Contemporaneous vs. Lagged Reserve Accounting: Implications for Monetary Control

By David S. Jones

To enhance the Federal Reserve System's ability to control the nation's supply of money and credit, commercial banks and other depository institutions are required by law to hold some of their assets as reserves. The amount of an institution's legal reserve requirement, which may be met with vault cash or demand balances at Federal Reserve Banks, is related to its deposit liabilities. Under the present system of lagged reserve accounting (LRA), the reserve requirement for a given settlement period—seven days ending each Wednesday—is based on deposit liabilities two weeks earlier.

The present LRA structure has been in place since September 1968. Previously, reserve accounting was contemporaneous in that the reserve requirement for a given settlement period was based on deposit levels for that same period.

Over the past few years, many economists have argued that a return to contemporaneous reserve accounting (CRA) would improve the

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precision of monetary control. Although other economists have questioned this claim, in the fall of 1980 the Board of Governors of the Federal Reserve System announced its disposition to return to CRA, pending a further review of its operational practicality. On October 9, 1981, the Board requested public comment on a specific CRA proposal that would introduce essentially contemporaneous reserve requirements on transactions accounts for medium-sized and large depository institutions.

The eventual decision to return to CRA or to continue with an LRA system must weigh any anticipated improvement in monetary control under CRA against the additional costs that CRA will impose on both the Federal Reserve and depository institutions. The central issue is whether the expected degree of improvement in monetary control under CRA compensates for the additional economic costs.

The purpose of this paper is to assess the likely improvement in monetary control that would accompany a return to CRA. A formal cost-benefit analysis is not undertaken, however, because reliable estimates of the additional costs associated with implementing CRA are not presently available. In the first section of the article, the history of the reserve accounting system is reviewed. The second section sets forth a simple theoretical model of the monetary control process and, within the context of this model, discusses the major empirical issues relating to monetary control under

LRA and CRA. The third section reviews the existing empirical research relating to monetary control under LRA and CRA. The fourth section then presents new evidence derived from simulations of a weekly econometric model of the U.S. money market developed for this study. A summary and concluding remarks appear in the fifth section.

THE PRESENT RESERVE ACCOUNTING SYSTEM

The present LRA system, as mentioned above, has been in place since September 1968. Previously, reserve accounting was contemporaneous in that an institution's reserve requirement for a given settlement period was based on its deposit liabilities during that same period.[1] Another important feature of the earlier reserve accounting system was that reserve vault cash consisted of vault cash held during the settlement period. Also, a limited "carryover provision" allowed a bank to carry forward into the following settlement period a reserve deficiency of up to 2 percent of its reserve requirement without penalty, although positive excess reserves could not be carried forward. Finally, while the settlement period for reserve city banks was one week ending each Wednesday, the settlement period for country banks was two weeks ending every other Wednesday.

A number of considerations motivated the abandonment of the earlier CRA system in favor of the present reserve accounting structure. One consideration was that, due to large revisions in required reserves and vault cash, CRA complicated the Federal Reserve's efforts to achieve its objectives for net free reserves, a

key operating target for monetary policy at the time.[2] Also, it was thought that the reserve accounting system contributed to sharp movements in the federal funds rate that sometimes occurred toward the end of statement weeks, as member banks scrambled to sell excess reserves in the federal funds market. A major reason for this volatility in the federal funds rate, it was thought, was the inability of member banks to carry positive excess reserves forward into the following settlement period. A contributing factor was thought to be the inability of banks to predict their reserve requirement accurately.[3] A third, but related, consideration was that CRA unduly exacerbated the burden of Federal Reserve membership.[4]

In light of the perceived problems with the earlier system, the Federal Reserve's Regulation D, which defines the reserve accounting structure, was amended effective September 12, 1968, to incorporate several important changes. New methods for computing required reserves and reserve vault cash were adopted to improve the estimates of these quantities. Required reserves under the new formula were based on deposit levels two weeks earlier, while reserve vault cash was redefined to consist of vault cash held two weeks earlier. In addition to simplifying the conduct of monetary policy, these modifications were expected to contribute to more efficient and less costly reserve management by member banks and, as a result, lessen the membership burden.

The carryover provision was also liberalized to permit member banks to carry forward into the following settlement period positive excess

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[1] There was, however, an effective lag of one day because required reserves were based on deposit levels at the beginning of the day, whereas reserves were equal to end-of-day balances at Federal Reserve Banks and beginning-of-day vault cash.

[2] See Federal Reserve Board Staff, "Impact of Lagged Reserve Accounting," October 6, 1977.

[3] For a discussion of the reserve management implications of CRA, see A. Gilbert, "Lagged Reserve Requirements: Implications for Monetary Control and Bank Reserve Management," *Review,* Federal Reserve Bank of St. Louis, May 1980, pp. 7-20.

[4] See Federal Reserve Board Staff, October 6, 1977.

reserves of up to 2 percent of reserve requirements. This action was expected to create an incentive for banks not to sell excess reserves into the federal funds market at temporarily depressed interest rates, thereby helping to moderate downside interest rate fluctuations toward the end of statement weeks.

In brief, the amendments to Regulation D were expected to simplify the conduct of monetary policy, ease the burden of reserve management for member banks, and temper intraweekly interest rate fluctuations. To some extent, these expectations were realized.[5] Federal Reserve estimates of required reserves and reserve vault cash did improve substantially after September 12, 1968. Moreover, member banks generally favored the lagged reserve accounting structure, especially small banks and banks with extensive branch systems. Contrary to expectations, however, intraweekly federal funds rate volatility initially intensified rather than diminished under the new system. This increased volatility was partially attributed to the greater sensitivity of the federal funds rate to reserve supply shocks under LRA.[6] The problem was arrested by an enlarged volume of defensive open market operations undertaken by the Federal Reserve. By 1974, intraweekly fluctuations in the federal funds rate had fallen back to levels comparable with those prevailing before September 1968.[7]

While LRA was partly successful in helping solve some problems faced by monetary policymakers in 1968, many economists and public officials have argued that a return to CRA would improve monetary control.[8] On August 15, 1980, the Board of Governors announced its disposition to return to CRA pending a further review of its operational practicality.[9] On October 9, 1981, the Board requested public comment on a specific CRA proposal which would introduce essentially contemporaneous reserve requirements on transactions accounts for medium-sized and large depository institutions.

