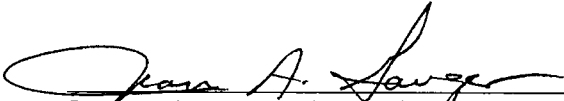
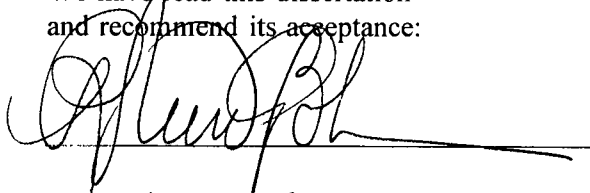
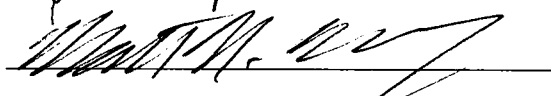
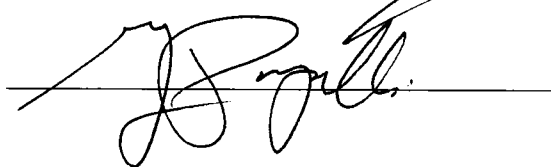


To The Graduate Council:

I am enclosing herewith a dissertation written by Russell Edward Dabbs entitled "A Structural Monetary Model Under *De Facto* Federal Funds Rate Targeting." I have examined the final copy of this dissertation for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Economics.


Jean A. Gauger, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:


Associate Vice Chancellor
and Dean of the Graduate School

**A STRUCTURAL MONETARY MODEL
UNDER *DE FACTO* FEDERAL FUNDS RATE TARGETING**

**A Dissertation
Presented for the
Doctor of Philosophy
Degree
The University of Tennessee, Knoxville**

Russell Edward Dabbs

May, 1996

ABSTRACT

This study constructs a multi-equation model of the U.S. monetary sector in which money, interest rates, and Federal Reserve behavior are all endogenously determined. Conventional money demand and money supply equations are specified; however, nonborrowed reserve supply behavior--normally treated as an exogenously determined explanatory variable in the supply equation--is cast as an endogenous variable. Under the reasonable assumption that, over the post-1970 era, the Federal funds rate has *de facto* served as the Fed's operating procedure, the supply of nonborrowed reserves becomes demand-determined. Moreover, by allowing the funds rate to enter the model recursively, a Federal Reserve reaction function is specified as an integral part of, rather than abstracted away from, the model. The model is estimated using three stage least squares for the sample period 1972:I-1993:I. Tests for structural stability are conducted using the interactive dummy variable method. Findings indicate that money demand and money supply were highly unstable over the full sample period. On the other hand, the nonborrowed reserve demand and Fed funds rate-Federal Reserve reaction function equations did not exhibit instability. In line with recent VAR evidence, a quantifiable liquidity effect is detectable between nonborrowed reserves and the Fed funds rate. In theory, the Fed's principal intermediate target over the 1972:I-1993:I period was observed money supply growth. However, results from this study indicate that the Federal Reserve was highly sensitive to lagged money growth only for the 1979:IV-1982:III subperiod; lagged money growth was not a statistically significant element of the Fed's information set for either the 1972:I-1979:III or 1982:IV-1993:I subperiods. Instead, findings suggest that lagged deviation of real GDP from trend and lagged unemployment rate were more important determinants of the Fed's information set for the 1972:I-1993:I period.

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CHAPTER 1

INTRODUCTION

This study builds and estimates a structural model of the U.S. monetary sector in which money, short term interest rates, and Federal Reserve behavior are all endogenously determined. The model stands in contrast with the conventional view that money is exogenously determined by the Federal Reserve (i.e., the model does not impose the restriction that the Fed initiates observed changes in the money stock independently from current conditions affecting money demand). The potential for endogenous feedback effects from money demand to money supply via the money multiplier is widely recognized; recent discussions include Garfinkel and Thornton (1991) and Black and Dowd (1994). More often, however, the consequences of money supply endogeneity are minimized or ignored. In addition, even studies that seriously address multiplier endogeneity (such as those mentioned above) usually maintain a presumption that monetary policy actions are reflected by independent movements in more narrowly-defined aggregates like the monetary base. To the extent that the Fed engages in interest rate targeting, base movements may in reality be significantly influenced by demand-side factors. The underlying premise of the model constructed in this study is that, over the period 1972:I-1993:I, the Federal Reserve conducted monetary policy using operating procedures that, directly or indirectly, amounted to Federal funds rate targeting. As a result, not only was the money supply potentially endogenous via the money multiplier, but so too was the supply of nonborrowed reserves (the aggregate by which the Fed implements open market operations, and a subset of the monetary base). Failure to account for this source of policy endogeneity runs the risk of mistakenly attributing observed movements in the money supply to policy actions, when in fact those movements are highly reflective of nonpolicy factors. Furthermore, the conventional assumption of exogenous monetary policy fails to systematically explain the behavior of the single most important player in the monetary sector,

the Federal Reserve. This study explicitly accounts for Fed behavior by specifying a Federal Reserve reaction function that serves as an integral part of the structural model.

The first section of this chapter offers preliminary remarks on the inadequacy of using changes in monetary aggregates as indicators of monetary policy actions. Recent evidence obtained from vector autoregression (VAR) models is used to buttress this claim. The second section briefly discusses the distinction between the nonstructural VAR literature and the structural methods used in this study. The third section provides a clarification of terminology. The fourth section concludes with an outline of the remaining chapters of this study.

The Inadequacy of the Money Supply as a Monetary Policy Indicator

In monetary models (and macroeconomic models generally), money supply behavior is usually assumed to be exogenously determined by the monetary authority. From a theoretical standpoint, the money supply exogeneity assumption allows one to treat changes in the money supply as the monetary policy indicator (or impulse factor) within monetary transmission mechanism models (i.e., models characterizing the logical chain of events leading from monetary policy actions to changes in economic activity). For instance, the standard Keynesian monetary transmission mechanism holds that monetary policy actions impact the real economy in the following manner:

$$\uparrow M \rightarrow \downarrow i \rightarrow \uparrow I \rightarrow \uparrow y,$$

where M is the money supply, i is the market rate of interest, I is investment spending (or any interest-sensitive spending), and y is national income. The first step in the process-- $\uparrow M \rightarrow \downarrow i$ --is referred to as the liquidity effect. Under the simple Keynesian framework, the ability of the monetary authority to effect intended changes in ultimate economic variables of interest depends upon its ability to accurately estimate money demand. If money demand is stable and predictable,

the monetary authority is then assumed to be able to alter the size of the money stock at will so as to generate any desired liquidity effect.¹

However, as has been well-documented, an empirically stable money demand function has proved to be elusive (see, eg., Goldfeld, 1976; Judd and Scadding, 1982; Hetzel and Mehra, 1989; and Duca, 1992). Nevertheless, due to its perceived importance in the monetary transmission process, the search for a stable demand function continues unabated. In the last two decades, considerable effort has been directed toward "repairing" the money demand equation, most prominently by redefining the appropriate definition of money, first from M1 to M2 (eg., Hetzel and Mehra, 1989), and then from M2 to "M2+" (eg., Collins and Edwards, 1994). In other words, an important feature of recent money demand literature has been an attempt to identify a structurally stable demand function by focusing on broader and broader measures of money.

This effort may be misguided. Recent research on the monetary transmission mechanism utilizing vector autoregressive (VAR) techniques indicates that even the "narrow" monetary aggregate M1 is too broadly defined to warrant treatment as the Fed's monetary policy indicator. In short, VAR evidence shows that changes in the money supply are *positively* rather than negatively related to interest rates--i.e., the presumed liquidity effect between money and interest rates appears to be counterfactual. This phenomenon is known as the "liquidity puzzle" (Strongin, 1995). The puzzle manifests itself whether money is as broadly defined as M2, or as narrowly defined as total bank reserves (Pagan and Robertson, 1995, p.39).

Previously, the liquidity puzzle was mainly attributed to the likelihood that the potential liquidity effect of an expansionary monetary policy action is dominated by a simultaneous and

¹Although other models abound, they too normally view money supply shocks as the impulse factor in the transmission mechanism, and view the subsequent impact of money supply changes on interest rates as a major link--if not the paramount link--in the transmission chain. For a brief overview of major theories of the transmission mechanism, see Mishkin (1995).

more-than-offsetting increase in anticipated inflation (Reichenstein, 1987). More recently, this explanation has been viewed as inadequate. Instead, researchers have begun to question the standard view that movements in monetary aggregates are reflective of independently-instigated policy actions, on the grounds that the Fed has since the 1960s used the Federal funds rate--directly or indirectly--as its operating target (Goodfriend, 1993, p.3). This results in Federal Reserve behavior that is at least partially accommodative of money demand shocks. If policy is in fact accommodative, movements in monetary aggregates will be a poor indicator of monetary policy actions, since those movements confound both demand and supply shocks. This may recommend that greater focus be placed upon narrower, rather than broader, aggregates if one wishes to identify truly "exogenous" policy disturbances. Indeed, the liquidity puzzle disappears when nonborrowed reserves is used as the monetary policy indicator in the transmission process, i.e., evidence points to a negative correlation between nonborrowed reserves and interest rates (Christiano and Eichenbaum, 1992; Chari, et al., 1995). This finding, combined with the "puzzling" positive correlation between interest rates and broader aggregates, suggests that "movements in nonborrowed reserves are dominated by exogenous shocks to monetary policy, while movements in the base and M1 are dominated by endogenous responses to nonpolicy shocks" (Chari, *et al.*, 1995, p.1355). Interestingly, the liquidity puzzle also disappears when the *price* of nonborrowed reserves, the Federal Funds rate, is used as the policy indicator (Sims, 1992; Bernanke and Blinder, 1992). Changes in the Federal funds rate, in turn, exhibit a close linkage with changes in other short-term market rates. Thus, an identifiable liquidity effect appears to exist between nonborrowed reserves and the Federal funds rate (and, via the funds rate, other short-term rates). Whether the best measure of the impulse factor is the former or the latter

remains, however, an unsettled question.² In any event, the emphasis placed on identifying a stable money demand function may be misplaced; even if researchers are able to identify a stable demand for a broadly-defined aggregate like M2, the endogeneity of M2 is such that its usefulness as a policy indicator in the monetary transmission process is very doubtful.

Toward a Structural Model

The VAR methodology on which the foregoing studies are based is a form of nonstructural model-building in which each element of a vector of endogenous variables is regressed upon lagged values of itself and each of the other variables in the model. Theoretical priors imposed upon the model are limited to the choice of variables and number of lags to include. The VAR methodology, introduced by Sims (1980), attempts to avoid building into the model identifying restrictions on the parameters of structural simultaneous equations models. In other words, VARs are designed to characterize, with a minimum of *a priori* theory, the behavior of the data. However, parameter estimates derived from VARs are reduced form estimates from which structural interpretations cannot be made.³ In the present study, a formal structural model of the monetary sector is constructed which explicitly specifies relationships between important variables based upon economic theory. The model is constructed based upon an explicit identifying assumption regarding the Fed's policy indicator, *viz.*, that *de facto* Federal funds rate targeting by the Fed over the period 1972:I-1993:I enables one to treat the Federal funds rate as

²Strongin (1995) constructs an alternative measure which he claims is superior to both nonborrowed reserves (NBR) and the Federal funds rate, which he calls "NBRX." The NBRX variable is NBR adjusted for observed changes in the "mix" of reserves between nonborrowed reserves and borrowed reserves (i.e., discount window borrowing). Bernanke and Mihov (1995) suggest that, for the period 1979-94, Strongin's measure is indeed the best measure of policy interventions, but that the Federal funds rate is superior when attention is focused on periods 1965-79 and 1988-94.

³It must be noted that the VAR studies noted above are *structural* VARs. A structural VAR is one in which identifying restrictions are placed, not on the parameters of the model, but on its error covariance matrix. Thus, *a priori* assumptions--supposedly avoided by use of the VAR methodology--are merely introduced at a different level. Furthermore, the parameter estimates remain reduced form estimates. For a critique of the VAR literature on monetary policy indicators, see Rudebusch (1995b). For a more general critique of the VAR literature, see Cooley and LeRoy (1985).

the monetary policy indicator. The literature supports the view that the Federal funds rate serves as a superior policy-identifying assumption relative to money supply aggregates such as M1 and M2. Given this assumption, structural interpretations regarding the linkage between money, short-term interest rates, and Federal Reserve behavior may then be empirically assessed using simultaneous equations estimation techniques. Thus, this study is designed to provide complementary evidence on the workings of the U.S. monetary sector using a theory-based structural modeling approach in which the Federal funds rate serves as the monetary policy indicator.

Endogeneity vs. Exogeneity: Definitions and Econometric Implications

The money supply exogeneity assumption is a controversial one that has been subject to longstanding debate. This debate is exacerbated by frequent confusion over what is meant by "exogeneity." Wray (1992) provides a useful taxonomy of money supply exogeneity. First, the money supply may be exogenous in a control sense. "Control exogeneity" refers to the monetary authority's ability--in theory, if not in practice--to manipulate its policy instruments so as to determine the money supply. This is the sense in which much of macroeconomic theory uses the term "money exogeneity." For example, McCallum (1989) states that even though

the money stock is not under the direct control of the monetary authority and indeed is not *precisely* controllable indirectly ... [this] should *not* be permitted to obscure the fact that the monetary authority can, under arrangements like those of the United States, strongly influence the behavior of the money stock and exert a considerable degree of control. Over the period of a year, the Fed can probably determine the money stock growth rate within two percentage points. ... Thus, it is reasonable, in the context of many monetary and macroeconomic issues, to think of the money stock as being accurately controllable by the monetary authorities. Indeed, the standard practice in much of macroeconomic analysis is to assume that the monetary authority directly controls the money stock (McCallum, 1989, p.71-72) [emphasis in original].

Second, the money supply may be exogenous in a theoretical sense, exhibiting strong or weak exogeneity.⁴ A variable is said to be strongly exogenous if it is independent of both contemporaneous and lagged values of the endogenous variables in the model. If a variable is independent of contemporaneous endogenous variables but not independent of lagged endogenous variables, it is said to be weakly exogenous. Standard practice treats the money supply as weakly exogenous. At any particular point, the Federal Reserve is assumed to determine the money supply independently of contemporaneous endogenous factors; however, the monetary authority often reacts to past behavior of endogenous variables in generating its supply decisions. Third, the money supply may be exogenous in a statistical sense. For this to occur, the money supply must be independent of contemporaneous factors which determine the money demand equation, *including* the disturbance term in the demand equation.

While the Fed is normally assumed to be able to exogenously determine the money supply in a control sense, control exogeneity is not a sufficient condition for exogeneity in the statistical sense. Cooley and LeRoy argue that this distinction is often unacknowledged or ignored:

[A]n elementary confusion [exists] between the two senses in which the term "exogenous" is used in the economics literature. In macroeconomic theory a variable, the level of which is set by government as an implementation of economic policy, is represented analytically as an exogenous variable....Analysis then centers on the effect of policy changes, represented by shifts in exogenous policy variable(s), on endogenous variables. The definition of exogeneity relevant for statistical estimation, however, is entirely different: a variable in a regression is statistically exogenous only if it is independent (in the probability sense) of the unobserved explanatory variables. *Whether a variable which is exogenous in the former sense is also exogenous in the latter and relevant sense depends...on the nature of the government's policy rule* (Cooley and LeRoy, 1981, p.838) [emphasis added].

⁴Weak vs. strong exogeneity concepts are discussed in detail in Hendry, Engle, and Richard (1983).

Thus, while the monetary authority may *theoretically* be able to control the money supply such that supply is fully independent of current demand, in practice it may adopt a policy rule whereby the instruments through which it implements its policy are highly sensitive to current money market conditions. Indeed, due to its longstanding desire to reduce interest rate volatility ("interest rate smoothing"), the Fed has implemented its policies using operating rules characterized by a high degree of sensitivity to current money market conditions (Roberds, 1992).⁵ Consequently, empirical studies which estimate money demand in isolation from money supply may encounter serious econometric complications.

The potential complications are twofold. First, if the money supply is endogenous, then the possibility exists that parameter estimates obtained via single equation ordinary least squares (OLS) are not uniquely associated with the demand function, but are instead the reflection of a mixture of data points associated with both demand *and* supply. That is, there is no assurance that the parameter estimates properly identify a demand function as opposed to a supply function. Second, if the money supply is endogenous, single equation estimation of a money demand function--even if the equation is identified--is not appropriate due to the existence of simultaneous equations bias. The application of OLS to demand equations in the presence of simultaneity generates biased and inconsistent parameter estimates (Kmenta, 1986, p.655). The present study faces these issues directly by specifying a multi-equation model in which the endogenous feedback effects between demand, supply, and Fed policies are accounted for, and by using an

⁵Since World War II, the Fed has operated under five official policy rules or operating regimes. Until the Federal Reserve-Treasury Accord of 1951, the Fed was constrained to use its policy instruments to peg the rate of return on short-term government securities at rates dictated by the Treasury. The four post-Accord operating procedures (operating targets)--discussed in greater detail in Chapter 2--were free reserves (until approximately 1970); Federal funds rate (1970-79); nonborrowed reserves (1979-82); and borrowed reserves (1982-Present). As will be argued in Chapter 3, each of these official post-Accord policy rules, in practice, approximated Federal funds rate targeting (with the possible exception of the nonborrowed reserves procedure). Under Federal funds targeting, the reserve supply behavior of the Fed is highly sensitive to current money market conditions.

appropriate simultaneous equations estimation procedure that yields consistent parameter estimates.

Outline of the Study

The study is organized as follows. Chapter 2 provides background information useful for building the structural model. The chapter presents a review of relevant literature on the monetary sector, focusing on empirical literature on money demand, money supply, and Federal Reserve operating procedures and policies. Chapter 3 details the step-by-step construction of the multi-equation model of the U.S. monetary sector. Chapter 4 presents estimation results and offers interpretive comments. Chapter 5 contains brief concluding remarks.

CHAPTER 2

BACKGROUND

The impact of money on the economy is an issue that dominates much of the macroeconomic literature. Macroeconomists seek a better understanding of (i) the magnitude and timing of money's impact on other economic variables such as output and inflation, and (ii) the details of the process--the transmission mechanism--connecting money with these other aggregate variables. The first step in this discovery process is an analysis of the factors determining the quantity of money that is observed. Consequently, research in monetary economics has largely focused on identifying the determinants of the demand for and supply of money. However, interest in theoretical and empirical demand side issues have overwhelmed supply side issues. The principal reason for this is the presumption that the detection of a well-understood, stable money demand function will facilitate the monetary authority's ability to control the money supply in the sense of meeting desired monetary targets. From an empirical standpoint, this asymmetry has been manifested by single equation regression estimates of money demand largely divorced from supply side considerations. As outlined in Chapter 1, single equation estimation of money demand is normally justified on the basis that the supply of money is an exogenous policy variable determined by the monetary authority independently of those factors which determine the demand for money. However, if the money supply is not exogenously determined, single equation regression techniques applied to money demand functions may yield suspect parameter estimates.

This chapter provides background information necessary to build a model of the monetary sector which does not bypass important supply side issues. The chapter is divided into five sections. The first section briefly summarizes relevant theoretical and empirical aspects of the money demand literature. The second section reviews previous empirical literature that estimate

the demand for and supply of money as a simultaneous system of equations. Particular emphasis will be given to the two seminal studies in this area of inquiry, Brunner and Meltzer (1964) and Teigen (1964). Although the *money supply* is not assumed to be exogenous in this body of literature, the *reserve supply* behavior of the monetary authority is so treated. In other words, for the U.S., the Federal Reserve is *not* assumed to exogenously determine the money supply, but *is* assumed to exogenously determine the level of bank reserves which (in the conventional base/reserve-multiplier money supply framework) serves as the principal driving force behind variations in the money supply. The appropriateness of this assumption is analyzed in the third section, which reviews the linkages between Federal Reserve operating procedures, the market for bank reserves, and the demand for money. Depending on the operating procedure the Fed employs, the linkage between reserves and money demand may cast doubt on the adequacy of the exogenous reserves assumption and instead warrant a respecification of the structural model of the monetary sector by the inclusion of reserves. This respecification would involve viewing reserves as an endogenous variable whose behavior is to be explained, rather than simply dismissed as variable whose behavior is determined "outside the model." The fourth section summarizes previous empirical evidence which questions the validity of the reserve exogeneity assumption. The fifth section briefly reviews some salient features of the Federal Reserve "reaction function" literature. Normally treated separately from the issue of money demand and supply estimation, the reaction function literature is designed to uncover the principal macroeconomic variables that influence Fed policy decisions. A contribution of this study is an attempt to integrate a Federal Reserve reaction function within a system of equations that treats the money market, the reserves market, and Fed policies all as endogenously determined variables.

Money Demand

Modern money demand theory is largely traceable to Keynes (1936), who in *The General Theory* proffered three motives for holding money, the transactions, precautionary, and speculative (or asset) motives. Keynes postulated an aggregate demand for liquidity function composed of two components: the transactions and precautionary demands, each positive functions of income (Y), and the speculative demand, a negative function of the interest rate (i). Subsequent to Keynes's analysis, monetary theory focused on refining the transactions and asset theories of money demand. Baumol (1952) and Tobin (1956) developed an "inventory-theoretic" transactions theory of money demand. In this model, real money demand is found to be a positive function of real income (proxying for total volume of transactions) and a negative function of the nominal interest rate. Thus, the theory assigns an important role for the interest rate even though it emphasizes money's role as a means of exchange rather than as an asset. On the other hand, Tobin (1958) focused on money's role as an asset. He elaborated on Keynes's speculative demand for money, reemphasizing the importance of the interest rate as a determinant of money demand. In short, Tobin developed a theory in which a positive relationship exists between risk and the expected return in an asset portfolio, where an increase in the bond interest rate provides an incentive to substitute away from security toward higher yield in a portfolio consisting of money and bonds. Thus, Tobin's theory reaffirmed the expectation of a negative relationship between the demand for money and the interest rate. Friedman (1956) took a broader view of money as an asset, emphasizing that money serves as an asset that generates a flow of services to the wealthholder, much as a consumer durable good provides a flow of services to the consumer over time. Money was viewed as but one asset among many to which the individual may allocate his or her wealth; other assets include bonds, equities, physical goods, and human capital. In short, Friedman theorized real money demand to be a stable function of a small number of factors

including the returns on bonds and equities, the ratio of human to nonhuman wealth, the relative prices of other goods, and the income flow from all forms of wealth, i.e., permanent income.

These models--in general terms, the transactions, portfolio, and the "modern quantity theory" asset models--served as the principal theoretical bases for the subsequent extensive empirical research that emerged which attempted to identify and estimate the money demand function. This research has covered a multitude of issues.¹ While the empirical definitions of variables (eg., narrow aggregate vs. broad aggregate, income vs. wealth or permanent income) and inclusion vs. exclusion of particular variables differ from model to model, most if not all money demand studies are bound together by a common thread traceable to Keynes: real money demand ($\frac{M^d}{P}$) is considered to be some positive function of the scale of real economic activity y (whether measured as current or permanent income or total wealth), and a negative function of some market interest rate or complex of rates on alternative assets i_m --i.e., the opportunity cost of holding money. In general terms, real money demand is thus expressed as:

$$(1) \quad \frac{M^d}{P} = f(i_m, y).$$

The bulk of empirical money demand literature has tended to support on a consistent basis a significant explanatory role for a scale variable and opportunity cost variable (each variously defined). At the same time, a *stable* money demand function has proved to be elusive. In an exhaustive and influential study, Goldfeld (1973) identified what appeared to be a relatively stable money demand (M1) function over the sample period 1952:II-1972:IV. However, in a follow-up study, Goldfeld (1976) found that forecasts generated by the so-called "Goldfeld equation" systematically overpredicted the subsequent behavior of M1. This finding spawned a vast amount

¹Extensive surveys of empirical money demand literature include Boorman (1982), Judd and Scadding (1982), Goldfeld and Sichel (1990), and Laidler (1993).

of literature devoted to "repairing" the empirical money demand equation. In a review of the post-1973 money demand literature, Judd and Scadding (1982) highlighted two main paths for reexamination: (i) reopening previous issues, eg., regarding the proper data series definitions of money (narrowly- vs. broadly-defined monetary aggregates) and for scale and opportunity cost variables; and (ii) analyzing the role of financial innovation in overturning previously-stable money demand relationships. While the authors concluded that the latter approach appeared to be the more fruitful line of inquiry, subsequent literature in the 1980s tended to meld both avenues of inquiry by focusing on the broader monetary aggregate, M2. For example, Hetzel and Mehra (1989) found that financial innovation helped create substantial asset substitution between M1 and M2 that in turn generated instability in M1 demand in the 1980s. However, these asset substitutions tended to net-out at the more broadly defined M2 level; hence M2 demand functions exhibited relative stability. More recently, though, M2 demand functions also began to break-down. Specifically, forecasts generated by M2 demand equations began to exhibit systematic overprediction of actual M2 in the early 1990s. This phenomenon has been noted in numerous articles, including Carlson and Parrott (1991), Duca (1992), and Mehra (1992). In response, much recent effort has been placed in repairing money demand equations through broadening the monetary aggregate even further to include mutual funds (eg., see Anderson, 1994).

Money Demand and Money Supply as a System of Equations

Most empirical studies of money demand proceed without explicitly accounting at the outset for supply side factors, thereby ignoring the potential for simultaneous equations bias in single equation money demand regressions. The principal theoretical justification for this is the presumption of money supply exogeneity.² Mainstream Keynesian and monetarist theory (the

²Sometimes single equation estimation of money demand functions is rationalized on the opposite grounds that the Federal Reserve controls the interest rate, thereby allowing the researcher to treat it as an exogenous variable. However, this reasoning is often employed in a rather schizophrenic manner--i.e., at variance with the researcher's overall theoretical perspective of exogenous money--to justify, *post hoc*, single equation

major theoretical perspectives from which most money demand studies emanate) both assume--at least as a first approximation--exogenous money when building their models of the money market. (For example, from the Keynesian perspective, see Keynes, 1936, p.200, and Hicks, 1937; from the monetarist perspective, see Friedman, 1966b, p.81, and 1970, p.10.) Since the principal focus of most initial empirical work was the legitimacy of Keynesian liquidity preference theory, most of the nascent literature focused on demand side issues without much reference to the supply side.

However, the potential complications posed by the simultaneous interaction of money supply and money demand did not go entirely unnoticed. For instance, in an early empirical study of money demand, Bronfenbrenner and Mayer (1960) acknowledged the potential identification problem encountered when supply side issues are ignored. They conceded that their study sidestepped the question by implicitly treating money supply as

a quantity whose movements through time are unaffected by any of our independent variables (the interest rate, the level of real wealth, the prior year money supply, or the level of real income). This assumption is open to question as regards all these variables. Insofar as it is rejected, the demand or liquidity function we have fitted may be a hybrid monstrosity. Our best hope is that our hybrids are approximately 99.44/100 per cent pure demand or liquidity function (Bronfenbrenner and Mayer, 1960, pp.819-20).

Eisner (1963) suggested that Bronfenbrenner and Mayer were being too hopeful. Eisner argued, first, that the advent of "easy money" policies around 1934 rendered at least part of the sample period used in their study subject to a severe endogeneity problem; during this period, money supply, rather than being independent of money demand, was in fact demand-determined. As a

estimation of money demand. For example, in their 1981 critique of the money demand literature, Cooley and LeRoy reviewed two separate arguments broached by David Laidler as possible justifications for single equation money demand estimation. Laidler (1977) argued that since reserves vary independently from factors which affect money demand, reserves can be counted on to help identify the demand function. Laidler (1980), on the other hand, argued that, in the U.S., the Fed's operating procedures have been geared toward controlling the interest rate. In this case, then, reserves are *not* independent of an important demand side factor, the interest rate. These issues will be discussed at greater length later in this chapter.

result, at least after 1934, observed data points for money were more likely to reflect demand shifts tracing out a supply function than supply shifts tracing out demand. Second, Eisner argued that Bronfenbrenner and Mayer were being inconsistent when they specified the interest rate as an exogenous variable in their liquidity preference functions. "[T]his hardly accords," Eisner noted,

with the economic theory to which it relates. Is it not our idea rather that the quantity of money varies (perhaps on the basis of monetary policy) and that the rate of interest then responds in accordance with the structural relation defined by the demand curve, but with an error term...? It is surely true, as expositors of monetary theory must confirm, that the quantity of money is taken as the known number, and it is the rate of interest which, with a disturbance, reacts (Eisner 1963, p.534).

In a rejoinder, Bronfenbrenner and Mayer (1963, p.341) expressed agreement with Eisner that in the post-1934 easy money era, "monetary supply functions...approximated horizontal lines," and argued that this fact actually helped buttress the inference that their estimated liquidity preference functions were indeed demand functions and not supply functions (or hybrids). They did not, however, address Eisner's second argument, which was that such an interpretation does not accord with the usual presumption that the interest rate responds to money and not the reverse.³

Another study which acknowledged, but did not attempt to address, the simultaneous equations issue was Meltzer (1963). In a thorough review of the principal empirical issues, Meltzer estimated single equation money demand functions of various stripes, using different definitions of money, scale variables, and interest rates. Meltzer's main conclusion was that real wealth, as opposed to real income, best served as the scale variable in money demand functions. However, Meltzer further noted that a proper construction of a stable money demand function required a better understanding of the supply side of the money market. Observing that the monetary authority controlled the stock of base money, but that base money constituted only a

³Eisner's second argument is thus consistent with the discussion in footnote 2 above regarding the frequent confusion with which the interest rate is employed as an exogenous variable in single equation money demand estimates.

portion of most researchers' definitions of money, Meltzer argued that accurate predictions regarding the impact of exogenous policy actions necessitated a theory regarding the supply of the non-base money components of the money supply. The need for such a theory becomes more acute, he suggested, the more broadly money is defined (in other words, the smaller is exogenous base money as a proportion of the money supply).

