predictions of our earlier work. As Artuç and Demiralp (2010) describe, reluctance to borrow from the Fed has several components. The non-price mechanism is the component attributable to the Federal Reserve's implementation of discount lending. Artuç and Demiralp show that this component declined significantly after the establishment of the revised facility in 2003. Meanwhile, a second type of stigma arises from the asymmetric information problems associated with discount window borrowing. Specifically, while most banks borrow from the discount window, the facility is also used by troubled or failing institutions. Because market participants cannot fully differentiate sound from troubled borrowers, they may view borrowing as a potential sign of weakness of any bank that visits the window. If this type of stigma increases at the early stages of a financial crisis, when institutions are trying to signal their good health, it could explain the spikes in the funds rate over the primary credit rate shown in Chart 1.[2] In addition, it is plausible that the capital crunch during the financial crisis left some institutions without sufficient collateral to apply for primary credit loans and thus forced them to bid for higher rates in the federal funds market, which is unsecuritized.

Chart 1

Primary Credit Outstanding

Weekly Average

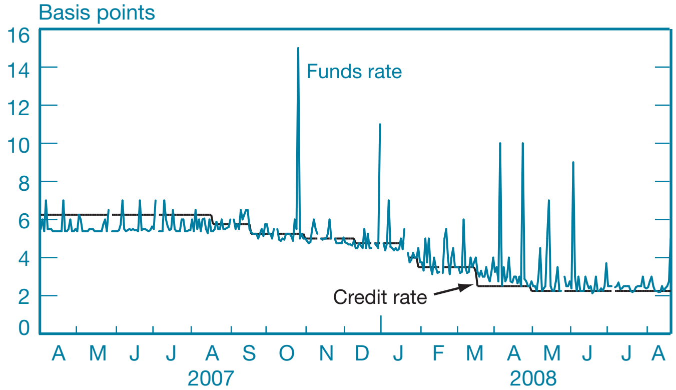


Source: Federal Reserve Statistical Release H.4.1.

Chart 2

Daily High Funds Rate and Primary Credit Rate

Weekly Average



Sources: Daily high funds rate: Federal Reserve Bank of New York (http://newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm); primary credit rate: Federal Reserve Statistical Release H.15.

3. The Model

The model we describe closely resembles the one developed in Artuç and Demiralp (2010), which can be viewed as an extension of the model proposed by Clouse and Dow (1999). Hence, our discussion relies heavily on Section 3 of Artuç and Demiralp (2010). We consider a framework in which bank *i*'s goal is to keep its daily reserves holdings at a level L_1. Daily reserve balances vary over the course of the maintenance period (see Carpenter and Demiralp [2006]). However, from the borrower's perspective, a bank's decision to borrow from the Fed is static based on liquidity conditions each day. Therefore, we do not differentiate across days of the maintenance period except for the settlement Wednesday, which may necessitate higher borrowing because banks have less flexibility in absorbing any reserve shortages on the last day of the maintenance period. On this day, the desired level of reserve holdings is determined by L_2.

Banks' balance holdings follow a stochastic process. During the day, there are aggregate and individual shocks to the average level of reserve balances ($\bar{R}$), which sets the balance of bank *i* equal to:

$$(1) \qquad R_t^i = \bar{R} + U_t + V_t^i,$$

where $U_t \sim N[0, X_U]$ is an aggregate shock[3] and $V_t^i \sim U[-X_v, X_v]$ is an individual shock where X_U is the standard deviation of the aggregate shock while X_V represents the support of the mean zero uniform distribution. Hence, the individual bank becomes a lender in the funds market if $R_t^i > L$ and demands funds if $R_t^i < L$ for $L = L_1, L_2$.

Banks that are short of reserves have two options: they can either borrow from the funds market or from the Federal Reserve. If the bank chooses to borrow ϕ_t dollars from the funds market, the cost per dollar is the market interest rate r_t. Alternatively, if the bank borrows ϕ_t dollars from the Federal Reserve, the cost per dollar is the discount rate (or the primary credit rate after 2003), r_f, plus a fixed cost *c*. Thus, total cost per dollar is $r_f + \frac{c}{\phi_t}$. Because of the fixed cost, partial borrowing from the Federal Reserve is not optimal, and a bank either prefers to borrow entirely from the Federal Reserve or from the funds market.[4]

In addition to borrowing from the Federal Reserve because of market conditions, banks borrow because of technical difficulties, such as network problems that force them to use the Fed regardless of market conditions. To capture this type of borrowing, we assume that a random fraction of banks, p_t, will face a technical problem in the system where p_t has a uniform distribution: $p_t \sim U[0, F]$.

We assume that there is a continuum of banks, indexed from 0 to 1. Thus, there are an infinite number of banks with zero individual measure whose measure integrates to 1. We index according to reserve balance levels, such that a bank with the lowest level of reserve balances is indexed to 0 and one with the highest level of reserve balances is indexed to 1.