Under the October 1981 proposal, CRA would apply only to institutions that report their deposit levels weekly to the Federal Reserve. Affected institutions would compute required reserves against transactions deposits and other reservable liabilities on the basis of average deposit levels over two-week computation periods ending on Monday. Required reserves against transactions deposits would be maintained during a two-week maintenance period ending on the Wednesday two days after the computation period. Required reserves against other reservable liabilities, however, would be posted in a two-week maintenance period beginning 17 days after the computation period, on a Thursday. Vault cash, eligible to be counted as a reserve during the maintenance period, would continue to be lagged and would be equal to vault cash holdings during the computation period ending 17 days prior to the beginning of the maintenance period. The proposal would retain

[5] For a detailed discussion of the amendments to Regulation D and their implications, see W. Coats, "The September 1968 Changes in Regulation D and Their Implications for Money Supply Control," Ph.D. dissertation, University of Chicago, 1972, and "Lagged Reserve Accounting and the Money Supply Mechanism," *Journal of Money, Credit, and Banking,* May 1976, pp. 167-80.

[6] A contributing factor was that, in addition to the amendments cited above, the September 1968 amendments to Regulation D also changed the settlement period of country banks from biweekly to weekly.

[7] A change in the U.S. Treasury's cash management procedures also complicated the Open Market Desk's efforts to reduce the volatility of the federal funds rate. See Federal Reserve Board Staff, October 6, 1977.

[8] See, for example, "Sprinkel Urges Contemporaneous Reserve Accounting," *American Banker,* July 24, 1981; W. Poole, "How to Make Reserves Control Work: Parts I and II," *American Banker,* October 30 and 31, 1979; and W. Poole and C. Lieberman, "Improving Monetary Control," *Brookings Papers on Economic Activity,* 1972:2, pp. 308-20.

[9]*Federal Register,* Vol. 45, No. 165, August 22, 1980, p. 56011.

the current limit of plus or minus 2 percent of daily average required reserves that applies to the carryover of reserve surpluses or deficiencies into the next reserve period. However, lengthening the reserve period from one week to two weeks would provide the same additional flexibility for managing reserve positions as would a doubling of the carryover limit with a one-week period.

The case for returning to CRA is based on the view that monetary control, especially in the shorter run of a month or so, would be more precise under CRA than under LRA.[10] Proponents of CRA argue that it is particularly attractive under a reserves targeting monetary control procedure like the nonborrowed reserves procedure adopted on October 6, 1979. CRA proponents also claim that, in practice, CRA is a prerequisite for adopting an operating procedure involving the targeting of total reserves or the monetary base, should the Federal Reserve wish to adopt either procedure at some future date.

Although monetary control might be enhanced under CRA, there are two reasons why returning to CRA may not be desirable. One is the implementation and operating costs to the Federal Reserve and to private institutions. While the Federal Reserve's membership problem has been solved, the System properly remains concerned about the economic cost of its regulatory actions. For the Federal Reserve, returning to CRA would necessitate reprogramming its computers and developing and administering new monitoring systems. For private depository institutions, the additional costs would be associated with modifying their existing internal deposit monitoring and reserve management systems.

The second reason that a return to CRA may not be desirable is that the possible improvement in monetary control may be small. Thus, the benefits of returning to CRA may not outweigh its attendant costs. In assessing CRA, therefore, it is useful to examine both the theoretical and empirical evidence on the monetary control issue.

RESERVE ACCOUNTING
AND MONETARY CONTROL

This section analyzes the theoretical implications of the reserve accounting system for short-run monetary control. The analysis is conducted within the framework of a theoretical model that shows how the weekly stock of money is determined and controlled.[11]

A Model of the Determination
of the Stock of Money

The stock of money, along with the short-term interest rate, is determined by the public's demand for money, by depository institutions' demand for reserves, and by the supply of reserves made available through the Federal Reserve. The quantity of money demanded by the public is related mainly to the short-term rate of interest and the level of economic activity—measured, for example, by the level of income. Increases in the market interest rate, other things equal, induce individuals and firms to transfer some of their money balances to higher yielding market instruments. For a given interest rate, as the level of income rises, the public requires a greater quantity of money to carry out a larger volume of economic transac-

10 See W. Coats, 1972 and 1976; S. LeRoy, "Monetary Control Under Lagged Reserve Accounting," *Southern Economic Journal,* October 1979, pp. 460-70; and Federal Reserve Board Staff, October 6, 1977.

11 The model is similar to one developed by D. Laufenberg in "Contemporaneous Versus Lagged Reserve Accounting," *Journal of Money, Credit, and Banking,* May 1976, pp. 239-45. For a more rigorous analytical derivation of the results reported below, see D. Jones, "An Empirical Analysis of Monetary Control Under Contemporaneous and Lagged Reserve Accounting," Federal Reserve Bank of Kansas City, Research Working Paper, forthcoming.

tions. Thus, the demand for money is related positively to the level of income and negatively to the level of the short-term interest rate.

The curve, MD, in the left-hand panel of Figure 1 illustrates the relationship between the demand for money and the short-term interest rate. For a fixed level of income, the curve shows the quantity of money demanded at different interest rate levels. Thus, given an interest rate, r_0, and income level, Y, the quantity of money demanded by the public is M_0. The MD schedule slopes downward, reflecting the presumption that the public holds less money as the short-term interest rate rises.

The effect of a change in income on the demand for money may be represented by a horizontal shift in the MD curve. For example, an increase in income from Y to Y' will shift the MD curve rightward—say, from MD to MD' in Figure 1—as the public demands more money balances at every interest rate in order to carry out a higher volume of economic transactions.