An early attempt to provide an empirically useful, systematic money supply theory was Brunner's (1961) base-multiplier approach. Brunner constructed what he termed a money supply "schema" in which banks were assumed to continuously seek to dispose of any surplus reserves (cash assets less required reserves) that materialized on the asset side of their balanced sheets. In the aggregate, Brunner's schema implied that banks' desire to eliminate surplus reserves (redress reserve deficiencies) acts to increase (decrease) the growth rate of the money supply via a multiplier effect, the size of the multiplier being determined by the banks' and the nonbank public's portfolio demands. Thus, surplus reserve injections, for instance those originated by Federal Reserve open market purchases, serve, within this framework, to increase the money supply by some multiplier of the reserve injection.

Combining Brunner's money supply framework with Meltzer's (1963) approach to money demand, Brunner and Meltzer (1964) attempted to empirically estimate money demand and money supply functions as an interdependent system of equations using what were, at the time, only recently developed simultaneous equations estimation techniques. Brunner and Meltzer postulated a "nonlinear money supply hypothesis," based on the Brunner schema, represented by equation (2):

$$(2) \quad M_i = m_i B^*, \quad i = 1, 2$$

where

$$(2a) \quad m_1 = \frac{1 + k}{(r + e - b)(1 + t) + k},$$

$$(2b) \quad m_2 = \frac{1 + k + t}{(r + e - b)(1 + t) + k},$$

and where M_i =monetary aggregate, m_i =money multiplier, B^a =adjusted monetary base (i.e., monetary base less borrowed reserves), r =the required reserve ratio, k =the currency-checkable deposit ratio, e =excess reserve-checkable deposit ratio, b =borrowed reserve-checkable deposit ratio, t =time deposit-checkable deposit ratio. (The ratios r , k , e , b , and d are referred to collectively as the component ratios of the money multipliers.) By logarithmically differentiating equation (2), Brunner and Meltzer obtained the following equation

$$(3) \quad \frac{dM_i}{M_i} = \frac{dB^a}{B^a} + \epsilon^{1i} \frac{dr^d}{r^d} + \epsilon^{2i} \frac{dr^t}{r^t} + \epsilon^{3i} \frac{dk}{k} + \epsilon^{4i} \frac{de}{e} + \epsilon^{5i} \frac{db}{b} + \epsilon^{6i} \frac{dt}{t},$$

which describes the change in the money stock as a function of (i) changes in the adjusted monetary base, and (ii) changes in the component ratios, operating through their impacts on the money multiplier, given by the elasticity of the multiplier with respect to component ratios (ϵ^{ji} , $j=1,\dots,6$, $i=1,2$). Brunner and Meltzer then partitioned equation (3) into its relatively exogenous and relatively endogenous components. They specified B^a , r^d , and r^t (reserve requirements on demand and time deposits, respectively) as variables under the control of the Federal Reserve, while k was deemed to be reflective of the public's exogenous currency-holding patterns.⁴ The authors collected these four terms into K , a portmanteau variable. Changes in K thus represented changes in variables assumed to be either "policy imposed on the system or currency behavior essentially independent of credit conditions [i.e., interest rates]," while "the relative changes in e , b , and t ...depend on similar changes in interest rates, including the discount rate" (Brunner and Meltzer, 1964, p.274).

⁴Brunner and Meltzer noted that endogenous influences on the currency-deposit ratio k are likely, particularly cyclical factors relating variations in k to variations in income, wages, or retail sales. However, they purposefully abstracted from this complication.

By assuming constant elasticities, integrating, and collecting terms, the partitioned equation (3) was transformed into the following estimating equation for money supply (variables in log form):⁵

$$(4) \quad M_t = K_t + \beta_1 i_{m,t} + \beta_2 DR_t + \eta_t,$$

where i_m represents a Treasury bond yield and DR is the Federal Reserve's discount rate, with the postulated signs $\beta_2 < 0 < \beta_1$. Brunner and Meltzer's empirical supply equation was then combined with an empirical demand equation drawn from Meltzer (1963), in which money demand is expressed a function of a market interest rate i_m , real wealth W/P , and the price level P :

$$(5) \quad M_t = \alpha_1 i_{m,t} + \alpha_2 \left(\frac{W}{P}\right)_t + \alpha_3 P_t + \epsilon_t,$$

with postulated signs $\alpha_1 < 0 < \alpha_2, \alpha_3$. Brunner and Meltzer then estimated equations (4) and (5) (and variations thereof) utilizing both ordinary least squares (OLS) and two stage least squares (2SLS) for sample period 1929-59 (annual data). Results with respect to money demand were broadly in agreement with theory for both OLS and 2SLS estimates, exhibiting negative and significant interest rate elasticity estimates ($\hat{\alpha}_1 < 0$), along with positive and significant elasticity estimates on the scale variable, real wealth ($\hat{\alpha}_2 > 0$). With respect to money supply, results were somewhat different according to whether OLS or 2SLS was utilized as the estimation procedure. Using OLS, the authors found that variations in the factors in K --adjusted monetary base, reserve requirement ratios, and currency-deposit ratios--accounted overwhelmingly for most of the variation in the monetary aggregates M1 and M2. Moreover, they found that the coefficient estimate on the interest rate ($\hat{\beta}_1$) was positive and significant only when M2 was used as the monetary aggregate, while the parameter estimate on the discount rate ($\hat{\beta}_2$) was negative and

⁵The authors investigated variations of equation (4), including regressing logged money on K and the interest rate i_m alone, while using, as an element of K , the monetary base *inclusive* of discount window borrowing (B) rather than the adjusted monetary base (B^*).

significant only for M1. In short, the OLS estimates suggested that the "exogenous factors" represented by K were strongly associated with the money supply, but that the link between interest rates and the money supply--the avenue of money supply endogeneity--was tenuous.

Reestimating money supply using two stage least squares, Brunner and Meltzer obtained noticeably different parameter estimates. The interest elasticities of money supply--under OLS, small in magnitude for both M1 and M2 and statistically insignificant for M1--were much larger and statistically significant for both M1 and M2 using 2SLS. Further, for M1, the 2SLS procedure yielded a negative and significant discount rate elasticity estimate ($\hat{\beta}_2 < 0$) with a greater absolute value than was obtained via OLS, while for M2 the estimate of β_2 was statistically significant at the 10 percent level (though not at the 5 percent level). Meanwhile, the estimate on the K variable remained closely within the neighborhood of that obtained using OLS. Overall, then, by accounting for potential simultaneity involved in their money supply-money demand model, Brunner and Meltzer were able to identify a greater role for interest rates in the money supply process, a role largely masked using single equation OLS. This therefore suggested that, to some nonnegligible extent, endogenous "credit market" factors were also at work in the money supply process, not simply exogenous factors related to Federal Reserve actions or the public's currency holding decisions. However, the robustness and strength of K--the "exogenous factors" in the money supply process--led Brunner and Meltzer to conclude that exogenous factors were nevertheless the dominant force in the determination of the money supply.

Teigen (1964) attempted to account for simultaneity in money demand and money supply by constructing a system of equations in which the money stock, interest rates, and national income were each cast as endogenous variables. Basing his empirical demand equation on the Baumol-Tobin transactions theory of money demand, Teigen specified the log of nominal money demand as a function of the logs of the market rate of interest (i_m), national income (Y), and

lagged money (the latter to account for inertia in households' adjustment of money balances to short run changes in i_m and Y).⁶ Teigen's supply equation, similar to the Brunner-Meltzer approach, delineated "exogenous money" from "endogenous money." Teigen defined M^* to be that portion of the money stock that was exogenously supplied by the Fed, nonborrowed reserves.⁷ Teigen then specified (M/M^*) , the ratio of observed money to exogenously supplied money, to be the dependent variable in his supply equation, while the spread between the market interest rate and the discount rate ($i_m - DR$) was used as the explanatory variable. Teigen posited that as the short-term market rate rises, it becomes more profitable for banks to expand their loan portfolios, and thus the amount of deposits. Conversely, the discount rate represents the cost of borrowing from the Fed; when the rate the Fed charges at the discount window rises, banks borrow less, and thereby reduce the amount of borrowed reserves in the system. Thus, under the Teigen hypothesis, endogeneity of the money supply would be captured by a positive and significant parameter estimate for the variable ($i_m - DR$). Finally, to complete the system of equations, Teigen utilized a simple equation to account for the endogeneity of income, one in which income (Y) is expressed as a function of current exogenous expenditures (E), net worth (NW), and lagged

⁶Teigen used seasonally unadjusted data, and therefore also incorporated seasonal dummies in each structural equation. Moreover, Teigen also estimated the demand equation in linear rather than log form, but concluded that log form was the superior specification. The other equations in Teigen's system were specified *a priori* in linear functional form.

⁷In a footnote, Teigen made the following highly relevant observation:

A case can be made for treating the Federal Reserve system endogenously, since the monetary authorities may respond predictively to certain combinations of economic phenomena. It is usual in models of this type to consider policy variables to be exogenous. Furthermore, the relationships involved are probably quite complex. Their study might prove fruitful; however, such a study was not possible for this project. For these reasons, exogeneity is assumed here (Teigen, 1964, p.478).

The present study may be thought of as an attempt to provide some insight into this issue.

income (and, as with the supply equation, the equation was expressed in linear rather than log form).⁸

Using quarterly data over the period 1946:IV - 1959:IV, Teigen first estimated the three equations described above, and several variants, using OLS. In general, Teigen found that, for money demand, results were in accord with theoretical priors: the interest rate variable was negative and significant, while coefficients on the income and lagged money variables were positive and significant. With respect to his money supply equation, Teigen obtained a positive and significant estimate on the interest rate-discount rate spread. Teigen concluded that this finding supported his basic hypothesis that "the usual assumption of exogeneity with respect to the stock of money is untenable" (Teigen, 1964, p.306).

To account for simultaneity, Teigen reestimated his structural model using 2SLS, then compared results with the OLS counterparts. In general, Teigen found that single equation estimates for money demand were not very different from those obtained using simultaneous equation techniques. However, the same could not be said for money supply. Single equation estimates of the interest rate-discount rate spread were substantially smaller (in absolute value) than their 2SLS counterparts. Thus, Teigen's findings were similar to those obtained by Brunner and Meltzer in that, whereas estimates of money demand were not much affected when simultaneity was explicitly accounted for, estimates on money supply were substantially altered when 2SLS was utilized as the estimation technique. More importantly, both studies claimed empirical support for the notion that there existed some nonnegligible portion of the money stock that was not under the exogenous control of the Fed. As a result, previous money demand studies

⁸National income (Y) enters recursively in Teigen's system, impacting money and interest rates, but with no reverse feedback. Specifically, Teigen disregards the impact of, say, interest rates on components of aggregate expenditure (E) operating via investment spending. In other words, Teigen specifies E as an exogenous variable. Teigen concedes that this may be too strong an assumption, but utilizes it as a first approximation of a well-specified structural model.

utilizing single equation estimates under the money supply exogeneity assumption were subject to a nontrivial degree of simultaneous equations bias.

Gibson (1972) attempted to rectify two perceived shortcomings in Teigen's 1964 study. First, Gibson questioned Teigen's use of one day, end-of-quarter data on money, reserves, and interest rates, as opposed to quarterly averaged data for all variables. Reestimating Teigen's model using quarterly average data yielded some qualitative and quantitative differences. Second, and more importantly for present purposes, Gibson showed that Teigen's supply equation was not in reality a supply equation, but instead a free reserves equation (i.e., an equation expressing the ratio of actual to "exogenous" money $[M/M^*]$ as a function of the level of excess reserves less borrowed reserves). "As such, [Teigen's 'supply' equation] is an interesting function, but it is not a money supply function, for it ignores changes [in factors such as reserve requirement ratios, currency-deposit ratios, etc.] whose variations are essential to variations in the stock of money" (Gibson, 1972, p.364). Consequently, Gibson reformulated the money supply equation as

$$(6) \quad M^s_t = f (R^a_t , i_{m_t} , DR_t),$$

where R^a denotes Federal Reserve member bank reserves adjusted for changes in reserve requirements, and where i_m and DR denote, as above, a market interest rate and the discount rate, respectively. Gibson hypothesized the money supply to be positively related to R^a and i_m and negatively related to DR "since *ceteris paribus* we expect banks to expand their earning assets when their reserves rise, market interest rates rise, and the discount rate falls" (Gibson, 1972, pp.365-66).

Combining the reformulated linear supply equation with Teigen's log demand and linear income equations, and utilizing quarterly average data for all variables, Gibson reestimated the basic Teigen model for sample period 1947:I to 1958:IV, and then compared his 2SLS estimates

with Teigen's. With respect to the demand equation, and similar to Teigen's findings, Gibson obtained significant coefficient estimates on the interest rate and income variables with the "correct" signs. Unlike Teigen's demand equation, however, Gibson found lagged money to be insignificantly different from zero, which Gibson attributed to Teigen's failure to use quarterly average data for all variables (Gibson, 1972, p.366). The implication of this, then, is that money holders adjust actual money balances to desired money balances within the quarter.

With respect to Gibson's money supply equation, the most striking result was that the estimated coefficients on the interest rate and discount rate variables were not statistically different from zero. However, the estimated coefficient on R^a , adjusted member bank reserves, was highly significant. Thus, Gibson concluded that the reserve aggregate played the dominant role in explaining variation in the money supply. Moreover, in contrast to the Brunner and Meltzer and Teigen studies discussed above, Gibson's results lent less support to the notion that the interest rate and discount rate were significant explanatory variables within the money supply process.

Teigen--and Gibson, in reformulating Teigen's basic model--specified *a priori* a logarithmic functional form for money demand and linear functional forms for both the supply equation and income equations. Spitzer (1977), drawing upon the Teigen-Gibson model, used a Box-Cox transformation to estimate a generalized money demand-money supply system of equations that did not impose these restrictions on functional form. While Spitzer's model differed from the Teigen-Gibson model in a number of other respects, his principal conclusion was that the functional forms chosen in the Teigen and Gibson studies were inappropriate. Using the sample period 1924-41 and 1946-73 (pooled), a likelihood ratio test was conducted which rejected the joint hypothesis implying--within the Box-Cox framework--that the appropriate functional forms for money demand and money supply were logarithmic and linear, respectively. However, for present purposes, the more relevant findings concern Spitzer's efforts to his contrast

his generalized (Box-Cox) *system estimates* of money demand and money supply with the estimates he obtained from application of generalized (Box-Cox) estimation to money demand and money supply separately, i.e., *single equation estimates* ignoring potential simultaneity. With respect to money demand, Spitzer found that while the coefficient estimate on the scale variable (defined as GNP) was positive and significant for both system and single equation estimates, the system estimate was slightly larger. The coefficient estimates on the interest rate variable were negative for both types of estimates, but of greater absolute value using single equation estimation.⁹ However, each was significant only at the 10 percent level. With respect to the supply equation, Spitzer obtained positive parameter estimates relating the money supply and the interest rate; however, these estimates were statistically insignificant. Overall, Spitzer found a number of a number of differences between system estimates and single equation estimates with respect to parameter estimates, as well as superior forecasting ability on the part of system estimates. He concluded that

[a]lthough the single-equation estimates fit the data well, the behavioral implications are at odds with the consistent estimates resulting from...systems estimates. These results should serve as a warning to future investigators concerning single-equation estimates when simultaneous equation methods are clearly called for. It now appears that the concerns of [Teigen and Gibson] were warranted. The estimation of single equations, whose included variables are known to be jointly determined in a simultaneous equations system, will apparently lead to inconsistent estimators (Spitzer, 1977, p.128).

Butkiewicz (1979) used a variation of the Brunner-Meltzer model in a study of the effect of outside wealth on money demand. His principal research question revolved around the observation that

⁹Spitzer's demand function includes a liquidity trap parameter and a long-term interest rate; thus, the interest rate estimate is not directly comparable to the Teigen-Gibson interest rate findings. The latter studies, which each obtained negative and significant interest rate parameter estimates in their money demand system estimates, did not address the liquidity trap issue and used a short term interest rate (the 4-6 month commercial paper rate).

[i]ncreases in the stock of publicly owned federal debt increase the public's perceived wealth. Increased wealth increases the demand for real balances, thus shifting the LM curve leftward and tending to further crowd out interest-sensitive private spending. And yet, none of the major macroeconometric models includes wealth among the explanatory variables in the demand for money function (Butkiewicz, 1979, p.250).

Butkiewicz thus specified real money demand as a function of real income, interest rates on alternatives to M1--specifically, rates on commercial paper and time deposits, respectively--and real government debt. In contrast to Brunner and Meltzer, Butkiewicz utilized quarterly rather than annual data; as a result, he employed lagged money in his demand equation to account for lagged adjustment of desired to actual money balances. "Another consideration," he noted, "is the endogeneity of the money supply. In any period, the money supply is not exogenous; it is an increasing function of the money market interest rate.... Thus, the money market interest rate is simultaneously determined by the demand for real balances and the money supply function" (Butkiewicz, 1979, p.252). Drawing explicitly from the Brunner-Meltzer nonlinear supply hypothesis, Butkiewicz specified the supply of (nominal) M1 as a function of nonborrowed reserves, a market interest rate, and the discount rate. In addition, and distinct from the Brunner-Meltzer approach, he included the currency-deposit ratio k in his supply equation, treating it as an endogenous variable (*cf.*, footnote 4 above). Thus, Butkiewicz estimated the following model (variables in log form):

$$(7) \quad \left(\frac{M^d}{P}\right)_t = \alpha_0 + \alpha_1 y_t + \alpha_2 i^c_t + \alpha_3 i^t_t + \alpha_4 wo_t + \alpha_5 \left(\frac{M}{P}\right)_{t-1} + \epsilon_t$$

$$(8) \quad M^s_t = \beta_1 NBR^*_t + \beta_2 k + \beta_3 i^c_t + \beta_4 DR_t + \eta_t,$$

where i^c = commercial paper rate, i^t = time deposit rate, NBR^* = adjusted nonborrowed reserves, wo = outside wealth, and other variables are defined as before. (Two different measures were used for outside wealth: the real value stock of publicly owned government debt, and real publicly owned government debt plus monetary base.)

Utilizing Sargan's 2SLS procedure, Butkiewicz obtained structural estimates of the α s and β s in equations (7) and (8) for sample period 1952:III-1975:III. Estimates of the structural demand parameters were in line with money demand theory for both the scale variable y (positive and significant) and the opportunity cost variables i^c and i^l (negative and significant).¹⁰ The major finding, given the author's principal research question, was positive and significant estimates of α_4 --i.e., the evidence suggested that real government debt *was* a significant variable explaining variations in real money demand. With respect to the supply function, the results were very similar to those obtained by Brunner and Meltzer. The estimated coefficient on adjusted nonborrowed reserves (β_1) was approximately unity, with a very large asymptotic t-value. This closely mimicked the results associated with Brunner and Meltzer's portmanteau "K" variable discussed above.¹¹ The interest elasticity of money supply (β_2) was positive and significant, but of a smaller magnitude than that exhibited in the Brunner-Meltzer study. Finally, the estimated discount rate elasticity (β_3) was of the hypothesized sign (negative), and significant at the 10 percent level. In sum, the Butkiewicz study provided another empirical investigation of money demand and money supply within a simultaneous equations framework. His results largely reinforced those produced by Brunner and Meltzer, but with a more recent sample period and with quarterly, as opposed to annual, data.¹²

¹⁰"While the commercial paper rate is a good measure of the best alternative available to wealthholders with large portfolios, market imperfections resulting from regulatory constraints suggest use of a separate measure of the best alternative return available to individuals with small portfolios. This is the reason for inclusion of the second interest rate variable" (Butkiewicz, 1979, p. 251).

¹¹Recall that changes in the Brunner-Meltzer K variable reflected changes in the monetary base (exclusive of discount window borrowing), reserve requirements, and the currency-deposit ratio. Each of these variables were regarded as exogenous by Brunner and Meltzer, reflective of Fed policy decisions and the public's currency-holding decisions. Butkiewicz, on the other hand, explicitly treated the currency-deposit ratio as endogenous. Thus, Butkiewicz's nonborrowed reserves variable and Brunner and Meltzer's K variable are generally, but not precisely, similar measures of exogenous money supply factors, or, in Brunner and Meltzer's terminology, "policy-imposed" factors that are "independent of credit market conditions."

¹²Unfortunately, Butkiewicz did not report single equation OLS estimates of money demand and money supply to compare with his 2SLS estimates.

Marothia and Phillips (1982) used Butkiewicz's methodology to estimate the supply of and demand for money using quarterly Canadian data over sample period 1970:I-1979:IV. The authors estimated the following system of equations (variables in log form):

$$(9) \quad \left(\frac{M^d}{P}\right)_t = \alpha_0 + \alpha_1 y_t + \alpha_2 i^c_t + \alpha_3 i^l_t + \alpha_4 wo_t + \alpha_5 \left(\frac{M}{P}\right)_{t-1} + \epsilon_t$$

$$(10) \quad M^s_t = \beta_1 MB_t + \beta_2 z_t + \beta_3 i^c_t + \beta_4 BR_t + \eta_t,$$

where M =narrowly defined money, y =real gross national expenditure, i^c =90 day commercial paper rate, i^l =10 year government bond rate, wo =real publicly owned government debt plus monetary base, MB =monetary base, z =cash reserve-deposit ratio (with an hypothesized *positive* sign, as opposed to Butkiewicz's use of the currency-deposit ratio k with an hypothesized *negative* impact on the money supply), and BR =Canadian central bank's bank rate. Preliminary estimation using OLS and 2SLS was conducted, the results of which suggested that, with respect to the demand equation, outside wealth (wo) and the 10 year government bond rate (i^l) were not statistically significant explanatory variables. These results were thus at variance with Butkiewicz's findings for the U.S.

After preliminary estimation, the authors dropped wo and i^l and reestimated money demand and money supply using OLS, 2SLS, 3SLS, and an additional instrumental variables (IV) method using a wider list of instruments than those contained in 2SLS and 3SLS. With respect to money demand, results were virtually identical for all estimation methods: the impact elasticity of the scale variable y was positive ($\hat{\alpha}_1 = 0.11$) and significant at the 5 percent level, while the impact elasticity of the opportunity cost variable i^c was negative ($\hat{\alpha}_2 = -0.05$) and significant at the 5 percent level. The estimate for the "adjustment parameter" (α_5 in equation (9)) was 0.86 and significant at the 5 percent level for all estimation methods. With respect to money supply, Marothia and Phillips similarly found that results were basically unchanged regardless of which

estimation method was utilized.¹³ The parameter estimates on the monetary base MB (β_1) and the cash reserve ratio z (β_2) were approximately 0.91 and 0.78, respectively, and statistically significant at the 5 percent level. However, estimates for the short-term interest rate i^e and the bank rate BR were not statistically significant, and, for i^e , were of the wrong sign (negative rather than positive) for all but the 2SLS estimate. In short, then, Marothia and Phillips' findings seemed to buttress, using Canadian data, several important previous results derived from U.S. data. First, systems estimation tended not to fundamentally alter money *demand* estimates. Second, system estimates of money *supply* did appear to be somewhat altered from single equation estimates. Third, the exogenous reserve aggregate in the supply equation--the monetary base for Marothia and Phillips--displayed a very strong influence on the money supply, dwarfing the potential endogenous effects of the short-term market interest rate and the central bank's bank rate. This last point suggested to the authors that, contrary to the Bank of Canada's practice, the monetary base rather than short-term market rates was therefore the superior instrument of monetary control (Marothia and Phillips, 1982, p.252).

In addition to studies which explicitly and in some detail modeled money supply and demand as a system of equations, some studies have briefly reported findings of instrumental variables estimates of money demand alone in an effort to assess potential simultaneous equations bias. A prominent example is Goldfeld (1973), who investigated the possibility of bias without specifying an explicit supply equation. Noting that "[i]n the absence of a complete model, the choice of means to carry out simultaneous equation estimation is somewhat arbitrary," Goldfeld selected a "plausible" set of instruments to conduct a two-stage least squares regression on what

¹³The authors overstate their results by suggesting that "while demand coefficients differ little among the equations for which differing estimation techniques were used, such is not the case for supply estimates" (Marothia and Phillips, 1982, p.259). While it is true that their supply results are not as *quantitatively* similar as their demand results, a perusal of their Table 3 (p.259) clearly reveals no *qualitative* differences between estimation techniques.

has come to be known as the standard "Goldfeld equation" (Goldfeld, 1973, p.621). The instrument set consisted of population, state and local government spending, the discount rate, and lagged money. Using the M1 definition of money and a sample period of 1952:I to 1972:IV, the instrumental variables technique yielded results very similar to those produced by OLS. More specifically, the two techniques were similar in terms of parameter estimate values and statistical tests of significance for the scale and opportunity cost variables, although when using the IV technique the adjustment parameter (the parameter estimate on lagged money) was somewhat smaller (implying a quicker speed of adjustment of actual to desired money balances). Overall, although Goldfeld was careful not to dismiss the potential for simultaneous equations bias, he concluded that "while it might have been desirable to use simultaneous equations techniques throughout [his paper], the generally comparable performance of the [OLS and IV] estimates suggests that the results would not be qualitatively affected by such a procedure" (Goldfeld, 1973, p.624).¹⁴

In summary, although the literature on the matter is relatively sparse, several studies have explicitly estimated money demand and money supply as a system of equations. In general, the findings of these studies have tended to support the notion that simultaneous equations bias, if present, is not "too serious" on the basis of relatively unaltered parameter estimates and significance tests of simultaneous equations estimates *vis-a-vis* their single equation counterparts. This is particularly the case with respect to the money demand function, which is the principal focus of attention. Thus, most researchers in the monetary field have tended to agree with Laidler (1993, pp.146-47) that "as far as investigating the role of the interest rate in the demand-for-

¹⁴Cooley and LeRoy refer to Goldfeld (1973) as "the study most often cited as justification for the abbreviated treatment of simultaneity in the large majority of recent studies of money demand" (Cooley and LeRoy, 1981, p.837).

money function is concerned, the identification problem is not usually a serious one, nor would it seem is the problem of simultaneity."

Closer examination of the issue, however, yields a couple of troubling concerns. First, the foregoing conclusion rests largely on the basis of a relatively few studies, the sample periods of which include only pre-1980 data. Indeed, the two most influential of such studies, Brunner and Meltzer (1964) and Teigen (1964), use pre-1960 data. The monetary sector has changed in many ways since then, and thus reliance on the results of studies drawn from an earlier data sample may be misleading. Second, as was noted briefly above (see footnote 2), two disparate theoretical justifications have been used to buttress the claimed validity of single equation estimates of money demand. The most typical reasoning is that the money supply is exogenous--i.e., as Bronfenbrenner and Mayer suggested above, money supply "is a quantity whose movements through time are unaffected by" the variables which affect money demand. On the other hand, sometimes single equation estimates are justified on the *opposite* rationale that money supply is *endogenous* due to policies followed by the monetary authority. Under the latter reasoning, attempts by the monetary authority to target the level of interest rates result in an exogenous interest rate in the demand equation and a demand-determined (endogenous) money supply. This reasoning, and its relationship to the empirical findings discussed above, is summarized by Thompson (1993) as follows:

Only a very few studies, such as Teigen (1964) and Brunner and Meltzer (1964), have actually attempted to analyse the demand for money in a simultaneous system, involving a supply function as well. These early studies, both of which used U.S. data, tended to indicate that explicit consideration of the supply function made little difference to the "demand" estimates obtained, so that the potential problem of simultaneous equations bias could be ignored. Indeed, it became accepted orthodoxy to dismiss the possible existence of an independent supply function when modelling the money market. Such an assumption has the effect of considerably simplifying the specification and estimation of the key money market equations, *and was largely uncontroversial in the 1950s and 1960s, when the stock of money could reasonably be taken to be demand determined* [emphasis added] (Thompson, 1993, pp.49-50).

However, the *empirical* findings of studies such as Brunner and Meltzer and the *theoretical* assertion of an endogenous money demand and an exogenous interest rate are *not* mutually supportive. This is because, in order for the theoretical argument to hold, the monetary authority must adjust its reserve supply behavior to accommodate whatever interest rate target it has chosen. In other words, reserve supply behavior must be subordinated to the monetary authority's exogenous interest rate target; reserves are thus endogenously determined. In contrast, in each of the studies discussed above treating money demand and money supply as a system of equations, *the reserve supply behavior of the monetary authority is specified a priori to be an exogenous variable*. Thus, if it is maintained on theoretical grounds that the interest rate is exogenous in demand equations, it must also be concluded that system studies such as Brunner and Meltzer (1964) and Teigen (1964) are misspecified, and that therefore their conclusions are not reliable. But, as the quote by Thompson above illustrates, the endogenous money-exogenous interest rate argument is often used in conjunction with, rather than in contradistinction to, these studies' empirical findings.

At first glance, the studies outlined above appear to circumvent the issue of what is endogenous vs. what is exogenous by explicitly treating money demand and money supply as a system of equations in which the interest rate, money demand, and money supply are *all* endogenous variables. However, as will be discussed in the next section, the validity of this approach depends upon the policy rule followed by the monetary authority.