Total demand for funds has two components: It can be met in the funds market or it can be met at the discount window. The equilibrium federal funds rate, r_t, is determined by the market equilibrium when the total supply of funds is equal to the total demand for funds. In modeling borrowing behavior, our focus is on individual trades in the funds market and on days of market tightness because borrowing from the Fed on

[2] Indeed, a closer look at the days with spikes in the funds rate reveals that market commentaries are consistent with elevated asymmetric information problems. An extreme example is October 25, 2007, when the highest traded funds rate exceeded the primary credit rate by almost 10 percentage points. On that date, Wrightson ICAP reported that "the stigma of discount window borrowing was heightened by the news that the New York Fed had extended $400 million of secondary-credit loans on Wednesday. If word got out that a given institution had tapped the window on Thursday, the market might speculate that the bank in question was the same one that had been forced to make use of the higher-cost secondary credit program for shaky institutions the day before. The reputational damage of a leak of that nature would be disastrous" (Wrightson ICAP, *Fed Funds Monitor*, http://www.wrightson.com).

[3] Because the original model is estimated by removing the outliers, we subtract 0.5 percent from the tails of the normal distribution.

[4] Without loss of generality, one may think of the fixed costs of borrowing as varying by bank, reflecting each bank's relative reluctance to borrow from the discount window based on factors such as the size of the borrowing, the history of borrowing, or the availability of credit lines in the funds market. While we model it in a homogenous manner for simplicity, modeling it in a heterogeneous manner is also trivial and does not change any implications of our model.

these days is more likely. Therefore, we set the daily high funds rate equal to:

$$(2) \qquad r_t^{high} = r_t + \omega_t \text{ where } \omega_t \sim (0, s).$$

Equation 2 shows that the maximum funds rate registered for a given day will differ from the equilibrium funds rate depending on the reserves need and the bargaining power faced by the counterparties of that particular trade, represented by ω_t.

Turning to the days without market tightness, we note that trades are almost always cleared in the funds market unless there is a technical problem. For that reason and without loss of generality, if supply is larger than demand, we simply set the funds rate (r_t) equal to the marginal benefit of holding balances, as in Clouse and Dow (1999). Hence, a bank can offer reserves in the funds market if the market rate is greater than the marginal benefit of holding balances.

If the fixed costs of borrowing decline in the period after 2003, then, all else equal, it implies a decline in the volatility of the funds rate in the post-2003 period and an increase in the sensitivity of discount window borrowing to the funds rate. (A more detailed discussion of the implications of the model can be found in Artuç and Demiralp [2010].) This implied change in volatility and the revival of the borrowing function allow us to identify the size of the implicit cost before and after 2003.

If we could attribute the entire decline in fed funds volatility to the revised discount facility, we could proceed with estimation without any second thoughts. However, the decline in fed funds volatility is also influenced by other developments, such as enhanced liquidity management by the Federal Reserve's Trading Desk (see Demiralp and Farley [2005]), improvements in internal information systems (including those that track a bank's Federal Reserve account balance), or banking industry consolidation. To minimize the effects of such factors on fed funds volatility, we keep our sample period relatively recent, starting it in 1998. Furthermore, to control for any remaining effects of such factors, we allow the distributions of U_t and V_t^i to widen or narrow in a linear fashion over time. That is, we let:

$$(3) \qquad X_U = A + D \times t \quad \text{and} \quad X_V = B + E \times t,$$

where t is the time trend, X_U and X_V are defined after equation 1.

To identify the potential decrease in the stigma associated with discount window borrowing, we consider the following specification for the implicit borrowing cost c:

$c = c_1$, prior to 2003

$c = c_1 + c_2$, after 2003.

Note that the above specification treats the implicit costs of borrowing as exogenously determined. An alternative and more plausible strategy would be to model the costs of borrowing as a function of the amount borrowed from the Federal Reserve. However, modeling the cost of borrowing endogenously cannot be identified in this study, so the issue remains a topic for future research.[5]

To estimate our model, we rely on "indirect inference," which uses the estimates of an auxiliary model (rather than moments) to compare actual and simulated data. Because we can think of data moments as the parameters of a simplified auxiliary model, Method of Simulated Moments (or GMM) can be considered special cases of indirect inference. An auxiliary model does not need to be "correct" for indirect inference to yield consistent results. As long as the selected auxiliary model summarizes the data well, the estimates of the actual model will be consistent and asymptotically normal. This is because the auxiliary model is used only to extract information on the underlying data-generating process and, provided that the parameter estimates from the actual data are close to those from the simulated data, whether both estimates are biased or not is of secondary importance. In other words, the auxiliary parameter estimates themselves do not carry much meaning other than being indicators of how closely the simulations match the data (see Artuç and Demiralp [2010]; for a more technical reading on indirect inference, see Gourieroux, Monfort, and Renault [1993] and Smith [1993]).

