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Abstract

Several researchers have argued that banks' discount window borrowing behavior should change if the Federal Reserve changes its short-run targets for monetary policy. This paper explores this issue by estimating borrowing equations for periods in which the Federal Reserve alternatively targeted the Federal funds rate, nonborrowed reserves, or borrowed reserves. The effect of the switch from lagged to contemporaneous reserve accounting is also examined. The results suggest that borrowing behavior did change with changes in operating procedures and reserve accounting procedures.

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The borrowing behavior of banks at the Federal Reserve's discount window is a component of most models of the monetary sector, including the model used by the Federal Reserve [Tinsley et. al. (1982)]. As several researchers have noted [Lindsey et. al. (1984), Dotsey (1989), among others], however, the policy importance of accurate predictions of borrowing behavior depends on the Federal Reserve's short-run operating procedure. If the Federal Reserve uses a Federal funds rate target to control money growth as it did in the 1970s, inaccurate predictions of borrowing behavior have no effect on money supply growth. If the Federal Reserve uses a nonborrowed reserves target, as is usually assumed for the October 1979 to October 1982 period, or a borrowed reserves target, as used after October 1982, then poor predictions of bank borrowing are a potentially significant source of errors in controlling money.[1]

Theoretical research suggests that bank borrowing depends upon a small number of variables; however, the relationship between these variables and bank borrowing is both complex and dependent upon the Federal Reserve's operating procedure. Optimizing models of bank borrowing decisions by Goodfriend (1983), Cosimano (1988), and Dotsey (1989) suggest that a key determinant of bank borrowing is banks' expectations about future movements in the spread between the Federal funds rate and the discount rate. In particular, Goodfriend's model predicts that increases in the spread that banks expect to be temporary have a larger impact on borrowing than increases that banks expect to be permanent. In

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[1] See Dutkowsky and Foote (1988, pp. 601-602) for an illustration of how errors in predicting bank borrowing affect monetary control.

addition to this effect, less predictable spreads resulting from changes in the operating procedures are likely to affect both banks' borrowing and excess reserve behavior. Since the stochastic behavior of the spread depends on the Federal Reserve's operating procedure, borrowing behavior, in turn, should depend on the Federal Reserve's operating procedure. Thus, the Federal Reserve should not assume that the borrowing equation in its model is invariant to changes in its operating procedure. As Goodfriend notes, such an assumption is another example of the Lucas critique. Bryant (1983) and Dutkowsky and Foote (1988) show that borrowing equations estimated during the period when the Federal Reserve targeted the Federal funds rate produce poor forecasts of borrowing after the October 6, 1979 regime change. These papers do not, however, provide evidence on how the borrowing equation changed after October 1979, or whether the changes support Goodfriend's theoretical model. This paper finds that the borrowing equation did change when the Federal Reserve adopted new procedures and that the changes are consistent with the general thrust of Goodfriend's model.

In addition to the changes in operating procedures, the Federal Reserve also changed the reserve accounting rules in February 1984, replacing lagged reserve accounting with contemporaneous reserve accounting. Although the effect of this switch on bank reserve management is difficult to predict, the increased uncertainty about reserve needs and the decrease in information about the aggregate demand for reserves make it plausible that banks became more risk averse, affecting their excess reserve behavior and their discount window borrowing.[2] This paper provides evidence consistent with banks adopting more

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[2] See Tarhan (1984) for a discussion of these issues. Sprenkle (1987) develops a model of bank behavior that predicts that the move to contemporaneous reserve accounting will increase excess reserves. The Federal Reserve's initial assumption was that the switch would have little effect on reserve management behavior. See "Monetary Policy and Open Market Operations," Quarterly Review,

conservative reserve management behavior after the switch to contemporaneous reserve accounting.

While different Federal Reserve operating procedures should produce different borrowing functions, different procedures also pose potential econometric problems for researchers who would estimate these functions. During most of the 1970s, the Federal Reserve used the Federal funds rate as the short-term policy instrument.[3] Since the Federal Reserve also sets the discount rate, the spread between the Federal funds rate and the discount rate can be treated as an exogenous variable and the usual approach of regressing borrowed reserves on the spread appears appropriate. From October 1979 to October 1982, the Fed is generally assumed to have used nonborrowed reserves as its short-term instrument. Keir (1981) points out that under this procedure, the spread should be considered an endogenous variable and the usual borrowing model should not be estimated by OLS. The degree to which the Federal Reserve kept to the nonborrowed reserve targets, however, is still a matter of debate. Spindt and Tarhan (1987) report mixed evidence, although they conclude that the Federal Reserve did pursue a nonborrowed reserves target.[4] In contrast, Feinman and Poole (1989) cite evidence that the Federal Reserve reacted to most of the weekly changes in money demand by making accommodating changes in nonborrowed reserves. Thus, for models

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Federal Reserve Bank of New York, Spring 1985, p.44.

[3] For discussions of the various operating procedures, see Gilbert(1985), Sellon(1986), and Wallich(1984).

[4] Spindt and Tarhan(1987) used tests of Granger-causality to investigate whether the Federal Reserve accommodated money supply changes by altering nonborrowed reserves or by allowing borrowed reserves to absorb the shocks. Using weekly data, they find that the Federal Reserve appeared to do both. Using data averaged over periods between FOMC meetings, and hence a small number of observations, they found that nonborrowed reserve targeting was consistent with the data.

of weekly borrowing, the endogeneity of the spread remains an empirical question. The estimated borrowing equations for this period reported below indicate that the Federal Reserve did accommodate shocks to the borrowing equation rather than allowing them to affect the spread.

Since October 1982, the Federal Reserve has used a borrowed reserves targeting procedure; this procedure also implies that the spread is endogenous unless the Federal Reserve accommodates shocks to the borrowing equation, as shown below. Again, however, there is uncertainty about whether the actual policy followed by the Federal Reserve differed from the Federal funds rate targeting policy.[5] This paper presents evidence that the Federal Reserve continued to accommodate shocks to the borrowing equation so that the borrowed reserves targeting procedure was essentially identical to the Federal funds rate targeting procedure.

The rest of the paper is organized as follows. Section 1 gives an overview of borrowing behavior during the alternative operating regimes. Section 2 presents the model of borrowing and illustrates how the operating procedure affects the endogeneity of the spread. Section 3 presents the estimated borrowing models and tests of differences across operating regimes. The final section summarizes the findings of the paper.

1. An Overview of Discount Window Borrowing Across Operating Regimes

Borrowing at the Federal Reserve System's discount window is categorized as adjustment borrowing, seasonal borrowing, or extended credit. Adjustment borrowing comprises short-term loans to meet unexpected liquidity needs. Seasonal

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[5] See Thornton (1988) for evidence suggesting that the Federal Reserve did accommodate shocks to the borrowing equation at least through 1986.

borrowing, as the name implies, is for recognized seasonal liquidity needs of smaller banks. Extended credit refers to longer-term loans to institutions facing exceptional problems. Consistent with previous research, this paper focuses on adjustment borrowing.

Five time periods are examined. The first period runs from January 8,1975 to October 3,1979. As discussed in Cook and Hahn (1989,p. 333), this period corresponds to an operating regime in which the Federal Reserve framed short-run monetary policy in terms of a tight Federal funds rate target (FFRT). The second period runs from October 10,1979 to October 6,1982, the interval in which the Federal Reserve is thought to have used a nonborrowed reserves targeting procedure (NBRT). After October 13, 1982 the Federal Reserve supposedly targeted borrowed reserves (BRT). Fourteen months later, the Federal Reserve switched from lagged reserve accounting (LRA) to contemporaneous reserve accounting (CRA), simultaneously changing the reserve maintenance period from one to two weeks.[6] Therefore, the third time period runs from October 13, 1982 to February 1, 1984, and corresponds to the period when both BRT and LRA were in place. The fourth period runs from February 15,1984 to October 14,1987, just before the stock market crash, because it has been observed that the crash appeared to discourage banks from borrowing at the discount window.[7] The fifth period runs from October 21, 1987 to December 27,1990.