The Reserve Aggregate and the Fed's Policy Rule

"The typical assumption underlying [money supply equations]," Lombra and Kaufman (1992, p.243) observe, "is the presumed exogeneity of reserves and, thus, central bank policy." In short, the presumption is that since, in principal, the Federal Reserve can control the level of reserves within the system, the reserve aggregate may be regarded as exogenous. The reserves

variable used in each of the simultaneous equations studies outlined above is specified *a priori* to be exogenous. While such an assumption (i) is more general than the usual assumption of exogenous money, and (ii) makes the estimated system much more tractable, there may nevertheless be good reason to question its validity. Specifically, the policy rule followed by the Federal Reserve--i.e., the procedure by which it implements monetary policy--may be closely linked to contemporaneous developments with respect to the demand for money. For instance, if demand disturbances generate unwanted variations in short-term interest rates, the Fed may seek to quickly offset such disturbances so that interest rate changes do not occur. Such attempts at interest rate "smoothing," as it is sometimes called, are implemented through the Fed's manipulation of bank reserves. Thus,

if in fact the central bank has over the past 25 years or so often pegged or moderated fluctuations in short-term interest rates over the short run...then demand disturbances and the Fed's partial or fully accommodating response would render the supply of reserves endogenous with respect to the money stock and interest rates (Lombra and Kaufman, 1992, p.243).

This possibility is illustrated in Figure 1, in which simple nominal money demand and nominal money supply curves are depicted, where money demand is a positive function of real income (y) and the price level (P) and a negative function of a short-term interest rate (i_m), and where money supply is a positive function of bank reserves (R) and the interest rate (i_m). Initial equilibrium is given by point a. Suppose that a positive demand shock occurs, such that the money demand shifts from M^d to M^d . *Ceteris paribus*, the new equilibrium will be at point b, associated with a higher market interest rate and a larger quantity of money. However, if the central bank engages in interest rate smoothing, i.e., attempts to limit the variability of the interest rate from its initial equilibrium value, it may seek to expand the level of reserves in the system so as to push the money supply curve rightward. In Figure 1, the monetary authority vigorously defends the initial interest rate and thereby shifts the money supply curve, via reserve expansion,

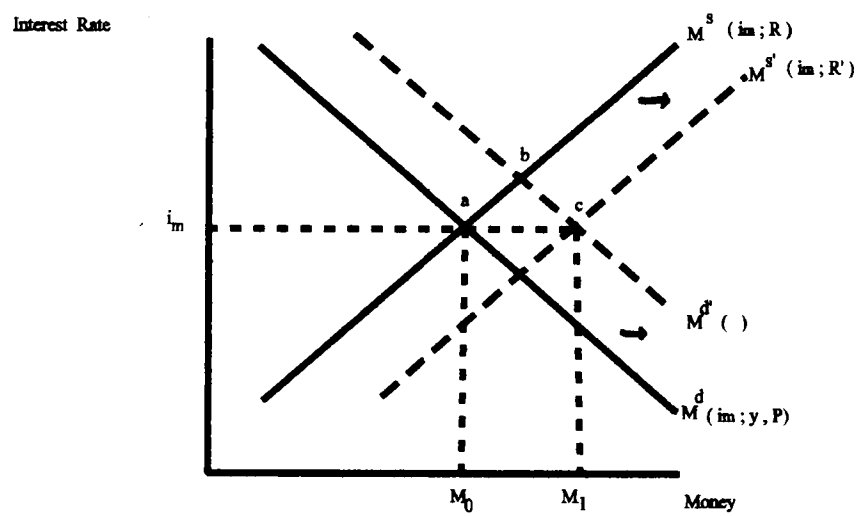


Figure 1. Money Demand and Money Supply.

to M^s . Thus, in this instance, the money supply cannot be said to be independent of money demand. Even more specifically, the reserve aggregate R cannot be said to be independent of money demand; instead, R is determined endogenously within the money market.

The potential endogeneity of the reserve aggregate in the money supply function may have important implications for identification and estimation of money demand and money supply. First, the presumed exogeneity of reserves, it is sometimes suggested, serves as an important justification for assuming that the money demand function is identified. Specifically, the reserve aggregate is normally viewed as (i) an exogenous variable within the system, which (ii) exhibits substantial variation over time, and (iii) is, crucially, excluded from the demand equation.

Cooley and LeRoy (1981) quote, then criticize, Laidler's (1977) summary of this reasoning:

...[T]he supply function of money shifts independently of the demand-for-money function [if] the supply function contains at least one variable that does not appear in the demand function. It is not hard to establish that this is the case, for the level of reserves made available by the central bank to the commercial banking system figures prominently in any theory of the supply of money and it does not appear in any theory of the demand for money. There is also ample evidence that this variable shifts around over time, permitting us to be sure that we can obtain observations taken at different points on the demand-for-money function (Laidler, 1977, pp.115-16; quoted in Cooley and LeRoy, 1981, p.837).

However, Cooley and LeRoy note that this view ignores the nexus between reserves and demand shocks. "[T]he condition that supply shifts independently of demand," they observe,

means that reserves must be excluded not only as an explicit independent variable on the demand side (Laidler is surely correct that it can be reasonably so excluded), but also as an explanatory variable for the unobserved determinants of money. Specifically, it is necessary to assume that the covariance of reserves and the error in money demand are zero....But surely the assumption that the random shifts in money demand are not at least partially accommodated by the Federal Reserve is even less plausible than the assumption that such shifts do not result in an interest rate response (Cooley and LeRoy, 1981, p.837).

Thus, if the monetary authority's policy rule is (at least partially) accommodative, reserves are linked in a systematic fashion to the demand-side. As a result, the assumption of exogenous reserves, and thus a seemingly persuasive rationale for assuming identification of money demand,

is jeopardized. Identification of money demand would require, then, some other variable in the supply function which (i) is exogenous, (ii) exhibits substantial variation over time, and (iii) is excluded from the demand equation.

A second potential problem posed by endogeneity of the reserve aggregate in money supply equations is that, even assuming that the demand equation can be identified, estimation of money demand and money supply may be plagued by specification error if reserves are wrongly assumed to be exogenous. If in fact the reserve aggregate is highly responsive to money demand shocks, it does not properly serve as a predetermined variable in a reduced form money demand-money supply model. Specifically, in such an instance, the reserves variable would not be independent of the reduced form disturbance term. Consequently, an estimation method such as two stage least squares--which utilizes consistent first stage reduced form parameter estimates as instruments for endogenous explanatory variables in second stage structural estimation--would yield inconsistent structural parameter estimates because the first stage reduced form regression itself yields inconsistent parameter estimates. Results, then, of empirical money demand-money supply models may be subject to question if reserves are erroneously assumed, *a priori*, to be predetermined.

These caveats regarding the potential identification and estimation problems which may arise if reserves are not exogenous hinge upon the nature of the policy rule embraced by the monetary authority, i.e., the central bank's operating procedure. The discussion thus shifts to an examination of the actual policy rules employed by the Federal Reserve over the sample period used in the present study. This first requires that a distinction be made between the Fed's *intermediate* target and its *operating* target. From 1970 until mid-1993, the Federal Reserve used money supply growth as its principal announced intermediate target of monetary policy. By focusing on the money supply as its intermediate target variable, the Federal Reserve's stated

policy was designed to exploit what appeared, particularly to monetarists, to be a predictable link between the behavior of the money supply and the Fed's ultimate policy goals of sustainable economic growth and price stability.¹⁵ During the 1970-93 period, the Fed employed three different types of policy rules or *operating procedures*. Each rule was designed to implement the Fed's intermediate money supply target as set by the Federal Open Market Committee (FOMC)--the policymaking arm of the Fed--which meets approximately every six weeks (slightly more frequently in the 1970s). The first rule, in force from 1970 until October 1979, was the Federal funds rate (FFR) procedure (or regime). The second rule, operative between October 1979 and October 1982, was the nonborrowed reserves (NBR) procedure. The third rule, the borrowed reserves (BR) procedure, has been in force since October 1982.

To facilitate an understanding of how each procedure functioned, it is useful first to segment reserves into uses of (demand for) reserves and sources of (supply of) reserves:

$$(11) \quad TR = RR + ER \quad (\text{Uses})$$

$$(12) \quad TR = NBR + BR \quad (\text{Sources})$$

where TR=Total Reserves, RR=Required Reserves, ER=Excess Reserves, NBR=Nonborrowed Reserves, and BR=Borrowed Reserves. The demand for reserves is principally based upon the need for reserves to back-up demand deposit liabilities (i.e., required reserves), and is thus closely linked to the demand for money. In other words, the demand for required reserves is a derived demand directly related to money demand; thus, variations in money demand will cause roughly concurrent variations in the demand for required reserves (Thornton, 1988, p.34n; Lombra, 1992, p.260). On the sources (supply) side, the Fed's ability to manipulate reserves operates via two

¹⁵For a discussion of the Fed's switch to an intermediate target strategy stressing control of the growth of monetary aggregates, see Maisel (1973, pp.228-54). Initially, M1 was the principal monetary aggregate for which the Fed developed growth targets. By the mid-1980s, the Fed had abandoned M1 targets in favor of M2 targeting. In mid-1993, the Fed formally announced that it was abandoning monetary aggregates as intermediate targets in favor of "equilibrium real interest rate" targeting.

markets, the market for borrowed reserves (of which the Fed is the monopoly supplier via the discount window), and the market for nonborrowed reserves (the overall stock of which the Fed is able to manipulate via open market operations).¹⁶ Under a Fed funds regime, the FOMC meets periodically to determine its intermediate monetary target. It then chooses a Fed funds rate target it deems consistent with its money growth target. The Federal Open Market Trading Desk (or simply, "the Desk") is then directed to buy or sell securities in the inter-meeting period so as to maintain the FFR target.¹⁷ In other words, the Desk is directed to supply nonborrowed reserves elastically at the chosen Fed funds rate target. If, in the intervening period between FOMC meetings, the actual growth rate of the monetary aggregate exceeds (falls short of) its target, the Fed ostensibly adjusts its Fed funds rate target upward (downward) at its next meeting, stepping up its open market sales (purchases) until the new FFR target is attained.

However, as has been well-documented (see, eg., Roberds, 1992), the Fed tended to not assiduously follow its intermediate targets during the 1970s. Instead, it tended to keep FFR targets relatively rigid, even when its intermediate targeting strategy called for a downward--or, more likely, upward--adjustment. In order to more closely link reserve supply behavior with intermediate policy targets, in October 1979 the Fed shifted to a nonborrowed reserves (NBR) operation procedure. Under a strictly observed NBR procedure, the FOMC sets a NBR target it deems consistent with its intermediate money growth target, and *does not* allow NBR to vary in the inter-meeting period, instead allowing the price of nonborrowed reserves, the Fed funds rate, to vary. More specifically, the Fed estimates the demand for total reserves ($\hat{TR}^d$) and borrowed reserves ($\hat{BR}^d$) it believes will arise if it hits its intermediate monetary target. Subtracting $\hat{BR}^d$

¹⁶Of course, the Fed can also alter reserves via changes in reserve requirements, but such changes are not used as part of its *operating* procedures.

¹⁷In practice, the Fed's funds rate target consisted of a *band* beyond which the rate was not normally allowed to fluctuate. However, the rate was allowed to fluctuate *within* the chosen band. This point, an important one for the present study, will be discussed further in Chapter 3.

from $\hat{TR}^d$ then yields the Fed's nonborrowed reserves target, NBR^* . The FOMC then directs the Desk to adhere to NBR^* over the course of the inter-meeting period, even if actual money demand--and therefore reserve demand--exceeds (or falls short of) its target. By doing so, the Fed funds rate is essentially allowed to "float" according to shifts in the demand for reserves.¹⁸

Concerned that the link between the money supply and aggregate spending had become less predictable, and therefore that the money supply was a less useful intermediate target, the Fed became more reluctant to accept the high levels and erratic behavior of the Fed funds rate that attended the NBR procedure. This ostensibly led the Federal Reserve to abandon the nonborrowed reserves procedure sometime during 1982 in favor of a borrowed reserves (BR) procedure (Wallich, 1984). Under a BR procedure, the FOMC sets a target level of borrowed reserves BR^* it deems consistent with its intermediate policy objective. It then allows nonborrowed reserves to fluctuate so as to maintain its borrowed reserves target (also called the borrowings assumption, since it represents the level of borrowed reserves the Fed assumes it must provide to obtain its intermediate policy objective).

Thus, under a strict FFR procedure, the level of nonborrowed reserves is allowed to fluctuate according to the Federal funds rate target, i.e., the Federal funds rate is the exogenously determined policy variable, while nonborrowed reserves is endogenously determined according to the Federal funds rate setting and reserve demand. Under a (strictly observed) nonborrowed reserves procedure, the opposite holds: nonborrowed reserves are exogenous, while the Federal funds rate endogenously varies given the NBR setting and reserve demand. Under a (strictly

¹⁸In practice, inter-meeting adherence to the NBR^* setting was often looser, as the Fed did not fully relinquish its tendency toward interest rate smoothing. See Roberds (1992, p.14), and Cook (1989). Moreover, upward pressure on reserve demand was accommodated in some measure through the Fed's discount window. However, there is little question that the NBR procedure represented a discernable shift away from the earlier regime (see, eg., Cosimano and Sheehan, 1994; Lombra, 1994). The question remains, though, as to whether the shift was quantitative or qualitative in nature. This will be discussed further in Chapter 3.

observed) borrowed reserves procedure, borrowed reserves are exogenous; nonborrowed reserves--and, consequently, the Federal funds rate--fluctuate endogenously according to the borrowings assumption. (However, as will be discussed at greater length in the next chapter, the Fed has not adhered to a strict borrowed reserves procedure since 1982. Indeed, most observers agree that the stated borrowed reserves procedure, in practice, has actually approximated the Federal funds rate procedure.)

Consequently, the policy rule employed by the Fed may have an important bearing on the validity of simultaneous equations models of money demand and money supply. Normally, the reserve aggregate is assumed to be an exogenous variable in money supply equations. But if the Fed employs a Federal funds rate procedure, it allows reserves to accommodate demand shifts, given an exogenously determined Fed funds rate. On the other hand, a nonborrowed reserves procedure allows one to properly specify reserves as an exogenous variable either exactly (if the NBR procedure is strictly observed and nonborrowed reserves is the reserve aggregate in the supply equation), or approximately (if the NBR procedure is approximately observed and/or total reserves are used as the reserve aggregate in the supply equation). Under a borrowed reserves procedure, the specification of reserves as an exogenous variable essentially depends on whether the procedure in practice more closely approximates a Fed funds rate regime or a nonborrowed reserves regime.

Given this discussion of Fed operating procedures since 1970, what are the implications for the money demand-money supply systems studies outlined above, each of which explicitly specified an exogenous reserve aggregate in the money supply equation? Each of the U.S. studies reviewed--Brunner and Meltzer (1964), Teigen (1964), Gibson (1972), Spitzer (1977), and Butkiewicz (1979)¹⁹--drew most or all data from pre-1970. This in fact makes them *more*

¹⁹Marothia and Phillips (1982) used Canadian data from 1970-79. However, they observed that the central bank of Canada explicitly targeted interest rates during their sample period.

susceptible to reserve endogeneity, since policies in the thirty years prior to the adoption of intermediate monetary targeting were, if anything, even *more* geared toward interest rate control and *less* geared toward money supply control. From 1941 until the Federal Reserve-Treasury Accord of 1951, the Fed was constrained to use its policy instruments to explicitly peg the rate of return on short-term instruments at rates specified by the U.S. Treasury. Thus, not only was the money supply not exogenously determined by the Fed, neither was the supply of bank reserves.

Whenever a central bank adopts a policy of pegging market interest rate, it gives up control over the supply of money. If the pegged rates are set too low, private sector demand for new government debt will be too small to take up the entire issue. To prevent bond prices from falling (and yields rising), the Fed must serve as the residual purchaser. *In so doing, the Fed automatically increases the reserves of the banking system* [emphasis added], allowing an expansion of the money supply. If the pegged rates are set too high, there will be an excess private demand for government securities, and the Fed must sell from its own portfolio of government security holdings in order to prevent interest rates from falling. In the process, banking sector reserves are reduced, leading to a fall in the supply of money (Walsh, 1993).

Following the 1951 Accord, the Fed was freer to adopt its own policies. The Fed tended to pursue an eclectic approach broadly termed "money market conditions," which focused on developments regarding short-term interest rates (principally the Fed funds rate and the three-month T-bill rate) and the level of free reserves.²⁰ In effect, during this period the Fed used a money market conditions strategy as both its intermediate target and operating procedure (see Maisel, 1973, pp.53, 78-86). Lombra and Kaufman observe that

[t]he key feature of this strategy for the determination of the money stock is that the money stock played no explicit role in the formulation or execution of policy. With its analytical significance virtually ignored, and thus with fluctuations in money growth playing no direct role in the adjustment of policy instruments, the unavoidable implication is that [during this period] the money supply was an endogenous variable (Lombra and Kaufman, 1992, pp.234-35).

²⁰Free reserves (FR) equals excess reserves (ER) less borrowed reserves (BR). Since $TR=RR+ER=NBR+BR$, $FR=NBR-RR$. Under a free reserves procedure, for a given level of required reserves, nonborrowed reserves adjusts to meet the Fed's free reserves target. See Burger (1971, p.175).

Moreover, with the money supply virtually ignored and with short-term interest rates the principal focus of the Fed, the reserve policies of the Fed were essentially dictated by the Fed's interest rate targets. Therefore, the studies mentioned above, upon which subsequent studies have explicitly or implicitly relied to help dispel identification and simultaneity questions, contain a potentially serious specification error that could invalidate their results.

The Potential Endogeneity of Reserves: Some Empirical Evidence

The potential for the Fed's operating procedure to accommodate money demand shocks led Lombra and Kaufman (1984) and Kaufman and Lombra (1986) to investigate the empirical behavior of conventional or "received" money supply functions. They hypothesized that received money supply functions ought to exhibit a substantial degree of instability because they do not (i) accurately represent the money supply process, and (ii) do not exhibit the flexibility required to capture *changes* in the Fed's policy rule. In their 1984 paper, Lombra and Kaufman focused on the potential for misspecification of the money supply as manifested by instability of parameter estimates over a period in which the Fed's policy rule was consistent (*viz.*, during a period in which the Fed relied on interest rate targeting). Utilizing monthly data over the period 1959:3 to 1973:12, the authors estimated a conventional money supply function of the following form (variables in logs):

$$(13) \quad \Delta M_t = \beta_0 + \beta_1 \Delta MB_t + \beta_2 \Delta FFR_t + \beta_3 \Delta MB_{t-1} + \epsilon_t ,$$

where $M=M1$, MB =monetary base, and FFR =Federal funds rate.²¹ Ordinary least squares regression results showed positive and significant coefficient estimates for monetary base and lagged money, while the coefficient estimate for the Federal funds rate that was negative but

²¹The authors stressed that their choice of money supply specification was dictated by the literature and that they made no effort themselves to furnish an alternative specification. Although the reader may observe various divergences from some of the money supply functions discussed above, the authors contended that "the Brunner-Meltzer (1964) models...are consistent with [the paper's money supply] formulation. We have also examined numerous other functions (levels, first differences, excluding interest rates, etc.). In general, the results reported...are unaffected by such alterations" (Lombra and Kaufman, 1984, p.1151n).

insignificantly different from zero. In order to explore the stability of the estimated coefficients, the authors employed the Brown-Durbin-Evans (BDE, or *cusum*) test of parameter stability. The results of the BDE procedure suggested the parameter estimates were not structurally stable over time, and that therefore the conventional money supply equation was misspecified. While the authors conceded that specification error can derive from a number of sources, they argued that one very plausible interpretation was that the reserve aggregate in the supply equation--in this case, the monetary base (MB)--was not independent of money demand. In other words, Lombra and Kaufman suggested that the Fed's policy rule led to an endogenous monetary base, and that therefore single equation OLS estimates of functions such as that given by (13) are subject to simultaneous equations bias that manifests itself through unstable parameter estimates.

In a follow-up paper, Kaufman and Lombra (1986) investigated the possibility of a distinct structural break occurring in the money supply process due to policy regime shifts. Using vector autoregressions (VARs), the authors contrasted two periods, one (1971:01 to 1979:09) associated with the Fed funds rate operating procedure, the other (1979:10 to 1982:08) associated with the nonborrowed reserves procedure. Three variables were entered in the VARs: M1, the Fed funds rate, and nonborrowed reserves. The authors hypothesized that if the money supply process remained stable over the two periods, the behavior of variance decompositions obtained from the VARs should be relatively invariant from one period to the next. More specifically, if the money supply process exhibited substantial stability over the two periods, the percentage forecast error variance of M1 explained by innovations in the Fed funds rate and nonborrowed reserves, respectively, should not be markedly different for each subperiod. Kaufman and Lombra, however, found evidence to the contrary. For the first (Fed funds targeting) period, the authors found that more of the forecast error variance of M1 was attributable to innovations in the Fed funds rate relative to innovations in nonborrowed reserves. For the second period, the

opposite held; innovations in nonborrowed reserves explained more of the forecast error variance of M1 than did the Fed funds rate. This finding was used to bolster Kaufman and Lombra's overall contention that the money supply process, contrary to its conventional treatment in the literature, was not structurally stable nor invariant to changes in Federal Reserve operating procedures (Kaufman and Lombra, 1986, p.1086).

Baghestani and Mott (1988) reported additional evidence suggesting that the money supply process is not invariant to policy regime shifts. They estimated the following money supply equation (variables in logs):

$$(14) \quad \Delta M_t = \beta_0 + \beta_1 \Delta R^a_t + \beta_2 \Delta i_t + \beta_3 \Delta DR_t + \beta_4 \Delta M_{t-1} + \epsilon_t,$$

where $M=M1$, R^a =total member banks reserves adjusted for reserve requirements, i =a short-term interest rate (the authors use, alternately, the Fed funds rate and the three month T-bill rate), and DR =discount rate. Equation (14) was estimated using quarterly data drawn from each of the post-1970 operating procedures: 1970:I to 1979:III (Fed funds rate regime), 1979:IV to 1982:III (nonborrowed reserves regime), and 1982:IV to 1986:IV (borrowed reserves regime).²² The estimation method was an instrumental variables technique (to account for simultaneity of the short-term interest rate), applied separately to each subperiod. Results for the Fed funds rate period showed that the reserve aggregate was positive and statistically significant; however, the interest rate variable and the discount rate were statistically insignificant. According to the authors, this finding was traceable to the Fed's interest rate targeting policy over the 1970-79 period: the regression of money on reserves and interest rate resulted in the variability of the money supply being overly-attributed to variations in reserves, when in fact the variability of

²²Note that their regressions leave relatively few degrees of freedom, particularly with respect to the nonborrowed reserves subperiod.

reserves was itself largely the result of the Fed's conscious attempts to reduce the variability of its operating target, the short-term interest rate.

Results for the nonborrowed reserves period, in contrast, revealed positive and significant parameter estimates on *both* reserves and the short-term T-bill rate, while the discount rate estimate was negative and significant.²³ Over this period, the Fed was less accommodative of money demand shocks, and therefore allowed the interest rate to vary more. This presumably led to the statistically significant estimate on the interest rate variable. Results for the borrowed reserves period, 1982-86, in general, showed statistically significant estimates on the reserves and discount rate variables, while the estimate for the short-term rate variable--regardless whether the Fed funds rate or the three month T-bill rate was used--was not significantly different from zero. Thus, the regression results for the borrowed reserves period appeared to reveal yet another regime shift. Consequently, the authors concluded from their findings that "the Fed cannot safely assume that an alteration of its policy procedures will not be met by an alteration of the money supply process itself" (Baghestani and Mott, 1988, p.489).

Federal Reserve Reaction Functions

As observed at the outset of this chapter, the money supply process is typically treated as exogenous in the monetary literature. Studies such as Brunner and Meltzer (1964) and Teigen (1964) have directly addressed the potential for interest rates and other factors to have feedback effects on the money supply, thereby rendering it endogenous. However, in these studies, the monetary authority's behavior continues to be exogenously determined. Thus, the exogeneity

²³Curiously, while the T-bill rate was significantly different from zero when entered in the supply equation, the Fed funds rate was not. The authors attribute this result to the possibility that "the treasury bill rate may be a better indicator of overall money market conditions motivating banks' decisions between loans or investments versus holding reserves"--and therefore more closely linked to the money supply--than is the Fed funds rate (Baghestani and Mott, 1988, p.489). Indeed, a short-term rate such as the T-bill is used as a proxy for the opportunity cost of money, whereas the Fed funds rate more properly represents the opportunity cost of (nonborrowed) bank reserves.

restriction is relaxed at only one level; the monetary authority's behavior, important as it is in the money supply process, is still treated as a variable whose movements vary independently from factors which affect money demand. As has been discussed at length above, the Federal Reserve's policy rule--the procedure by which it implements its targets--may serve as a link between money demand shocks and the Fed's reserve supply behavior, thereby rendering the latter endogenous within a system of equations consisting of money demand, money supply, and the market for bank reserves. As a result, the variable which is most properly viewed as exogenously determined is the target that is set at each FOMC meeting. For example, under a Fed funds operating procedure, the Fed sets the Fed funds rate target, then manipulates reserves--given the behavior of money and therefore reserve demand--so as to attain that target.

The process by which the Fed alters or does not alter, from meeting to meeting, the level of its operating target constitutes the Federal Reserve's "reaction function." Reaction functions "attempt to *describe* the behavior of the Fed in conducting monetary policy. They measure the relationship between the Fed's policy instrument (such as bank reserves or the Fed funds rate) and key variables that the Fed typically responds to in adjusting the stance of policy (such as inflation, real GDP and the unemployment rate)" (Judd and Trehan, 1995). Since the "key variables" to which the Fed reacts--i.e., the information set upon which the Fed's operating target is conditioned--are ostensibly predetermined variables, the reaction function literature has evolved in large part separately from the money demand-money supply literature. In other words, at the most general level, if the money supply is assumed to be exogenously determined by the Fed, then the money supply is in effect determined by a separate process, one that is independent of, and therefore not stochastically linked to, money demand. Similarly, even if the demand for and supply of money and bank reserves are endogenously determined, the level of the Fed's operating target (whether it is the Fed funds rate, nonborrowed reserves, or borrowed reserves) is

determined, it would appear, independently of contemporaneous developments in the money and reserves markets. However, for reasons that will be outlined in Chapter 3, it may in fact be more appropriate to specify an explicit stochastic linkage between money, reserves, and the Fed's reaction function. Consequently, to facilitate the specification of an adequate reaction function, this section presents a brief overview of representative literature. While a consensus on which variables affect Fed policies has by no means been formed, the literature is highly suggestive of a likely set of "candidate variables" for inclusion in the Fed's information set.

An early attempt to describe the Fed's reaction function was by Wood (1967). Using quarterly data over the period 1952-63, Wood constructed a reaction function in which the Fed's holdings of government securities were specified as a function of a number of potentially important explanatory variables. Of particular interest was the extent to which the Fed altered its securities holdings--and thereby its free reserves operating target--on the basis of important macroeconomic variables such as income, unemployment, and inflation. Wood concluded that while much of the variation in the Fed's security holdings was attributable to defensive actions such as seasonal provision of reserves and float management, "a small but statistically significant part of its behavior is in direct response to the targets and target variables specified in the Employment Act of 1946," *viz.*, GNP, the price level, unemployment, and the balance of payments (Wood, 1967, p.156).

Froyen (1974) specified a reaction function in which the monetary base (both inclusive and exclusive of borrowed reserves) was used as an indicator of the overall stance of monetary policy over data period 1953-72. (It should be noted that, more specifically, the Fed's operating regime was geared toward interest rate targets over that period. However, the monetary base varied according to chosen interest rate targets, so would also reveal--at least generally--the thrust of Fed policy actions.) Froyen hypothesized that movements in the monetary base could be

attributed to lagged values of a variety of variables, including the deviations of unemployment, inflation, and the balance of payments from "desired" levels, as well as the scale of economic activity (proxied by manufacturing and trade sales), the long-term interest rate, publicly-held government debt, and a variable measuring the overall stance of fiscal policy (the full employment federal budget surplus). Using monthly data, Froyen estimated his reaction function over three subperiods: the Eisenhower period (1953:02-1961:01), the Kennedy-Johnson period (1961:02-1969:01), and the Nixon period (1969:02-1972:12). Over the first subperiod, only the unemployment rate and scale of economic activity variables displayed significant systematic effects on monetary base movements. The same variables, plus inflation and the fiscal policy variable, were significant during the Kennedy-Johnson period, regardless of the definition of monetary base as inclusive or exclusive of borrowed reserves. Only the balance of payments and the bond rate failed to impact the stance of monetary policy using either monetary base definition. The third subperiod, 1969-72, revealed systematic influences on the monetary base--utilizing either definition--for scale of activity, unemployment, balance of payments, and publicly-held debt, while the fiscal policy variable, inflation, and the bond rate did not exhibit significant influences.

Abrams, Froyen, and Waud (1980) observed that the Federal Reserve is not likely to be totally backward-looking in its determination of intermediate and operational targets. Instead, the Fed was likely to base its policy decisions not only on the past behavior of relevant economic variables, but also on the projected values of such variables. Thus, the authors developed a reaction function in which the dependent variable--the Fed funds rate--was regressed on "consistent forecasts" of values of inflation, balance of payments surplus, as well as deviations of actual values from desired levels of the following variables: the money stock, the unemployment rate, and the exchange rate. Using monthly data over the period 1970-77, split at 1973 (to

separate the fixed and floating exchange rate periods), the authors found that the Fed did tend to make systematic adjustments of its operating target to changes in major macroeconomic variables. For instance, they concluded that the Fed did make some attempt to offset deviations of money from intermediate target (desired) levels by adjusting its operating target, the Fed funds rate.