The short-term interest rate, on which the demand for money partially depends, is deter- mined by the demand for and supply of reserves, that is, the short term rate of interest adjusts until reserve demand and supply are equal. The supply of total reserves available to depository institutions equals the sum of borrowed reserves—reserves that institutions borrow from the Federal Reserve through the discount window—plus nonborrowed reserves, NBR, that is, reserves arising from all other sources. The Federal Reserve proximately controls the level of nonborrowed reserves through open market operations. Borrowed reserves, on the other hand, are determined by the willingness of despository institutions to borrow at the discount window. Borrowings tend to be positively related to the spread between the short-term market interest rate and the discount rate, which is taken to be fixed in this analysis. The greater this spread, the more profitable it is for banks to borrow from the discount window and, hence, the greater the level of borrowed reserves. Administrative pressure and bankers' traditional reluctance to borrow from the discount window account for the failure of banks

Figure 1
THE MONEY AND RESERVES MARKET
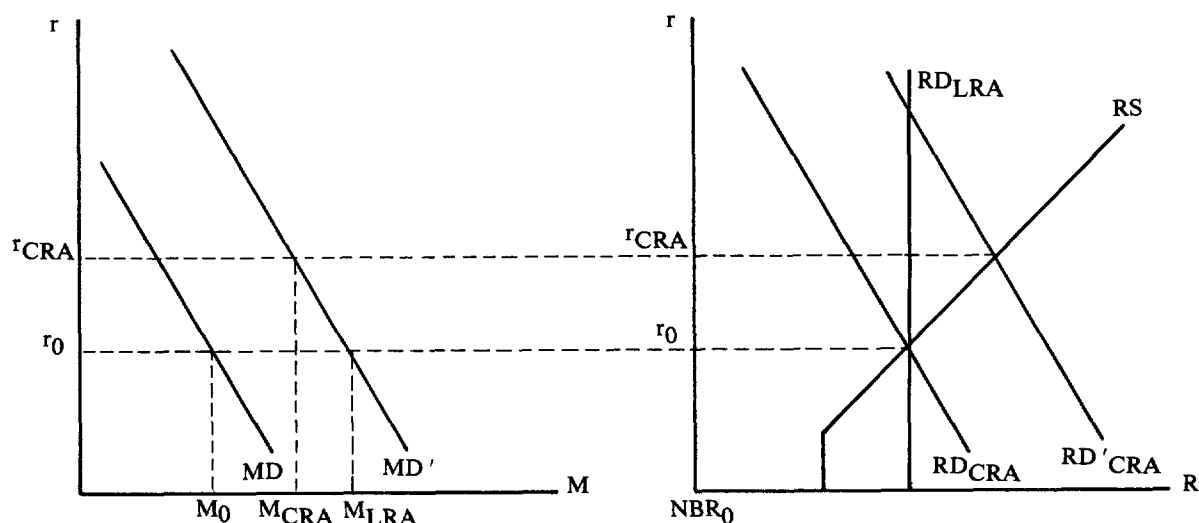
to completely arbitrage away differences between the short-term market interest rate and the discount rate.

The RS curve in the right-hand panel of Figure 1 represents the supply of total reserves to the financial system at various rates of interest. This curve is drawn assuming a fixed level of nonborrowed reserves, NBR_0. RS is vertical for short-term interest rates below the discount rate, reflecting the fact that discount borrowing is minimal at such levels because it is unprofitable from the standpoint of institutions. For interest rates above the discount rate, RS is positively sloped as higher money market rates induce higher levels of borrowings.[12]

A change in the level of nonborrowed reserves is represented by a horizontal shift in the RS curve. For instance, an increase in NBR will shift the entire RS curve rightward by the amount of the increase.

The demand for reserves is the sum of depository institutions' required reserves and desired excess reserves. Because required reserves are computed differently under LRA and CRA, the demand for reserves in each case must be treated separately. Under LRA, required reserves in any week are predetermined by deposit levels two weeks earlier. Thus, under LRA, given the assumption that the demand for excess reserves does not depend on interest rates,[13] the demand for total reserves in any week may be represented by a vertical curve, such as RD_{LRA} in Figure 1. Changes from week to week in desired excess reserves or in required reserves—due, say, to a shift in the MD curve of Figure 1—imply rightward or leftward shifts in RD_{LRA} as the sum of required and desired excess reserves increases or decreases. However, under LRA, the reserve demand curve will *not* shift in the same week as the shift of the MD curve. Rather, RD_{LRA} will shift in later weeks as future reserve requirements are affected.

Under CRA, the demand for reserves is not represented by a vertical curve in any given week. This is because changes in interest rates during the week may affect required reserves in the same week by affecting the public's holdings of money. For instance, under CRA an increase in the rate of interest will generally lower the quantity of money demanded by the public, thereby lowering required reserves for the same week. The reserve demand schedule under CRA, therefore, is negatively related to the interest rate as illustrated by RD_{CRA} in Figure 1.

Because reserve demand is contemporaneously linked to money demand under CRA, a shift in the money demand curve in a given week will induce a sympathetic shift in the reserve demand curve. To illustrate, suppose a rise in income causes MD to shift to MD' in Figure 1. This shift will induce a rightward shift in RD_{CRA}, say, to RD_{CRA}', as required reserves rise along with the increase in the demand for money.

The money demand and reserve supply and demand curves in Figure 1 can be used to illustrate graphically the process which determines the money supply and short-term interest rates. Suppose LRA is in effect and that, given past deposit levels, the demand for reserves may be represented by RD_{LRA}. Also suppose that the Federal Reserve pursues a nonborrowed reserves operating strategy, setting the level

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[12] The shape of the RS curve is affected by the Federal Reserve's choice of operating target. For example, the RS curve in Figure 1 presumes a nonborrowed reserves operating target. That is, over the operating period—say, one week—the level of nonborrowed reserves is fixed. Under a total reserves targeting procedure, the RS curve would be vertical at that level of total reserves supplied by the Federal Reserve. Operationally, the Federal Reserve could implement a total reserves targeting procedure either by ensuring that the discount rate always exceeded money market rates or by continually adjusting nonborrowed reserves over the operating period to offset discount window borrowings.

[13] The results of this section are not qualitatively affected if excess reserves are interest-sensitive.

of NBR at NBR_0 during the week. Under these demand and supply conditions, the short-term interest rate that equilibrates the reserves market is r_0. For rates below r_0, reserve demand will exceed supply and banks will bid more aggressively for reserves, pushing the level of short-term rates toward r_0. For rates above r_0, reserves supply exceeds demand and banks will lower their bids for reserves.

Given the equilibrium interest rate, r_0, and the level of income—assumed predetermined during the week—the money demand schedule can be used to determine the equilibrium stock of money. This is done graphically in the left-hand panel of Figure 1, which shows that the equilibrium money stock is M_0.

Under CRA, essentially the same process determines the money stock and the short-term interest rate. Under CRA, however, the RD schedule is different from that under LRA, as shown in Figure 1. Nonetheless, Figure 1 is drawn so that the equilibrium short-term interest rate and the money stock are the same under CRA and LRA, given MD and NBR.