We contemplate a simple borrowing function as the auxiliary model. The auxiliary borrowing function summarizes how borrowing from the Fed changed over time and after the policy change in 2003 through a simple ordinary least squares (OLS) regression, shown in equation 4. In addition to OLS estimates, we use the mean and the variances of borrowing and the spread between the daily high funds rate and the target as part of the auxiliary model (equations 5-8). We also add the lowest 50 percent of the spread between the daily high funds rate and the target to capture funds rate volatility in the absence of market tightness (equations 9 and 10). The estimation strategy is to find the parameters that will make the simulations of the model and the actual data look as similar as possible with respect to the auxiliary model's OLS estimates and moments. Specifically, our auxiliary model is:

$$(4) \quad BR_t = \beta_1 + \beta_2 \tilde{r}_t + \beta_3 t + \beta_4 t \tilde{r}_t + \beta_5 D^{2003} \tilde{r}_t + \beta_6 D^{Settl.\ Wed.} + \varepsilon_t$$

$$(5) \quad BR_t = \beta_7 + \varepsilon_{2t}$$

$$(6) \quad \tilde{r}_t = \beta_8 + \varepsilon_{3t}$$

$$(7) \quad (BR_t - \beta_7)^2 = \beta_9 + \varepsilon_{4t}$$

$$(8) \quad (\tilde{r}_t - \beta_8)^2 = \beta_{10} + \varepsilon_{5t}$$

[5] We thank Carolyn Wilkins for bringing this point to our attention.

(9) $$\tilde{r}_{2t} = \beta_{11} + \varepsilon_{6t}$$

(10) $$(\tilde{r}_{2t} - \beta_{11})^2 = \beta_{12} + \varepsilon_{7t}$$

and

$$\beta = [\beta_1 \beta_2 \ldots \beta_{12}],$$

where BR_t is the amount of borrowing from the Fed normalized by required operating balances, $\tilde{r}_t$ is the spread between the funds rate and the funds rate target, t is the time trend, D^{2003} is a dummy for days after the policy change, $D^{Settl.\ Wed.}$ is a dummy for the settlement Wednesday, ε_t is an *iid* random shock, T is sample size, and $\tilde{r}_{2t}$ is the lowest 50 percent of $\tilde{r}_t$.

Let $\hat{\beta}$ be an OLS estimate of β from the actual data and $\tilde{\beta}$ be an estimate of from the simulated data. We select the model's parameters $[ABc_1c_2DEF\bar{R}sL_2|]$ such that $(\hat{\beta} - \tilde{\beta})\, W\, (\hat{\beta} - \tilde{\beta})'$ is minimized, where W is the weighting matrix that is equal to the inverse of the covariance matrix of β .

In estimating the model, we exclude those days on which the daily high funds rate exceeds the target rate by more than 25 percent to obtain a more realistic distribution of shocks. Our estimation results, presented in the appendix, suggest that the implicit fixed cost of borrowing declines about 90 percent (from 0.054 to 0.007) after the policy change in 2003. This result offers strong evidence that the Fed's new policy was indeed successful in reducing the stigma associated with discount window borrowing.

4. Simulation Analysis

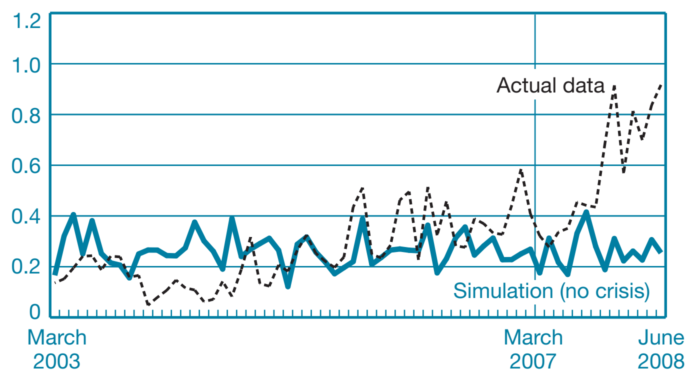
In this section, we use our model to analyze the role of the Federal Reserve's primary credit lending facility in stabilizing the money markets in the face of the liquidity crisis. Specifically, we ask the following questions:

1. What are the effects of the establishment of the revised lending facility on total borrowing and interest rates? In particular, how would the crisis picture look if the implicit costs of borrowing had not been reduced with the new regime in 2003?
2. What are the implications of the increased term of discount lending in the funds markets?
3. What are the effects of narrowing the spread between the primary credit rate and the target rate in stabilizing the money markets?
4. What are the implications for discount window borrowing of paying interest on reserves?