In a similar vein, McNees (1986 and 1992) estimated reaction functions that combined past realizations of major macroeconomic with forward-looking explanatory variables. McNees (1986, p.5) observed that "[u]nfortunately, because data on expectations are not commonly available, empirical work is often conducted with historical data which therefore serve the dual role of proxies for expectations and measures of past economic performance." In an attempt to rectify this shortcoming, McNees included the Fed's own staff forecasts of important macro variables, augmented by forecasts provided by a well-known forecasting service, as variables explaining variations in the Fed's operating target (the Fed funds rate). His findings suggested that the Fed tended to respond both to past actual data as well as forecast data. In a follow-up, McNees (1992) found that the pattern of response by the Fed to various backward- and forward-looking variables depended somewhat on upon the policy regime that was in force, but that in general "[t]he standard, common sense conclusion seems reconfirmed, that forecasts of inflation and economic activity, the actual level of economic activity, and the pace of money growth are the primary factors determining monetary policy" (McNees, 1992, p.11), as evidenced by variations in the Fed funds rate over the period 1970-92.

Hakes and Gamber (1992) examined the Federal Reserve's reaction function over the period 1975-86 (monthly), focusing on the Fed's response to deviations of actual money growth from desired (targeted) levels. They specified the following reaction function

$$(15) \quad \Delta OT_t = \beta_0 + \beta_1 \Delta U_{t-1} + \beta_2 \Delta \ln PPI_{t-1} + \beta_3 \Delta \ln IP_{t-1} + \beta_4 MT_{t-1} + \epsilon_t,$$

where OT=the Fed's operating target, U=the unemployment rate, PPI=producer price index,

IP=industrial production index, and MT="errant money growth." The full data period was split into subperiods according to which operating target was appropriate: for 1975-79, OT=Fed funds rate; for 1979-82, OT=(logged) nonborrowed reserves; for 1982-87, OT=(logged) borrowed reserves. Separate regressions were run for each subperiod using first M1, then M2, as the monetary aggregate in the variable MT. The authors' principal finding was the Fed tended to correct for positive (negative) deviations of actual money from targeted levels by correcting the Fed funds rate upward (downward) for the period 1975-79, and nonborrowed reserves downward (upward) for the 1979-82 period. However, for the 1983-87 period, the Fed did not tend to adjust borrowed reserves in a systematic fashion according to deviations from stated monetary targets. This result accords with the general notion that around 1982 the Fed began to substantially downplay the role of money supply movements in formulating policy. A similar finding was reported by Mehra (1994). Mehra estimated a reaction function in which policy actions were evidenced by the behavior of the Fed funds rate over the period 1979-92 (quarterly). He found that the Fed funds rate exhibited sensitivity to actual inflation, the long-term real bond rate, deviations of real GDP from trend, and the behavior of the long run (equilibrium) Federal funds rate. In addition, the Fed appeared to respond to changes in lagged money growth. However, Mehra found that this tendency was more pronounced in the early segment of the data period (1979-82) using M1 as the intermediate target variable, than the later period (1983-92), using M2 as the monetary target, perhaps indicating "that the Fed may have discounted the leading indicator properties of money as measured by M2" (Mehra, 1994, p.18).

While only a handful of studies investigating the Federal Reserve's reaction function has been reviewed, they nevertheless capture the flavor of the literature. In general, the Federal Reserve appears to respond to various macroeconomic variables, such as real GDP, unemployment, and inflation. It also may be responsive to lagged money growth or deviations of

the money supply from targeted levels, although the responsiveness apparently lessened during the mid-1980s. Expectations of the Fed regarding future behavior of important macroeconomic variables may also be useful in explaining variations in the Fed's policy instrument. In the next chapter, the reaction function literature will be called upon to help close the present study's structural model by linking Federal Reserve policy decisions with its operating procedures, the reserves market, and the money market.

Summary

This chapter has reviewed a number of relevant issues from the literature pertaining to the empirical estimation of money demand and money supply functions. In the first section, a brief overview of the main issues surrounding money demand estimation was presented. The second section reviewed the relatively sparse literature that exists which explicitly estimate money demand and money supply as an interdependent system of equations. The principal findings from this body of literature were that while single equation estimates of money demand are technically incomplete due to potential difficulties regarding identification and simultaneity, abstracting from supply issues tended not to radically alter empirical results. As a result, it became generally accepted practice to abstract from supply issues, and instead treat the money supply as exogenously determined by the monetary authority. However, the systems studies that have helped reinforce this practice may suffer from a potentially serious specification error. Specifically, in each of the studies reviewed, the reserve aggregate in the money supply function is treated as a variable that is exogenously determined by the monetary authority. An analysis of Federal Reserve operating procedures in the third section revealed that, since the Fed often targets the level of short-term interest rates--an important explanatory variable in money demand functions--variations in bank reserves are often traceable to the Fed's attempt to control short-term rates. Thus, reserves may in reality be closely linked to factors which affect the demand for

money and, consequently, it may be incorrect to specify, *a priori*, reserves to be an exogenous variable in a money demand-money supply equation system. The fourth section outlined some empirical evidence that has been used to cast doubt on the idea that the reserve aggregate in money supply functions is (i) exogenously determined by the Fed, and (ii) invariant to changes in the Fed's operating procedure. The fifth and final section of the chapter discussed some salient features of the Federal Reserve "reaction function" literature that will be useful for the present project. Chapter 3 will build upon the literature discussed in this chapter by constructing a structural model of the monetary sector which links money together with, rather than abstracts it from, the market for bank reserves, the Fed's operating procedures, and the Fed's reaction function.

CHAPTER 3

THE MODEL

This chapter presents a model of the monetary sector in which money, reserves, and Federal Reserve policies are endogenously determined. The first section outlines the theoretical model and the structure of the auxiliary empirical model. The second section outlines estimation strategy. The final section contains a brief summary of the chapter.

Theoretical Model and Empirical Counterpart

In the conventional model of the monetary sector, supply side issues are largely ignored by assuming that money is exogenously determined by the monetary authority. As a first step to a more complete theory, this study views the money supply--in conventional textbook fashion--as a multiplicative function of the money multiplier and a reserve aggregate. However, as discussed in Chapter 2, studies such as Brunner and Meltzer (1964) have allowed for potential endogeneity of the money supply operating through the multiplier, where the principal source of endogeneity is the potential dependence of the multiplier on changes in the endogenously determined interest rate. Moreover, it was also observed in Chapter 2 that these studies nevertheless maintained a lower-level presumption of exogenous monetary policy by specifying exogenous determination of reserves (variously defined). Such treatment assumes (i) that the market for bank reserves is independent of the money market, and (ii) that the monetary authority's choice of operating procedure is irrelevant. Instead of abstracting from these issues, the present study assumes a close interdependence between money, reserves, and the policies of the monetary authority. A model is therefore constructed that integrates the market for (nonborrowed) reserves with the money market, conditioned upon the operating procedure utilized by the monetary authority.

This section is divided into five subsections. These subsections cumulatively serve to outline the theoretical underpinnings of the estimating equations used in the empirical model. The

first subsection presents the conventional theoretical structure of money demand and a basic empirical money demand equation that "operationalizes" the theory. The second subsection outlines the conventional base-multiplier theory of the money supply and its operational counterpart. The third subsection examines the demand side of the Fed funds market (the market for nonborrowed reserves). A demand-for-nonborrowed-reserves equation is constructed stressing the potential interdependence of reserve demand with contemporaneous developments in the money market. The fourth subsection looks at the supply side of the market for nonborrowed reserves, stressing its dependence upon the operating procedure utilized by the Federal Reserve. The final subsection closes the model by specifying a basic Federal Reserve reaction function. The discussion proceeds under the following data assumptions: (i) the definition of money is M1; (ii) data frequency is quarterly; and (iii) the sample period is 1972:I-1993:I, the period consistent with the Fed's stated focus on monetary aggregates as its principal intermediate target.¹ (Complete definitions and sources of data are given in Appendix A.)

Money Demand

As observed in Chapter 2, a voluminous literature has been produced attempting to estimate the demand for money. The model employs a standard demand function,

$$(1) \quad \frac{M^d}{P} = f(i_m, y, \dot{P}),$$

where $(\frac{M^d}{P})$ represents real money demand, considered to be a negative function of an

¹The monetary aggregate (intermediate) targeting strategy was officially adopted in early 1970. However, the implementation of many of the details of the new strategy occurred with a lag. Thus, the sample begins in 1972:I. For a discussion of the process by which the Fed adopted the new strategy, see Maisel (1973, pp.228-54). In July 1993 the Fed officially announced that it had abandoned monetary targeting in favor of "equilibrium real interest rate" targeting. On the assumption that the Fed had already abandoned monetary targeting at the time of the announcement, 1993:I is chosen as the end point of the sample. (Indeed, some would argue that the Fed had *de facto* abandoned monetary targeting much earlier, even as early as 1982.)

opportunity cost variable (i_m), a positive function of a variable representing the scale of real economic activity (y), and a negative function of the inflation rate ($\dot{P}$).²

Following the usual procedure used in empirical work on money demand, the underlying functional form of the theoretical money demand equation is specified as

$$(2) \quad \left(\frac{M^d}{P}\right)_t = \gamma y^{\alpha_1}_t i_m^{\alpha_2}_t \dot{P}^{\alpha_3}_t \xi_t,$$

where γ is a constant and ξ is a disturbance term. As noted above, the definition of money is M1; the scale variable is real GDP, and inflation is represented by the annualized rate of change in the consumer price index. The opportunity cost variable is defined as the interest rate spread (i_s) between the 4-6 month rate on commercial paper and the weighted average rate of return on M1.³ Logarithmic transformation of (2) then yields an expression convenient for estimation purposes:

$$(3) \quad \ln \left(\frac{M^d}{P}\right)_t = \alpha_0 + \alpha_1 \ln y_t + \alpha_2 \ln i_{s,t} + \alpha_3 \ln \dot{P}_t + \epsilon_t,$$

where $\epsilon_t = \ln \xi_t$ and the expected signs of the coefficients are $\alpha_2, \alpha_3 < 0 < \alpha_1$.

Money Supply

The supply function is based upon the conventional base-multiplier framework, traceable to Brunner (1961) and Brunner and Meltzer (1964). Brunner and Meltzer postulate a "nonlinear hypothesis" in which the money supply is expressed as a multiplicative function of a reserve aggregate (such as monetary base, total reserves, or nonborrowed reserves) and its associated

²Inflation is often, but not always, included in money demand functions. It is included here, following recent studies such as Hetzel and Mehra (1989) and Arize and Darrat (1994). Conceivably, rising inflation results in a substitution away from money toward real physical assets.

³Prior to 1980, explicit returns were rarely paid on checkable deposit accounts. Thus, money demand was normally specified as a function of the price of a substitute interest-bearing asset, with the own-price of M1 assumed to be zero. Since 1980, there has been a proliferation of deposit accounts which earn explicit (if relatively modest) rates of return. Thus, it has become a frequent--though not universal--practice more recently to represent the opportunity cost of M1 as the spread between the yield on a substitute asset (such as commercial paper) and M1's (nonzero) rate of return.

money multiplier. Following basic conceptual treatments (eg., as presented in Garfinkel and Thornton, 1991, and Rasche, 1992), the supply of narrowly defined money (M1) is given as

$$(4) \quad M1 = m_1 MB ,$$

where MB is the monetary base and m_1 is the M1 multiplier, defined as:

$$(5) \quad m_1 = \frac{1 + k}{r^r (1 + t) + e + k} .$$

The symbols used in (5)--referred to as the *component ratios* of the money multiplier--are defined as follows: $r^r = \frac{r_D D + r_T T}{D + T}$, the weighted average reserve requirement ratio for all deposits subject to reserve requirements (here, for simplicity, limited to two classes of deposits, checkable deposits or transactions deposits, denoted D, and nontransactions time deposits, T, subject to reserve requirement ratios r_D and r_T , respectively); $k = C/D$, the currency-checkable deposit ratio; $e = ER/D$, the excess reserve-checkable deposit ratio; and $t = T/D$, the time deposit-checkable deposit ratio.

The typical textbook treatment of the money supply process, given by equation (4), assumes a very stable (if not constant) multiplier that is neither (i) systematically affected by variables that impact money demand (in particular, interest rates), nor (ii) affected by variations in the Fed-determined monetary base. Similarly, the monetary base is treated an exogenous variable which varies according to Fed policies, independently from the multiplier and from money demand. In reality, the base and its associated multiplier are not free-standing, independent variables. To illustrate, note that the monetary base (MB) is composed of total reserves (TR) and currency holdings (C); further, total reserves are composed of borrowed reserves (BR) and nonborrowed reserves (NBR). Thus, since $MB = TR + C = NBR + BR + C$, variations in the monetary base may reflect not only Federal Reserve actions to alter nonborrowed reserves via open market operations, but also discount window activity of depository institutions (BR) and

currency-holding patterns of the nonbank public (C). While the Fed designs the parameters of discount borrowing (eg., by setting the discount rate), in an important sense discount window borrowing reflects reserve demands of the banking sector rather than the independent supply behavior of the Fed.⁴ Moreover, the Fed cannot directly control the public's propensity to hold assets in the form of currency rather than bank deposits. Using the monetary base as the reserve aggregate, then, runs the risk of mistakenly attributing some behavior of depository institutions and the nonbank public to Fed actions.

In order to help avoid these potential endogenous influences, nonborrowed reserves (NBR) are used as the reserve aggregate. This aggregate ostensibly better represents an independent "choice variable" for the Fed in the sense that the Fed may control the level of nonborrowed reserves supplied to the system via open market operations (Burger, 1971, p.19). Thus, using NBR in preference to MB more adequately segregates "independent" actions of the Federal Reserve into the reserve aggregate and the actions of banks and the nonbank public into the multiplier. By adjusting the monetary base and the multiplier accordingly (eg., see Rasche and Johannes, 1987, p.18), the nonlinear money supply function can be expressed in terms of nonborrowed reserves :

$$(6) \quad M1 = m_1 (MB - BR - C) = m_1 NBR ,$$

where

$$(7) \quad m_1 = \frac{1 + k}{r' (1 + t) + e - b} ,$$

and where b represents the ratio of borrowed reserves to total checkable deposits, BR/D.

Discount window borrowing is thus captured in the money supply process through the b ratio in

⁴Except under a strict borrowed reserve procedure, in which the Fed maintains a targeted level of borrowed reserves. Even then, discount borrowing may principally reflect borrowed reserve demand rather than independent supply decisions if the Fed closely gears its target to meet expected demand.

the money multiplier, while currency-holding patterns are reflected in the multiplier by the currency-deposit ratio k .⁵ Thus, equation (6) suggests that the Federal Reserve is able to alter the money supply by varying nonborrowed reserves, although the precise functional relationship between NBR and M1 depends upon the component ratios of the multiplier (r^* , k , e , t , and b).

Whereas variations in k , e , t , and b mainly reflect the behavior of depository institutions and the public, the multiplier can also be affected by Fed-induced changes in the structure of reserve requirements, represented by the weighted average reserve requirement ratio, r^* .

Fortunately, an additional adjustment can be made to separate the effects of changes in reserve requirements out of the multiplier and subsume them instead into nonborrowed reserves. Doing so has the effect of combining two major monetary policy tools--open market operations and changes in reserve requirements--into the reserve aggregate, thereby leaving the multiplier to reflect mainly the behavior of banks and the nonbank public (Rasche and Johannes, 1987, p.11). In other words, making this adjustment presumably better separates the "exogenous" actions of the Fed (open market operations and reserve requirement settings) from the "endogenous" influences operating through the money multiplier. It is accomplished via the Reserve Adjustment Magnitude (RAM):

$$(8) \quad RAM = (\bar{r}^* - r_t^*)' Dep_t,$$

where $\bar{r}^*$ is a vector of all reserve requirement ratios set by the Federal Reserve during a chosen base period, r_t^* is a vector of reserve requirement ratios set at time t , and Dep_t is a vector reflecting the distribution of all deposit types subject to reserve requirements at time t . RAM is then added to nonborrowed reserves to obtain adjusted nonborrowed reserves (NBR^a):

$$(9) \quad NBR^a = NBR + RAM.$$

⁵This isolation into respective spheres is not complete, of course. For example, changes in the discount rate engineered by the Fed may affect the borrowed reserve ratio, b .

Thus, during the base or reference period, $RAM=0$. If the Fed subsequently raises reserve requirement ratios relative to $\bar{r}^*$, RAM falls and the level of available reserves falls; if the Fed lowers reserve requirements, RAM increases and more reserves become available to the system (Haslag and Hein, 1992, pp.433-34; Garfinkel and Thornton, 1991, p.49).⁶ Following this adjustment, equations (6) and (7) may be rewritten as

$$(10) \quad M1 = m_1 NBR^*,$$

and

$$(11) \quad m_1 = \frac{1 + k}{\bar{r}^* (1 + t) + e - b},$$

where $\bar{r}^* = \frac{\bar{r}_D D + \bar{r}_T T}{D + T}$, the adjusted weighted average reserve ratio. In this way, reserve requirement ratios are related to their base period values, and the multiplier is thereby made invariant to changes in reserve requirements (Brunner and Meltzer, 1990, p.378).

As a result of this adjustment, variations in the nonborrowed reserves multiplier given by (11) can be expressed as a function of variations in its remaining component ratios, k , e , t , and b . The marginal impacts on the nonborrowed reserves multiplier are $\frac{\partial m_1}{\partial k} > 0$, $\frac{\partial m_1}{\partial e} < 0$, $\frac{\partial m_1}{\partial t} < 0$, and $\frac{\partial m_1}{\partial b} > 0$. Normally, however, the component ratios of the money multiplier are treated, if not as constants, at least as highly stable variables. This leads as a corollary to the treatment of the multiplier as a constant (or a highly stable variable that may be approximated as a constant). In this way, the behavior of a reserve aggregate like nonborrowed reserves--an aggregate presumably determined exogenously by the Fed--is the preeminent determinant of variations in the money supply, since the multiplier itself is an approximately constant value.

⁶Shifting of assets among deposit classes that are subject to different reserve requirements may also affect RAM , and therefore adjusted nonborrowed reserves, even if the Fed does not change reserve requirements. While the exact extent of the impact of deposit shifting is unclear, the evidence suggests that the principal determinant of variations in RAM are reserve requirement changes, and that the impact of deposit shifting on RAM is of "second order magnitude" (Haslag and Hein, 1992, p. 434).

In recent years, however, the M1 multiplier has evidenced less stable behavior, thereby casting doubt on the ability of the Fed to control the money supply with desired precision. This has provoked a number of studies analyzing the various component ratios as potential sources of observed multiplier variability. Garfinkel and Thornton (1991) and Gauger and Black (1991) found that most of the variability of the M1 multiplier was traceable to the behavior of the dominant component ratio within the M1 multiplier, the currency-deposit ratio k . Closer examination of k revealed that its own variability primarily reflected fluctuations in deposits; in contrast, currency exhibited a slow and stable pattern of growth.

One potential source of the observed fluctuations in deposits is increased substitutability between checkable deposits and non-M1 assets and a concomitant increase in interest rate sensitivity of checkable deposits to returns on non-M1 assets. Thus, k may be positively related to the opportunity cost variable, represented by a market rate of interest i_m or, more precisely, the interest rate spread (i_s), defined above. This is because, as the opportunity cost of holding checkable deposits increases, there may conceivably be a shift out of such deposits, while currency tends to remain essentially unaffected; consequently, the k ratio rises.⁷

In addition to its potential impact on k , interest rates may affect the excess reserve ratio (e), the borrowed reserve ratio (b), and the time deposit ratio (t). As a result, e , b , and t may also experience fluctuations leading to greater variability in the multiplier (although these ratios are substantially less significant components of the multiplier than k).⁸ Theoretically, as interest rates

⁷Cyclical factors may also impact the k ratio, thereby creating cyclical variability in the multiplier. This point was noted, but not formally addressed, by Brunner and Meltzer (1964, p. 274). Some preliminary evidence has been marshalled in support of a systematic relationship between real personal income and the multiplier, operating through k ; see Gauger (1995, p.11).

⁸In reality, e , b , and t tend to be small and have little impact on the multiplier. For instance, Gauger and Black (1991, p.680) observe that "since the emergence of a highly organized federal funds market, excess reserves generally behave as an autoregressive process [and] comprise such a small portion of reserves and of the denominator [of the multiplier]...that the impact upon the multiplier of excess reserve volatility is minimal." Much the same can be said for the borrowed reserve ratio, although its responsiveness to the Fed

rise, the excess reserve ratio may fall as banks attempt to minimize holdings of excess reserves in order to increase lending (Teigen, 1964, p.481; Baye and Jansen, 1995, p.484). Similarly, as interest rates rise, banks may attempt to obtain more reserves for the purpose of expanding their loan portfolios. One source of such reserves is the Fed's discount window. As the market rate of interest rises (holding the discount rate constant), it becomes more attractive for banks to obtain more borrowed reserves (Burger, 1971, p.67). Finally, the t ratio may be subject to variations in i_s , although the impact may be more ambiguous (see Burger, 1971, pp.73-78). Following Burger (p.75), it is assumed that the substitution between time deposits and higher-earning, non-money assets dominates the substitution of demand deposits to higher-earning assets following changes in i_s . Thus, variations in the endogenously-determined opportunity cost variable i_s , by impacting the component ratios k , e , b , and t , may cause endogenous influences on the money supply via the money multiplier (although as an empirical matter, most of the observed variability in the M1 multiplier has operated through k). The postulated marginal impacts of the opportunity cost variable on the components ratios are $\frac{\partial k}{\partial i_s} > 0$, $\frac{\partial e}{\partial i_s} < 0$, $\frac{\partial t}{\partial i_s} < 0$, and $\frac{\partial b}{\partial i_s} > 0$.

The component ratios e and b may also be impacted by variations in the discount rate, DR. First, as the discount rate increases (decreases), *ceteris paribus*, the e ratio may rise (fall) as banks seek to hold more excess reserves as a buffer against a potential shortfall in its reserves that would otherwise require borrowing at the discount window at the new, higher discount rate. Second, as the discount rate rises (falls), the b ratio may fall (rise) as it becomes relatively more (less) expensive to borrow from the Fed. Thus, by operating through e and b , the discount rate

funds rate-discount rate spread may be substantial when the spread is positive and discount lending is not rationed by the Fed. See Rasche (1992, p. 45). Finally, t represents the ratio of time deposits subject to reserve requirements, which are a relatively small part of total time deposits; in fact, all reserve requirements on time deposits were eliminated in December 1990 (Garfinkel and Thornton, 1991, p.48n). Thus, while e , b , and t may all theoretically impact the multiplier, most of the observed variability in the M1 multiplier has operated through the currency-deposit ratio, k .

may be negatively related to the money multiplier and thus, by extension, the money supply.⁹ The postulated marginal impacts of the discount rate on e and b are $\frac{\partial e}{\partial DR} > 0$ and $\frac{\partial b}{\partial DR} < 0$

Given then the possible influences of i_t and DR on the money multiplier, equation (10) may be rewritten as

$$(12) \quad M1 = m_1 [k(i_t), e(i_t, DR), b(i_t, DR)] NBR^s,$$

with the hypothesized relations $\frac{\partial M1}{\partial m_1} > 0$, $\frac{\partial M1}{\partial NBR^s} > 0$, $\frac{\partial m_1}{\partial i_t} > 0$, and $\frac{\partial m_1}{\partial DR} < 0$. From (12), an estimable log linear money supply equation is specified:

$$(13) \quad \ln M^s_t = \beta_0 + \beta_1 \ln NBR^s_t + \beta_2 \ln i_{t-1} + \beta_3 \ln DR_t + \eta_t,$$

where the expected signs of β_1 and β_2 are positive and β_3 is expected to be negative.

The Demand for Nonborrowed Reserves

It is typically assumed in empirical monetary studies that the Federal Reserve exogenously controls, if not the money supply, then certainly a reserve aggregate such as adjusted nonborrowed reserves. In the present case, this would mean that NBR^s in (13) is assumed, *a priori*, to be exogenous. As a result, the interplay of the demand for and supply of nonborrowed reserves is ignored, since it is assumed that the observed quantity of nonborrowed reserves is determined by the Fed's supply decisions, regardless of the demand for nonborrowed reserves. This assumption is normally justified on the basis that, in principal, the Fed has the ability to manipulate at will (via open market operations) the level of nonborrowed reserves, independently from developments on the demand side. If true, the model is closed with the inclusion of the identities

$$(14) \quad \ln \left(\frac{M^d}{P} \right)_t = \ln M^d_t - \ln P_t$$

$$(15) \quad \ln M^d_t = \ln M^s_t,$$

⁹Once again, as an empirical matter, the impact of the discount rate on the multiplier tends to be very small because e and b tend to be small. See footnote 8.

where (14) makes explicit the relationship between real and nominal money demand, and (15) is an equilibrium condition expressing the usual assumption of continuous market clearing in the money market. The model then consists of four endogenous variables (M^d , M^s , M^d/P , and i) and five predetermined variables (y , P , $\dot{P}$, NBR^a , and DR). It can be shown that both the demand equation (3) and the supply equation (13) are identified (more specifically, overidentified) and thus estimable according to the rank and order conditions.

However, as outlined in Chapter 2, in practice the Fed normally uses operating procedures that are, to varying degrees, accommodative of reserve demand. This may call into question the presumption of nonborrowed reserves as a predetermined variable. Now, accommodation alone is insufficient to render reserves endogenous in a money demand-money supply model. Even if the supply of reserves is fully subordinated to reserve demand, so long as there is no linkage with *money* demand, it is possible that the observed level of reserves is exogenously determined with respect to a money *supply* function such as the one given in equation (13). However, the absence of such a linkage is highly unlikely. Since the very existence of reserves derives from the need of depository institutions to maintain in highly liquid form a fraction of their deposit liabilities (liabilities which, viewed from the assets side, constitute the bulk of what is regarded as "money"), the demand for reserves can scarcely be considered to vary independently from developments in the money market. If for this reason nonborrowed reserves are in fact endogenous, the model outlined thus far becomes one with four equations and *five* unknowns. The simple demand equation (3) and supply equation (13) each violate the rank condition for identification; consequently, it is impossible to estimate the structural parameters of these equations without augmenting the model with other information (such as adding additional predetermined variables to the equations or imposing restrictions on the model). Moreover, even if additional information

is brought into the model to identify the equations, treating adjusted nonborrowed reserves as a predetermined variable when it is in fact endogenous introduces simultaneous equations bias.

One way the model may be improved to avoid these potential difficulties is if the nonborrowed reserves variable is explicitly endogenized and explained. There are three potential advantages to such an approach. First, adding an equation(s) to explain nonborrowed reserves may introduce additional information (i.e., other predetermined variables) into the model that can help identify money demand and money supply. In so doing, the information is brought in via other structural equations rather than arbitrary inclusion of additional predetermined variables (such as lagged values of existing variables) or model restrictions. Thus, identification may be achieved in a theoretically satisfying manner. Second, whereas the potential simultaneous equations bias traceable to endogenous reserves can be corrected through a single equation instrumental variables method such as 2SLS, a more efficient estimation technique such as 3SLS requires that the structure of the entire model be specified. In that case, at least one additional equation must be added to explain the behavior of nonborrowed reserves. Finally, and perhaps most importantly, adding equation(s) brings into the model interesting information regarding the money supply process that is normally ignored, namely, the behavior of the Fed *vis a vis* the Federal funds market. The Fed funds market is the market for bank deposits held for reserve purposes by banks; the price of borrowing Federal funds is the Federal funds rate (FFR). The Fed funds market is thus the market for nonborrowed reserves--i.e., reserves other than those obtained at the discount window. Intervention in the Fed funds market by the central bank is a central feature of the U.S. money supply process. As summarized by Carlson, et al. (1995),

[t]he Federal Open Market Committee (FOMC), the main policymaking arm of the Federal Reserve System, communicates an objective for the fed funds rate in a directive to the [Open Market] Trading Desk....Actions taken to change an intended level of the fed funds rate are motivated by a desire to accomplish ultimate policy objectives, especially price stability. Permanent changes in the fed funds rate level are thus the consequence of deliberate policy decisions....

Indeed, over most of the post-World War II period, the fed funds rate or its equivalent has been the Fed's policy instrument (p.20).

All of this institutional detail, including an explanation of the policy objectives of the monetary authority, is lost if nonborrowed reserves are treated as exogenously determined. For each of these reasons, then, the discussion turns to augmenting the model to explain the behavior of the endogenously determined level of nonborrowed reserves.

The first step in an expanded model is the specification of a demand function for nonborrowed reserves. The following general demand equation is postulated:

$$(16) \quad \text{NBR}^d = f(\text{FFR}, \text{DR}, \text{M}^d).$$

First, it is assumed that the demand for nonborrowed reserves is negatively related to the price of obtaining them, the Fed funds rate (FFR). Second, the demand for nonborrowed reserves is assumed to be positively related to the discount rate (DR), i.e., the price of the substitute good, borrowed reserves. Third, as observed above, the main purpose of holding reserves is for meeting reserve requirements. Thus, it is assumed that the demand for nonborrowed reserves is positively related to the nominal demand for money (M^d). This follows Thornton (1988, p.34n), who observes that "the demand for required reserves can be thought of as a derived demand, derived from the demand for money via the relationship between checkable deposits and required reserves."¹⁰ In other words, while the literature typically models a one-way avenue of causation from reserves to money, it is here postulated explicitly that there exists bi-directional causality between money and reserves.