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[6] The reserve accounting system is not fully contemporaneous, since the computation period runs from Tuesday to the second Monday and the maintenance period runs from Thursday to the second Wednesday. Thus, on the last two days of the maintenance period, banks know their required reserves.

[7] Discussions of the reluctance of banks to borrow at the discount window following the stock market crash are given in "Monetary Policy and Open Market Operations during 1987," Quarterly Review, Federal Reserve Bank of New York, Spring 1988, pp.41-58, and "Monetary Policy and Open Market Operations during 1988," Quarterly Review, Federal Reserve Bank of New York, Winter-Spring 1989, pp. 83-102.

Plots of adjustment borrowing, the spread, and the relationship between adjustment borrowing and the spread show significant differences across the five periods. The top panel of Figure 1 shows the pattern of adjustment borrowing during the FFRT period, while the middle panel gives the spread between the Federal funds rate and the discount rate. All data are weekly averages of daily data, with weeks measured from Thursday to Wednesday corresponding to the reserve maintenance week. During the first half of the period, the spread was usually negative and, not surprisingly, borrowing was quite low. Borrowing levels then rose when the spread became positive in the second half of the period. The bottom panel is a scatter diagram of borrowing versus the spread and illustrates the positive relationship between borrowing and the spread when the spread is positive.

Figure 2 presents similar graphs for the NBRT period. Several differences are apparent. First, the range of borrowing levels and the range of the spread are considerably larger. Second, the spread is almost always positive. Third, as the bottom panel illustrates, there appears to be a looser relationship between borrowing and the spread.[8]

Figure 3 presents the same information for the BRT period while LRA was in force. Both the level of borrowing and the spread returned to ranges roughly similar to those in the FFRT period, although the spread was only rarely negative. The bottom panel shows a positive correlation between borrowing and the spread.

Figure 4 displays graphs for the pre-crash BRT period with CRA in force. These data are bi-weekly averages of daily data, corresponding to the two-week

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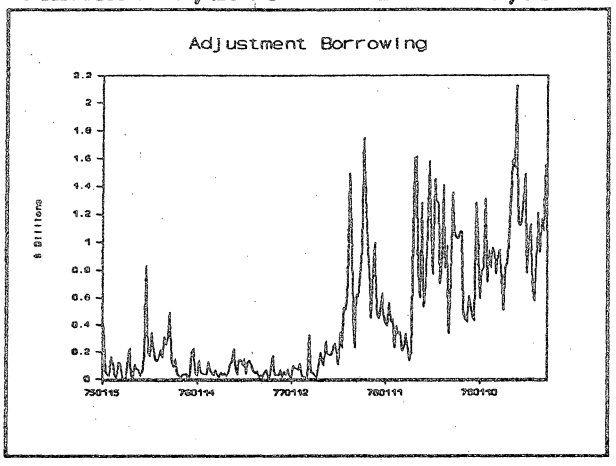
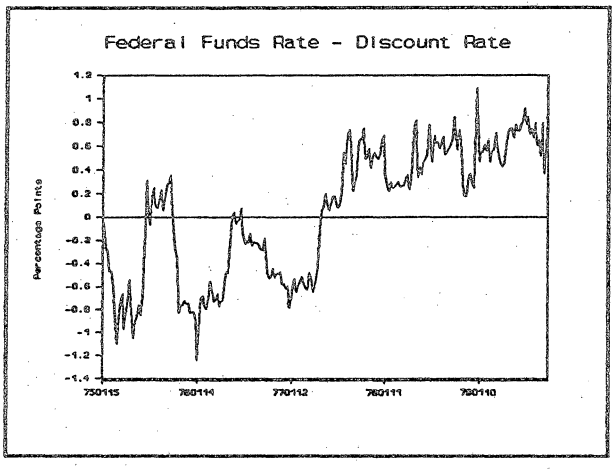
[8] As discussed in more detail below, analyzing borrowing in this period is complicated by the occasional imposition of a surcharge added to the basic discount rate for large,frequent borrowers.

FIGURE 1
FEDERAL FUNDS RATE TARGETING PERIOD
JANUARY 8,1975 - OCTOBER 3,1979





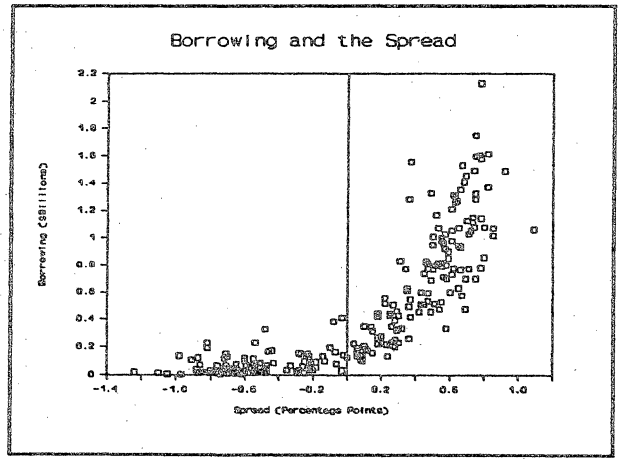
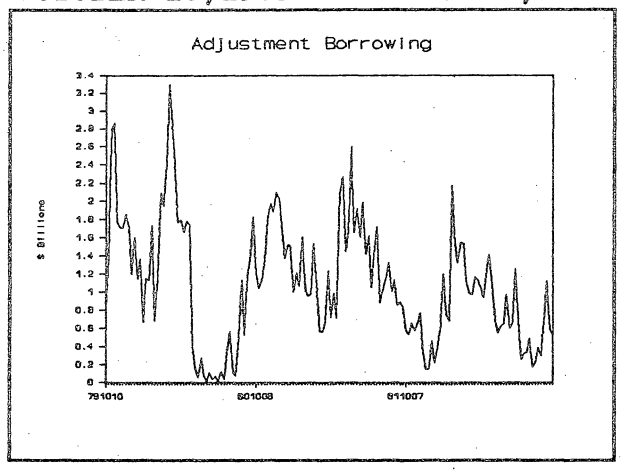
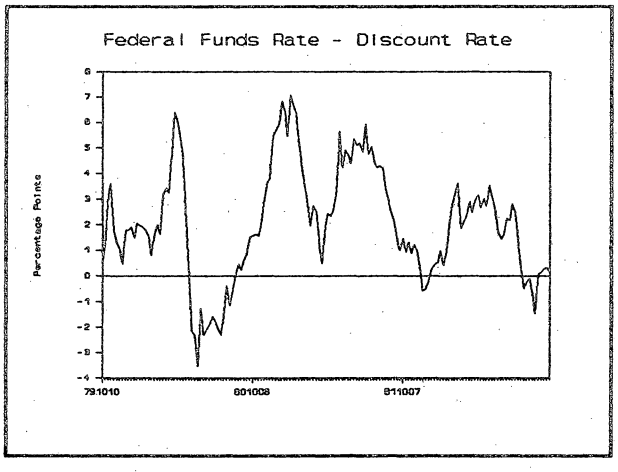