Recall that the model described earlier is designed to capture the "normal times" of healthy functioning markets. Our estimation period captures a period of a relatively stable structural environment. The sample starts on June 30, 1998, with the switch from contemporaneous reserves accounting to lagged reserves accounting. It ends on March 19, 2007, a few months prior to the onset of the liquidity crisis in August 2007. Indeed, if we use the estimates from our model for out-of-sample simulations, the severity of the crisis and the model's inability to forecast this environment become clear. Charts 3 and 4 compare actual data with the model's out-of-sample simulations for the deviation of the daily high funds rate from the target and for primary credit outstanding, respectively.

Chart 3

Daily High Funds Rate Less Target

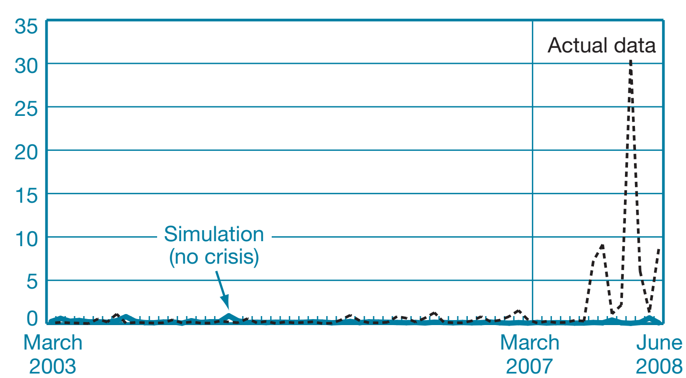


Sources: Federal Reserve Bank of New York (daily high funds rate: http://newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm); (target: http://newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm); simulated series: authors' calculations.

Chart 4

Primary Credit Outstanding

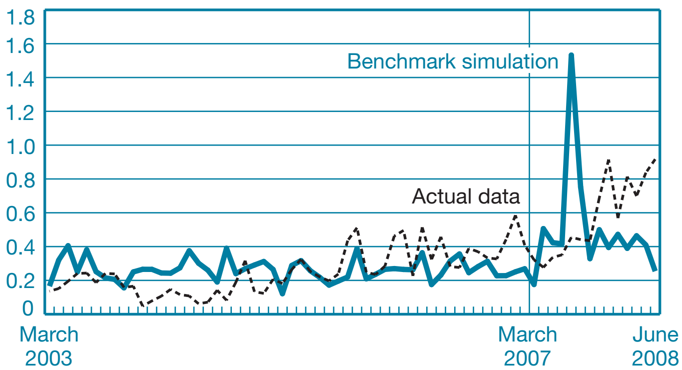
Normalized with Required Operating Balances



Sources: Primary credit outstanding: Federal Reserve Statistical Release H.4.1; required operating balances: Federal Reserve Board; simulated series: authors' calculations.

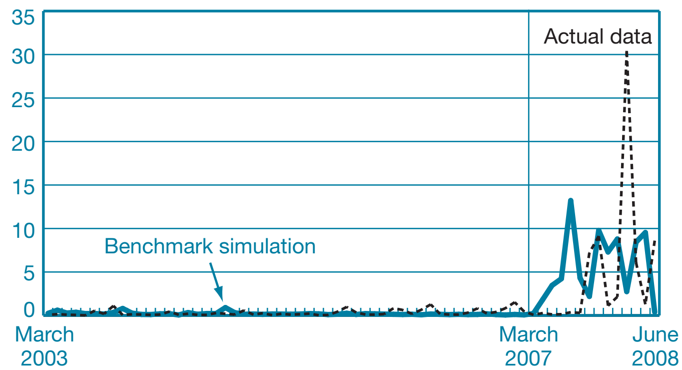
Note: Required operating balances is the sum of required reserve balances and contractual clearing balances.

Chart 5
Daily High Funds Rate Less Target (with Benchmark Simulation)



Sources: Federal Reserve Bank of New York (daily high funds rate: http://newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm); (target: http://newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm); simulated series: authors' calculations.

Chart 6
Primary Credit Outstanding (with Benchmark Simulation)
Normalized with Required Operating Balances



Sources: Primary credit outstanding: Federal Reserve Statistical Release H.4.1; required operating balances: Federal Reserve Board; simulated series: authors' calculations.

Note: Required operating balances is the sum of required reserve balances and contractual clearing balances.

While it is a daily model, we present the results in terms of monthly averages for visual clarity. The vertical line in each chart corresponds to the end of our estimation period in March 2007. There is a wide discrepancy between the data and the model's simulations, indicating that the period after August 2007 represents quite extraordinary circumstances that cannot be captured by the estimates prior to August 2007, as we would expect.