While the underlying behavioral expression for nonborrowed reserves demand is given by equation (16), this variable must also account for the fact that the nonborrowed reserves aggregate in the money supply equation (13) is *adjusted* nonborrowed reserves. That is, (16) must be

¹⁰See also Gilbert (1994, p.57) and Carlson, et al. (1995, p.22).

adjusted to account for the inclusion of the reserve adjustment magnitude, RAM. From equation (9) it can be seen that $NBR \equiv NBR^a - RAM$; substituting into (16) yields

$$(17) \quad NBR^a - RAM = f(FFR, DR, M^d).$$

Thus, an operational expression convenient for estimation purposes is given by (18):

$$(18) \quad \ln NBR_t^a = \gamma_0 + \gamma_1 \ln M_t^d + \gamma_2 \ln FFR_t + \gamma_3 \ln DR_t + \gamma_4 RAM_t + \mu_t.$$

Expected signs for the coefficients are $\gamma_1 > 0$, $\gamma_2 < 0$, $\gamma_3 > 0$, $\gamma_4 > 0$.¹¹

The Supply of Nonborrowed Reserves

The supply of nonborrowed reserves is assumed to be dependent upon the operating target chosen by the Fed, OT:

$$(19) \quad NBR^s = f(OT).$$

As discussed in Chapter 2, there were three distinct operating procedures ostensibly followed by the Federal Reserve over the period 1970-93: (i) a Fed funds procedure (1970-79), (ii) a nonborrowed reserves procedure (1979-82), and (iii) a borrowed reserves procedure (1982-93).

To the extent the Fed strictly adhered to the stated operating procedures, the variable OT in equation (19) is FFR^T for the first period, NBR^T for the second period, and BR^T for the third period, or:

$$(19a) \quad NBR^s = f(FFR^T) \quad (\text{Fed funds rate targeting period})$$

$$(19b) \quad NBR^s = NBR^T \quad (\text{Nonborrowed reserves targeting period})$$

$$(19c) \quad NBR^s = f(BR^T) \quad (\text{Borrowed reserves targeting period}).$$

In (19a), the Fed accommodates shifts in the demand for NBR^s in order to maintain a given FFR target (see Figure 2). In this case the "supply" of nonborrowed reserves becomes effectively

¹¹Ideally, the RAM variable should be expressed in log form with its coefficient restricted equal to unity. However, since there are negative values of RAM, the log of RAM is undefined for many observations. Thus, RAM is entered unlogged without parameter restriction.

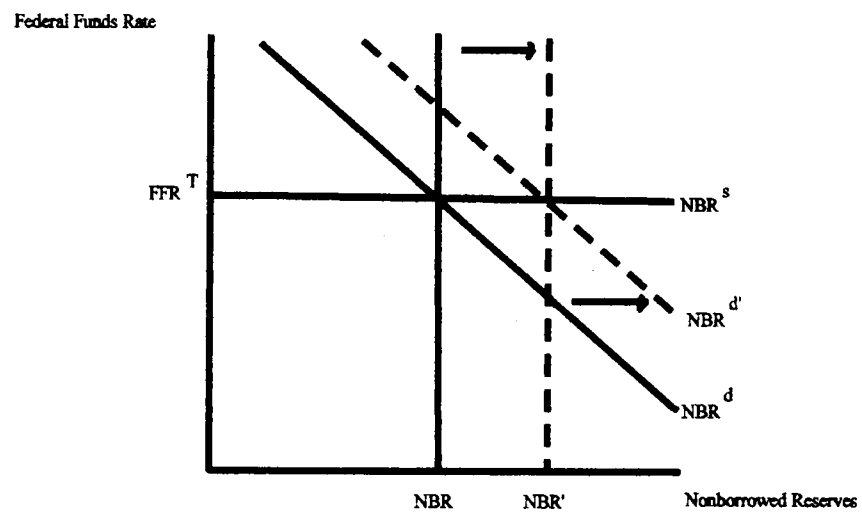


Figure 2. Strict Federal Funds Rate Targeting.

horizontal at the targeted Fed funds rate.¹² In (19b), the Fed holds fast to a given level of NBR^a (NBR^T) regardless of the behavior of reserve demand (see Figure 3). In (19c), how the Fed decides to accommodate shifts in reserve demand is dependent upon whether it is willing to allow the Fed funds rate to fluctuate. Under a borrowed reserves procedure, if the Fed funds rate-discount rate spread is positive, an increase in total reserve demand places upward pressure on discount window borrowing. If the Fed holds fast to its targeted level of borrowed reserves, it forces banks to meet all of the increase in reserve demand in the Fed funds market. As a result, the Fed funds rate will edge upward. If the Fed does not wish to allow the funds rate to rise, it must respond by supplying additional reserves to the Fed funds market via open market operations.

Two important issues arise in the development of an empirical counterpart to (19). First, unlike the money demand, money supply, and nonborrowed reserve demand equations developed above, strictly speaking not one but *three* different supply equations would be required over the full sample to account for regime shifts. That is, if the Fed assiduously adhered to *different* operating procedures over the 1970-93 period, the model should not be estimated for the entire period using the *same* reserve supply equation. The ideal solution would be to estimate the model separately for the Fed funds rate period, the nonborrowed reserve period, and the borrowed reserves period. However, doing so would reduce available degrees of freedom when quarterly data are used, particularly with respect to the nonborrowed reserves targeting period (1979:IV-1982:III). Secondly, there is the issue as to *how* assiduously the Fed actually adhered to its *stated* operating procedures. Were there three distinct operating regimes *in practice*? Interestingly, most observers agree that the borrowed reserves procedure that replaced NBR targeting in 1982

¹²For evidence that the supply of nonborrowed reserves was approximately horizontal over the Fed funds rate targeting period, see Bermanke and Blinder (1992, pp.914-16).

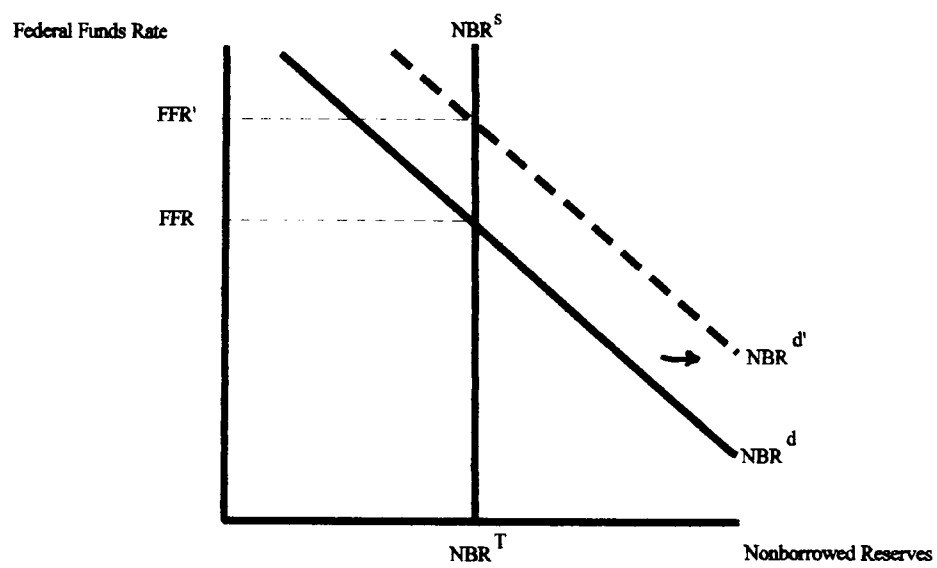


Figure 3. Strict Nonborrowed Reserves Targeting.

has *not* been, in practice, very different from a Fed funds targeting procedure. This is because, as noted above, a strict borrowed reserves procedure requires that the Fed be willing to allow the funds rate to vary according to shifts in the demand for total reserves. In practice, the Fed has tended to be reluctant to let the funds rate vary, and instead has been tolerant of deviations from its borrowed reserves target (Feinman, 1993, p.245). Thus, the borrowed reserve procedure closely approximates a Fed funds rate procedure, albeit an indirect or "noisy" one. See, for example, Roberds (1992, p.14), Walsh (1990, pp.16-18), Lombra and Kaufman (1992, p.238), Goodfriend (1993, pp.3-4), Broadbuss (1995, p.3), Thornton (1988), Rudebusch (1995a), and Carlson, et al. (1995).¹³ As a result, a convenient maintained hypothesis is that the Fed effectively followed a Fed funds rate operating procedure over *both* the 1970-79 and 1982-93 periods. This allows one to simplify the model by dropping equation (19c).

It is less clear whether such a simplification can be extended to cover the nonborrowed reserves targeting period 1979-82. Most observers agree that, although the Fed did not always adhere strictly to its nonborrowed reserve targets during the 1979-82 period, the nonborrowed reserves period nevertheless represented a distinct structural break with respect to the Fed funds rate procedure. However, in a detailed examination of the Fed's policy actions over the period, Cook (1989) concluded that only about one-third of the variation in the Fed funds rate was attributable to automatic adjustments to the ostensibly rigid nonborrowed reserve targets. Rather, Cook attributed most of the variation in the funds rate to deliberate judgmental adjustments by the

¹³Poole (1990, p.38) asserts that the Fed "knows that borrowed reserves are, from the standpoint of economics, a silly policy target. The system is purely and simply a cover for controlling the federal funds rate, although that control is somewhat less tight than during the 1970s. A formal analysis shows that the borrowed reserves procedure provides noisy interest rate control, but only to the extent that the Federal Reserve is willing to see interest rates move."

A dissenting opinion is given by Cosimano and Sheehan (1994), who found evidence using VARs that, at least initially, the Fed followed a true borrowed reserve procedure. However, they note that at around the time of the 1987 stock market crash, the Fed's operating procedure began to approximate a Fed funds regime. The authors admit, moreover, that their results "indicate the difficulty of distinguishing between a Federal Funds rate procedure and a Borrowed Reserve procedure" (Cosimano and Sheehan, 1994, p.586).

Fed. Roberds (1992, p.14) observes that "if this estimate is even approximately correct, then the distinction between the open market policies in the NBR and fed funds rate targeting periods is perhaps best characterized as quantitative rather than qualitative." As a result, the 1979-82 may perhaps more accurately regarded as an "aggressive Fed funds rate targeting period" rather than a true nonborrowed reserves regime (Goodfriend, 1993, p.4).

Thus, at least as a first approximation, this study will also treat the 1979-82 period as if characterized by a Fed funds rate regime. This allows one to simplify the model further by dropping equation (19b). Therefore, equation (19a) will be utilized to represent the Fed's operating procedure and the concomitant behavior of NBR supply. If then the Fed *exogenously* controls the Fed funds rate, NBR supply becomes perfectly elastic, i.e., fully accommodates all shifts in NBR demand, and the nonborrowed reserves market can be characterized, for empirical purposes, by equation (18) above (noting that the equilibrium condition of continuous market clearing in the nonborrowed reserves market yields the identity $\ln NBR^s_t = \ln NBR^d_t$).

However, specifying an *exogenous* Fed funds rate may be too restrictive. Regardless of operating procedure utilized, the Fed rarely maintains a completely rigid value of its targeted variable. As noted by Carlson, et al. (1995, p.20), the Fed is not able to completely control the Fed funds rate on a daily basis (in contrast with, for instance, the institutionally dictated discount rate), but it is effectively able to do so on average such that "the monthly average is generally close to the rate specified by the FOMC." Moreover, the Fed has in the past allowed its operating target to fluctuate within (normally) a relatively narrow range (*cf.* Figure 2 with Figure 4). Thus, an additional empirical consideration concerns the fact that the Fed funds rate may be nearly, but not strictly, exogenous. As a result, equation (18) is adjusted to reflect the fact that the observed Fed funds rate is composed of its intended or targeted rate, FFR^T , plus a random disturbance term, v_t :

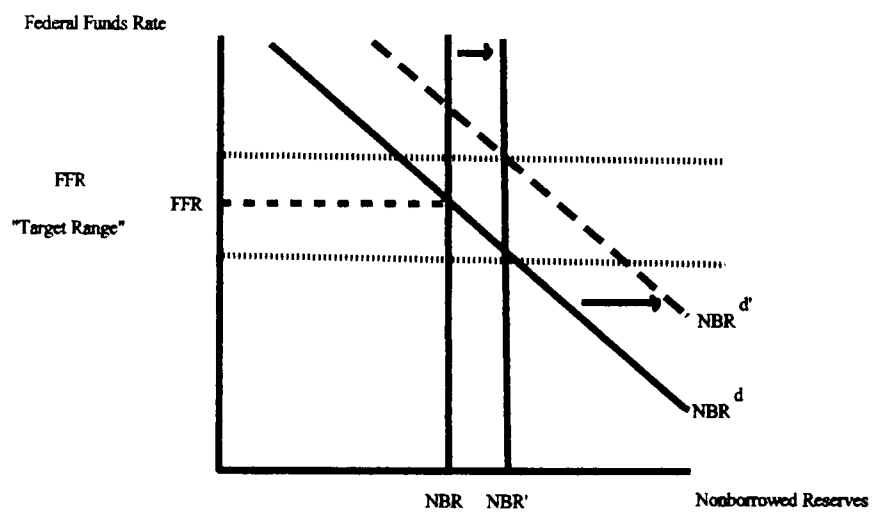


Figure 4. Federal Funds Rate Targeting and the Funds Rate Target Range.

$$(20) \quad \ln NBR \cdot \frac{d}{t} = \gamma_0 + \gamma_1 \ln M_t^d + \gamma_2 \ln (FFR^T + v)_t + \gamma_3 \ln DR_t + RAM_t + \mu_t .$$

Potential covariance between v and μ (and, through μ , with the disturbances in the money demand and supply equations) may render the Fed funds rate endogenous in (20). To deal with this potential endogeneity, an additional equation is specified that explains the variation in the observed Fed funds rate as a function of FFR^T and v . Such an equation constitutes the Fed's reaction function.

Federal Reserve Reaction Function

Given its chosen operating procedure, the Federal Open Market Committee periodically sets and resets the level of its operating target, OT. The setting of its operating target is conditioned on the Fed's information set. The relationship between the Fed's operating target and the variables which constitute its information set is referred to as the Fed's "reaction function." As discussed in Chapter 2, there are a wide variety of variables that may potentially enter the Fed's information set. While the issue is by no means settled, most reaction function studies include a fairly similar set of variables, such as real GDP growth, the inflation rate, the unemployment rate, and the growth rate of the money supply (or deviations of the actual money supply from targeted levels). Lagged values are included rather than contemporaneous values because the latter are presumably not available--except perhaps in preliminary form--at the time the Fed chooses its target settings. (As noted by McNees, 1986 and 1992, and others, the Fed may alter its operating targets based upon its *forecasts* of important macroeconomic variables. However, Fed policymakers tend to "distrust [their own] forecasts, believing (correctly) that they are often quite wide of the mark" (Lombra, 1992, p.263)).

Drawing from recent studies which have specified Fed reaction functions, principally McNees (1992), Hakes and Gamber (1992), Tanner and Devereux (1993), and Mehra (1994), the model used in the present study is "closed" with a Federal Reserve reaction function in which the

operating target is a function of lagged values of the percentage deviation of real GDP from trend ($\frac{y - y^*}{y^*}$), inflation ($\dot{P}$), the unemployment rate (UR), a real long-term bond rate ($b - \dot{P}$), and the growth rate of money ($\dot{M}$):¹⁴

$$(21) \quad OT = f \left(\left(\frac{y - y^*}{y^*} \right)_{-1}, \dot{P}_{-1}, UR_{-1}, (b - \dot{P}), \dot{M}_{-1} \right).$$

The money growth rate variable $\dot{M}_{-1}$ represents the principal indicator to the Fed of the behavior of its intermediate target. However, whereas the stated intermediate target over the period 1970-93 was money growth, the aggregate most closely followed and the intensity with which it affected policy varied over the course of the period. That is, sometime in 1982 the Fed began to deemphasize the indicator properties of M1 in favor of M2. Moreover, the Fed appears to have been most sensitive to the growth rate of money (in the sense of adjusting its operating target according to movements in observed money growth) in the "monetarist experiment" period of 1979-82; it appears to have been somewhat less sensitive to money growth in the early 1970-79 period, and even less so in the latter period (1982-93). Following McNees (1992) and Mehra (1994), the apparent variance in responsiveness to money growth is accounted for by replacing the $\dot{M}_{-1}$ variable with the variables $D1\dot{M}_{-1}$, $D2\dot{M}_{-1}$, and $D3\dot{M}_{-1}$, where $D1 = 1$ for 1972:I - 1979:III, 0 otherwise; $D2 = 1$ for 1979:IV - 1982:III, 0 otherwise; and $D3 = 1$ for 1982:IV - 1993:I, 0 otherwise.

¹⁴Variables such as $(y - y^*)/y^*$, $\dot{P}$, and UR are typically included in Fed reaction functions to represent the Fed's mandate to "foster economic stability and sustainable growth, in the continued progress over time toward price stability" (Greenspan, 1990). The real bond rate is included as an indicator of the term structure of interest rates. This variable is included on the basis that an increase (decrease) in the spread between a long term bond rates and the inflation rate may contain information about expected inflation that is not reflected in the actual inflation rate (Mehra, 1994, p. 7). Thus, increases in this variable may induce the Fed to attempt to combat inflationary expectations by increasing the funds rate. Following Mehra, the real bond rate is entered contemporaneously. Finally, lagged $\dot{M}$ is included to account for the Fed's keen interest in the behavior of its intermediate target, the growth rate of the money supply. An increase (decrease) in the growth rate of past observed money may induce the Fed to attempt to tighten (loosen) monetary policy by increasing (decreasing) the Fed funds rate.

Given the discussion in the preceding subsection regarding the appropriate specification of the Fed's operating procedure, the variable OT in (21) is assumed to be the Fed funds rate target, FFR^T . Since, from (20), $FFR = FFR^T + v$, the Fed's target variable can be expressed as $FFR^T = FFR - v$. Substituting the latter on the left hand side of (21), rearranging, and adjusting the $\dot{M}_1$ variable as outlined above, yields

$$(22) \quad FFR = f \left(\left(\frac{y - y^*}{y^*} \right)_{t-1}, \dot{P}_{t-1}, UR_{t-1}, (b - \dot{P}), D1\dot{M}_{1,t-1}, D2\dot{M}_{1,t-1}, D3\dot{M}_{2,t-1} \right) + v.$$

Thus, from (22), a convenient empirical representation of the Fed's reaction function is obtainable:

$$(23) \quad \ln FFR_t = \delta_0 + \delta_1 (\ln y - \ln y^*)_{t-1} + \delta_2 \ln \dot{P}_{t-1} + \delta_3 \ln UR_{t-1} + \delta_4 \ln (b - \dot{P})_t \\ + \delta_5 D1\dot{M}_{1,t-1} + \delta_6 D2\dot{M}_{1,t-1} + \delta_7 D3\dot{M}_{2,t-1} + \varpi_t,$$

where $\varpi_t = \ln v_t$. The expected signs of the parameters in (23) are $\delta_1 > 0$, $\delta_2 > 0$, $\delta_3 < 0$, $\delta_4 > 0$, $\delta_5 > 0$, $\delta_6 > 0$, and $\delta_7 > 0$. The only endogenous variable in (23) is the funds rate; hence, the equation representing the Fed reaction function is recursive with respect to the remainder of the model. That is, unlike equations (3), (13), and (20) of the model, the Federal Reserve reaction function equation (23) only feeds into the model with no systematic feedback from the other equations to the reaction function.

Thus, the basic empirical model consists of the behavioral equations (3), (13), (20), and (23), plus the money market identities given by (14) and (15) and the adjusted nonborrowed reserves identity given by (24):

$$(24) \quad \ln NBR^{ad}_t = \ln NBR^{ns}_t.$$

In present form, all variables are expressed in levels. Since many macroeconomic data series are nonstationary in levels (i.e., do not have constant means and finite variances), application of classical regression methods to the equations outlined above runs the risk of obtaining spurious inferences. Results of unit root tests suggest that the data may be characterized as stationary in

first difference form.¹⁵ Consequently, each data series is first differenced to induce stationarity.¹⁶ For convenient reference, the expanded model of the monetary sector is given in Table 1. It can be shown that the behavioral equations are all identified (more specifically, overidentified) according to the rank and order conditions.

Estimation Strategy

The expanded model of the monetary sector, outlined above and summarized in Table 1, serves as the basic framework for empirical analysis. The next chapter reports econometric estimates obtained from the expanded model, as well as from restricted versions of the model. First, a restricted version is estimated that allows simple comparisons between single equation estimates and simultaneous equation estimates of money demand and supply. This submodel imposes a constant-parameter restriction for the full sample period 1972:I-1993:I. Next, the simple two equation money demand-supply model is estimated using a simultaneous equations technique, but with parameters allowed to vary across the full period according to the different stated Federal Reserve operating procedures. Formal tests of structural stability will then help to assess whether money demand and money supply have exhibited instability over the full sample period. Finally, the unrestricted expanded model of the monetary sector is estimated, again allowing parameters to change across the three Fed regime subperiods (1972:I-1979:III, 1979:IV-1982:III, 1982:IV-1993:I). Again, tests for structural stability will be utilized to assess the stability of the four behavioral equations that are estimated.

¹⁵Results of unit root tests on the data are given in Appendix B.

¹⁶One exception is deviation of real GDP from trend ($\ln y - \ln y^*$), which is expressed in level form. Unit root tests on this variable suggest that this variable is $I(0)$ --i.e., stationary in level form--and estimation results using the variable in first-difference form generate peculiar results suggestive of overdifferencing. Some evidence also suggests that the log of the unemployment rate ($\ln UR$) and M2 growth ($D3 M2$) may also be $I(0)$ variables. However, the evidence is somewhat weaker for these variables; consequently, they will be treated as $I(1)$ and first-differenced along with the rest of the data.

TABLE 1
Expanded Model of the Monetary Sector

Money Demand: (3) $\Delta \ln \left(\frac{M^d}{P} \right)_t = \alpha_0 + \alpha_1 \Delta \ln y_t + \alpha_2 \Delta \ln i_{t-1} + \alpha_3 \Delta \ln \dot{P}_t + \epsilon_t$

Money Supply: (13) $\Delta \ln M^s_t = \beta_0 + \beta_1 \Delta \ln NBR^{ss}_t + \beta_2 \Delta \ln i_{t-1} + \beta_3 \Delta \ln DR_t + \eta_t$

NBR Demand: (20) $\Delta \ln NBR^{sd}_t = \gamma_0 + \gamma_1 \Delta \ln M^d_t + \gamma_2 \Delta \ln FFR_t + \gamma_3 \Delta \ln DR_t$
 $+ \gamma_4 \Delta \ln RAM_t + \mu_t$

Reaction Function: (23) $\Delta \ln FFR_t = \delta_0 + \delta_1 (\ln y - \ln y^*)_{t-1} + \delta_2 \Delta \ln \dot{P}_{t-1} + \delta_3 \Delta \ln UR_{t-1} + \delta_4 \Delta (b - \dot{P})_t$
 $+ \delta_5 \Delta D1M1_{t-1} + \delta_6 \Delta D2M1_{t-1} + \delta_7 \Delta D3M2_{t-1} + \varpi_t$

Identity: (14) $\Delta \ln \left(\frac{M^d}{P} \right)_t \equiv \Delta \ln M^d_t - \Delta \ln P_t$

Identity: (15) $\Delta \ln M^d_t \equiv \Delta \ln M^s_t$

Identity: (24) $\Delta \ln NBR^{sd}_t \equiv \Delta \ln NBR^{ss}_t$

Endogenous Variables: $\frac{M^d}{P}, M^d, M^s, i_{ss}, NBR^{sd}, NBR^{ss}, FFR$

Expected Signs of Parameters: $\alpha_2 < 0 < \alpha_1, \alpha_3; \beta_2 < 0 < \beta_1, \beta_3; \gamma_2 < 0 < \gamma_1, \gamma_3, \gamma_4;$
 $\delta_3 < 0 < \delta_1, \delta_2, \delta_4, \delta_5, \delta_6, \delta_7$

The simultaneous equations techniques used in this study is three stage least squares (3SLS). The 3SLS procedure takes into account cross-equation correlation of structural disturbances. In contrast, two stage least squares (2SLS) is a single equation instrumental variables method that does not account for cross-equation disturbances. As a result, 3SLS estimates are asymptotically more efficient than 2SLS estimates. A potential drawback to 3SLS estimation is that any misspecification bias in one equation of the structural model is transmitted across the entire model. The 2SLS technique, since it does not require that the entire model be estimated to obtain estimates, does not suffer from this problem. However, the expanded model developed above assumes that the systematic and random behavior of money, reserves, and Fed policies are closely linked. Thus, random disturbances are not viewed as possibly related across a set of seemingly unrelated equations, but rather as very likely related across a closely linked set of structural equations. As a result, this study utilizes 3SLS as the appropriate simultaneous equations estimation procedure.

Summary

This chapter has outlined an expanded model of the monetary sector that takes explicit account of interactions between the money market, the nonborrowed reserves market, and Federal Reserve policies. In the first section, the theoretical model and its operational counterpart were detailed. In the second section, the estimation strategy was briefly discussed. Empirical findings are reported in the next chapter.

CHAPTER 4

FINDINGS

This chapter presents empirical findings obtained for restricted and unrestricted versions of the structural monetary model outlined in Chapter 3. The chapter is divided into three sections. The first section reports "benchmark" estimates of a simple two equation money demand-money supply model. These estimates embody the restriction of exogenous reserves in the supply equation and thereby accord with prior studies--discussed in Chapter 2--that treat money demand and money supply as a simultaneous system of equations. The first benchmark estimates reported assume constant parameters over the full sample period (1972:I-1993:I). Next, the extent to which parameter estimates differ across subperiods corresponding to different stated operating procedures is examined. Structural stability of money demand and money supply is assessed using the interactive dummy variable method. The method, detailed below, allows one to construct formal tests of overall stability of the estimating equations. The method also allows for an assessment of parameter stability for individual variables within each equation.

Principal findings are reported in the second section of the chapter. The second section reports estimation results of the unrestricted version of the expanded model constructed in Chapter 3. The model is unrestricted in the sense that (i) the assumption of exogenous reserves is relaxed, and (ii) parameter estimates are allowed to vary over the three relevant operating regime subperiods. Tests of structural stability are conducted, again using the interactive dummy variable approach. Findings of this section indicate that M1 money demand and supply have been structurally unstable over 1972:I-1993:I. This is in line with most research, particularly with respect to the frequently estimated demand equation. However, findings in this section do not indicate structural instability in the nonborrowed reserve demand and Fed reaction function equations. The third section provides an assessment of chapter findings.

**Benchmark Estimates:
Money Demand-Money Supply System with Exogenous Nonborrowed Reserves**

Chapter 2 contained a review of the relatively sparse body of literature which attempted to estimate money demand and money supply as a system of equations. It was observed that these studies primarily use pre-1970 data. Since numerous changes in the monetary sector have occurred over the past quarter century, it is useful to begin the empirical analysis by providing updated system estimates of conventional money demand and money supply equations using post-1970 data.

An expanded model of the monetary sector was specified in Chapter 3 in which money, reserves, and Fed policies were all endogenously determined. In contrast, previous studies such as Brunner and Meltzer (1964) and Teigen (1964) treated the reserve supply behavior and Fed policies as exogenous variables. This section reports updated estimates by placing restrictions on the expanded model so that it is in closer accord with prior studies. Estimates for the expanded (unrestricted) model follow this section.

Benchmark Model I: Ordinary Least Squares vs. Three Stage Least Squares

The restricted model is specified as follows:

- (1) $\Delta \ln \frac{M^d}{P}_t = \alpha_0 + \alpha_1 \Delta \ln y_t + \alpha_2 \Delta \ln i_{s,t} + \alpha_3 \Delta \ln \dot{P}_t + \alpha_4 \Delta \ln \frac{M^d}{P}_{t-1} + \epsilon_t$
- (2) $\Delta \ln M^s_t = \beta_0 + \beta_1 \Delta \ln NBR^s_t + \beta_2 \Delta \ln i_{s,t} + \beta_3 \Delta \ln DR_t + \beta_4 \Delta \ln M^s_{t-1} + \eta_t$
- (3) $\Delta \ln \frac{M^d}{P}_t = \Delta \ln M^d_t - \Delta \ln P_t$
- (4) $\Delta \ln M^d_t = \Delta \ln M^s_t$

As discussed in Chapter 3, the expected signs of the parameters are as follows: For real money demand, $\alpha_2, \alpha_3 < 0 < \alpha_1$; for nominal money supply, $\beta_3 < 0 < \beta_1, \beta_2$. (Lagged dependent variables are also included in equations (1) and (2) since previous studies often attempted to account for potential lagged adjustment by inclusion of lagged dependent variables in one or both of the equations. The expected signs of α_4 and β_4 are both positive.) The endogenous variables

are the first-differenced log values of real money demand ($\frac{M^d}{P}$), nominal money demand (M^d), nominal money supply (M^s), and an interest rate spread given by the commercial paper rate less the return on M1 (i_s). The predetermined variables are the first-differenced log values of adjusted nonborrowed reserves (NBR^a), real GDP (y), the discount rate (DR), the GDP deflator (P), inflation ($\dot{P}$), and the lagged dependent variables in both the demand and supply equations. The *a priori* specification of the reserve aggregate as a predetermined variable thus serves to eliminate the reserve demand and Fed reaction function equations from explicit consideration. In addition, when estimated over the full sample period, the model given by equations (1) - (4) imposes the restriction of constant parameters across time.