FIGURE 2
NONBORROWED RESERVES TARGETING PERIOD
OCTOBER 10,1979 - OCTOBER 6,1982





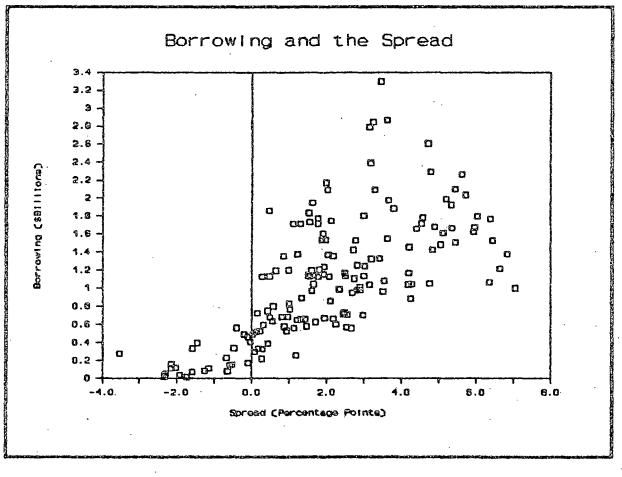
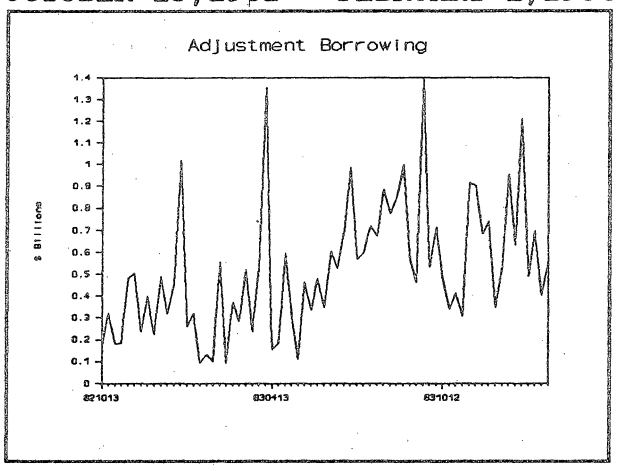
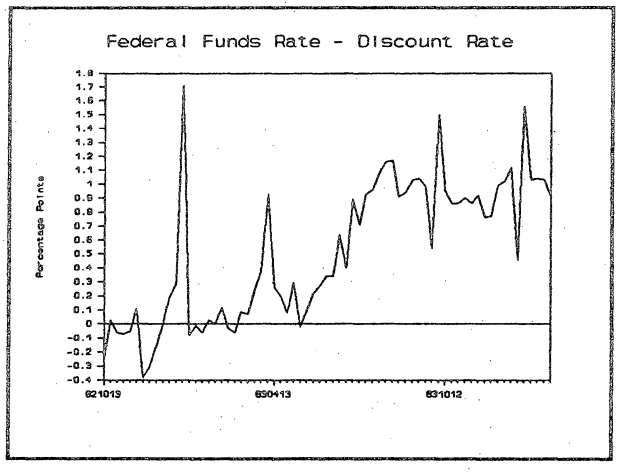


FIGURE 3
BORROWED RESERVES TARGETING PERIOD
UNDER LAGGED RESERVE ACCOUNTING
OCTOBER 13,1982 - FEBRUARY 1,1984





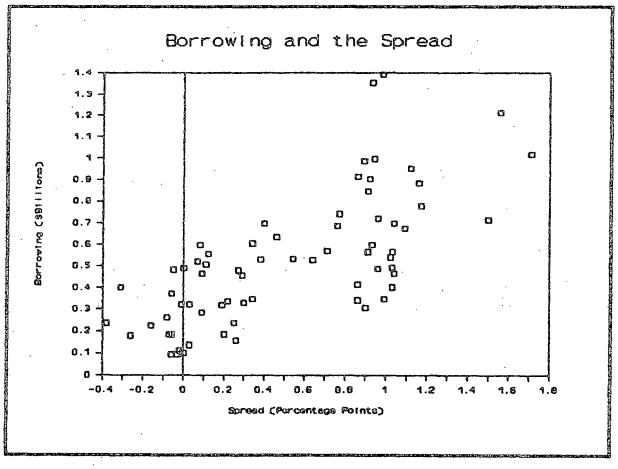
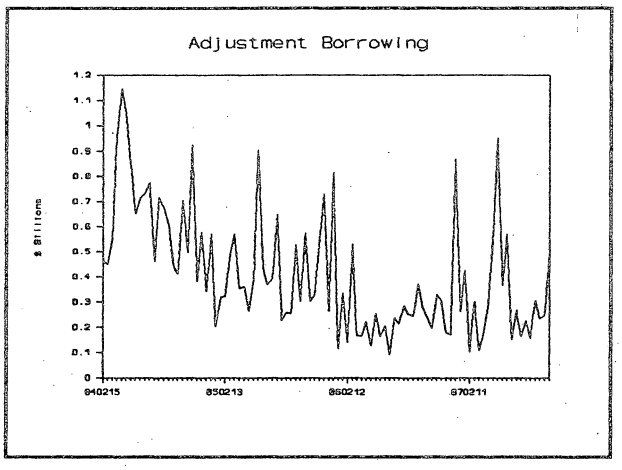
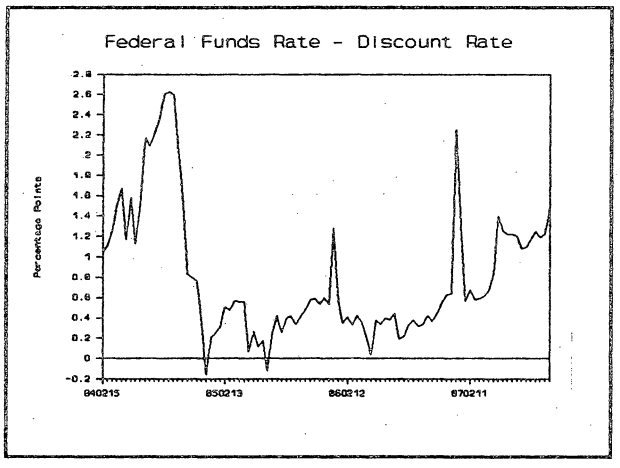