The sizable discrepancy between the data and the simulations for the crisis period suggests that we should incorporate the crisis circumstances into our model before we can conduct counterfactual experiments on the efficiency of the Federal Reserve's policies. At this point, we make several assumptions to replicate conditions during the crisis. To capture the overall need for short-term liquidity, we increase the volatility of the aggregate shock U_t. Furthermore, the increase in the term of the borrowing is expected to reduce the implicit costs of borrowing by making it more convenient to lengthen the duration of a loan.[6]

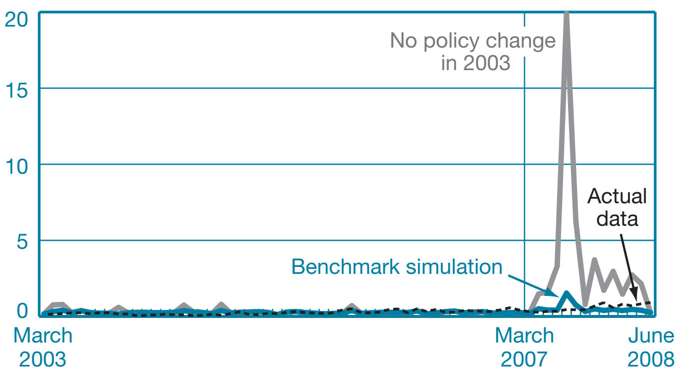
To match the moments of the data, we double the standard error of the aggregate shock U_t and reduce the costs of borrowing by one half, which allows us to obtain more reasonable estimates for the interest rate spread and the volume of borrowing during the crisis period (Charts 5 and 6). We call these simulations the "benchmark simulations." In evaluating the model's performance, one should be careful not to use the "eyeball metric" to compare the simulated series with the actual data, because it gives the wrong impression that the model's goal is to match the actual data on a day-by-day basis. Instead, our goal is to match the underlying data-generating process, and our estimation results, presented in the appendix, show that the model does reasonably well in achieving this goal. Indeed, even if we match the underlying data-generating process perfectly, the simulated series will differ from the actual data because of the presence of random shocks.

We now analyze the questions raised at the beginning of this section. The first involves the effects of the 2003 policy change on mitigating the crisis after 2007. In other words, had the Fed not changed its lending policy in 2003, how would the funds market look? Based on our findings in Artuç and Demiralp (2010), we would expect funds market volatility to worsen significantly in the absence of the new regime because the current practice allows institutions in need of funds to utilize this service without much hesitation. Chart 7 confirms our expectations. The chart plots the actual spread between the daily high funds rate and the target (the dashed line) as well as the simulations generated by our benchmark model (the blue line). In addition, it shows the spread under the counterfactual experiment, where the cost of borrowing remains at its pre-2003 level (the gray line). As the chart reveals, the counterfactual series skyrockets during the crisis period, suggesting that the Federal Reserve's switch to the new lending

[6] The Federal Reserve may have also reduced the implicit costs of discount borrowing indirectly by introducing several other lending facilities and making overall borrowing more accessible.

Chart 7

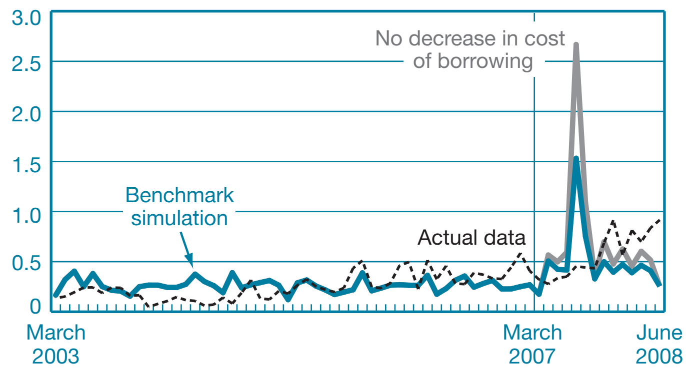
Daily High Funds Rate Less Target
(with No Policy Change in 2003)



Sources: Federal Reserve Bank of New York (daily high funds rate: http://newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm); (target: http://newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm); simulated series: authors' calculations.

Chart 8

Daily High Funds Rate Less Target
(with No Decrease in Cost of Borrowing)



Sources: Primary credit outstanding: Federal Reserve Statistical Release H.4.1; required operating balances: Federal Reserve Board; simulated series: authors' calculations.

Note: Required operating balances is the sum of required reserve balances and contractual clearing balances.

regime was very effective in containing the severity of the crisis in the money markets.

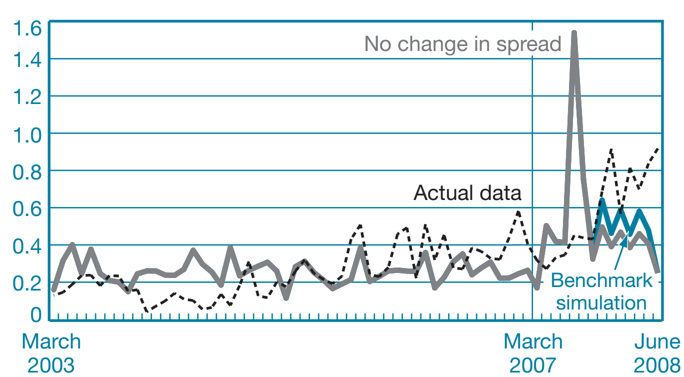
Turning from prices to quantities, we note that the volume of borrowing cannot differ between the two regimes because in our model banks have to borrow the necessary amount of reserve balances to avoid an overdraft or a reserve deficiency. For this reason, in reporting our simulation results, we present only the spread between the daily high funds rate and the target rate and not the borrowing behavior when the latter is unaffected under different scenarios.