The behavioral real money demand and nominal money supply equations (1) and (2) are first estimated using both ordinary least squares (OLS) and three stage least squares (3SLS) over the full sample period (1972:1-1993:1).¹ Results are reported in Table 2. Table 2a reports OLS and 3SLS estimates of real money demand in columns 1 and 2, respectively. The OLS estimates of money demand, at first glance, accord with prior expectations. The principal explanatory variables for real money demand--the scale variable (y) and the opportunity cost variable (i_s)--are both of the theoretically correct sign (positive and negative, respectively), and are statistically significant at the 10 percent level or better. In addition, inflation ($\dot{P}$) is negative and significant, in line with theory.

Are the reported OLS demand estimates also plagued with simultaneous equations bias?

To provide an informal gauge of potential bias, OLS estimates are compared with the 3SLS

¹The specification of (1) and (2) is comparable to most of the empirical studies outlined in Chapter 2. However, it is by no means suggested that the specifications of money demand and money supply under constant parameters over time sufficiently represent money demand behavior and the money supply process over the 1972-93 period. The simple restricted model is used for comparison purposes and as a base for subsequent discussion.

TABLE 2
OLS vs. 3SLS Estimates of Equations (1) and (2)

a. Equation (1): Real Money Demand, Dependent Variable = $\Delta \ln \frac{M}{P}$					
		(1)		(2)	
Variable	Parameter	OLS Estimate	Std. Error	3SLS Estimate	Asymptotic Std. Error
Constant	α_0	-0.001	0.001	-0.001	0.002
$\Delta \ln y$	α_1	0.246*	0.135	0.397**	0.153
$\Delta \ln i_s$	α_2	-0.018**	0.009	-0.053***	0.012
$\Delta \ln \dot{P}$	α_3	-0.013***	0.004	-0.009**	0.004
$\Delta \ln \left(\frac{M}{P}\right)_{-1}$	α_4	0.619***	0.089	0.611***	0.097
Adjusted R Square		0.442		---	
Durbin h		-2.469***		-7.636***	
b. Equation (2): Money Supply, Dependent Variable = $\Delta \ln M$					
Constant	β_0	-0.010***	0.002	0.010***	0.002
$\Delta \ln NBR^a$	β_1	0.064***	0.023	0.082**	0.034
$\Delta \ln i_s$	β_2	0.034***	0.010	0.053*	0.030
$\Delta \ln DR$	β_3	-0.081***	0.016	-0.100***	0.034
$\Delta \ln M_{-1}$	β_4	0.400***	0.085	0.385***	0.104
Adjusted R Square		0.427		---	
Durbin h		-0.222		1.228	
System Weighted R Square					
		---		0.493	

Notes: Durbin h is statistic for presence of first order serial correlation when lagged dependent variable is included.

* denotes significance at the 10 percent level

** denotes significance at the 5 percent level

*** denotes significance at the 1 percent level

estimates reported in column 2 of Table 2a.² Results for both OLS and 3SLS estimates are qualitatively similar with respect to the signs and statistical significance of the regressors. However, 3SLS estimation reveals stronger responses by real money to variations in real GDP and the interest rate spread than were generated using OLS. In other words, failing to account for supply side factors may lead one to obtain income and interest elasticities of money demand that are too small (in absolute value).

Turning next to money supply estimates contained in Table 2b, it is first of all striking that the estimates on each explanatory variable has the theoretically expected sign and is statistically significant at the 10 percent level or better, regardless of estimation technique. The most relevant variable with respect to potential simultaneity bias is the endogenously determined market interest rate spread, i_s . The OLS rate spread estimate ($\hat{\beta}_2$ in column 1) is presumably biased downward, reflecting a confusion of the positive impact of the interest rate on money supply with its negative impact on money demand (assuming the underlying theory is correct). Thus, one would expect 3SLS estimates of β_2 to be somewhat larger in absolute value relative to its OLS counterpart. This expectation is confirmed, as revealed in column 2.

How do these results compare to previous studies with similarly formulated models? Recall from the discussion in Chapter 2 that the principal concern of most studies is whether potential simultaneity bias is a critical issue with respect to money *demand*. Reassuringly, prior literature judged money demand estimates to be fairly robust whether estimated using single equation or simultaneous equations methods. This led to a widespread neglect of system estimation of money demand and supply on the reasoning that simultaneous equations bias, if present, was not "too serious" (see, eg., Laidler, 1993, pp.146-47). However, the findings of

²Of course, it must be stressed that although comparisons of single equation and simultaneous equations estimates may provide an *indication* of potential simultaneous equations bias, observed differences in parameter estimates do not necessarily *imply* the presence of simultaneous equations bias.

Table 2 call this conclusion into question. Estimates for money demand derived from the simple restricted model suggest that contemporaneous structural parameters on the scale variable (y) and, even more starkly, the opportunity cost variable (i_s) may be substantially underestimated (in absolute value) when using OLS. The simultaneous equations estimate of the opportunity cost variable is approximately three times greater, in absolute value, than its OLS counterpart. Thus, given the weight placed upon the magnitude of opportunity cost and scale variable elasticities in the literature, the updated estimates on money demand using the general methodology of previous studies contradict the conclusion that the simultaneity problem is not "too serious."

Benchmark Model II: System Estimates with Allowance for Parameter Change

A glaring shortcoming of the simple model outlined in equations (1) - (4) is that it forces all parameters to be constant across time. Changes in the monetary sector created considerable upheaval over the course of the post-1970 era. Sources of possible structural change over the past quarter century include changes in stated Federal Reserve operating procedures, as well as financial deregulation and innovation.³ Consequently, the restriction of constant parameters across the full sample period is highly suspect. This subsection reports results of system estimation of money demand and supply that allows for changes in parameters over time.

Following the interactive dummy variable method outlined in Johnston (1984, p.227), the demand and supply equation equations (1) and (2) above are modified as follows:

³The model assumes that the Fed funds rate serves as the *de facto* policy instrument of the Fed over the full sample period, 1972:I-1993:I. Even so, the way in which the Fed manipulates the funds rate may differ from period to period. For instance, as observed in Chapter 3, the *stated* instrument of the Fed over the period 1979:IV-1982:III was the level of nonborrowed reserves. However, the Fed did not strictly adhere to a true nonborrowed reserves procedure over that time. In fact, evidence suggests that the period may better be characterized as one of "aggressive Fed funds rate targeting." As such, both the 1972:I-1979:III and 1979:IV-1982:III periods may be characterized by *de facto* funds rate targeting, but they may still be structurally different because the latter period manipulated the funds rate with a markedly higher level of aggressiveness. Moreover, the banking system and the nonbank public's own responses may differ according to changes in *stated* in Federal Reserve operating procedures, even if the new procedures are not in practice very different.

$$\begin{aligned}
(1) \quad \Delta \ln \frac{M^d}{P}_t &= \alpha_{03} + \sum_{i=1}^2 a_{0i} D_i + \alpha_{13} \Delta \ln y_t + \sum_{i=1}^2 a_{1i} D_i \Delta \ln y_t \\
&\quad + \alpha_{23} \Delta \ln i_{s,t} + \sum_{i=1}^2 a_{2i} D_i \Delta \ln i_{s,t} + \alpha_{33} \Delta \ln \dot{P}_t + \sum_{i=1}^2 a_{3i} D_i \Delta \ln \dot{P}_t + \epsilon_t \\
(2) \quad \Delta \ln M^s_t &= \beta_{03} + \sum_{i=1}^2 b_{0i} D_i + \beta_{13} \Delta \ln NBR^s_t + \sum_{i=1}^2 b_{1i} D_i \Delta \ln NBR^s_t \\
&\quad + \beta_{23} \Delta \ln i_{s,t} + \sum_{i=1}^2 b_{2i} D_i \Delta \ln i_{s,t} + \beta_{33} \Delta \ln DR_t + \sum_{i=1}^2 b_{3i} D_i \Delta \ln DR_t + \eta_t
\end{aligned}$$

where D_i are dummy variables corresponding to periods associated with the first two of the three stated operating procedures in existence over the full sample period; i.e., $D1=1$ for 1972:I-1979:III, 0 otherwise; $D2=1$ for 1979:IV-1982:III, 0 otherwise. $D1$ thus corresponds to the Federal funds rate targeting era, while $D2$ corresponds to the nonborrowed reserves targeting era. The terms without the dummy variables correspond to the arbitrarily chosen base period, 1982:IV-1993:I, i.e., the borrowed reserves targeting era.⁴

Estimating (1') and (2') over the full period is equivalent to estimating (1) and (2) over each of the three regime subperiods separately. The parameters α_{ji} and β_{ji} represent the structural parameters of the j th variable for the i th subperiod; thus, α_{j3} and β_{j3} in equations (1') and (2') are the structural parameters associated with the j th variable for the third subperiod. The parameters a_{ji} and b_{ji} in (1') and (2') measure *differences* from the base period parameter values for the j th variable. That is, estimates of a_{j1} and b_{j1} represent the estimated differences in the parameters for the 1972:I-1979:III period relative to those for the base period, while estimates of a_{j2} and b_{j2} represent the estimated differences in the parameters for the 1979:IV-1982:III period relative to the base period. Thus, a straightforward test of overall structural stability of the money demand

⁴In the simple model given by equations (1) - (4), the real money demand and nominal money supply equations also included lagged dependent variables. As noted above, this was to facilitate comparability with previous studies. However, this approach to dynamic adjustment is a crude *ad hoc* treatment. Utilizing the lagged dependent variable imposes a "Koyck" lag adjustment scheme in which the speed of adjustment is the same for all explanatory variables and where lagged adjustment follows a smooth, geometrically declining pattern. Since there is little theoretical justification for this sort of lag structure, it is likely that estimates obtained using the lagged dependent variable for this purpose are subject to a form of misspecification bias. However, there is indeed *no* good theory of lag structure for the monetary sector. Since the principal interest of this study is focused on the contemporaneous impacts of explanatory on dependent variables, the lag structure issue is not addressed.

equation is a test of the null hypothesis $H_0: a_{1i} = a_{2i} = a_{3i} = 0$, for $i = 1, 2$. Instability is then indicated if the null is rejected at conventional levels of significance. Similarly, structural instability of the money supply equation over the full period is indicated if $H_0: b_{1i} = b_{2i} = b_{3i} = 0$, for $i = 1, 2$, is rejected.

Now, if H_0 is rejected, there is no indication as to which variable or variables serve as the likely source of structural change. An advantage of the interactive dummy variable approach is that it may help shed light on this issue, in that a statistically significant asymptotic t-statistic on an individual interactive term indicates that the parameter estimate for the variable in question is significantly different from the estimate for the base period.⁵ Moreover, the parameter estimates for the first two periods (i.e., α_{ji} and β_{ji} for all j and for $i=1,2$) are easily recoverable from the interactive dummy variable estimates. For example, $a_{11} = \alpha_{11} - \alpha_{13}$, i.e., a_{11} equals the difference between the value of the coefficient on real GDP in the demand equation for the first period (1972:I-1979:III) and the base period (1982:IV-1993:I) value. Thus, estimation of equation (1') yields both $\hat{a}_{11}$ and $\hat{\alpha}_{13}$, from which $\hat{\alpha}_{11}$ is computable.

While the choice of break points 1979:III and 1982:III is reasonable *a priori* with respect to the money supply equation, the question may be raised as to whether the same break points are relevant for money demand. Evidence in the literature points to a distinct structural break with respect to real M1 demand occurring around 1980 (see, eg., Mehra, 1989, and Goldfeld and Sichel, 1990, p.305). This structural change is normally attributed to the significant amount of

⁵It is recognized, as noted by Maddala (1992, p.319), that inferences regarding the stability of individual parameter estimates using the t-statistics on the interactive dummy terms may be misleading, since the t-statistics may be underestimated. Interpreting parameter insignificance as evidence that no significant differences exist runs the risk of committing a Type II error. Nevertheless, it is useful to examine the individual (asymptotic) t-statistics in the present case since if insignificant estimates may be underestimated, it stands to reason that significant estimates are, if anything, underestimated as well. Thus, a significant t-statistic on an interactive dummy variable term should be a reliable indicator of parameter instability. Insignificant estimates may also provide useful information, but the possibility of committing a Type II error must be kept in mind; the t-statistics in this case must therefore be interpreted with caution.

financial deregulation occurring around that time, flowing principally from the Depository Institutions and Monetary Control Act (DIDMCA) of 1980. Additional important deregulatory legislation followed in 1982--the Depository Institutions Act (Garn-St. Germain) of 1982. By hastening further deregulatory actions, Garn-St. Germain may have served as the impetus for an additional structural change occurring approximately 1983. More significant, though, is the simple recognition that the period between the break points, 1979:IV to 1982:III, was very unusual. The 1970s were characterized in large measure by gradually rising inflation and stagnating economic growth; the post 1982 period was largely characterized by relatively low and stable inflation and stronger economic growth. The intervening period was characterized by general-economic and financial sector-specific upheaval, making the middle period unusual relative to the preceding and succeeding periods. Consequently, the same two break points are used for both the money supply and money demand equations.

Results for the modified two equation model are reported in Table 3, panels a and b. Three stage least squares estimates of equation (1')--real money demand--are given in column 1 of Table 3a. Column 2 of Table 3a contains the underlying structural parameter estimates for each regime period, derivable from equation (1') estimates. Column 2 reveals that parameter estimates for the scale variable and the opportunity cost variable for the base period (1982:IV-1993:I) align closely with theoretical expectations. The estimate on real GDP ($\hat{\alpha}_{13}$) is positive and significant, while the estimate on the opportunity cost variable ($\hat{\alpha}_{23}$) is negative and significant. On the other hand, the estimate for inflation ($\hat{\alpha}_{33}$) is positive and significant, rather than negative as theory predicts.

Examination of the two preceding periods' parameter estimates reveal some interesting differences from base period findings. First, with respect to the scale variable (y), the estimate for the first period ($\hat{\alpha}_{11}$) is noticeably smaller relative to the base period estimate ($\hat{\alpha}_{13}$). Is the

TABLE 3
3SLS Estimates of Equations (1') and (2')

a. Equation (1'): Real Money Demand, Dependent Variable = $\ln \frac{M}{P}$						
		(1)			(2)	
Variable	Parameter	3SLS Estimate	Asymptotic Std. Error	Parameter	3SLS Estimate	Asymptotic Std. Error
Constant	α_{03}	-0.004	0.004	α_{03}	-0.004	0.004
D1	a_{01}	-0.001	0.005	α_{01}	-0.005*	0.004
D2	a_{02}	-0.002	0.006	α_{02}	-0.006	0.004
$\Delta \ln y$	α_{13}	1.407**	0.395	α_{13}	1.407**	0.395
D1 $\Delta \ln y$	a_{11}	-1.013**	0.450	α_{11}	0.394*	0.215
D2 $\Delta \ln y$	a_{12}	-0.011	0.816	α_{12}	1.396*	0.715
$\Delta \ln i_s$	α_{23}	-0.127***	0.027	α_{23}	-0.127***	0.027
D1 $\Delta \ln i_s$	a_{21}	0.142***	0.032	α_{21}	0.015	0.018
D2 $\Delta \ln i_s$	a_{22}	0.066	0.052	α_{22}	-0.061	0.044
$\Delta \ln \dot{P}$	α_{33}	0.015**	0.006	α_{33}	0.015**	0.006
D1 $\Delta \ln \dot{P}$	a_{31}	-0.028***	0.010	α_{31}	-0.014*	0.007
D2 $\Delta \ln \dot{P}$	a_{32}	-0.065**	0.022	α_{32}	-0.050**	0.020
DW = 1.652						
$H_{10}: a_{11} = a_{21} = a_{31} = a_{12} = a_{22} = a_{32} = 0:$		$F_{6,146} = 9.120***$				
$H_9: a_{11} = a_{21} = a_{31} = 0:$		$F_{3,146} = 14.501***$				
$H_8: a_{12} = a_{22} = a_{32} = 0:$		$F_{3,146} = 12.048***$				

Notes: See End of Table.

TABLE 3 (con't)
3SLS Estimates of Equations (1') and (2')

b. Equation (2'): Money Supply, Dependent Variable = $\Delta \ln M$						
Variable	Parameter	(1)		Parameter	(2)	
		3SLS Estimate	Asymptotic Std. Error		3SLS Estimate	Asymptotic Std. Error
Constant	β_{03}	0.015***	0.001	β_{03}	0.015***	0.001
D1	b_{01}	-0.001	0.003	β_{01}	0.015***	0.002
D2	b_{02}	-0.003***	0.005	β_{02}	0.012***	0.004
$\Delta \ln NBR^a$	β_{13}	0.075**	0.034	β_{13}	0.075***	0.034
D1 $\Delta \ln NBR^a$	b_{11}	0.146	0.199	β_{11}	0.221	0.196
D2 $\Delta \ln NBR^a$	b_{12}	0.095	0.206	β_{12}	0.170	0.204
$\Delta \ln i_s$	β_{23}	0.079**	0.034	β_{23}	0.079**	0.034
D1 $\Delta \ln i_s$	b_{21}	0.033	0.100	β_{21}	0.112	0.093
D2 $\Delta \ln i_s$	b_{22}	-0.001	0.045	β_{22}	0.078**	0.030
$\Delta \ln DR$	β_{33}	-0.190***	0.048	β_{33}	-0.190***	0.048
D1 $\Delta \ln DR$	b_{31}	0.085	0.115	β_{31}	-0.105	0.104
D2 $\Delta \ln DR$	b_{32}	0.082	0.063	β_{32}	-0.107**	0.042
DW = 1.547						
$H_0: b_{11} = b_{21} = b_{31} = b_{12} = b_{22} = b_{32} = 0:$		$F_{6,146} = 3.931***$				
$H_0: b_{11} = b_{21} = b_{31} = 0:$		$F_{3,146} = 7.720***$				
$H_0: b_{12} = b_{22} = b_{32} = 0:$		$F_{3,146} = 2.342**$				

Notes: See End of Table.

TABLE 3 (con't)

3SLS Estimates of Equations (1') and (2')

System Weighted Mean Square Error: 0.511

System Weighted R Square = 0.551

Notes: DW=Durbin-Watson Statistic for presence of first order serial correlation.

* denotes significance at the 10 percent level

** denotes significance at the 5 percent level

*** denotes significance at the 1 percent level

difference statistically significant? Information contained in column 1 suggests that it is, as the estimate of a_{11} is significantly different from zero at the 5 percent level. Conversely, the second period estimate on y ($\hat{a}_{12}$) is positive and significant and nearly identical to the base period estimate; evidence contained in column 1 indicates that no statistical distinction can be made between the second and third period estimates for this variable. Even more interesting results are obtained regarding the opportunity cost variable (i_t) and inflation ($\dot{P}$), since they are qualitatively different from base period findings. With respect to inflation, $\hat{a}_{31}$ and $\hat{a}_{32}$ (column 2) are both negative and significant, as theory predicts; this contrasts sharply with the finding of a positive and significant coefficient on inflation for the base period. The statistically significant estimates of a_{31} and a_{32} in column 1 indicate that the impact of inflation on real money demand during in high-and-variable inflation years 1972:I-1982:III was structurally different from its impact over the subsequent 1982:IV-1993:I period, which was more quiescent in terms of price level behavior.

The most notable finding revealed in Table 3 is with regard to the opportunity cost variable, i_t . Money demand theory suggests that the interest elasticity of real money demand is negative, and although the empirical relevance of the interest rate on money demand has at times been questioned (see, eg., Friedman, 1956 and 1966a), the expectation of a negative and significant estimate on an interest rate variable is a nearly universal feature of the money demand literature. However, in the present case, money demand theory is clearly supported only for the third, post-1982:III period ($\hat{a}_{23} = -0.127$). In contrast, the coefficient on the interest rate is not statistically distinguishable from zero for the first and second periods. Now, it is true also that the estimate for the second period (1979:IV-1982:III) is also not statistically distinguishable from the negative and significant base period estimate, as revealed by the insignificance of $\hat{a}_{22}$ in column 1. But there is a strong indication a structural distinction between the first and third periods, evidenced by the statistical significance of $\hat{a}_{21}$ in column 1. Indeed, the estimate on the interest

rate spread for the 1972:I-1979:III period ($\hat{\alpha}_{21}$) is *positive* (though not statistically different from zero). The failure to obtain a negative and significant estimate on the interest rate spread is curious--and revealing--in light of the fact that the finding of a negative interest rate elasticity tends to be an empirical regularity in money demand studies.⁶ The implication is that inflation, rather than interest rates, had the dominant negative impact on real M1 balances for the 1979:IV-1982:III period and, especially, for the 1972:I-1979:III period.

Given the findings for the individual variables across subperiods, it is not surprising that the null hypothesis of the overall stability of the money demand equation is rejected. As described above, the relevant null hypothesis is $a_{ji} = 0$ for all j, i . The F-test reported at the bottom of Table 3 easily rejects the null at the 1 percent level. F-tests also reject the following subhypotheses: (i) that the first subperiod estimates are not different from base period estimates ($H_0: a_{j1} = 0$ for all j); and (ii) that the second subperiod estimates are not different from the base period estimates ($H_0: a_{j2} = 0$ for all j).

Next, attention is turned to 3SLS estimates of the money supply equation given by equation (2'), reported in Table 3b. Whereas the constant-parameter estimates of money supply confirmed prior expectations in terms of parameter signs and significance (see Table 2b), results in Table 3b differ markedly according to subperiod. Parameter estimates for the base period ($\hat{\beta}_{j3}$) accord with the conventional money supply theory outlined in Chapter 3--adjusted nonborrowed

⁶On this point, it is interesting to briefly refer to Cooley and LeRoy's widely-cited 1981 critique of the money demand literature. In their paper, Cooley and LeRoy report findings from a series of extreme bounds tests. These tests focused on the confidence one can place on the interest rate elasticity of money demand for various conventional specifications of money demand found in the literature. Using data from the period 1952:II to 1978:IV, the authors found that the confidence bounds for interest elasticity for a wide-range on confidence levels are themselves quite wide and include both negative and positive values. In other words, they found that it was *not* unlikely to obtain a *positive* interest rate elasticity for money demand. Indeed, their findings led them to charge that most money demand studies "reflect the unacknowledged prior belief of the researcher and not the information content of the data. Based only on sample evidence and those priors directly implied by theory, it is next to impossible to say anything about the interest elasticity of money demand. The data are such that a modestly energetic specification search will give back almost whatever interest rate elasticity one wishes to extract..." (Cooley and LeRoy, 1981, p.836).

reserves (NBR^a) and the interest rate spread (i_s) are both positive and significant, while the discount rate (DR) is negative and significant. However, examination of the individual parameter estimates for the two previous subperiods, 1972:I-1979:III and 1979:IV-1982:III, reveals a number of items that are at variance with the theoretically appealing base period estimates. For the first period, none of the variables is statistically distinguishable from zero. The rather wide divergences between first period estimates for each variable in column 2 relative to the base period estimates would also lead one to expect statistically significant estimates on the interactive dummy variable terms in column 1, thereby implying the existence of significant differences between first and third period estimates. Oddly, none of these latter estimates ($\hat{b}_{ji}$) is significant. The problem lies with the imprecision of the first period estimates, as evidenced by their high asymptotic standard errors relative to base period standard errors. The first period supply estimates are simply too imprecise to elicit any clear-cut statistical conclusions. The second period supply estimates ($\hat{\beta}_{j2}$ in column 2) are somewhat clearer. With respect to i_s and DR, parameter estimates are in line with theory and appear to be quite similar to (indeed, statistically indistinguishable from) the base period estimates. This is not the case, however, with respect to the estimate for NBR^a, which is more similar to that obtained for the first period. Once again, though, the interactive dummy variable method fails to detect a statistically significant distinction between the second and third period estimates for this variable, as evidenced by the insignificance of $\hat{b}_{12}$ in column 1. Finally, the F-test for overall stability leads one to reject the null hypothesis of $b_{ji} = 0$ for all j, i ($F = 3.931$, which is significant at the 1 percent level). F tests also reject the separate subhypotheses $H_0: b_{j1} = 0$ and $H_0: b_{j2} = 0$ for all j .

In summary, results from this section suggest that substantial structural changes occurred in the monetary sector over the 1972-93 period. Of course, this is hardly surprising. With respect to money demand, a vast amount of literature has been produced regarding the break-down of the

standard money demand equation during the 1970s since Goldfeld (1976) first called attention to it. Results in Table 3 reinforce previous findings, particularly by highlighting the failure of sample data drawn from the 1972:I-1982:III period to support a key feature of standard theory, the negative interest elasticity of money demand. With respect to money supply, the results suggest that the money supply equation is not invariant to stated changes in Federal Reserve operating procedures. These findings are thus consistent with the findings of prior studies, outlined in Chapter 2, that investigated "received" supply functions and found evidence of instability according to Federal Reserve regime shifts (see Lombra and Kaufman, 1984, Kaufman and Lombra, 1986, and Baghestani and Mott, 1988). Recognition that the money supply process is subject to regime shifts calls for greater attention to the details concerning how the Fed formulates and implements its policies. Chapter 3 developed an expanded model of the monetary sector which attempted to incorporate some of these details. The next section reports estimation results for the expanded model.

The Expanded Model: Money Demand-Money Supply System with Endogenous Reserves

In the preceding section, real money demand and nominal money supply were estimated as a system of equations. As a result, the quantity of money and its price--i.e., the interest rate spread representing the opportunity cost of money--were treated as endogenously determined variables. Consequently, the model was less restrictive than the conventional money demand model in which the money supply is specified *a priori* to be exogenously determined by the monetary authority. Nevertheless, while the two equation model did not specify the money supply to be exogenous, it maintained the presumption that the monetary authority exogenously determined the reserve aggregate. Adjusted nonborrowed reserves was thus specified as a predetermined variable *a priori*. As argued in Chapters 2 and 3, this presumption essentially ignores Federal Reserve operating procedures. "Exogenous reserves" implies that the level of

reserves is a choice variable of the Fed. However, as noted by Goodfriend (1993, p.3,5), "[t]hroughout its history, the Fed's policy instrument has been the Federal funds rate or its equivalent.... To view the Federal Reserve's policy instrument as the Fed funds rate is thus to set money to the side, since at any point in time money demand is accommodated at the going interest rate." If the Fed's policy instrument is the funds rate, then the accommodation operates through the reserve aggregate, thereby making untenable the presumption that the reserve aggregate is a choice variable of the Fed.

Based upon this reasoning, an expanded model of the monetary sector was constructed in Chapter 3. The expanded model specified, up front, an endogenously determined reserve aggregate, and pulled into the model a Federal Reserve reaction function with the Federal funds rate as the Fed's policy instrument. The model, within the framework allowing for parameter change according to changes in the Fed's stated operating procedure, is given in Table 4. The model has seven equations: four behavioral equations (equations 5 - 8) and three identities (equations 9 - 11). The seven endogenous variables are real money demand ($\frac{M^d}{P}$), nominal money demand and supply (M^d and M^s), the demand for and supply of adjusted nonborrowed reserves (NBR^{ad} and NBR^{as}), the interest rate spread (i_s), and the Federal funds rate (FFR). Thus, in this model, the reserve aggregate is treated as an endogenous variable. As discussed in Chapter 3, the Fed's policy instrument, FFR, enters the model recursively.