FIGURE 4
BORROWED RESERVES TARGETING PERIOD UNDER CONTEMPORANEOUS RESERVE ACCOUNTING FEBRUARY 15,1984 - OCTOBER 21,1987





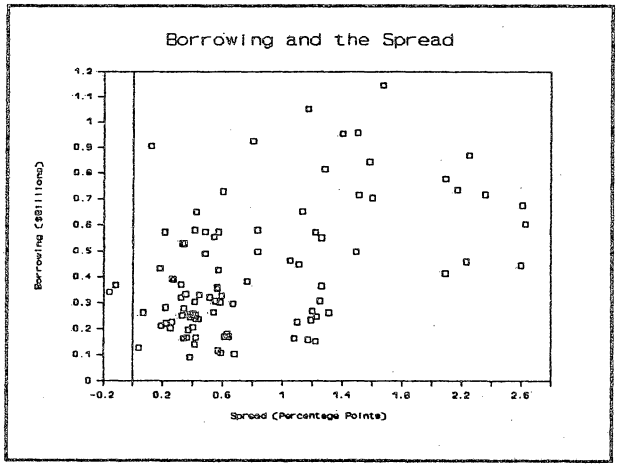
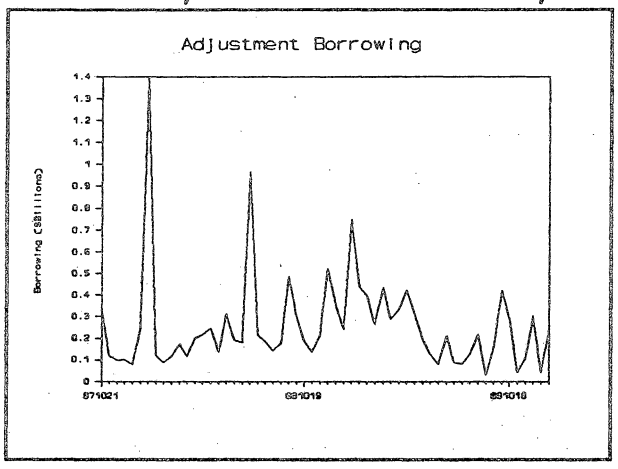
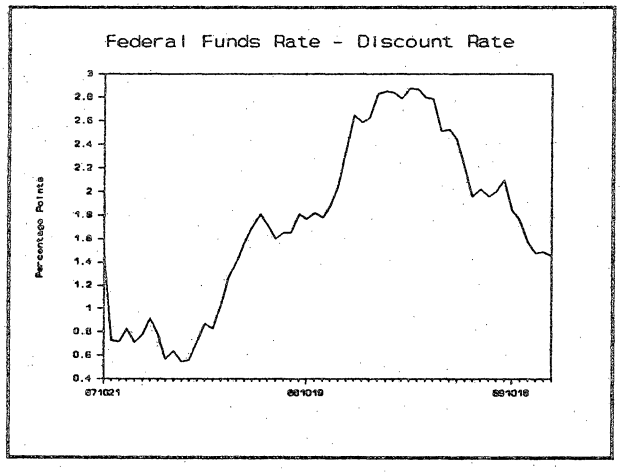
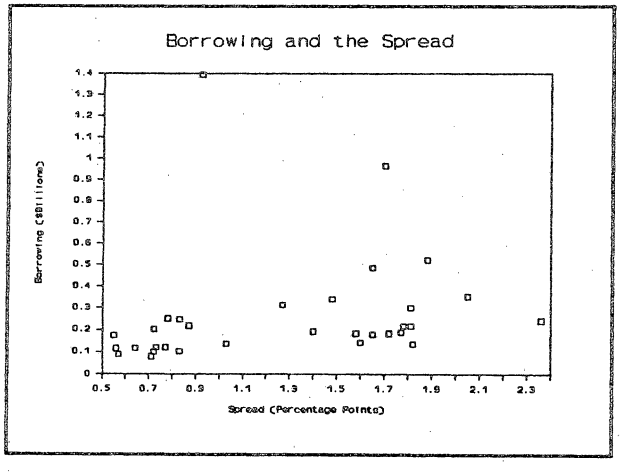


FIGURE 5
BORROWED RESERVES TARGETING PERIOD
UNDER CONTEMPORANEOUS RESERVE ACCOUNTING
NOVEMBER 4,1987 - DECEMBER 27,1989







reserve maintenance period instituted under CRA. During this period, the range of borrowing was smaller than in the other periods, while the range of the spread was lower than the NBRT period but higher than the FFRT period.[9] The spread was again almost always positive. The bottom panel shows the scatter diagram of borrowing against the spread. No strong relationship between the spread and borrowing is apparent in this period.

Figure 5 presents graphs for the post-crash period. Borrowing was relatively low for most of this period despite high spreads. The bottom panel illustrates that there is little association between borrowing and the spread in this period.

Table 1 reports descriptive statistics for the subperiods examined. As indicated in the figures, there are substantial differences across periods. Comparing the FFRT period to the NBRT period, the data reveal that adjustment borrowing more than doubled in the latter period while the average spread, excluding negative spread weeks, increased about eight-fold. Excess reserves also rose in the latter period from about $208 million to $308 million despite the higher spread. This is not a scale effect, as indicated by the ratio of excess reserves to total reserves. During the BRT period when LRA was in force, borrowing was, on average, only slightly larger than in the FFRT period despite an average spread, again excluding negative weeks, that was twice as large. The ratio of excess reserves rose again to an average of 1.24 percent of total reserves. From the initiation of CRA in February 1984 to the stock market crash in October 1987, adjustment borrowing fell back below the level in the FFRT

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[9] The very large borrowing by Continental of Illinois in May 1984, which subsequently was classified as extended credit, and the loan to the Bank of New York in November 1985, which was necessitated by a computer breakdown, are eliminated from aggregate adjustment borrowing.

Table 1

Descriptive Statistics

{ .....Lagged Reserve Accounting in Force.....} { Contemporaneous Reserve Accounting in Force}

	FFRT Period 1975(1)-79(10)		NBRT Period 1979(10)-82(10)		BRT Period 1982(10)-84(1)		BRT Period 1984(2)-87(10)		BRT Period 1987(10)-89(12)	
	Mean	Minimum	Mean	Minimum	Mean	Minimum	Mean	Minimum	Mean	Minimum
Variable	S.D.	Maximum	S.D.	Maximum	S.D.	Maximum	S.D.	Maximum	S.D.	Maximum
Adjustment	453.3	5	1095.0	12	522.6	94	414.6	91	259.6	31
Borrowing	470.6	2129	672.0	3298	295.2	1391	242.6	1146	225.9	1394
Spread	.04	-1.24	2.06	-3.25	.52	-.38	.82	-.16	1.73	.55
	.56	1.09	2.20	7.06	.51	1.71	.65	2.63	.73	2.88
PSPR	.27	.00	2.26	.00	.54	0	.82	.00	1.73	.55
	.29	1.09	1.90	7.06	.48	1.71	.64	2.63	.73	2.88
Spread - surcharge			.89	-3.25						
			1.70	4.06						
Change in	14.3	-1797	-12.9	-3221	-12.7	-2432	248.9	-3647	46.9	-2470
Req. Res.	694.6	3433	851.6	2135	894.5	2257	1083.1	2674	1307.3	2620
Excess	207.9	-227	308.2	-207	486.8	219	849.3	349	1001.9	223
Reserves	163.4	864	174.6	738	159.0	992	266.0	2048	241.9	1603
Ratio of	.57	-.66	.74	-.48	1.24	.54	1.80	.79	1.63	.36
ER to TR	.44	2.47	.42	2.28	.40	2.39	.48	3.34	.39	2.54

NOTES: All variables are in $ millions except for Spread, PSPR, (Spread - surcharge), and ratio of ER to TR which are in percentage points
Data are weekly averages of daily data up to 1984(2) and then are biweekly averages of daily data
S.D. = standard deviation
Spread= Federal funds rate - discount rate
PSPR= max(Spread,0)
ER = excess reserves
TR = total reserves

period even though the average spread, excluding negative spread weeks, was three times as large. The move to CRA was also accompanied by another increase in excess reserves, with the ratio of excess reserves to total reserves averaging 1.8 percent. The post-crash period was characterized by very low levels of adjustment borrowing despite the large average spread. Excess reserves in this period fell slightly as a percentage of total reserves, but this ratio was still twice that of the NBRT period. These data are consistent with the description of the Federal Reserve Bank of New York that the bank borrowing equation shifted down substantially after the crash.[10]

2. Modeling Discount Window Borrowing

Several models of discount window borrowing have been posited in the literature [see Dutkowsky and Foote (1988) for a survey]. The basic model employed here follows the approach of Goodfriend (1983), who examined the borrowing decision in terms of an intertemporal optimization plan by an individual bank. As Goodfriend and others have noted, the Federal funds rate should never exceed the discount rate in the absence of other costs. The usual positive spread is evidence, therefore, that the Federal Reserve imposes other costs on, or rations credit to, borrowing banks. The officers administering the discount window at each regional Federal Reserve Bank monitor the frequency of a bank's borrowing and the reasons for borrowing. Borrowing at the window and then lending in the Federal funds market, for example, is expressly forbidden.