The overall strategy of monetary control under a nonborrowed reserves operating procedure can be conveniently described with the above diagramatic apparatus. The Federal Reserve first estimates the positions of the money demand and reserve demand schedules, and the shape of the reserve supply curve, that is, the shape of the relationship between borrowing and the short-term interest rate. Given these estimates, the Federal Reserve then determines the level of nonborrowed reserves thought to be consistent with its short-run objective for the money stock.[14]

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[14] Under a total reserves targeting procedure, the strategy is similar, except that the RS curve under total reserves targeting is vertical. Of course, the procedures actually employed by the Federal Reserve are in practice more complex than those described here. However, these differences are not important to the LRA-CRA debate.

To illustrate, suppose that LRA is in effect, that the MD and RD_{LRA} curves in Figure 1 represent estimates of the demand for money and for reserves, and that the RS curve has the estimated shape of the reserve supply schedule. Suppose further that M_0 is the money stock objective. Figure 1 reveals that—conditional on forecasts of MD, RD, and the shape of RS—a nonborrowed reserves target of NBR_0 is consistent with the money stock objective of M_0. Thus, the Federal Reserve attempts to provide this targeted amount of nonborrowed reserves during the week. A similar procedure would be followed under CRA. Figure 1 is constructed so that NBR_0 is the targeted amount of nonborrowed reserves under both CRA and LRA.

Monetary Control Under CRA and LRA

Under the reserves targeting procedure described above, if the Federal Reserve's forecasts of the demand for money, the demand for reserves, and the supply of reserves are accurate, then the actual money stock during the week will equal the objective. In practice, however, forecast errors associated with one or more of these curves generally cause the actual money stock to differ from the objective. Whether LRA or CRA yields more precise short-run monetary control depends upon the sources and magnitudes of these forecast errors and the behavioral structure of the financial system.

Sources of Forecast Errors. There are potentially three sources of forecast errors corresponding to the MD, RS, and RD curves. A forecast error arises when the actual position of one of these three curves is different from that anticipated by the Federal Reserve.

If MD is the source of forecast errors, monetary control will be more precise under CRA than under LRA. This is illustrated in Figure 1 where it is assumed that an unexpectedly high level of income in the current

week causes the actual money demand curve, MD ', to lie to the right of that forecast, MD. In this situation, the actual money stock deviates from the objective, M_0, under both CRA and LRA.

Under CRA, the deviation in the actual money stock from the objective is smaller than the deviation under LRA. Graphically, the difference in CRA and LRA may be seen by noting that under CRA, the actual reserve demand lies to the right of that forecasted by the Federal Reserve as higher than anticipated money holdings on the part of the public imply higher than anticipated required reserves in the current week. Thus, in Figure 1, the actual reserve demand curve, RD_{CRA} ', lies to the right of the forecasted curve shown as RD_{CRA}. In contrast, the actual reserve demand curve under LRA, RD_{LRA}, is the same as that forecast because the higher than anticipated money holdings are not accompanied by greater reserve demand in the current week. The flatter reserve demand curve, together with the greater reserve demand under CRA compared with LRA, leads to a higher interest rate under CRA than under LRA. Thus, with CRA, the misforecast of MD implies a misforecast of the interest rate, which through its effect on money demand partly offsets the forecast error in MD. This effect is absent under LRA, where the actual money stock deviates from the objective by the full amount of the MD forecast error.

The graphical analysis may be extended to show that CRA also leads to more precise monetary control when forecast errors emanate from the reserve supply schedule, RS, or from the demand for excess reserves. In both cases, the improvement in monetary control under CRA reflects an interaction of the interest-sensitive money demand curve and a smaller interest rate forecast error under CRA.

CRA will not improve monetary control, however, to the extent that forecast errors are associated with the demand for required reserves. In principle, such misforecasts are not important under LRA, since required reserves are predetermined and known before the current settlement week begins. This is not true of CRA. For example, suppose that under CRA, an unanticipated increase in the average reserve ratio against monetary deposits causes an underforecast of the RD curve in the current week, as illustrated in Figure 2. The figure shows that the actual money stock under CRA, M_{CRA}, falls short of the objective, M_0, as the higher than expected demand for reserves causes the actual interest rate to be higher than expected. With LRA, on the other hand, the higher than expected reserve ratio does not affect required reserves until two weeks later, giving the Federal Reserve ample time to recognize the situation and accommodate the increase in required reserves.

Table 1 summarizes the short-run monetary control implications of LRA and CRA for various types of forecast errors, showing that neither CRA nor LRA results in superior monetary control under all circumstances. Generally speaking, CRA implies more precise short-run monetary control when forecast errors emanate from the demand for money, the supply of reserves, and the demand for excess reserves. CRA impairs monetary control when forecast errors emanate from the demand for required reserves that the Federal Reserve would have time to offset them under LRA.

The Behavior of the Financial System. In general, for a particular type of forecast error, the degree of improvement in monetary control under CRA or LRA depends on the size of the error and the behavioral structure of the financial system. Clearly, if forecast errors are small, the difference in monetary control under LRA and CRA is small. With regard to the structure of the financial system, monetary control is not much different under LRA and CRA if money demand is interest-inelastic, so that MD is nearly vertical: if discount window borrowings are

Figure 2
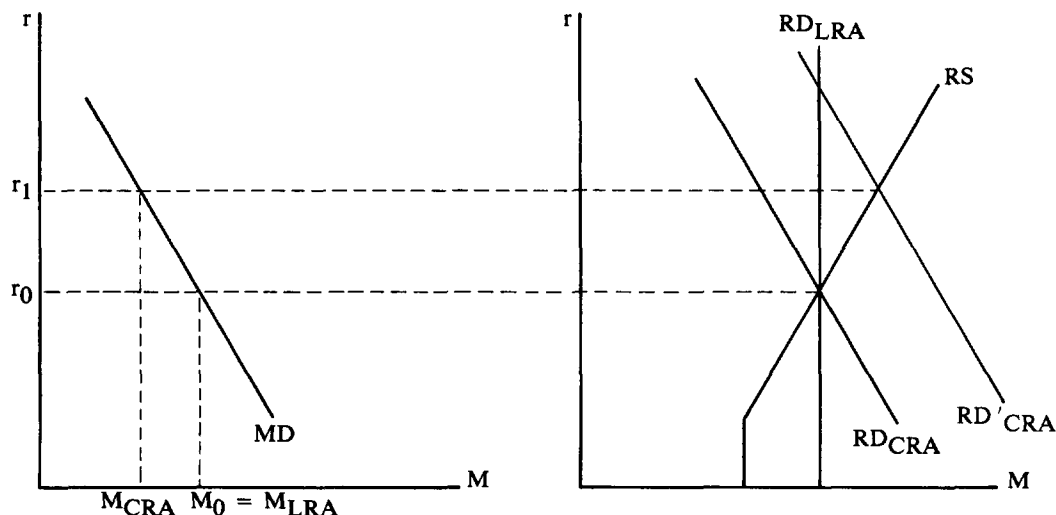## IMPACT OF MISFORECAST OF REQUIRED RESERVES