Initial estimation results for the expanded model are provided in Table 5, panels a - d. Reference is first made to the F-test for structural stability at the bottom of each panel. Table 5a exhibits structural instability of real money demand, as evidenced by statistically significant F-tests with respect to the appropriate null hypotheses. The same is true for the money supply equation, results of which are reported in Table 5b. Consequently, the same general conclusion regarding structural stability of money demand and money supply that was revealed by the simple

TABLE 4
Expanded Monetary Model with Allowance for Parameter Change

-
- (5)
$$\Delta \ln \frac{M^d}{P}_t = \alpha_{03} + \sum_{i=1}^2 a_{0i} Di + \alpha_{13} \Delta \ln y_t + \sum_{i=1}^2 a_{1i} Di \Delta \ln y_t$$

$$+ \alpha_{23} \Delta \ln i_{st} + \sum_{i=1}^2 a_{2i} Di \Delta \ln i_{st} + \alpha_{33} \Delta \ln \dot{P}_t + \sum_{i=1}^2 a_{3i} Di \Delta \ln \dot{P}_t + \epsilon_t$$
- (6)
$$\Delta \ln M^s_t = \beta_{03} + \sum_{i=1}^2 b_{0i} Di + \beta_{13} \Delta \ln NBR^{ss}_t + \sum_{i=1}^2 b_{1i} Di \Delta \ln NBR^{ss}_t$$

$$+ \beta_{23} \Delta \ln i_{st} + \sum_{i=1}^2 b_{2i} Di \Delta \ln i_{st} + \beta_{33} \Delta \ln DR_t + \sum_{i=1}^2 b_{3i} Di \Delta \ln DR_t + \eta_t$$
- (7)
$$\Delta \ln NBR^{sd}_t = \gamma_{03} + \sum_{i=1}^2 c_{0i} Di + \gamma_{13} \Delta \ln M^d_t + \sum_{i=1}^2 c_{1i} Di \Delta \ln M^d_t + \gamma_{23} \Delta \ln FFR_t$$

$$+ \sum_{i=1}^2 c_{2i} Di \Delta \ln FFR_t + \gamma_{33} \Delta \ln DR_t + \sum_{i=1}^2 c_{3i} Di \Delta \ln DR_t + \gamma_4 \Delta \ln RAM_t + \mu_t$$
- (8)
$$\Delta \ln FFR_t = \delta_{03} + \sum_{i=1}^2 d_{0i} Di + \delta_{13} \Delta (\ln y - \ln y')_t + \sum_{i=1}^2 d_{1i} Di \Delta (\ln y - \ln y')_t$$

$$+ \delta_{23} \Delta \ln \dot{P}_{t-1} + \sum_{i=1}^2 d_{2i} Di \Delta \ln \dot{P}_{t-1} + \delta_{33} \Delta \ln UR_{t-1} + \sum_{i=1}^2 d_{3i} Di \Delta \ln UR_{t-1}$$

$$+ \gamma_{43} \Delta (b - \dot{P})_t + \sum_{i=1}^2 d_{4i} Di \Delta (b - \dot{P})_t + \delta_5 D1 \Delta \dot{M}_{1,t-1}$$

$$+ \delta_6 D2 \Delta \dot{M}_{1,t-1} + \delta_7 D3 \Delta \dot{M}_{2,t-1} + \omega_t$$
- (9)
$$\Delta \ln \frac{M^d}{P}_t \equiv \Delta \ln M^d_t - \Delta \ln P_t$$
- (10)
$$\Delta \ln M^d_t \equiv \Delta \ln M^s_t$$
- (11)
$$\Delta \ln NBR^{sd}_t \equiv \Delta \ln NBR^{ss}_t$$
-

TABLE 5
3SLS Estimates of Equations (5) - (8)

a. Equation (5): Real Money Demand, Dependent Variable = $\Delta \ln \frac{M}{P}$						
Variable	Parameter	(1)		Parameter	(2)	
		3SLS Estimate	Asymptotic Std. Error		3SLS Estimate	Asymptotic Std. Error
Constant	α_{03}	0.003	0.003	α_{03}	0.003	0.003
D1	a_{01}	-0.008*	0.004	α_{01}	-0.004	0.003
D2	a_{02}	-0.010**	0.005	α_{02}	-0.006*	0.004
$\Delta \ln y$	α_{13}	0.655**	0.300	α_{13}	0.655**	0.300
D1 $\Delta \ln y$	a_{11}	-0.382	0.350	α_{11}	0.272	0.177
D2 $\Delta \ln y$	a_{12}	-0.226	0.582	α_{12}	0.428	0.498
$\Delta \ln i_s$	α_{23}	-0.079***	0.020	α_{23}	-0.079***	0.020
D1 $\Delta \ln i_s$	a_{21}	0.098***	0.026	α_{21}	0.019	0.019
D2 $\Delta \ln i_s$	a_{22}	0.078**	0.037	α_{22}	-0.001	0.031
$\Delta \ln \dot{P}$	α_{33}	0.006	0.005	α_{33}	0.006	0.005
D1 $\Delta \ln \dot{P}$	a_{31}	-0.014*	0.008	α_{31}	-0.009	0.006
D2 $\Delta \ln \dot{P}$	a_{32}	-0.032*	0.016	α_{32}	-0.026*	0.016
DW = 1.412						
$H_0: a_{11} = a_{12} = a_{21} = a_{22} = a_{31} = a_{32} = 0:$				$F_{6,285} = 3.514***$		
$H_0: a_{11} = a_{21} = a_{31} = 0:$				$F_{3,285} = 5.114***$		
$H_0: a_{12} = a_{22} = a_{32} = 0:$				$F_{3,285} = 4.949***$		

Notes: See End of Table

TABLE 5 (con't)
3SLS Estimates of Equations (5) - (8)

b. Equation (6): Money Supply, Dependent Variable = $\Delta \ln M$						
Variable	Parameter	(1)		Parameter	(2)	
		3SLS Estimate	Asymptotic Std. Error		3SLS Estimate	Asymptotic Std. Error
Constant	β_{03}	0.016***	0.002	β_{03}	0.016***	0.002
D1	b_{01}	0.001	0.003	β_{01}	0.017***	0.002
D2	b_{02}	-0.004***	0.004	β_{02}	0.012***	0.004
$\Delta \ln NBR^a$	β_{13}	0.054	0.082	β_{13}	0.054	0.082
D1 $\Delta \ln NBR^a$	b_{11}	-0.143	0.153	β_{11}	-0.089	0.131
D2 $\Delta \ln NBR^a$	b_{12}	0.094	0.193	β_{12}	0.149	0.175
$\Delta \ln i_s$	β_{23}	0.008	0.021	β_{23}	0.008	0.021
D1 $\Delta \ln i_s$	b_{21}	-0.002	0.047	β_{21}	0.006	0.043
D2 $\Delta \ln i_s$	b_{22}	0.056*	0.030	β_{22}	0.064***	0.022
$\Delta \ln DR$	β_{33}	-0.084**	0.038	β_{33}	-0.084**	0.038
D1 $\Delta \ln DR$	b_{31}	0.092	0.059	β_{31}	0.008	0.052
D2 $\Delta \ln DR$	b_{32}	0.017	0.049	β_{32}	-0.067**	0.032
DW = 1.389						
$H_0: b_{11} = b_{12} = b_{21} = b_{22} = b_{31} = b_{32} = 0:$				$F_{6,285} = 3.056***$		
$H_0: b_{11} = b_{21} = b_{31} = 0:$				$F_{3,285} = 5.089***$		
$H_0: b_{12} = b_{22} = b_{32} = 0:$				$F_{3,285} = 2.680**$		

Notes: See End of Table

TABLE 5 (con't)
3SLS Estimates of Equations (5) - (8)

c. Equation (7): Adjusted Nonborrowed Reserve Demand, Dependent Variable = $\Delta \ln \text{NBR}^a$						
Variable	Parameter	(1)		Parameter	(2)	
		3SLS Estimate	Asymptotic Std. Error		3SLS Estimate	Asymptotic Std. Error
Constant	γ_{03}	-0.001	0.019	γ_{03}	-0.001	0.019
D1	c_{01}	0.010	0.039	γ_{01}	0.009	0.037
D2	c_{02}	0.001	0.033	γ_{02}	0.001	0.027
$\Delta \ln M^d$	γ_{13}	0.950	1.074	γ_{13}	0.950	1.074
D1 $\Delta \ln M^d$	c_{11}	-0.953	2.325	γ_{11}	-0.003	2.224
D2 $\Delta \ln M^d$	c_{12}	-0.170	1.902	γ_{12}	0.780	1.622
$\Delta \ln \text{FFR}$	γ_{23}	-0.317	0.261	γ_{23}	-0.317	0.261
D1 $\Delta \ln \text{FFR}$	c_{21}	0.147	0.277	γ_{21}	-0.170	0.181
D2 $\Delta \ln \text{FFR}$	c_{22}	0.182	0.294	γ_{22}	-0.135	0.140
$\Delta \ln \text{DR}$	γ_{33}	0.123	0.320	γ_{33}	0.123	0.320
D1 $\Delta \ln \text{DR}$	c_{31}	0.023	0.351	γ_{31}	0.146	0.266
D2 $\Delta \ln \text{DR}$	c_{32}	0.038	0.444	γ_{32}	0.159	0.307
ΔRAM	γ_4	-0.002	0.003	γ_4	-0.002	0.003
DW = 1.913						
$H_0: c_{11} = c_{12} = c_{21} = c_{22} = c_{31} = c_{32} = 0:$				$F_{6,285} = 0.703$		
$H_0: c_{11} = c_{21} = c_{31} = 0:$				$F_{3,285} = 0.706$		
$H_0: c_{12} = c_{22} = c_{32} = 0:$				$F_{3,285} = 1.115$		

Notes: See End of Table

TABLE 5 (con't)
3SLS Estimates of Equations (5) - (8)

d. Equation (8): Fed Reaction Function, Dependent Variable = $\Delta \ln \text{FFR}$						
Variable	Parameter	(1)		Parameter	(2)	
		3SLS Estimate	Asymptotic Std. Error		3SLS Estimate	Asymptotic Std. Error
Constant	δ_{03}	-0.037**	0.017	δ_{03}	-0.037**	0.017
D1	d_{01}	0.048*	0.027	δ_{01}	0.010	0.020
D2	d_{02}	0.063	0.046	δ_{02}	0.026	0.043
$(\ln y - \ln y^*)_{-1}$	δ_{13}	0.655	0.715	δ_{13}	0.655	0.715
D1 $(\ln y - \ln y^*)_{-1}$	d_{11}	1.848	1.209	δ_{11}	2.502**	0.976
D2 $(\ln y - \ln y^*)_{-1}$	d_{12}	1.772	1.632	δ_{12}	2.426	1.467
$\Delta \ln \dot{P}_{-1}$	δ_{23}	-0.007	0.062	δ_{23}	-0.007	0.062
D1 $\Delta \ln \dot{P}_{-1}$	d_{21}	-0.018	0.103	δ_{21}	-0.025	0.082
D2 $\Delta \ln \dot{P}_{-1}$	d_{22}	-0.147	0.148	δ_{22}	-0.155	0.135
$\Delta \ln \text{UR}_{-1}$	δ_{33}	-1.321***	0.439	δ_{33}	-1.321***	0.439
D1 $\Delta \ln \text{UR}_{-1}$	d_{31}	0.637	0.569	δ_{31}	-0.684*	0.362
D2 $\Delta \ln \text{UR}_{-1}$	d_{32}	0.352	0.816	δ_{32}	-0.968	0.688
$\Delta(b - \dot{P})$	δ_{43}	0.007	0.018	δ_{43}	0.007	0.018
D1 $\Delta(b - \dot{P})$	d_{41}	-0.005	0.020	δ_{41}	0.002	0.011
D2 $\Delta(b - \dot{P})$	d_{42}	0.031	0.024	δ_{42}	0.039**	0.016
D1 $\Delta \dot{M}1_{-1}$	δ_5	0.293	0.566	δ_5	0.293	0.566
D2 $\Delta \dot{M}1_{-1}$	δ_6	1.929***	0.416	δ_6	1.929***	0.416
D3 $\Delta \dot{M}2_{-1}$	δ_7	0.004	0.381	δ_7	0.004	0.381

DW = 1.892

(con't)

TABLE 5 (con't)

3SLS Estimates of Equations (5) - (8)

d. Equation (8): Fed Reaction Function, Dependent Variable = $\Delta \ln \text{FFR}$ (con't)	
$H_0: d_{11} = d_{12} = d_{21} = d_{22} = d_{31} = d_{32} = d_{41} = d_{42} = 0:$	$F_{8,285} = 1.036$
$H_0: d_{11} = d_{21} = d_{31} = d_{41} = 0:$	$F_{4,285} = 0.827$
$H_0: d_{12} = d_{22} = d_{32} = d_{42} = 0:$	$F_{4,285} = 0.865$

System Weighted Mean Square error: 0.900

System Weighted R square: 0.391

Notes: DW=Durbin-Watson test for presence of first order serial correlation.

* denotes significance at the 10 percent level

** denotes significance at the 5 percent level

*** denotes significance at the 1 percent level

two equation model is also revealed in the expanded model, with the implication that one should not treat the demand and supply parameters as constant across the full 1972:I-1993:I sample period. However, when one examines Table 5c and 5d, a different picture emerges. Table 5c reports 3SLS estimates of the adjusted nonborrowed reserve demand equation. The F tests for overall stability across the full period are not statistically significant. Moreover, all of the parameters on the interactive dummies (c_{ji}) are also insignificant. These findings indicate that it is *not* inappropriate to treat the parameters as constant over the full sample period. The same conclusion may be reached when looking at Table 5d, which reports 3SLS estimates of the Federal Reserve's reaction function. The F-tests for structural stability suggest that the Fed's reaction function has been stable across the full period. Further examination of Table 5d reveals that none of the interactive dummy variable estimates (d_{ji}) are statistically significant, providing additional reason to believe that it is not inappropriate to treat the reaction function parameters (the δ s) as constant across the full sample period.

These observations regarding the stability of the reserve demand and reaction function equations suggest that a more parsimonious specification of the expanded model can be made, and indeed is warranted. Accordingly, the expanded model was pared-down by imposing parameter constancy (except for subperiod intercepts) across the full sample period for the nonborrowed reserve demand and Fed reaction function equations. Attention is thus turned to the results of the re-specified expanded model--referred to as the parsimonious estimates--given in Table 6.

Money Demand

Table 6a reports estimates for the real money demand equation. First, note that F tests for overall stability continue to reject the null of structural stability, reinforcing the view that M1 demand was unstable over the 1972:I-1993:I period. The estimates of the structural parameters across subperiods, given in column 2, are similar to previous findings for the exogenous reserves

TABLE 6

Parsimonious 3SLS Estimates of Equations (5) - (8)†

a. Equation (5): Real Money Demand, Dependent Variable = $\Delta \ln \frac{M}{P}$						
(1)				(2)		
Variable	Parameter	3SLS Estimate	Asymptotic Std. Error	Parameter	3SLS Estimate	Asymptotic Std. Error
Constant	α_{03}	0.001	0.004	α_{03}	0.001	0.004
D1	a_{01}	-0.005	0.004	α_{01}	-0.004	0.003
D2	a_{02}	-0.007	0.005	α_{02}	-0.006*	0.004
$\Delta \ln y$	α_{13}	0.888***	0.340	α_{13}	0.888***	0.340
D1 $\Delta \ln y$	a_{11}	-0.625	0.392	α_{11}	0.263	0.193
D2 $\Delta \ln y$	a_{12}	-0.343	0.776	α_{12}	0.545	0.657
$\Delta \ln i_s$	α_{23}	-0.097***	0.023	α_{23}	-0.097***	0.023
D1 $\Delta \ln i_s$	a_{21}	0.112***	0.031	α_{21}	0.015	0.020
D2 $\Delta \ln i_s$	a_{22}	0.081	0.051	α_{22}	-0.016	0.042
$\Delta \ln \dot{P}$	α_{33}	0.009	0.006	α_{33}	0.009	0.006
D1 $\Delta \ln \dot{P}$	a_{31}	-0.021**	0.009	α_{31}	-0.012*	0.007
D2 $\Delta \ln \dot{P}$	a_{32}	-0.036*	0.019	α_{32}	-0.027	0.019
DW = 1.523						
$H_0: a_{11} = a_{12} = a_{21} = a_{22} = a_{31} = a_{32} = 0:$				$F_{6,299} = 3.291***$		
$H_0: a_{11} = a_{21} = a_{31} = 0:$				$F_{3,299} = 5.240***$		
$H_0: a_{12} = a_{22} = a_{32} = 0:$				$F_{3,299} = 4.145***$		

Notes: See End of Table.

TABLE 6 (con't)
Parsimonious 3SLS Estimates of Equations (5) - (8)†

b. Equation (6): Money Supply, Dependent Variable = $\Delta \ln M$						
Variable	(1)			(2)		
	Parameter	3SLS Estimate	Asymptotic Std. Error	Parameter	3SLS Estimate	Asymptotic Std. Error
Constant	β_{03}	0.015***	0.002	β_{03}	0.015***	0.002
D1	b_{01}	0.001	0.003	β_{01}	0.016***	0.002
D2	b_{02}	-0.003	0.004	β_{02}	0.015***	0.004
$\Delta \ln NBR^a$	β_{13}	0.136	0.098	β_{13}	0.136	0.098
D1 $\Delta \ln NBR^a$	b_{11}	-0.040	0.190	β_{11}	0.096	0.165
D2 $\Delta \ln NBR^a$	b_{12}	0.026	0.218	β_{12}	0.162	0.188
$\Delta \ln i_s$	β_{23}	0.024	0.023	β_{23}	0.024	0.023
D1 $\Delta \ln i_s$	b_{21}	0.008	0.059	β_{21}	0.033	0.055
D2 $\Delta \ln i_s$	b_{22}	0.030	0.035	β_{22}	0.054**	0.024
$\Delta \ln DR$	β_{33}	-0.094**	0.045	β_{33}	-0.094**	0.045
D1 $\Delta \ln DR$	b_{31}	0.080	0.069	β_{31}	-0.014	0.065
D2 $\Delta \ln DR$	b_{32}	0.0036	0.057	β_{32}	-0.057*	0.045
DW = 1.459						
$H_0: b_{11} = b_{12} = b_{21} = b_{22} = b_{31} = b_{32} = 0:$				$F_{6,299} = 1.900^*$		
$H_0: b_{11} = b_{21} = b_{31} = 0:$				$F_{3,299} = 3.399^{**}$		
$H_0: b_{12} = b_{22} = b_{32} = 0:$				$F_{3,299} = 1.675$		

Notes: See End of Table.

TABLE 6 (con't)

Parsimonious 3SLS Estimates of Equations (5) - (8)†

c. Equation (7): Adjusted Nonborrowed Reserve Demand, Dependent Variable = $\Delta \ln \text{NBR}^a$

Variable	(1)			(2)		
	Parameter	3SLS Estimate	Asymptotic Std. Error	Parameter	3SLS Estimate	Asymptotic Std. Error
Constant	γ_{03}	-0.028*	0.016	γ_{03}	-0.028*	0.016
D1	c_{01}	-0.008	0.010	γ_{01}	-0.036**	0.017
D2	c_{02}	0.001	0.013	γ_{02}	-0.028	0.017
$\Delta \ln M^d$	γ_1	2.646***	0.855	γ_1	2.646***	0.855
$\Delta \ln \text{FFR}$	γ_2	-0.187*	0.105	γ_2	-0.187*	0.105
$\Delta \ln \text{DR}$	γ_3	0.216	0.176	γ_3	0.216	0.176
ΔRAM	γ_4	-0.001	0.003	γ_4	-0.001	0.003
DW = 1.803						

Notes: See End of Table.

TABLE 6 (con't)

Parsimonious 3SLS Estimates of Equations (5) - (8)†

d. Equation (8): Fed Reaction Function, Dependent Variable = $\Delta \ln \text{FFR}$						
Variable	Parameter	(1)		Parameter	(2)	
		3SLS Estimate	Asymptotic Std. Error		3SLS Estimate	Asymptotic Std. Error
Constant	δ_{03}	-0.034**	0.017	δ_{03}	-0.034**	0.017
D1	d_{01}	0.051*	0.026	δ_{01}	0.017	0.020
D2	d_{02}	0.084**	0.038	δ_{02}	0.050	0.033
$(\ln y - \ln y^*)_{-1}$	δ_1	1.492***	0.520	δ_{13}	1.492***	0.520
$\Delta \ln \dot{P}_{-1}$	δ_2	-0.021	0.044	δ_{23}	-0.021	0.044
$\Delta \ln \text{UR}_{-1}$	δ_3	-0.975***	0.246	δ_{33}	-0.975***	0.246
$\Delta(b - \dot{P})$	δ_4	0.009	0.007	δ_{43}	0.009	0.007
D1 $\Delta \dot{M}1_{-1}$	δ_5	0.250	0.526	δ_5	0.250	0.526
D2 $\Delta \dot{M}1_{-1}$	δ_6	1.975***	0.394	δ_6	1.975***	0.394
D3 $\Delta \dot{M}2_{-1}$	δ_7	0.019	0.364	δ_7	0.019	0.364
DW = 1.920						
System Weighted Mean Square error: 0.996						
System Weighted R square: 0.374						

Notes: †Estimates of equations (5) - (8) under the following restrictions: $c_{11} = c_{12} = c_{21} = c_{22} = c_{31} = c_{32} = 0$ for equation (7); $d_{11} = d_{12} = d_{21} = d_{22} = d_{31} = d_{32} = d_{41} = d_{42} = 0$ for equation (8).

DW=Durbin-Watson statistic for presence of first order serial correlation.

* denotes significant at the 10 percent level

** denotes significant at the 5 percent level

*** denotes significant at the 1 percent level

model reported in Table 3a. Base period estimates on real GDP ($\hat{\alpha}_{13}$) are positive and significant, while the estimate on the interest rate spread ($\hat{\alpha}_{23}$) is negative and significant. These results thus align closely with standard money demand theory. Standard theory with respect to these variables is not supported, however, for the first two subperiods. The only statistically significant structural parameter estimate for either of two subperiods is the estimate on first subperiod inflation ($\hat{\alpha}_{31}$).

The most interesting finding in Table 6a is with respect to the interest elasticity of money demand. As observed in the prior discussion of the two equation model, the finding of a significantly negative interest elasticity is an empirical regularity in the money demand literature. However, few studies focus attention on the 1970s alone; normally, estimates are generated over longer sample periods (say, using quarterly data for 1950-1990). This study, by allowing parameters to vary across time, highlights how perverse the empirical behavior of money demand was in the 1970s, particularly with respect to the interest elasticity. As with the two-equation exogenous reserves model, the expanded model reports a *positive* (albeit statistically insignificant) interest rate elasticity ($\hat{\alpha}_{21} = 0.015$). Furthermore--unlike the results obtained for the two equation model--the estimate on the relevant interactive dummy variable is significant at the 1 percent level ($\hat{\alpha}_{21} = 0.112$). This finding thus emphasizes in the starkest of terms just how differently real M1 demand reacted in the first subperiod relative to the third with respect to contemporaneous variations in the opportunity cost of holding money.

Money Supply

Attention is focused next on money supply estimates, reported in Table 6b. Standard money supply theory suggests that NBR^a and i_s are positively related, and DR is negatively related, to the M1 money supply. A quick inspection of column 2 of Table 6b shows that the signs of the parameter estimates accord with theory across subperiods; however, most of these estimates are not significantly different from zero. Moreover, none of the interactive dummy

variable terms in column 1 are significant, though the null hypothesis of overall stability across subperiods is nevertheless rejected at the 10 percent level ($F = 1.900$). Three principal points of interest emerge from the parameter estimates contained in Table 6b: (i) the interest rate spread is positive and significant for period 1979:IV-1982:III only; (ii) the discount rate is negative and significant for both periods 1979:IV-1982:III and 1982:IV-1993:I; and (iii) adjusted nonborrowed reserves insignificant for each subperiod. Each of these points merits detailed discussion.

(i) Interest rate spread. The explanation regarding the behavior of the interest rate spread is most likely tied to the shift away from, and subsequently back toward, interest rate targeting. Prior to October 1979, the Fed attempted to maintain, via open market operations, its funds rate operating target in the interim between Federal Open Market Committee (FOMC) meetings. The Fed thus allowed the reserves to expand and contract elastically to maintain its funds rate target, resulting in significant funds rate "smoothing" over the period. Now, all short-term rates are tightly linked with innovations in the Fed funds rate, including the representative short term rate (the commercial paper rate-return on M1 spread) used in this study (see Figure 5). As a result, smoothing of the Fed funds rate caused similarly "smoothed" behavior on the part of the representative short term rate during the 1970s. The behavior of the M1 money supply, meanwhile, was fairly volatile during the 1970s, as depicted in Figure 6. The volatility of M1, coupled with the dampened fluctuations of short-term interest rates, most likely explains the failure to detect a statistically significant contemporaneous relationship between M1 and i_s over the funds rate targeting period. In contrast, the shift to nonborrowed reserves targeting announced in October 1979 was ostensibly constructed so as to keep a tighter rein on reserve growth. As observed in Chapter 3, it is not clear whether the new procedure was actually intended as a strict means of nonborrowed reserve control or merely as a *modus vivendi* for aggressive Fed funds rate targeting. What *is* clear is that the Fed funds rate manifested greater variability over the period

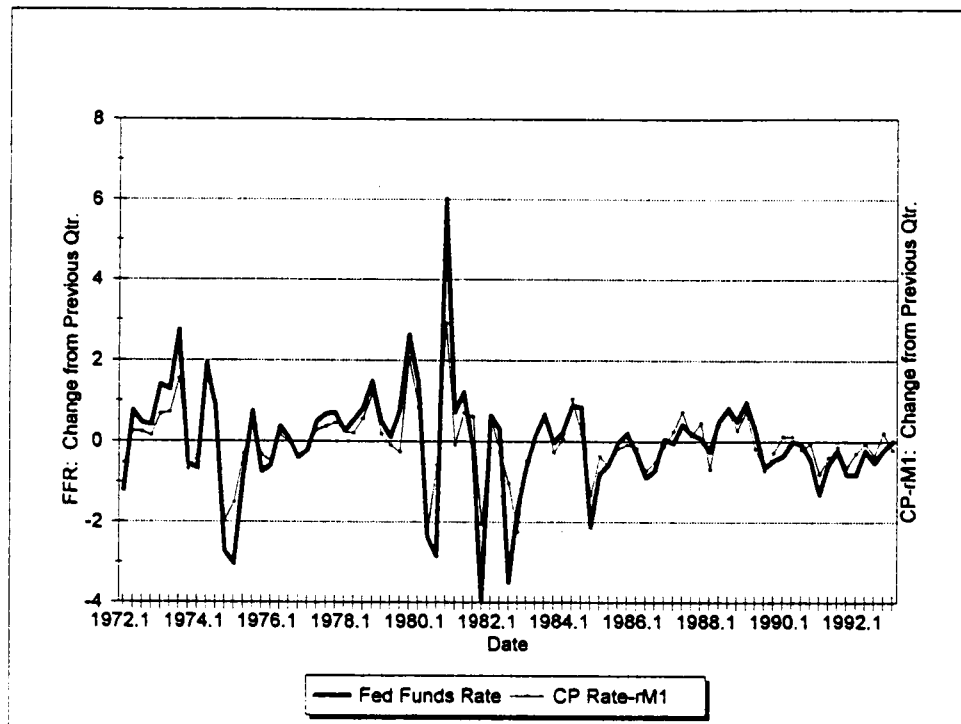


Figure 5. Rate Spread Between the Federal Funds Rate and the Commercial Paper-Return on M1 Spread

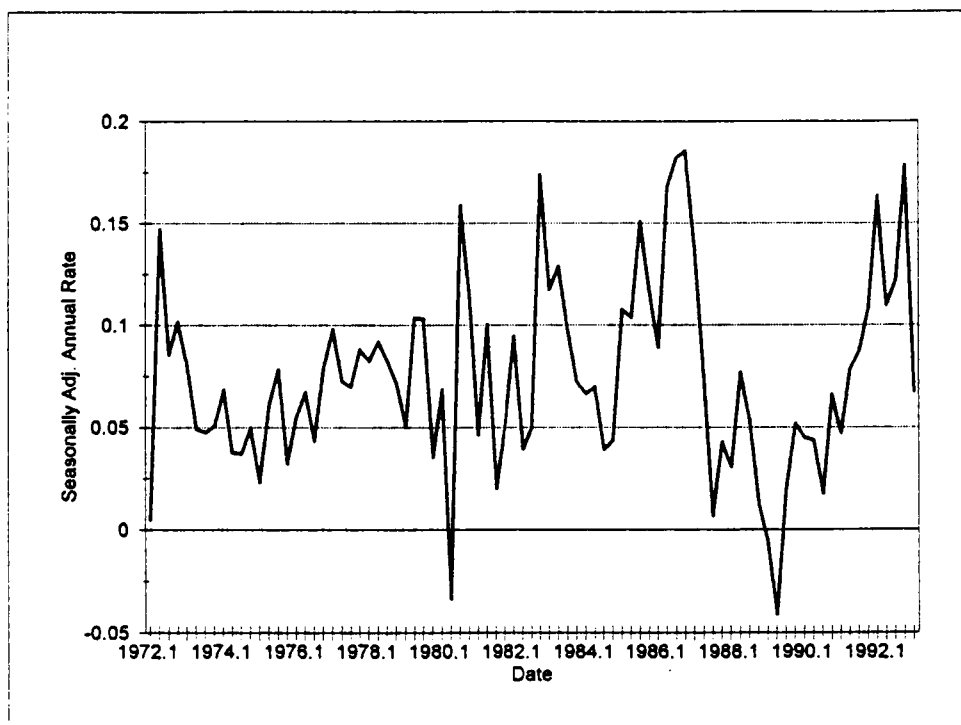


Figure 6. M1 Growth

1979:IV-1982:III than was previously observed (*cf.* 1972:I-1979:III and 1979:IV-1982:III in Figure 5). At the same time, the M1 money supply also exhibited considerable volatility during the nonborrowed reserves regime, reflecting the Fed's continued difficulty in controlling short-term behavior of the money supply (refer again to Figure 6). As a result, the volatility of M1 was closely associated with interest rate volatility over this period. This contrasts with the 1972:I-1979:III period, in which the money supply was volatile, but interest rates were less volatile. Thus, the statistically significant estimate on i_t for the 1979:IV-1982:III period likely results from the Fed's retreat from interest rate smoothing. Conversely, the switch back to statistical insignificance by i_t during the third period, 1982:IV-1993:I, likely reflects a move back toward interest rate control. (Note, from Figure 5, the reduced volatility of the funds rate in the period since the abandonment of the nonborrowed reserves procedure.)⁷

(ii) Discount Rate. Money supply theory suggests that the discount rate is negatively related to the money supply. While this is empirically supported for the second and third periods, the discount rate is not statistically different from zero for the first period. A straightforward explanation for this is offered. One reason why the discount rate is in theory negatively related to the money supply is that the discount rate and borrowed reserves are, *ceteris paribus*, inversely related. This implies that, so long as the Fed funds rate-discount rate spread (FFR-DR) is positive, an increase in the discount rate (holding the funds rate constant) results in a shift in demand by banks away from borrowed reserves toward nonborrowed reserves (i.e., funds obtainable in the Fed funds market). Thus, FFR-DR should be positively related to the quantity of reserves

⁷The period since the abandonment of the nonborrowed reserves procedure has been technically characterized by borrowed reserves targeting, not Fed funds rate targeting. However, as discussed in Chapter 3, the borrowed reserves procedure is widely regarded as a disguised attempt to return to Fed funds rate control. Fed officials themselves initially viewed the shift as a half-step back to funds rate targeting, but not a full-step (see Wallich, 1984). More recently, the pretense that the borrowed reserves procedure is operationally distinct from a Fed funds rate targeting regime appears to have been dropped (see, eg., Rudebusch, 1995b, and Carlson, et al., 1995).

borrowed at the discount window. Figure 7 traces the behavior of FFR-DR and borrowed reserves over the period used in this study; in general, it can be seen that the greater the spread between the funds rate and the discount rate, the greater the amount of discount window borrowing (which, in turn, means a larger potential size of the money stock). Increases in the discount rate (*ceteris paribus*) reduce the funds rate-discount rate spread, thereby reducing the level of borrowed reserves and, consequently, M1.