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10 "In the tumultuous environment, not only did banks generally seem less inclined than normal to use the discount window, but the demand for excess reserves seemed to escalate." ["Monetary Policy and Open Market Operations during 1987," Quarterly Review, Federal Reserve Bank of New York, Spring 1988, pp. 41-58.]

Goodfriend's model implies that banks should forecast future spreads, and hence the attractiveness of future borrowing, when deciding on current borrowing.[11] If banks assume that the spread follows a mean-reverting process such as an AR(1)

$$S_t - \mu = \rho\ (S_{t-1} - \mu) + \epsilon_t \qquad 0 < \tau < 1 \qquad (1)$$

where S_t = Federal funds rate - discount rate,

μ = mean of S,

ϵ_t = random error term,

this leads to the following model for bank borrowing:

$$B_t = b_0 + b_1\ S_t + b_2\ B_{t-1} + u_t \qquad (2)$$

where B_t = adjustment borrowing,

u_t = random error term.

Goodfriend assumed that S was always positive. In the model, b_2 is negative because past borrowing is assumed to raise the cost of current borrowing. The coefficient on S, b_1, is positive but depends on the stochastic process generating S, equation (1).[12] The larger is ρ, the more persistent is any change

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[11] Waller (1990) provides a game theoretic model of discount borrowing in which banks also need to predict future spreads. Under certain informational assumptions, Waller's model predicts different dynamics than that of Goodfriend.

[12] In Goodfriend's model, bank borrowing depends on past borrowing, the current spread, and the expected spread next week:

$$B_t = c_0 + c_1\ S_t + c_2\ S^e_{t+1} + c_3\ B_{t-1} + u_t \qquad \begin{matrix} c_1 > 0 \\ c_2, c_3 < 0. \end{matrix}$$

Given the autoregressive process for the spread, equation (1), the expected spread is simply:

$$S^e_{t+1} = \rho\ S_t + (1 - \rho)\ \mu,$$

so that the borrowing equation becomes:

$$B_t = c_0 + c_2(1 - \rho)\ \mu + (c_1 + c_2\rho)\ S_t + c_3\ B_{t-1} + u_t.$$

in the spread and hence the less the incentive to substitute intertemporally. But if ρ is small, an increase in S this period is not expected to persist, and thus there is an incentive to borrow more this period. This leads to the prediction that b_1 will change if the Fed changes the way S evolves over time.

While Goodfriend's model predicts that lagged borrowing has a negative effect on current borrowing, all else equal, previous studies of aggregate borrowing have always found positive coefficients [see Dutkowsky and Foote (1988)]. One possible explanation is that borrowing may extend beyond the one-week interval when the liquidity problem is severe. Another possible explanation for the positive coefficients is that aggregation across banks produces positive autocorrelation in total borrowing.[13]

Changes in the Federal Reserve's operating procedure may introduce a simultaneous equations problem for the estimation of an aggregate borrowing equation. This can be illustrated using a model of the market for reserves such as that of Thornton (1988) or a simplified version of the model of Dotsey (1989).[14] Assume that the demand for reserves can be expressed as:

$$R^D = RR + ER = RR_0 + e_0 - e_1 S + \omega \quad \text{under LRA,} \quad (3)$$

$$= r_0 - r_1 F + \upsilon + e_0 - e_1 S + \omega \quad \text{under CRA,} \quad (4)$$

where RR = required reserves,

ER = excess reserves,

Thus, b_1 in equation (2) equals $(c_1 + c_2\rho)$, and hence b_1 falls as ρ increases, since $c_2 < 0$.

[13] Goodfriend notes that "the non-price rationing costs imposed on banks to discourage continuous borrowing are much more complicated and difficult to explicitly identify; so the relationship between current and lagged borrowing is in practice difficult to specify."(p.350)

[14] The model is also similar to the monthly model discussed in Karamouzis and Lombra (1989).

F = Federal funds rate,

ω = random error term in excess reserve equation,

υ = random error term in required reserve equation under CRA.

Under LRA, required reserves are predetermined (RR_0), while under CRA required reserves would be negatively related to the interest rate if deposits are negatively related to the interest rate. The supply of reserves is:

$$R^S = NBR + B \tag{5}$$

where NBR = nonborrowed reserves (changed by open market operations),

B = borrowed reserves.[15]

The borrowed reserves equation is

$$B = b_0 + b_1 S + b_2 B_{t-1} + u \tag{6}$$

where u = random error term.

The equilibrium condition is

$$R^D = R^S. \tag{7}$$

Equation (6) is the borrowing function that is typically estimated. The question is whether S and u are correlated.[16]

There are three operating procedures in terms of the short-run target set by the Federal Reserve: (a) Federal funds rate target(FFRT):[17] $S = S^*$

(b) nonborrowed reserves target(NBRT): $NBR = NBR^*$

(c) borrowed reserves target(BRT): $B = B^*$

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[15] I am ignoring seasonal borrowing and extended credit.

[16] As indicated above, the coefficients in the behavioral equations are likely to change with the operating procedure. Walsh (1984), for example, argues that the money demand equation, and hence the derived demand for reserves under CRA, may become less interest elastic when the Federal Reserve allows more variability in the interest rate.

[17] Since the Federal Reserve controls the discount rate, a Federal funds rate target is identical to a spread target.

Under each procedure it is assumed that the Federal Reserve has a desired money supply target and an estimate of the money demand equation. Under (a), FFRT, the Federal Reserve simply picks the interest rate, here assumed F*, for which money demand is expected to equal the targeted money supply on average. Shocks to reserve demand or borrowing are fully accommodated by changes in NBR to keep F=F*; hence there should be no relationship between u and S.

Under (b), NBRT, the money supply target again determines an interest rate target, but this in turn is used in conjunction with the borrowing equation to derive an expected level of borrowing. The nonborrowed reserves target is then set at the level that equals the predetermined level of required reserves plus the expected level of excess reserves less the expected level of borrowed reserves. Thus there is a relationship between u and S, since any shock to the borrowing equation gets reflected in a change in S. This can be seen from the reduced form equation for S, derived by substituting (6) into (5), setting (5) equal to (3), and letting NBR=NBR*:

$$S = \theta\ (e_0 - b_0) + \theta\ (RR_0 - NBR^*) - \theta\ b_2\ B_{t-1} + \theta\ (\omega - u) \qquad (8)$$

where $\theta = 1/(b_1 + e_1)$.

Thus the covariance between S and u is negative.