Table 1
THE EFFECT OF RESERVE ACCOUNTING STRUCTURE ON SHORT-RUN RESPONSE OF MONEY MARKET TO ALTERNATIVE ERRORS

	Type of Forecast Error			
	MD Error*	RS Error†	Excess Reserves Error	Required Reserves Error‡
Reserve Accounting Structure Yielding Smallest Change in Contemporaneous Money	CRA	CRA	CRA	LRA
Reserve Accounting Structure Yielding Smallest Change in Contemporaneous Interest Rate	LRA	CRA	CRA	LRA

*An example of an MD error is an unanticipated increase in personal income causing the MD curve and RD_{CRA} to unexpectedly shift to the right.

†An example of an RS error is an unanticipated increase in float which causes the RS curve to unexpectedly shift to the right.

‡This is meant to reflect unforeseen changes in required reserves not induced by MD or RS errors. Examples of such an error are an unexpected change in the average reserve ratio against demand deposits due to a redistribution of deposits between banks, or an unanticipated increase in reservable nonmonetary liabilities of banks.

very interest-elastic, so that the vertical portion of RS is very flat; or if the reserve ratio against monetary liabilities is small, so that RD is nearly vertical.

Monetary control is not affected by the reserve accounting structure when money demand is interest-inelastic because the only link between the stock of money and the reserve accounting system is the interest rate and its effect on money demand. If money demand is insensitive to the rate of interest, then neither the demand for nor the supply of reserves has an effect on the stock of money.

When discount window borrowings are sensitive to the interest rate, implying that RS is very flat for interest rates above the discount rate, the interest rate responses to forecast errors are nearly identical under LRA and CRA. And if the short-term interest rate is virtually independent of the reserve accounting system, the money stock is also independent. Similarly, if the reserve ratio applicable to monetary deposits is small and RD is nearly vertical under CRA as well as under LRA, monetary control under the two systems is about the same.

To summarize, under a nonborrowed reserves operating procedure, CRA will significantly enhance monetary control to the extent that (1) forecast errors emanating from the demand for money, the supply of reserves, and the demand for excess reserves are large in comparison to those emanating from the demand for required reserves, and (2) short-run money demand is interest-elastic, the borrowing function is inelastic, and the reserve ratio applicable to monetary deposits is large.

In actual practice, the Federal Reserve does not attempt to maintain close control of the money stock from week to week as implied by the above model. Instead, its current operating procedures focus on influencing changes in the monetary aggregates, especially M1-B, over periods between FOMC meetings, while the directive establishes money growth objectives

over horizons of several months. Extending the above analysis to control horizons exceeding one week will not qualitatively alter conclusions concerning the major determinants of the improvement in monetary control forthcoming under CRA. Since both the direction and the magnitude of the change in monetary control associated with CRA revolve around empirical relationships which cannot be determined by theory alone, the article next turns to the empirical evidence.

PREVIOUS EMPIRICAL STUDIES

A number of empirical studies have been undertaken to investigate the short-run monetary control impact of LRA vs. CRA. These studies may be broadly divided into money supply regression studies and econometric simulation studies.

Reduced Form Regression Studies

One study compares the closeness of the supply relationship between money and reserves in the pre-September 1968 period and the post-September 1968 period.[15] The authors of this study argue that if the relationship is closer in the pre-1968 period, this is evidence that CRA provides better monetary control. To measure the closeness of the money-reserves relationship, the study uses monthly data to estimate regressions of money on current nonborrowed reserves, the discount rate, and a short-term interest rate. One regression is performed using pre-1968 data and another using post-1968 data. The closeness of the relationship within each period is measured by that period's regression standard error. The study finds that the regression standard error is substantially smaller in the pre-1968 period, suggesting that

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15 See Federal Reserve Board Staff, October 6, 1977. In addition to using total reserves as a regressor, the study also performs the same analysis using nonborrowed instead of total reserves.

short-run monetary control would be enhanced under a return to CRA.

Because several significant changes to Regulation D went into effect simultaneously with LRA in 1968, and because Federal Reserve operating procedures and objectives have changed since LRA was introduced, the authors do not immediately attribute all of the deterioration in the regression performance to LRA. To measure the deterioration associated with LRA, an additional regression using post-September 1968 data was performed in which total reserves led one month were included as an additional explanatory variable. The reduction in the regression standard error of the post-September 1968 regression due to this additional regressor was interpreted as the deterioration in the money supply relationship due to LRA. The authors find that the decrease in the regression standard error associated with the additional regressor is large. In fact, the inclusion of reserves led one month reduces the uncertainty of the post-Sepember 1968 money supply relationship back to that for the pre-September 1968 period, suggesting that most of the observed deterioration in the money supply function from pre- to post-September 1968 was due to LRA.

This study may be criticized on two grounds. First, differences in the money supply relationship under the present two-week LRA system and CRA may not be accurately revealed by the authors' empirical procedures using monthly data. Analyses using weekly data would avoid this time aggregation problem.