Next, we analyze the effectiveness of changes in the primary credit facility that the Federal Reserve introduced at the beginning of the crisis. Recall that our benchmark model implies a 50 percent decline in borrowing costs during the crisis period. In assessing the implications of extended terms of borrowing, we keep the fixed cost of borrowing at its precrisis level and simulate the interest rate spread under this scenario. Chart 8 displays our results. The elevated volatility under the counterfactual scenario indicates that extending the borrowing term was an effective action in reducing the implicit costs of borrowing and hence controlling funds market volatility.

In addition to extending the borrowing term, the Federal Reserve also narrowed the spread between the primary credit rate and the target rate from 100 basis points to 25 basis points during the crisis. Our earlier findings in Artuç and Demiralp (2010) would suggest that the primary credit rate works as an upper bound in the absence of market stigma and that a decline in this rate should decrease deviations of the funds rate from the target. Our next simulation keeps the spread between the primary credit rate and the target unchanged at 100 basis points. As shown in Chart 9, the counterfactual spread is at least as high as the benchmark simulation, if not higher. This elevated volatility suggests that the narrowing of the spread was an effective action, even though the difference between the counterfactual and benchmark simulations is not as outstanding as in the previous exercises, probably because of the increased need for collateral under the crisis conditions. That is, because federal funds borrowing is unsecuritized, whereas discount window borrowing requires collateral,

Chart 9

Daily High Funds Rate Less Target
(with No Change in Spread)



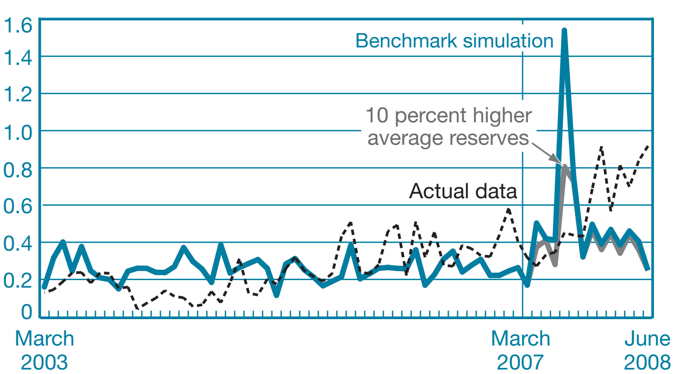
Sources: Federal Reserve Bank of New York (daily high funds rate: http://newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm); (target: http://newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm); simulated series: authors' calculations.

certain banks may still need to borrow in the funds market and pay a higher premium if they lack sufficient collateral for discount borrowing.

Recently, the Federal Reserve has been granted the authority to pay interest on reserve balances. In addition to placing a theoretical lower bound on the funds rate, interest payments on reserve balances may increase the demand for balances simply because the cost of holding these balances has been reduced. Our last exercise considers the impact of a higher level of balances on controlling funds rate volatility. While it is difficult to estimate the precise magnitude of the change in reserve balances, we increase the average normalized reserve balances by 10 percent in our counterfactual experiment. Chart 10 shows that control over interest rates improves while Chart 11 shows that the need for borrowing declines if the average balance holdings increase, as predicted under this new regime. Together, these results suggest that any policy change that leads to an increase in reserve holdings, such as interest payments on reserves, is useful in stabilizing the money markets.

Chart 10

Daily High Funds Rate Less Target (with 10 Percent Higher Average Reserves)



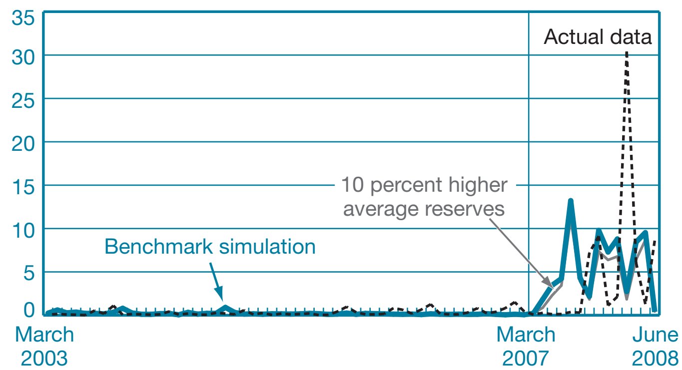
Sources: Primary credit outstanding: Federal Reserve Statistical Release H.4.1; required operating balances: Federal Reserve Board; simulated series: authors' calculations.