Under (c), BRT, there will also be a relationship between S and u. To see this, note that the desired money supply again determines a desired average interest rate. The estimated borrowing equation then determines the expected level of borrowing consistent with the desired interest rate.[18] If the derived level of borrowing is

$$B^* = b_0 + b_1\ (F^* - D) + b_2\ B_{t-1}, \qquad (9)$$

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[18] The Federal Reserve does not refer to an interest rate target. Targets are in terms of "reserve restraint" and "money market firmness".

then for actual borrowing to equal this target, the Federal funds rate must be set such that:

$$F = F^* - (1/b_1)\, u. \qquad (10)$$

This implies that NBR completely accommodate shocks to reserve demand but not shocks to borrowing.[19] As in the case of NBR targeting, the Federal funds rate is negatively correlated with the error term in the borrowing equation.[20]

The above models assume that there is strict adherence to the particular target during each regime. Blow-by-blow descriptions of open market operations as given in the annual reviews of monetary policy in the Federal Reserve Bank of New York's Quarterly Review make clear, however, that deviations from targets were allowed if judgment warranted. In particular, these descriptions suggest that shocks to borrowing often were accommodated with changes in nonborrowed reserves to prevent sharp movements in the Federal funds rate or in borrowing. Some sample quotes from the Quarterly Review illustrate this tendency:

"...some modification to the nonborrowed reserve objective might be made to avoid pursuing a nonborrowed reserve level that implies very sharp short-run changes in the level of borrowing." [Summer 1980, p.61]

"From time to time, adjustments to the nonborrowed reserve path were also made when it appeared that there were shifts in the demand for borrowing." [Spring

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[19] The reduced form equation for NBR is:

$$NBR = (r_0 + e_0 - b_0) - (r_1 + e_1 + b_1)\, F^* + (e_1 + b_1)\, D - b_2\, B_{t-1} + \upsilon + \omega + ((r_1 + e_1)/ b_1)\, u$$

[20] Dotsey (1989) derives a similar result for his more complete model.

1982, p. 42]

"In this situation (actual borrowing was below the target) the Desk aimed for nonborrowed reserves a little above the path level rather than force a sharp rise in borrowing." [Spring 1985, p.53]

If the Federal Reserve often accommodated borrowing shocks, the correlation between the spread and such shocks will be reduced and the simultaneous equations bias decreased.

3. Estimated Borrowing Equations

The model of the reserves market developed above indicates that the behavioral equation for borrowing and the appropriate method of estimating it should vary with the Federal Reserve's operating procedure. If the Federal Reserve actually pursued short-run policy as characterized by the above model, then OLS yields consistent estimates of the borrowing equation during the Federal funds rate targeting period but not under the other regimes.

Because bank borrowing depends, in part, on forecasts of future spreads, evidence of changes in the stochastic behavior of the spread coincident with changes in operating procedures would support the hypothesis that bank borrowing behavior also changed. Although banks may use more information than the known history of the spread when forecasting next period's spread, it seems useful as a benchmark to estimate a model of the stochastic process generating the spread in each of the five periods to see whether it changed with changes in the operating procedure. Because only positive spreads are relevant, the subperiod of 1977(5)

through 1979(10) is investigated for the FFRT period. A Dickey-Fuller test for nonstationarity indicates that the spread was stationary over this period. An AR(1) model fits the data adequately, so that the spread exhibits mean reversion during this period.[21] For the NBRT period, the Dickey-Fuller test for a unit root indicated that the spread was nonstationary. The data do not reject a random walk model for the spread, so in this period shocks to the spread appeared permanent.[22] For the BRT period with LRA in force, the Dickey-Fuller test again indicates stationarity and the data exhibit mean reversion.[23] For the BRT period with CRA in force, tests on the bi-weekly average spread indicate that one cannot reject the hypothesis of a nonstationary spread and that a random walk model fits the data adequately.[24] The qualitative implications of these results, assuming that banks are forward-looking and use simple time series models to predict the

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[21] The model fitted is:

$$S_t = \underset{(3.90)}{.124} + \underset{(13.01)}{.757}\, S_{t-1} \qquad \begin{array}{l} SEE = .149 \\ Q(12) = 6.7 \\ Q(36) = 34.5 \end{array}$$

where t-ratios are in parentheses, SEE = standard error of estimate, and Q is the Box-Ljung statistic testing for serially correlated errors.

[22] The first difference of the spread appeared serially uncorrelated during this period, with a standard error of .808 and Q statistics of 12.6 for 12 degrees of freedom and 46.3 for 36 degrees of freedom.

[23] The fitted model is:

$$S_t = \underset{(1.50)}{.076} + \underset{(3.75)}{.412}\, S_{t-1} + \underset{(3.94)}{.433}\, S_{t-2} \qquad \begin{array}{l} SEE = .337 \\ Q(12) = 7.4 \\ Q(36) = 35.6 \end{array}$$

Spindt and Tarhan (1987) also report evidence that the spread was nonstationary during the NBRT period but not during the FFRT period or during the period October 1982 through December 1984.

[24] For the pre-crash period from February 1984 to the crash, the first difference of the spread appeared to be serially uncorrelated with a SEE of .324 and Q statistics of 9.55 for 12 degrees of freedom and 43.5 for 36 degrees of freedom. For the post-crash period, the SEE was .169 and the corresponding Q statistics were 13.42 and 34.60 respectively.

spread, are that the spread should have larger effects on borrowing in the FFRT period and the BRT-LRA period and smaller effects in the NBRT and BRT-CRA periods. [25]

A. The Federal Funds Rate Targeting Regime

As noted above, the model assumes that the spread between the Federal funds rate and the discount rate is positive. The spread was, however, often negative during the Federal funds rate targeting period and occasionally negative thereafter. Since banks cannot lend to the Federal Reserve at the discount rate, there is an asymmetry such that borrowing is expected to be close to zero for all negative spreads.[26] In addition, banks may "window-dress" their balance sheets at the end of the calendar year, so borrowing may behave differently in the week that includes December 31. To allow for these effects, the model for borrowing is modified as follows:

$$B_t = b_0 + b_1 \, PSPR_t + b_2 \, B_{t-1} + b_3 \, WD_t + u_t \qquad (11)$$

where $PSPR = F - D$ if $F > D$,

$= 0$ otherwise,

$WD = 1$ if the week includes December 31,

$= 0$ otherwise.

Under the assumption that the Federal Reserve was targeting the Federal funds rate, equation (11) can be consistently estimated by OLS. The data are

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[25] A potential econometric problem is that the presence of a nonstationary variable on the right-hand side might invalidate using standard distributions for hypothesis tests. Tests for co-integration of adjustment borrowing and the spread, as suggested in Engle and Granger (1987), indicate that borrowing and the spread are co-integrated in all sub-periods so that the standard distributions are likely to be appropriate.

[26] The observable Federal funds rate is an average, so some banks may face a positive spread when the average spread is negative.

weekly observations on adjustment borrowing (B) and the average daily spread between the Federal funds rate and the discount rate for the period January 1975 through October 3,1979. Weeks correspond to the reserve maintenance weeks of Thursday to the following Wednesday.

Table 2 reports estimates of the borrowing equation for this regime. Equation 2.1 gives the estimated model when the asymmetry introduced by negative spreads is ignored. An increase in the spread of one percentage point is associated with an increase in borrowing of about $340 million. The coefficient on WD, the window dressing dummy variable, is negative but not significant. Expanding the model to allow for a scale variable, the change in required reserves (CHRR), does not change the results much as indicated by equation 2.2.[27] These results are similar to those reported by Keir (1981) for this period. Equation 2.3 reports the estimate of equation (11) and indicates that allowing for the asymmetry caused by negative spreads affects the results substantially. The coefficient on the spread variable more than triples and implies that an increase in the spread of one percentage point is associated with an increase in adjustment borrowing of about $1 billion. The coefficient on WD becomes statistically significant, indicating that borrowing fell by about $240 million, all else constant, in the week that includes the last business day of the year. This suggests a desire by banks to reduce end-of-year outstanding liabilities to the Federal Reserve.[28] Similar to the results of other studies, the coefficient

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[27] This is the scale variable used by Keir, and he also found that it did not add substantially to the model.