Second, the conventional money supply relationship between the contemporaneous money stock and contemporaneous total reserves, which the authors attempt to estimate, is not relevant for monetary control under LRA because there is no automatic link between required reserves and the money stock during the same week. Since the study also ignores money demand, the authors' tests do not provide

reliable information concerning either the direction or the degree of improvement in monetary control likely to be forthcoming under CRA.[16]

Econometric Model Simulation Studies

A second class of empirical studies focuses on complete structural models of the money supply process in an effort to estimate the overall effect of the reserve accounting structure on monetary control.[17] These structural models of the money supply process include separate equations for the demand for money and the supply of and demand for reserves. The basic methodology of the two papers in this category involves specifying alternative structural models for LRA and CRA systems and simulating these models under identical simulated money demand and/or money supply forecast errors. The differences in the simulated money stocks in the two models give an indication of the degree to which monetary control under LRA and CRA would differ. These simulation studies suggest that monetary control, over operating periods of three months or more, would be virtually the same under LRA and CRA for both nonborrowed and total reserves targeting procedures, provided that future money supply and money demand forecast errors are similar to those experienced historically.

Much as with the first study discussed above, these simulation studies may be criticized. The use of monthly data in one study subjects it to

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16 A criticism essentially identical to that described above can be levied against the authors' regressions which employ nonborrowed instead of total reserves.

17 See J. A. Cacy, B. Higgins, and G. Sellon, "Control Over Reserves and Money Under Contemporaneous and Lagged Reserve Accounting," Research Working Paper RWP 80-05, Federal Reserve Bank of Kansas City, August 1980, and J. Judd, "The Quantitative Impact of Lagged Reserve Requirements on Monetary Control," Research Working Paper No. 7713, Federal Reserve Bank of New York. 1977.

the same potential time aggregation problem that was alluded to earlier. In addition, neither of these studies really attempts to estimate the impact of the reserve accounting structure on monetary control over periods as short as, say, one month.

NEW EVIDENCE FROM A WEEKLY MONEY MARKET MODEL

This section presents new evidence on the LRA-CRA monetary control issue. The first subsection describes a structural weekly model of the money supply process that was constructed to analyze short-run monetary control under LRA and CRA. Then, the methodology used to stochastically simulate this model is described.[18] Finally, the results are presented.

The Model

To avoid potential time aggregation problems and to analyze the short-run monetary control implications of LRA and CRA within a setting more closely resembling the environment faced by actual policymakers, a structural weekly, rather than monthly, model of the U.S. money supply process was constructed.[19] The overall structure of this model is in many respects similar to that of the theoretical model discussed in the section entitled "Reserve Accounting and Monetary Control." After the model was specified, the behavioral equations of the model were estimated using nonseasonally adjusted data over sample periods ranging from 1974:1 through 1978:52.[20]

There are four equation blocks within the weekly econometric model: a money demand block, a reserve supply block, a reserve demand block, and a block of term-structure equations. In addition, a reserve market equilibrium identity ensures that reserve supply and demand are equal and proximately determines the federal funds rate.

In the demand for money block are conventional behavioral equations explaining the demand for nominal currency, transactions and time and savings deposits in terms of nominal personal income, market interest rates, and seasonal dummy variables.[21]

The reserve supply block consists of equations for nonborrowed reserves and for borrowed reserves. The equation for nonborrowed reserves is definitional and states that nonborrowed reserves is equal to excess reserves plus required reserves minus borrowed reserves. The equation for borrowed reserves is a behavioral relationship, stating that discount window borrowings depend mainly on a scale variable—required reserves lagged one week—and the current spread between the federal funds rate and the discount rate. The specification of this equation is consistent with the facts that aggregate borrowed reserves cannot be negative and that the relationship between borrowings

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[18] Similar experiments using a monthly model have recently been reported by P. Tinsley, "A Field Manual for Stochastic Money Market Impacts of Alternative Operating Procedures," mimeo, Special Studies Section, Board of Governors of the Federal Reserve System, June 1981.

[19] This empirical model is described in detail in David S. Jones, Federal Reserve Bank of Kansas City, Research Working Paper, forthcoming.

[20] The GLS procedure used to estimate the equations assumed additive autoregressive errors with lags ranging from 1 to 52 weeks.

[21] Nominal rather than real specifications were employed for these demand equations because when current and lagged prices were included as separate regressors in the nominal specifications, their coefficients were not significantly different from zero at the 5 percent confidence level. The implied long-run income elasticities for currency and time and savings deposits are 0.82 and 0.72, respectively. The long-run income elasticity for transactions deposits was constrained to be unity; however, this hypothesis could not be rejected at the 5 percent level of significance.

The interest rate appearing in the transaction deposits equation is the 3-month prime commercial paper rate. The own yield appearing in the time and savings deposits equation is the rate on large 3-month certificates of deposit, while the cross yield is the 3-month Treasury bill rate. The implied long-run interest elasticity for transactions deposits is −0.12, while the long-run own and cross yield elasticities for time and savings deposits are 0.22 and −0.21, respectively.

and the spread appears to be highly nonlinear.[22]

Within the reserve demand block are two sub-blocks. The first determines excess reserves as a function of required reserves from the previous week—a scale variable, the expected change in the federal funds rate as measured by the negative of the current change in the federal funds rate, aggregate potential net carryover into the current week, and seasonal factors. Net carryover, in turn, depends upon lagged excess reserves, the lagged level of the federal funds rate, and seasonal factors.[23]

The second sub-block within the reserve demand block determines required reserves. Since the computation of required reserves differs under LRA and CRA, two versions of the model—one for LRA and one for CRA—are constructed. The two versions differ only in their treatment of the determination of required reserves.

In both the LRA and CRA versions of the model, required reserves equal the sum of required reserves againsts transactions deposits, required reserves against time and savings deposits at member banks, and miscellaneous required reserves. Miscellaneous required reserves are treated as exogenous in this study. Required reserves against transactions deposits and time and savings deposits depend on the levels of these deposits—in the relevant week—together with the appropriate average required reserve ratio. The average required reserve ratios against transactions and time and savings deposits are endogenously determined within both versions of the model. These ratios depend exclusively on their own lagged values

and seasonal factors.[24]

Within the LRA version of the model, the required reserves computation is based on transactions and time and savings deposits levels from two weeks earlier. Under the CRA version, while required reserves against transactions deposits are based on current deposit levels, required reserves against time and savings deposits continue to be based on deposit levels from two weeks earlier.[25] This scheme is consistent with the view that the Federal Reserve is primarily interested in controlling M1-B.

The final block of equations consists of term-structure equations, which relate the model's longer term interest rates to the federal funds rate. These longer term interest rates are the 3-month prime commercial paper rate, the 3-month bank large CD rate, and the 3-month Treasury bill rate.