Note: Required operating balances is the sum of required reserve balances and contractual clearing balances.

Chart 11

Primary Credit Outstanding (with 10 Percent Higher Average Reserves)

Normalized with Required Operating Balances



Sources: Federal Reserve Bank of New York (daily high funds rate: http://newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm); (target: http://newyorkfed.org/markets/omo/dmm/fedfundsdata.cfm); simulated series: authors' calculations.

5. Conclusion

This paper analyzes the effectiveness of various changes adopted by the Federal Reserve since the onset of the liquidity crisis in August 2007. We show that the steps taken to reduce the implicit costs of borrowing were more effective in stabilizing the money markets while the narrowing of the spread between the primary credit rate and the target was not as effective.

Would the Federal Reserve be well served to retain these changes to its borrowing facility indefinitely? Our results suggest that the spread between the primary credit rate and the target rate could be increased back to 100 basis points without much impact on the financial markets. Meanwhile, the recent policy change of paying interest on reserves should make it easier for the Federal Reserve's Trading Desk to maintain the target permanently, not only by placing a lower bound on the funds rate, but also by increasing the level of reserve balances—which should reduce the demand for borrowing and ease the resulting tightness in the funds markets.

Appendix

Panels A and B of the table on the next page present ordinary least squares estimates of the auxiliary model parameters using actual as well as simulated data along with the mean and the variance of borrowing and $\tilde{r}_t$. Comparing columns 2 and 4 of panel A, we note that the auxiliary model's estimates from the simulated data and the actual data are fairly similar, as the algorithm minimizes the distance between those two estimates. However, they are not identical, as the auxiliary model has more parameters than the true underlying model. As shown in row 5, borrowing responsiveness to the interest rate spread ($\tilde{r}_t$) increases significantly after the Federal Reserve policy change in 2003, consistent with a decline in market stigma associated with discount window borrowing and the revival of the borrowing function. Panel B provides a similar comparison between the moments generated by the actual data (column 2) and those computed from the simulated data (column 3). Similar to panel A, the two sets of statistics display a strong resemblance.

Panel C presents the parameter estimates of the true underlying model and their standard errors. The most interesting parameters for our purposes are displayed in rows 1 and 2. Notice that the implicit fixed cost of borrowing declines about 90 percent (from $c_1 = 0.054$ to $c_1 + c_2 = 0.007$) after the policy change in 2003. This result provides strong evidence that the Fed's new policy was indeed successful in reducing the stigma associated with discount window borrowing. In addition to estimating the fixed cost of borrowing from the discount window, we are also interested in determining whether this implicit cost exhibits any gradual changes over time. In particular, one may expect a gradual decline in the implicit cost of borrowing in the post-2003 period because of the market's slow adjustment to the new regime. To address this issue, we experimented with an alternative model that allows for a time trend in the implicit cost of borrowing prior to and after 2003 (not shown). However, the trend terms associated with the implicit cost of borrowing were not significant in either sample. This finding suggests that there may not be a gradual adjustment to the new regime in the second sample. Our results may also be driven by the fact that we may not have a sufficient number of observations to identify such a time trend.

Row 3 of panel C shows that the aggregate reserve shock U_t ranges between -0.43 and 0.43 in the beginning of the sample, while row 4 shows that the bank-specific reserve shock V_t^i varies between -0.34 and 0.34 initially. Rows 5 and 6 show that there is a significant time trend in these shocks. In fact, when we substitute the estimates for D and E in equation 3, we observe that the aggregate reserve shock exhibits a negative trend while the bank-specific shock exhibits a positive trend. The estimate of E implies that the standard error of U_t decreases about 0.05 percent per year while the estimate of D implies that the range of V_t^i increases about 15 percent each year. The mild negative time trend in the aggregate shock, U_t, could reflect improvements in the Federal Reserve Trading Desk's reserve management ability over time, as we observe in this paper.

Row 7 of panel C shows that the estimated ratio of banks that incur a technical problem, and thus are forced to borrow from the Fed rather than the markets, varies from 0 to 0.04. This result indicates that no more than 4 percent of banks are affected by this type of condition at any time. Row 10 indicates that banks seek to attain a higher level of balances on the last day of the maintenance period, consistent with our expectations.