[28] Daily borrowing data are not publicly available. Outstanding total borrowing, which includes adjustment, seasonal, and extended credit, is reported for December 31 of each year in Table 2 of the Annual Report of the Board of Governors of the Federal Reserve System. For the years 1975 through 1978, borrowing on December 31 is always less than that for the week including December 31:

Table 2
Estimated Borrowing Equations
Federal Funds Rate Targeting Period

Weekly, January 1975-October 1979

Equation Number	Constant	B_{t-1}	Spread	PSPR	$PSPR^2$	CHRR	WD	R^2	SEE DH
2.1	206.67	.52	343.35				-58.45	.77	225.40
	(8.09)	(10.50)	(8.34)				(-.51)		1.20
2.2	198.69	.54	327.71			.047	-94.01	.77	223.55
	(7.76)	(10.82)	(7.91)			(2.24)	(-.83)		1.14
2.3	39.73	.28		1071.50			-221.57	.84	190.45
	(1.50)	(5.79)		(12.80)					.63
2.4	46.31	.30		888.79	213.81	.028	-266.90	.84	189.83
	(2.55)	(6.09)		(5.40)	(1.10)	(1.55)	(-2.66)		.66

NOTES: PSPR = Spread if Spread > 0
= 0 if Spread $\leq$ 0

CHRR = Change in required reserves

WD = 1 if week includes December 31
= 0 otherwise

DH = Durbin's H statistic

on lagged borrowing is always significantly positive, but is smaller when the asymmetry is imposed.[29] Adding a scale variable to this specification and allowing for a nonlinear effect of the spread, equation 2.4, does not add anything to the explanatory power of the model. The model does a reasonable job of accounting for weekly fluctuations in borrowing with no evidence of serially correlated errors.

B. The Nonborrowed Reserves Targeting Period

Estimating the borrowing equation in the NBRT regime is more difficult for two reasons. First, as noted above, the spread is not exogenously determined if the Federal Reserve pursues this operating procedure and does not accommodate shocks to the borrowing equation. Second, a surcharge was added to the basic discount rate for large, frequent borrowers.[30] Since the surcharge did not apply

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	1975	1976	1977	1978
Average total borrowing in week including Dec. 31 (millions)	$253	$31	$506	$1183
December 31 borrowing	161	19	226	717

The data suggest that banks typically reduced their borrowing on December 31 in these years.

[29] The data fail to reject the hypothesis that borrowing is unaffected by changes in the spread when the spread is negative. Allowing the coefficient on lagged borrowing to depend on whether the spread was positive or negative did not affect the estimates. Re-estimating the model for the FFRT period after May 1977, a period when the spread was always positive, produces results similar to those from the whole FFRT period using PSPR.

[30] Large banks were defined as banks with deposits of $500 million or more and frequent was defined as borrowing two weeks in a row or borrowing in more than four weeks in a quarter. The schedule of the surcharge was:

March 17,1980 - May 7,1980	3 percent
November 17,1980 - December 4,1980	2 percent
December 5, 1980 - May 4,1981	3 percent
May 5, 1981 - September 21,1981	4 percent
September 22,1981 - October 11,1981	3 percent
October 12,1981 - November 16,1981	2 percent

to all borrowers, it is added to the model as a separate variable rather than used to redefine the spread.

Table 3 reports estimates of the borrowing equation for the NBRT period. Because the squared spread term is always significant, the reported models include this variable. Equations 3.1 and 3.2 are the OLS estimates of the model with and without the WD dummy. They indicate that increases in the spread, when positive, are again associated with increases in borrowing, but that the effect is considerably smaller than in the FFRT period. From equation 3.2 an increase in the spread from, say, 1 percent to 2 percent is associated with an increase in borrowing of about $223 million or about a quarter of the increase that would have been predicted using the model estimated for the FFRT period. The surcharge had a significantly negative effect on borrowing, with the 3 percent surcharge reducing borrowing by about $186 million. The WD dummy had a positive coefficient but was not significant.

Equations 3.3 and 3.4 report estimates of the model using 2SLS. The exogenous variables added as instruments were the levels of required reserves and nonborrowed reserves, both of which are exogenous under NBRT and LRA. As the estimates indicate, the 2SLS results are not greatly different from the OLS estimates. From equation 3.4, the effect of an increase in the spread from, say, 1 to 2 percent is about $244 million, only slightly larger than that implied by the OLS estimate. The effect of the surcharge is estimated to be somewhat less, while the WD dummy again is insignificant. These results indicate that the simultaneous equations problem does not affect the estimated coefficients substantially, implying that shocks to the borrowing equation generally were accommodated, so they did not substantially affect the funds rate.

Given the similarity of the OLS and 2SLS estimates, it seems reasonable

Table 3
Estimated Borrowing Equations
Nonborrowed Reserves Targeting Period

Weekly, October 1979 - October 1982

Equation Number	Constant	B_{t-1}	PSPR	$PSPR^2$	SURCH	WD	R^2	SEE DH(ρ)*
3.1	119.47	.55	316.31	-31.78	-61.85	167.26	.68	381.68
(OLS)	(1.85)	(8.52)	(5.15)	(-3.61)	(-2.40)	(.72)		1.97
3.2	122.01	.55	318.86	-31.94	-62.96		.68	381.13
(OLS)	(1.92)	(8.52)	(5.21)	(-3.63)	(-2.47)			1.80
3.3	99.34	.55	354.57	-39.84	-53.80	170.49	.68	383.02
(2SLS)	(1.52)	(7.86)	(4.71)	(-3.60)	(-1.98)	(.77)		.099
3.4	102.72	.54	357.78	-39.49	-57.20		.68	382.18
(2SLS)	(1.56)	(7.78)	(4.73)	(-3.54)	(-2.11)			.098

NOTES: See notes for Table 2

SURCH = Surcharge imposed on large, frequent borrowers

* for 2SLS estimates, the estimated first order autocorrelation coefficient is reported.

2SLS instruments included the predetermined RHS variables, lagged values of the endogenous RHS variables, and the levels of required reserves and nonborrowed reserves

to test formally whether the coefficients of the borrowing equation were significantly different in the NBRT period than in the FFRT period. Because the standard errors of the separate regressions suggest that combining the periods would introduce heteroskedasticity, the data for the FFRT period were divided by the SEE from the separate FFRT period and the data from the NBRT period were divided by the SEE from that period. The transformed data were combined and an equation allowing different coefficients for the NBRT period was estimated. The joint hypothesis that the coefficients were equal across periods is easily rejected for models with and without the squared spread term.[31]

C. The Borrowed Reserves Target Period

Table 4 reports estimates of the borrowing equation for the BRT period. Equation 4.1 gives the OLS estimates for the BRT period with LRA.[32] For this period, a one percentage point increase in the spread was associated with an increase in borrowing of about $437 million, roughly twice as much as in the NBRT period but only about half as much as in the FFRT period. Past borrowing appeared to have little effect on current borrowing during this period and the window-dressing variable was not significant. Formal tests reject the hypotheses that the coefficients in this period are identical to those in the FFRT or the NBRT periods.[33]

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[31] The F statistics are 20.25 (5,390 degrees of freedom) and 38.58 (4,392 degrees of freedom) for models with and without the squared spread term, respectively. Separate tests that the effect of the spread alone was equal across periods also reject the hypothesis of equality.

[32] The squared spread variable is never significant in the BRT periods and is therefore excluded.