To summarize, the model's major endogenous variables are currency, transactions deposits, time and savings deposits, the federal funds rate, excess reserves, aggregate potential net carryover, borrowed reserves, the average reserve ratios against transactions and time and savings deposits, required reserves, the 3-month Treasury bill rate, the 3-month prime commercial paper rate, and the 3-month large CD rate. The model's exogenous variables, on the other hand, are nominal personal income, miscellaneous required reserves, seasonal factors, and

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[22] The estimated borrowings equation implies that, over the sample period, a 100 basis point increase in the spread generated, on average, $495 million in discount window borrowings.

[23] The estimated excess reserves equation implies that, over the sample period, a 100 basis point increase in the federal funds rate would, on average, have reduced excess reserves in that week by $95 million.

[24] These ratios and the data for required reserves have been break-adjusted so as to remove the effects of changes in required reserve ratios. The nonborrowed reserves series has also been break-adjusted. In effect, these break-adjustments are designed to make these series behave as if the October 1, 1981, reserve requirement structure had been in place over our entire sample period.

[25] This simulated CRA structure assumes identical one-week reserve computation and settlement periods. Consequently, this CRA structure differs from that proposed by the Board on October 9, 1981, which involves two-week computation and settlement periods.

nonborrowed reserves.

The Simulation Methodology

The stochastic simulation methodology described below was designed to estimate the short-run—one-month—improvement in monetary control associated with moving to the CRA structure described above. Three steps were taken to design a stochastic simulation procedure capable of addressing this issue. First, a simulation period was chosen. This period was taken to be the four weeks of January 1978. Given the stochastic simulation methodology used in this study, the simulation results are not sensitive to this particular choice.

In the second step, weekly target paths were constructed for nonborrowed reserves. In constructing these paths, three assumptions were made. First, it was assumed that the four weekly targets for nonborrowed reserves were constructed by the Federal Reserve immediately before the start of the simulation period and *not* revised during the period. Second, it was assumed that the monetary authority expected the time paths of the model's exogenous variables to equal their actual historical values over the simulation period. Third, it was assumed that, in the absence of any forecast errors, the federal funds rate implied by the Federal Reserve's weekly target path for nonborrowed reserves would be constant over the simulation period.

Given these assumptions, the four weekly targets for nonborrowed reserves were constructed by using the model to solve for the weekly nonborrowed reserve levels that, in the absence of forecast errors, would yield a prespecified level of the federal funds rate during the simulation period. Since the weekly model is nonlinear, simulations were performed using three different federal funds rate assumptions, 6.5, 7.5, and 9.5 percent. In the absence of forecast errors, these alternative federal funds

rate assumptions would have generated spreads between the federal funds rate and the discount rate of 0.5, 1.5, and 3.5 percentage points, respectively. The simulated total reserves operating procedure was identical to the nonborrowed reserves procedure described above, except in its treatment of the discount rate during the simulation period. The discount rate was held fixed during the simulation period under the nonborrowed reserves procedure. Under the total reserves procedure, the discount rate was varied from week to week so that it exceeded the simulated federal funds rate by 2 percentage points. This procedure ensured that borrowings would remain at very low levels so that total reserves would be approximately equal to nonborrowed reserves.

Finally, in the third step, for both the nonborrowed and the total reserves targeting procedures, the LRA and CRA versions of the model were dynamically simulated 100 times over the simulation period. Each simulation assumed a different set of forecast errors, constructed to reflect, as nearly as possible, the degree of uncertainty actually faced by monetary policymakers.[26] For each reserve accounting system and each operating procedure simulated, the 100 sets of simulated forecast errors produced a series of weekly and monthly deviations of the simulated money stock,

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[26] To facilitate cross-comparisons between models, each alternative model specification was stochastically simulated with the same sets of forecast errors. Simulated forecast errors were taken to be normally distributed with zero means. The simulated forecast errors associated with the model's estimated structural equations were taken from populations having the same joint variance-covariance matrix as the residuals from the estimated equations. The variance of the simulated forecast errors for the logarithm of nonborrowed reserves was taken to be .0052, approximately the actual variance of the Federal Reserve's Wednesday morning forecast errors (in percentage terms) for weekly nonborrowed reserves during 1978. These forecast errors were assumed to be independent of the other forecast errors in the model.

In addition to the simulated forecast errors described above, simulated projection errors were also generated for monthly personal income during the simulation period and transactions and time and savings deposits for the two

Table 2
STOCHASTIC SIMULATION RESULTS USING THE WEEKLY MONEY MARKET MODEL: M1-B

Federal Funds Rate Assumption	Operating Target	Reserve Structure	RMSE for Monthly M1-B*
6.5	NBR	LRA	5.3
6.5	NBR	CRA	4.9
6.5	TR	LRA	19.9
6.5	TR	CRA	15.3
7.5	NBR	LRA	5.3
7.5	NBR	CRA	5.0
7.5	TR	LRA	19.7
7.5	TR	CRA	15.1
9.5	NBR	LRA	5.3
9.5	NBR	CRA	5.1
9.5	TR	LRA	18.8
9.5	TR	CRA	14.5

*The RMSE is a measure of the imprecision of monetary control. The RMSE's in this table are expressed in terms of annualized growth rates, computed by multiplying the root-mean-squared errors of the logarithmic deviations between actual and targeted monthly M1-B by 12. Thus, they measure the extent that the growth rate of M1-B may be expected to deviate from the targeted growth rate. For example, an RMSE of 5 indicates that there is a 33 percent probability that M1-B's actual growth rate will deviate from its targeted growth rate by more than 5 percentage points.

M1-B, from the target money stock implied by the weekly nonborrowed reserves targets. A series of deviations of the simulated federal funds rate from its expected value was also generated. These deviations are analyzed in the next subsection.