Auxiliary Model and Indirect Inference Estimations

Panel A: Auxiliary Model Ordinary Least Squares Regression

	Actual Data		Simulated Data	
	Coefficient	Standard Error	Coefficient	Standard Error
1. Constant	0.48**	0.07	0.53**	0.04
2. $\tilde{r}_t$	0.26**	0.05	0.35**	0.03
3. t	-0.04**	0.01	-0.05**	0.004
4. $t \times \tilde{r}_t$	0.06**	0.01	0.05**	0.005
5. $D^{2003} \times \tilde{r}_t$	0.86**	0.22	1.01**	0.10
6. $D^{Settl.Wed.}$	0.46**	0.11	0.48**	0.07

Panel B: Auxiliary Model Moments

	Actual Data	Simulated Data
1. Mean(BR)	0.46	0.45
2. Mean($\tilde{r}_t$)	0.42	0.37
3. Mean($\tilde{r}_{2t}$)	0.25	0.25
4. Var(ζ)	3.01	2.15
5. Var($\tilde{r}_t$)	1.14	1.93
6. Var($\tilde{r}_{2t}$)	0.14	0.08

Panel C: Indirect Inference Estimation

	Coefficient	Standard Error
1. c_1	0.0541**	0.002
2. c_2	-0.0485**	0.004
3. A	0.4257**	0.001
4. B	0.3432**	0.0008
5. D	-0.0010**	0.0005
6. E	0.2001**	0.0007
7. F	0.0421**	0.0004
8. $\bar{R}$	0.8594**	0.0034
9. s	0.0027	0.00001
10. L_2	0.4828	0.0016

Where:

BR	normalized borrowing from the Federal Reserve
$\tilde{r}^t$	daily high funds rate minus target rate
$\tilde{r}_{2t}$	lowest 50 percent of daily high funds rate less target rate
t	time trend
D^{2003}	dummy variable for period after January 6, 2003
$D^{Settl.Wed.}$	dummy variable for last day of maintenance period
c_1	implicit cost prior to 2003
c_2	implicit cost after 2003
A	interval parameter for aggregate shock
B	interval parameter for bank-specific shock
D	time trend parameter for aggregate shock
E	time trend parameter for bank-specific shock
F	interval parameter for probability of technical problem
$\bar{R}$	average reserve balances
s	variance of noise parameter for daily high funds rate
L_2	implicit reserve target on last day of maintenance period

Source: Authors' calculations.

* Statistically significant at the 95 percent confidence level.

** Statistically significant at the 99 percent confidence level.

References

Artuç, E., and S. Demiralp. 2010. "Discount Window Borrowing after 2003: The Explicit Reduction in Implicit Costs." Journal of Banking and Finance 34, no. 4 (April): 825-33.

Carpenter, S., and S. Demiralp. 2006. "The Liquidity Effect in the Federal Funds Market: Evidence from Daily Open Market Operations." Journal of Money, Credit, and Banking 38, no. 4 (June): 901-20.

Clouse, J. A., and J. P. Dow, Jr. 1999. "Fixed Costs and the Behavior of the Federal Funds Rate." Journal of Banking and Finance 23, no. 7 (July): 1015-29.

Darrat, A. F., K. Elkhal, G. Banarjee, and M. Zhong. 2004. "Why Do U.S. Banks Borrow from the Fed? A Fresh Look at the 'Reluctance' Phenomenon." Applied Financial Economics 14, no. 7 (August): 477-84.

Demiralp, S., and D. Farley. 2005. "Declining Required Reserves, Funds Rate Volatility, and Open Market Operations." Journal of Banking and Finance 29, no. 5 (May): 1131-52.

Dow, Jr., J. P. 2001. "The Recent Behavior of Adjustment Credit at the Discount Window." Journal of Macroeconomics 23, no. 2 (spring): 199-211.

Dutkowsky, D. H. 1993. "Dynamic Implicit Cost and Discount Window Borrowing: An Empirical Investigation." Journal of Monetary Economics 32, no. 1 (August): 105-20.

Furfine, C. H. 2001. "The Reluctance to Borrow from the Fed." Economics Letters 72, no. 2 (August): 209-13.

———. 2003. "Standing Facilities and Interbank Borrowing: Evidence from the Federal Reserve's New Discount Window." International Finance 6, no. 3 (winter): 329-47.

Goodfriend, M. 1983. "Discount Window Borrowing, Monetary Policy, and the Post–October 6, 1979 Federal Reserve Operating Procedure." Journal of Monetary Economics 12, no. 3 (September): 343-56.

Gourieroux, C., A. Monfort, and E. Renault. 1993. "Indirect Inference." Journal of Applied Econometrics 8, December (Supplement): S85-S118.

Madigan, B., and W. Nelson. 2002. "Proposed Revision to the Federal Reserve's Discount Window Lending Programs." Federal Reserve Bulletin 88, no. 7 (July): 313-9.

Pearce, D. K. 1993. "Discount Window Borrowing and Federal Reserve Operating Regimes." Economic Inquiry 31, no. 4 (October): 564-79.

Peristiani, S. 1998. "The Growing Reluctance to Borrow at the Discount Window: An Empirical Investigation." Review of Economics and Statistics 80, no. 4 (November): 611-20.

Smith, Jr., A. A. 1993. "Estimating Nonlinear Time Series Models Using Simulated Vector Autoregressions." Journal of Applied Econometrics 8, December (Supplement): S63-S84.