[33] The F statistic for the hypothesis test that the coefficients in the FFRT period equal those in the BRT-LRA period is 31.83 (4,305 degrees of freedom), while the F statistics for the NBRT versus BRT-LRA periods are 6.96 (5,215

Table 4
Estimated Borrowing Equations
Borrowed Reserves Targeting Period

Equation Number	Constant	B_{t-1}	PSPR	WD	R^2	SEE DH(ρ)*
A. Weekly, October 21,1982 - February 1,1984						
4.1	320.93	-.07	437.72	118.75	.48	213.17
(OLS)	(6.04)	(-.73)	(6.47)	(.70)		.53
4.2	322.91	-.06	423.10	134.97	.48	213.24
(2SLS)	(6.04)	(-.60)	(5.24)	(.76)		.03
B. Bi-Weekly, February 1984 - October 1987						
4.3	158.84	.36	118.42	353.03	.35	194.89
(OLS)	(3.76)	(3.90)	(3.44)	(3.02)		.11
4.4	158.78	.36	118.61	352.91	.35	194.89
(2SLS)	(3.80)	(3.92)	(3.20)	(3.07)		.01
C. Bi-Weekly, October 1987 - December 1989						
4.5	144.27	.06	39.63	838.82	.46	165.46
(OLS)	(2.43)	(.69)	(1.31)	(7.04)		.06
4.6	162.32	.07	28.47	839.53	.46	165.67
(2SLS)	(2.69)	(.74)	(.92)	(7.04)		.00

NOTES: See notes for Tables 2 and 3
* for 2SLS estimates, the estimated first order autocorrelation coefficient is reported
2SLS instruments include the predetermined RHS variables, lagged values of the endogenous RHS variables, and the borrowed reserves target

As noted above, borrowing behavior is thought to have changed after the stock market crash on October 19,1987, so separate estimates for the pre- and post-crash BRT periods with CRA in force are presented. Equation 4.3 gives the OLS estimate of the borrowing equation for the pre-crash period and indicates that borrowing became even less sensitive to changes in the spread after the switch to CRA. An increase in the spread of one percentage point was associated with an increase in borrowing of about $120 million. The estimated coefficient on the WD dummy is significantly positive and indicates that borrowing was about $350 million higher in the last settlement period of the calendar year. This is the reverse of the finding for the FFRT period. A closer examination of the data suggests that banks have changed their end-of-year behavior and have been "puffing up" their assets for the end-of-year annual reports by borrowing substantially on December 31. The data indicate that bank borrowing is always higher for December 31 than for the bi-weekly average that includes December 31, and the daily Federal funds rate tends to have a spike at the end of the year as banks strive to borrow to build up asset totals.[34]

Equation 4.5 reports the OLS estimate of the borrowing equation for the post-crash period. As suggested by the scatter plot in the bottom panel of Figure

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degrees of freedom) for the model including the squared spread term and 10.88 (4,217 degrees of freedom) for the model excluding the squared spread term. The correction for heteroskedasticity discussed in the text was also used for these tests.

[34] The data on average and December 31 total borrowing are:

	1984	1985	1986	1987	1988
Average borrowing for bi-weekly period including Dec. 31 ($millions)	$2690	$1337	$1186	$1944	$2048
Borrowing on December 31	$3577	$3060	$1565	$3815	$2170

I wish to thank Alton Gilbert for a helpful discussion of this issue.

5, borrowing was even less sensitive to the spread after the crash. The window-dressing effect was larger, with average borrowing increasing by about $840 million in the maintenance period containing the last day of the year.[35] The hypothesis that the coefficients of the borrowing model are equal before and after the crash is easily rejected.[36]

As shown in section 2, if the Federal Reserve kept to a strict borrowed reserves target, the spread would be correlated with the error term of the borrowing equation. To allow for the possible bias resulting from this, the equations are re-estimated using 2SLS. The targeted level of borrowing is an exogenous variable under this operating procedure so it was employed as an instrument.[37] As equations 4.2, 4.4 and 4.6 indicate, there is little evidence of simultaneous equations bias. Thus these results are consistent with the Federal Reserve accommodating shocks to the borrowing equation so that they do not get transmitted to the spread.

D. Summary of results

The results from estimating the borrowed reserves equation for the five periods are summarized in Table 5. The estimated borrowing equations indicate that the sensitivity of adjustment borrowing to the spread did change when the

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[35] The models for the BRT period were re-estimated dropping the observations that included December 31. The resulting estimates are very close to those reported in Table 4, indicating that these observations were adequately captured by the WD dummy. The R^2 for the post-crash period did fall substantially. This is because the large amount of year-end borrowing, picked up by the WD dummy, inflates the R^2 for this short period.

[36] The relevant F statistic is 9.95 with 4 and 145 degrees of freedom.

[37] The borrowings target is for seasonal and adjustment borrowing, but increases in this target correspond to a decision to raise the Federal funds rate. The borrowings target data are from the spring issues of the Federal Reserve Bank of New York's Quarterly Review.

Table 5
Summary of Results

	FFRT-LRA	NBRT-LRA	BRT-LRA	BRT-CRA pre-crash	BRT-CRA post-crash
Stochastic Process for Spread	mean-reverting	random walk	mean-reverting	random walk	random walk
Increase in Borrowed Reserves for an Increase in the Spread from 1% to 2% ($millions)	$1072	$220	$438	$118	$40

Notes: FFRT = Federal funds rate targeting period
NBRT = nonborrowed reserves targeting period
BRT = borrowed reserves targeting period
LRA = lagged reserve accounting
CRA = contemporaneous reserve accounting

Estimated increases in borrowing are from estimated eqautions 2.1, 3.1, 4.1, 4.3, and 4.5 respectively.

Federal Reserve changed operating procedures. The qualitative predictions of Goodfriend's (1983) model are supported in that borrowing was more sensitive to the spread when the spread was mean-reverting and less sensitive when it was non-stationary. The switch to CRA appeared also to reduce the sensitivity of borrowing to the spread. Since the October 1987 stock market crash, borrowing has been virtually unresponsive to movements in the spread. The lack of evidence of a substantial simultaneous equations bias in the estimated borrowing equations during the NBRT and BRT periods implies that the Federal Reserve generally accommodated shocks to the borrowing equation.

4. Conclusions

Several researchers have argued that bank borrowing at the discount window should depend on the operating procedures employed by the Federal Reserve. If the Federal Reserve changes procedures in such a way that the stochastic process characterizing the spread between the Federal funds rate and the discount rate changes, the sensitivity of bank borrowing to the spread should change. If the spread is mean-reverting so that changes in the spread are temporary, borrowing should be more sensitive to the spread than when the changes in the spread appear to be permanent. In addition, it would not be surprising to find that institutional changes such as the move from lagged to contemporaneous reserve accounting changed bank borrowing behavior and reserve management.

This paper has provided empirical evidence supporting the hypothesis that bank borrowing behavior did change when the Federal Reserve altered its short-run operating procedures. Under a Federal funds rate target, when the spread was mean-reverting, borrowing was very sensitive to changes in the spread when the spread was positive. Under a nonborrowed reserves target in which the spread was

much more variable and changes in the spread were permanent, bank borrowing became much less sensitive to the spread. Borrowing became more sensitive to the spread during the period characterized by a borrowed reserves target with lagged reserve accounting and a mean-reverting spread. Finally, after the switch to contemporaneous reserve accounting, the spread again became nonstationary and bank borrowing became relatively insensitive to the spread, particularly after the October 1987 stock market crash. This last finding, combined with the increase in excess reserves under contemporaneous reserve accounting, is consistent with banks adopting a more risk-averse approach to reserve management.

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