Stochastic Simulation Results

Table 2 reports the root-mean-squared errors (RMSE's) of the series of deviations of simulated monthly M1-B from target expressed

weeks prior to the simulation period. Each of these errors was assumed to be serially independent over time and independent of the other forecast errors in the model. Their simulated variances were set equal to estimates of these quantities derived from analysis of the actual projection errors committed by the Federal Reserve during the late 1970s.

in terms of annualized growth rates. These RMSE's give an indication of the likely imprecision of monetary control under alternative operating procedures and reserve accounting structures. The higher the RMSE for any alternative, the greater the degree of imprecision of monetary control. Monetary control is enhanced under CRA regardless of the operating procedure. Under a nonborrowed reserves operating procedure, however, this improvement is quite small. For the month as a whole, this improvement amounts to only a few tenths of 1 percentage point in terms of annualized growth rates. The percentage decline in the RMSE associated with moving from LRA to CRA under the nonborrowed reserves operating procedure is only about 6 percent under the 7.5 percent federal funds rate assumption.[27]

With total reserves targeting, the improvement in monthly monetary control associated with CRA is considerably larger than under the nonborrowed procedure, being around 4.5 percentage points in terms of annualized growth rates. The improvement associated with CRA is about 23 percent with the 7.5 percent federal funds rate assumption.[28] The RMSE's associated with total reserves targeting under both LRA and CRA are uniformly greater than those for the nonborrowed reserves procedure under either LRA or CRA.

The RMSE's reported in Table 3 measure the federal funds rate uncertainty—that is the extent that the funds rate would deviate from its expected value—associated with LRA and CRA

[27] Similar results are reported by P. Tinsley, June 1981. These results are not qualitatively affected when the variance-covariance matrix of the simulated forecast errors are estimated from the models out of sample, rather than within sample, prediction residuals.

[28] P. Tinsley, June 1981, reports almost a 50 percent reduction in RMSE associated with CRA under total reserves targeting.

under nonborrowed and total reserves targeting. The stochastic simulation results suggest that federal funds rate uncertainty under LRA and CRA would be about the same with nonborrowed reserves targeting. Under total reserves targeting, however, CRA is seen to substantially reduce this uncertainty relative to LRA. However, federal funds rate uncertainty is substantially higher with total reserves than with nonborrowed reserves targeting.

The RMSE's relating to monetary control and interest rate uncertainty under LRA and CRA and nonborrowed and total reserves operating procedures are not very sensitive to the federal funds rate assumption.

The above simulation results are subject to an important bias that affects the LRA results more than those for CRA. This bias arises

because the simulation methodology does not permit the nonborrowed or total reserves paths to be revised during the simulation period. In practice, these paths are adjusted weekly in light of new information on money demand, reserve supply, and reserve demand. By not permitting such midcourse revisions to the reserves paths, the simulation procedure overstates the true uncertainties associated with monetary control and interest rates. This bias affects the LRA results more than those for CRA, having a greater impact on the LRA RMSE's than on the CRA RMSE's.[29] Thus, the simulation results reported in Table 2 probably overstate the degree of improvement in monetary control that would be expected to result from a return to CRA, given the model's specifications of the structure of the financial system and assumptions about Federal Reserve forecast errors. Given these specifications and assumptions, the results reported in Table 2 provide a measure of the upper limit of any

Table 3
STOCHASTIC SIMULATION RESULTS USING THE WEEKLY MONEY MARKET MODEL: FEDERAL FUNDS RATE

Federal Funds Rate Assumption	Operating Target	Reserve Structure	RMSE for Monthly Average Federal Funds Rate*
6.5	NBR	LRA	0.8
6.5	NBR	CRA	0.7
6.5	TR	LRA	12.2
6.5	TR	CRA	7.5
7.5	NBR	LRA	0.5
7.5	NBR	CRA	0.5
7.5	TR	LRA	12.5
7.5	TR	CRA	8.0
9.5	NBR	LRA	0.5
9.5	NBR	CRA	0.5
9.5	TR	LRA	13.1
9.5	TR	CRA	8.9

*These RMSE's are written as percentage points. Multiplying these numbers by 100 will convert them to basis points.

29 Under LRA, the bias is also likely to be larger for the total reserves simulation than for the nonborrowed reserves simulations. Beyond the bias mentioned in the text, the simulation results are subject to additional biases, although these biases do not appear to favor either LRA or CRA.

One bias arises from the assumption, used in the simulations, that the forecast errors are normally distributed, which was made for convenience, but appears to be violated in practice. Preliminary evidence suggests that the actual distribution of regression residuals are more heavily tailed than the normal distribution. This misspecification would tend to cause the RMSE's reported in Tables 2 and 3 to underestimate the true uncertainties associated with monetary control and interest rates. There is, however, no reason to expect that this bias favors either LRA or CRA systematically.

Another potential problem with the above simulation procedure, as well as the other studies reviewed in this article, concerns the implicit assumption that the behavioral relationships in the model are invariant to the Federal Reserve's operating procedures and the reserve accounting system. This assumption is especially dubious for comparisons between nonborrowed and total reserves operating procedures, since interest rate uncertainty is so much larger under total reserves targeting than under nonborrowed reserves targeting. The problem may be less important for comparisons between LRA and CRA since interest rate uncertainty under each reserve system is of the same order of magnitude.

CRA-related improvement in monetary control. Under the nonborrowed reserves operating procedure now being employed by the Federal Reserve, the estimate of this upper limit is small, suggesting that a return to CRA may at best provide only a slight improvement in monetary control.

Finally, the simulation results suggest that, under a total reserves operating procedure, at the upper limit CRA would result in moderately better monetary control than LRA. However, the results also suggest that, under both LRA and CRA, monetary control may be worse under a total reserves operating procedure than under the nonborrowed reserves procedure now being employed. In other words, the results suggest that a return to CRA accompanied by the adoption of a total reserves operating procedure would worsen monetary control.[30]

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[30] The poor performance of the total reserves operating procedures is due to a large extent to the existing structure of reserve requirements across depository institutions. As the structure established under the Monetary Control Act of 1980 is phased in, the relative performance of the total reserves operating procedure would be expected to improve.

SUMMARY AND CONCLUSIONS

This paper has attempted to examine the implications for monetary control of moving from the present lagged reserve accounting system to a system of contemporaneous reserve accounting. A theoretical analysis of this issue indicated that the degree of improvement in monetary control under CRA would depend on the sources and magnitudes of forecast errors made by the Federal Reserve and by the behavioral structure of the financial system.

To obtain quantitative estimates of the likely improvement in monetary control under CRA, the existing empirical evidence on this issue was reviewed and new evidence derived from stochastic simulations of a structural weekly money market was presented. In general, the existing evidence and the new evidence presented in this paper suggest that returning to CRA would not appreciably improve the precision of short-, medium-, or long-run monetary control under the nonborrowed reserves operating procedure now being employed by the Federal Reserve.