The discount rate is normally set below the Fed funds rate. A significant counterexample occurred during the mid-1970s. As is observable in Figure 7, an extended period in the mid-1970s was characterized by a *negative* spread between FFR and DR. In such an instance, the relationship between FFR-DR and borrowed reserves breaks down, since under most circumstances it is then preferable for banks to borrow at the lower Fed funds rate. Figure 7 indicates that borrowed reserves fell to and remained at near-zero over the period in which FFR-DR was persistently negative (but variable). This situation likely contributed to the failure to detect a statistically significant estimate on the discount rate over the 1972:I-1979:III period. In contrast, Figure 7 shows that the funds rate fell below the discount rate (on average) in only one quarter since 1978. This reflects the Fed's reluctance to allow such a situation to persist during the nonborrowed reserve and borrowed reserve targeting periods ⁸

⁸Under both the nonborrowed reserves and borrowed reserves procedures, the Fed generally does not allow the Fed funds rate to fall below the discount rate. This is because, under both procedures, reserve targets are set based upon the so-called "borrowing assumption." Under a nonborrowed reserve procedure, the nonborrowed reserves target is set by subtracting the borrowing assumption from total estimated reserve need; borrowed reserves are then allowed to vary when total reserves fall short of (exceed) estimated total reserve need. Under a borrowed reserve procedure, the borrowings assumption itself is targeted, and nonborrowed reserves are allowed to vary between FOMC meetings. The estimate of the borrowing assumption is thus critical in the functioning of both procedures. The borrowing assumption is obtained by estimating the demand for borrowed reserves. The Fed models the demand for borrowed reserves under the explicit assumption that borrowed reserves are principally a positive function of the funds rate-discount rate spread. Since there exists a floor for discount window borrowing (zero), calculation of the borrowing assumption breaks down if the Fed allows funds rate falls below the discount rate. See, eg., Cook (1989).

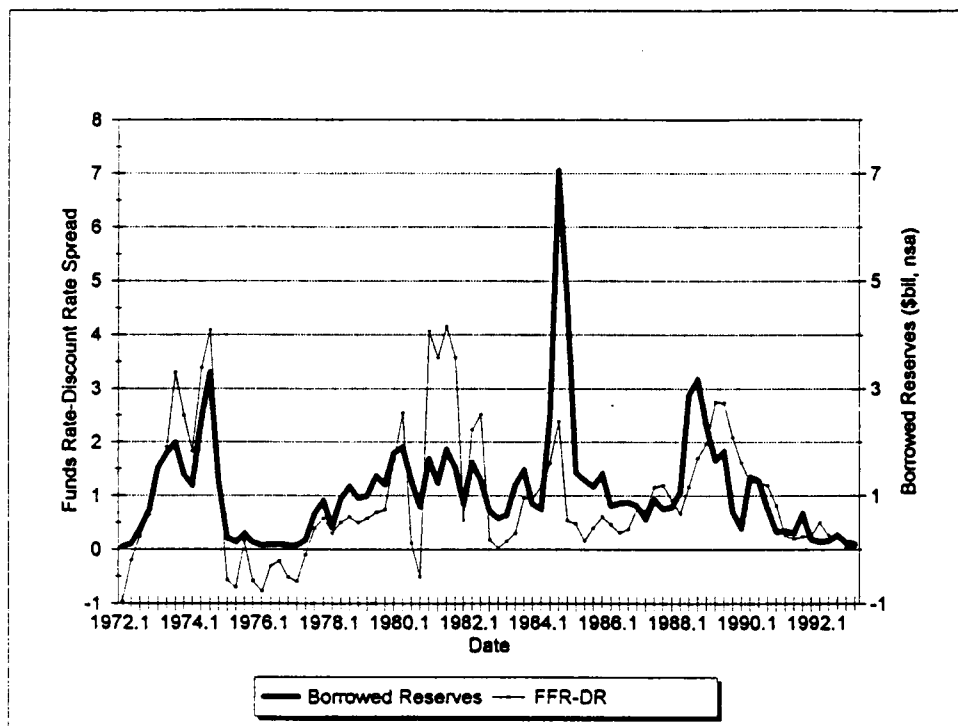


Figure 7. Borrowed Reserves and the Federal Funds Rate-Discount Rate Spread

(iii) Adjusted Nonborrowed Reserves.

Standard money supply theory holds that the money supply is a multiplicative function of a Fed-controlled reserve aggregate and its associated multiplier. Assuming a stable multiplier, money supply movements are then traceable to Fed-initiated changes in reserves. In the constant-parameter two-equation model outlined above, this explanation looked empirically plausible: the estimate on adjusted nonborrowed reserves was positive and significant, as theory predicts (see $\hat{\beta}_{13}$ in Table 2b). However, when the variable-parameter version of the model was estimated, standard theory regarding the reserve aggregate was supported only for the base period (see Table 3b). In the expanded model, the statistical significance of the reserve aggregate for even the base period disappears (see $\hat{\beta}_{13}$ in Table 6b).

The most likely explanation for this finding involves the concept of "long and variable lags." Failure to detect a statistically significant estimate on the reserve aggregate may simply be due to a lag between a reserve impulse and its long-run impact on money. If the issue is simply one of lag structure, empirical analysis can be trained on the timing of Fed-induced changes in reserves and ultimate impacts.

But are reserve supply shocks always Fed-induced? Granted, by construction, the present model assumes that the Fed controls the Fed funds rate and thereby allows the supply of nonborrowed reserves to adjust to changes in nonborrowed reserve demand. However, some support, if not for the exogeneity of NBR supply, then its predeterminedness, may be reclaimed if money demand does not contemporaneously impact NBR demand. Then, not only does NBR^s have no contemporaneous impact on money supply, money demand does not have a reverse contemporaneous impact on NBR^d and, therefore, (via the NBR^d - NBR^s identity) on NBR^s . In other words, if money demand shocks do not contemporaneously impact NBR^d , they do not contemporaneously impact NBR^s in the money supply equation. Thus, money demand shocks do

not systematically and contemporaneously feed into money supply. In this way, the assumption of NBR^s predeterminedness in the money supply equation may be rescued. That is, NBR^s may then be viewed as a predetermined variable, impacting the money supply over time; this view would be acceptable so long as there is no reverse contemporaneous correlation between money and reserves. Examination of Table 6c casts doubt on this proposition.

Nonborrowed Reserve Demand

Table 6c shows results from the parsimonious specification of adjusted nonborrowed reserve demand. First, as expected, the Federal funds rate is negative and significant, reflecting the fact that the funds rate is the own-price of Federal funds. This relationship represents the liquidity effect that is so relevant with respect to models of monetary transmission mechanism. Changes in the Fed's policy instrument--the Federal funds rate--cause movements along the nonborrowed reserve demand curve, thereby altering the equilibrium level of nonborrowed reserves in an inverse direction. Second, the discount rate has the anticipated positive sign, but is statistically insignificant. This result may reflect that while borrowed reserves and nonborrowed reserves are substitutes, they are imperfect substitutes.

Third, and most interesting, is the estimated contemporaneous impact of money on nonborrowed reserves. As discussed previously, the demand for nonborrowed reserves is a derived demand due to a systematic linkage between bank reserves and transactions deposit liabilities (the largest component of M1). That is, since transactions deposits are subject to reserve requirements, it is reasonable to expect that variations in M1 demand are closely linked with variations in nonborrowed reserves. For example, a positive shock to money demand may induce an increase the demand for nonborrowed reserves. To the extent that Fed behavior is accommodative, the shift causes an increase in the aggregate level of nonborrowed reserves. This increase then feeds into the money supply function, leading (with a lag) to a future

increase in money supply. Thus, the ultimate impact of nonborrowed reserves on money may reflect money *demand* shocks. This view is supported in Table 6c, as the estimate of γ_1 in Table 6c is positive and significant at the 1 percent level, as predicted. This suggests that movements in nonborrowed reserve supply is "contaminated" by demand-side effects, thus limiting its value as an indicator of monetary policy actions. On the other hand, the Federal funds rate is explicitly targeting by the Fed, and its is not allowed to veer very far away from target. Thus, the best place to analyze Fed actions is neither the money supply nor the supply of nonborrowed reserves, both of which are highly subject to endogenous, nonpolicy influences, but instead the Fed funds rate. Innovations in the funds rate carry much less ambiguous informational content about Fed actions than do innovations in nonborrowed reserves.⁹ Thus, useful information about Federal Reserve behavior can be introduced into the model by specifying and estimating the a funds rate reaction function. The discussion thus turns to the results obtained for the funds rate reaction function used in this study.

Federal Reserve Reaction Function

Table 6d presents results of the parsimoniously-specified Federal Reserve reaction function. As discussed in Chapter 3, the reaction function literature used for this study closely hews to the established reaction function literature in its specification of the appropriate dependent variable (the funds rate) and plausible explanatory variables. For purposes of this study, it is assumed that the funds rate enters the model recursively, on the assumption that the Fed reacts to

⁹These points are also supported by evidence marshalled in a recent study by Bermanke and Blinder (1992). Utilizing a variety of nonstructural estimation methods, the authors similarly conclude that the Federal funds rate "is a good indicator of monetary policy, even for the period after 1979 [in which Fed funds targeting was ostensibly abandoned]. The funds rate is probably less contaminated by endogenous responses to contemporaneous economic conditions than is, say, the money growth rate" (Bermanke and Blinder, 1992, p.919).

past, available information.¹⁰ Results contained in Table 6d suggest that the Fed is sensitive to cyclical economic behavior. This is evidenced by the statistical significance of the deviation of real GDP from trend (δ_1 positive and significant) and lagged unemployment (δ_3 negative and significant). That is, the Fed tends to ease (tighten) monetary policy by cutting (raising) the funds rate when real GDP falls below (exceeds) its "potential" or long-run average level. The Fed is also sensitive to employment conditions, easing (tightening) its policy by cutting (raising) the funds rate when the unemployment rate rises (falls).¹¹

The Fed's principal stated intermediate target between 1970 and 1993 was the growth rate of the monetary aggregates. In this study, it is postulated that the lagged growth rate of money should be positively related to the Fed funds rate, i.e., the Fed attempts to dampen past observed money supply growth by adjusting the funds rate upward. Results in Table 6d suggest that, under the Fed funds rate regime, the Fed did not systematically respond to past M1 growth by altering the funds rate. This is evidenced by the finding that δ_5 is statistically insignificant.¹² In contrast,

¹⁰The exception is the real long term bond rate, which is entered contemporaneously, following Mehra (1994). See footnote 14, Chapter 3.

¹¹It is probably more appropriate for the employment conditions variable to be entered as the deviation of the unemployment rate from its "natural" level. In such a case, the deviation of real GDP from trend and deviation of unemployment from its natural levels may be redundant variables, each reflecting the nonaccelerating inflation rate of employment (NAIRU) concept. There is little question that the Fed is a strong follower of the NAIRU principle, and that in the face of the breakdown of confidence in monetary aggregates as meaningful intermediate targets, the Fed has relied even more heavily in recent years on estimates of the NAIRU for policy guidance.

¹²If an M1 growth rate intermediate target is *strictly adhered to*, Fed funds rate operating targets should be very sensitive to past M1 growth (or deviations from targeted M1 growth). If so, then reserve growth is ostensibly quelled through aggressive movements in the funds rate. That is, the major criticism of Fed funds rate targeting was not that it *could not* restrain reserve--and, hence, M1--growth. Rather, criticism tended to focus on the Fed's reluctance to allow short term rates to fluctuate as much as necessary to offset undesired rates of M1 growth, particularly in the late 1970s. In other words, Fed funds rate targeting required the FOMC to move more forcefully and frequently in altering the funds rate than it did in practice. The reluctance to move rates decisively due to its concerns about interest rate fluctuations was, from Fed Chairman Paul Volcker's point of view,

a psychological trap [whose] implications became worse as the inflationary momentum grew....[T]he risks almost always seem greater in raising interest rates than in lowering them. After all, no one likes to risk recession, and that is when the political flak ordinarily

the Fed moved very forcefully during the nonborrowed reserves regime to restrain money supply growth, as evidenced by the positive and significant estimate of δ_6 . However, the high variability of interest rates during the nonborrowed reserves era imposed a high cost in terms of its impact on financial sector and general economic conditions. As a result, not only did the Fed drop the nonborrowed reserves operating procedure in late 1982, it also *de facto* abandoned M1 as a useful intermediate target (McNees, 1992, p.5). Instead, the Fed focused more on M2 growth as a policy guide. However, the Fed's lack of faith in M2 growth is also evident from Table 6d, as the estimate for lagged M2 growth (δ_7) is statistically insignificant. This accords to some degree with evidence presented by Mehra (1994, p.18), who suggests that the Fed "may have discounted in recent years the leading properties of money as measured by M2."

Assessment of Results

A vital link in monetary transmission mechanism models is a liquidity effect depicting an inverse relationship between a Fed-controlled monetary aggregate and short-term interest rates. However, as discussed in Chapter 1, studies have failed to identify the presumed liquidity effect. As a result, researchers have increasingly questioned the appropriateness of the standard assumption that movements in the money supply aggregates represent the independent policy actions instigated by the Fed. Taylor (1995) succinctly identifies two empirical flaws inherent in the standard view of the transmission mechanism:

hits. The corollary is that there is a tendency to make moves, and especially moves to tighten money, only in small increments to "test the waters." That may be all fine and prudent when the prices and expectations are stable. But in the midst of accelerating inflation, what the Fed might think of as prudent probing looked to the rest of the world like ineffectual baby steps" (Volcker and Gyohten, 1992, p.166).

Evidence presented in Table 6d supports the widely-held view that the Fed did not use its Fed funds rate operating instrument aggressively enough to counter undesired M1 growth during the 1970s.

First, the money demand equations appear to be too unstable to yield a reliable estimated effect [on interest rates] of a given change in the money supply. Second, central bank behavior is not accurately described by such a one-time change in the money supply. Instead, most central banks today are taking actions in the money market to guide the short-term interest rate in a particular way. In other words, rather than changing the money supply by a given amount and then letting the short-term interest rate take a course implied by money demand, the central banks adjust the supply of high-powered money so as to give certain desired movements to the federal funds rate. A complete story of the monetary transmission mechanism should thus include a description of the central bank's reaction function...(Taylor, 1995, pp.14-15).

The present study provides a means for investigating the structural behavior of the monetary sector by incorporating the Fed reaction function into, rather abstracting it away from, the analysis. Results from estimates on the expanded model of the monetary sector support the view that money demand has been very unstable over the 1972:I-1993:I period. In contrast, the Fed funds reaction function equation appeared to be stable across the same time period. As noted by McNees (1992, p.12), to the extent that a Fed funds reaction function "is regarded as sensible and essentially stable, it raises questions about the appropriateness of macroeconomic models that take 'money' to be the exogenous policy instrument." Accordingly, researchers are abandoning as unreliable the use of innovations of the money supply as an exogenous policy indicator in favor of the Fed funds rate. For instance, Bernanke and Blinder (1992, p.903) suggest that "it is reasonable to treat the funds rate...as a measure of Federal Reserve policy which, though not statistically exogenous, is at least predetermined within each month." The present study suggests that the Fed funds rate does not even need to be predetermined, but instead can be treated as an endogenous variable that enters the model recursively.

The Fed's ability to control the Fed funds rate, and its tendency to do so on a regular basis, suggests that the first link in the chain of causality in the transmission process-- $M \rightarrow i$ --is incorrect. In fact, the Fed directly alters the Fed funds rate, with changes in money being a residual, consequent element that is highly dependent upon the behavior of banks and the nonbank

public. This has interesting implications for both the transmission mechanism process and Federal Reserve targeting strategy. Under the simple Keynesian model, the liquidity effect leads to changes in investment or other interest-sensitive spending, and thus to changes in other macroeconomic variables of interest. The findings of the present study are suggestive of an alternative transmission process quite different from the standard model. Consider the representation of the transmission process given by Figure 8. Under this monetary transmission

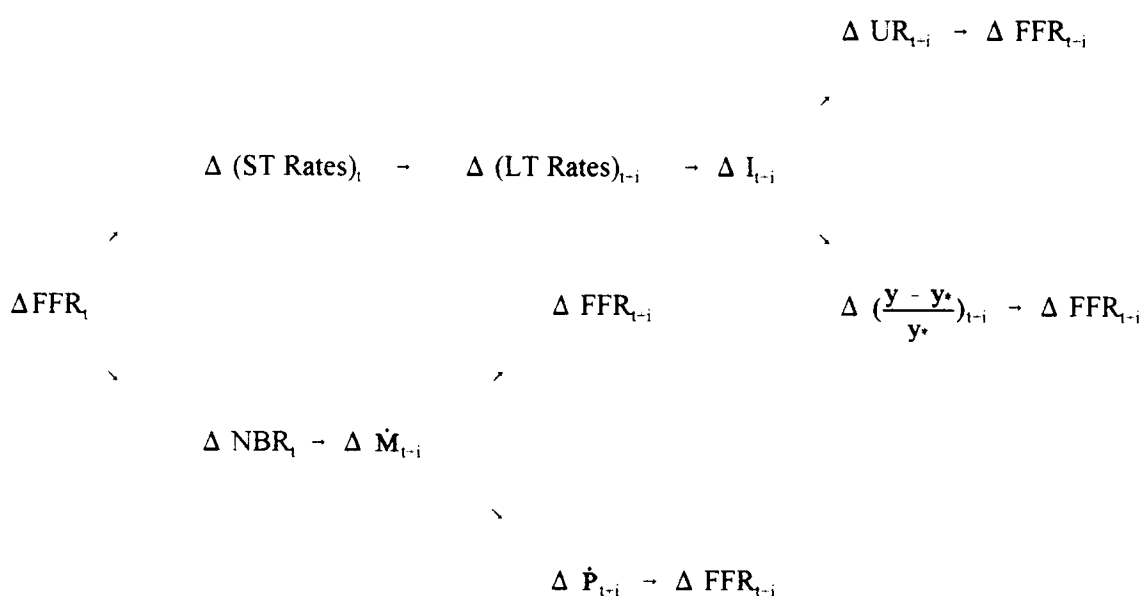


Figure 8. An Alternative Monetary Transmission Mechanism.

schema, the Federal Reserve initiates changes in the stance of monetary policy by altering the funds rate in time period t . The transmission of the policy disturbance to the ultimate macro variables is dual-tracked. On one track, the funds rate change impacts other short-term rates contemporaneously. Subsequently, the policy change filters through to interest rates of longer maturities. The timing, magnitude, and persistence of the impact on long-term rates is a critical

issue--perhaps the central issue of the transmission process. However, under the assumption--shared by the standard Keynesian transmission mechanism--that such an impact occurs (with an unknown lag), an easing (tightening) of monetary policy then works to stimulate (retard) interest-sensitive spending, thus leading to a decline (increase) in the unemployment rate and an increase (decline) in the deviation of real GDP from trend (again, in each instance, with unknown lags). These variables, in turn, are important components of the Fed's policy information set. For instance, when the Fed observes a surging economy, reflected by falling unemployment and rising real GDP, it will at some point become concerned about the prospects for an attendant surge in rising inflation. Thus, the Fed may subsequently respond by pushing up the funds rate. Thus, these variables--the deviation of real GDP from trend and the unemployment rate--serve as intermediate targets, changes in which "feed back" to the Federal funds rate. Results in Table 6d conform to this view: parameter estimates on deviation of real GDP from trend and the unemployment rate are positive and significant and negative and significant, respectively. In other words, empirical findings for the 1972-93 period support the widely-held current view that the Fed takes a highly NAIRU¹³-based approach to policy determination.

The second track of the alternative transmission process reflects the "residual" element of the liquidity effect. Changes in the funds rate yield resultant changes in the level of nonborrowed reserves, which then impacts--again, with an uncertain lag structure--the growth rate of the money supply. In turn--to the extent that the Federal Reserve is serious about using lagged money growth as an intermediate target--the Fed uses observed lagged money growth as an input in deciding whether to adjust the funds rate. Furthermore, changes in money growth ultimately lead to changes in the inflation rate. As with the money growth rate, inflation potentially serves as an important intermediate target variable for the Fed. Interestingly, however, neither of these

¹³Nonaccelerating Inflation Rate of Unemployment.

variables were positive and significant (as the theory predicts) in Table 6d--with one exception. The exception is lagged M1 growth for the second period of the sample--1979:IV-1982:III. This likely reflects the fact that the 1979:IV-1982:III period served as the "monetarist experiment," i.e., the period in which the Fed held most assiduously to money growth as its stated intermediate target by aggressively altering its *de facto* operating target, the funds rate. Conversely, the lagged growth rate of M1 and M2 were not statistically significant for the previous and succeeding periods, suggesting that the Fed was less interested in the behavior of money growth as an intermediate target than is often believed. With respect to inflation, evidence from Table 6d indicates that the Fed did not systematically respond to lagged inflation. Two potential explanations are offered for this finding. First, the inclusion of the real bond rate ($b - \dot{P}$) in the Fed's reaction function may introduce some multicollinearity into the equation, thus reducing the precision of the parameter estimates for both inflation and the real bond rate. Second, the Fed tends to view the inflation rate as a misleading intermediate target, since the seeds of rising inflation are planted prior to its realization. Thus, the Fed is more likely to respond to variations in NAIRU-related variables such as the deviation of real GDP from trend and the unemployment rate. These variables are viewed as better indicators of future inflation than is past observed inflation. As noted above, findings contained in Table 6d confirms that these variables were significant contributors to the Fed's information set.

The primacy of the Federal funds rate in the transmission process is a view widely held by financial market participants and observers. However, economists have often ignored how the Fed actually operates, instead focusing on it operates in theory. The importance of the funds rate due to Fed operating procedures, and thus in the transmission process, is dismissed as a short-run diversion from the real issue: how movements in the money supply ultimately impact aggregate economic activity. It is argued that the Fed funds rate only *appears* to be important; the Fed may

alter the funds rate "in the short run," but in so doing the money supply will vary ("with long and variable lags") such that, in the long run, it is the money supply that is in reality the variable that is more tightly linked with movements in aggregate macroeconomic variables. Acceding to a popular view stressing the role of the Federal funds rate would thus yield to a misguided emphasis on short-run variables and neglect of more important long-run relationships. However, in recent years numerous studies have documented an apparent breakdown of these presumed long-run relationships. For instance, Friedman and Kuttner (1992) and Bernanke and Blinder (1992) have presented evidence that the money supply is much less effective than short-term interest rates (variously defined) in terms of its usefulness as a predictor of long run future movements in both real and nominal macroeconomic variables. Friedman and Kuttner go so far as to conclude that "there is no evidence that fluctuations in money contain any information about subsequent movements in income and prices" (Friedman and Kuttner, 1992, p.491). It may therefore be unwise to ignore the empirical importance of "short run" interest rate movements in favor of the standard theoretical--but less empirically grounded--"long run" monetary relationships.

In sum, much effort has been expended over the past two decades attempting to identify a stable money demand function, on the grounds that if a stable function can be identified, then the Fed can gear the money supply to suit its ultimate macroeconomic objectives. However, a stable money demand function has been difficult to uncover. One avenue by which stability is sought is by expanding the definition of the appropriate monetary aggregate for empirical purposes to include more types of assets. However, this effort may be misguided, since broader aggregates are less useful as policy indicators of the Fed, due to endogeneity of the money supply. Instead, more attention should be placed on the role played by the Federal funds rate in the monetary transmission process. This study accords with recent research which suggests that the Fed funds rate is a superior indicator of monetary policy actions. In contrast to money demand and money

supply, findings suggest that the Federal Reserve reaction function that explains movements in the funds rate has been relatively stable over the 1972:I-1993:I sample period. An implication of this finding is that more effort should be placed in refining the Federal Reserve reaction function. A second implication is that more effort should be shifted from money to the Fed funds rate in analyzing the monetary transmission mechanism, both in terms of its linkage with other market rates, as well as its ability to explain long run movements in important macroeconomic variables like income, unemployment, and prices.

CHAPTER 5

SUMMARY AND CONCLUSION

The way in which money enters the economy is an important issue in macroeconomic modeling. The standard approach is to treat the money supply as exogenously controlled by the monetary authority, with the short-term market rate of interest determined by the interaction of the exogenously controlled money supply and an endogenously determined money demand. Under this conceptualization of the money supply process, movements in the money supply reflect exogenous policy actions on the part of the monetary authority--i.e., the money supply serves as the indicator of monetary policy. Given the public's demand for money, desired changes in short-term interest rates--the liquidity effect--are effected by purposeful changes in the money supply by the monetary authority. The transmission of changes in monetary policy to ultimate macroeconomic variables of interest depends, then, upon the monetary authority's ability to accurately forecast money demand, and upon the strength of the desired liquidity effect. Thus, two important features of empirical monetary modeling have been (i) the search for a stable, predictable demand for money, and (ii) the search for an empirically detectable liquidity effect. However, despite a prodigious amount of research over the past thirty years, a stable demand for money and a quantifiable liquidity effect have proved to be elusive targets. Moreover, recent evidence suggest that the two strains of literature work at cross-purposes. The search for a stable money demand usually involves broadening the definition of money, while the detection of a liquidity effect requires using much narrower bank reserve aggregates. The apparent presence of a liquidity effect at the reserves level and its absence at the broader level of monetary aggregates suggests that movements in the money supply, when defined as broadly as M1 or M2, is a poor indicator of monetary policy due to endogenous (non-policy related) influences.

In the present study, a multi-equation structural model of the monetary sector was constructed and estimated, using U.S. data over the period 1972:I-1993:I. In the model, M1 money supply and money demand were each cast as endogenous variables, along with a short-term interest rate representing the opportunity cost of holding money. Also integrated into the model was the behavior of the reserves market, endogenously linked to money demand behavior. Finally, under the maintained hypotheses that the Federal funds rate served as the Fed's *de facto* policy indicator, and that it entered the model recursively, the model was closed by specifying a Federal Reserve reaction function. Normally treated as a separate line of research, the integration of the Fed reaction function into the model allows one to characterize within the model, rather than abstract from the model, the behavior of the single most important player in the monetary sector: the Federal Reserve. The model also allowed for a liquidity effect, operating in the reserves market via Fed-induced changes in its policy indicator, the Federal funds rate.

The model was estimated using three stage least squares, and incorporated the interactive dummy variable technique to assess structural stability. In line with expectations based upon prior empirical literature, findings indicate that money demand and money supply were structurally unstable over the 1972-93 period. However, behavior both in the reserves market and on the part of the Federal Reserve's reaction function exhibited did not exhibit significant instability. Moreover, a statistically significant liquidity effect was manifested between nonborrowed reserves and the Fed's policy indicator, the Federal funds rate. Perhaps most interesting were findings regarding the Federal Reserve's reaction function. Over the 1972-93 period, the Fed's principal *stated* intermediate target was the growth rate of the money supply. That is, if the Fed in fact adheres assiduously to a monetary intermediate target, lagged money growth should be a significant contributor to the Fed's information set (i.e., a statistically significant explanatory variable in the Fed's reaction function). However, results from this study indicate that the Fed was

highly sensitive to lagged money growth only during the 1979:IV-1982:III period. Instead, the principal explanatory variables in the Fed's reaction function were the deviation of real GDP from trend and the unemployment rate. This is consistent with the view that, despite its stated adherence to lagged money growth as its principal intermediate target, the Fed in practice has usually been more sensitive to the behavior of variables closely related to the concept broadly known as NAIRU--the nonaccelerating inflation rate of unemployment.

Finally, this study is consistent with recent research that emphasizes the Federal funds rate as the Fed's policy indicator. In the last thirty years, much effort has been expended attempting to estimate money demand in order to find a stable and predictable demand relationship useful for policy purposes. Too frequently this research has neglected the practical importance of actual Fed operating procedures and the resulting indicator properties of the Federal funds rate. If the funds rate is indeed a superior policy indicator relative to monetary aggregates, it would be fruitful to devote considerably more research to the role of the funds rate in the monetary transmission process.

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APPENDICES

APPENDIX A

TABLE 7

DEFINITIONS AND SOURCES OF DATA

Variable	Definition	Source
M	Money Supply (M1), seasonally adjusted.	FRED
$\frac{M}{P}$	Real Money Supply (M1), seasonally adjusted; deflated by GDP implicit deflator.	FRED
y	Real Gross Domestic Product (GDP), seasonally adjusted; deflated by GDP implicit deflator.	FRED
i_s	Interest Rate Spread: 4-6 Month Commercial Paper Rate less Rate of Return on M1 (weighted average of returns on M1 assets).	4-6 Month Commercial Paper Rate: FRB, Various Issues; Rate of Return on M1 Assets: FRED.
$\dot{P}$	Inflation Rate, Consumer Price Index, SAAR.	FRED
NBR ^a	Adjusted Nonborrowed Reserves (nonborrowed reserves adjusted for changes in reserve requirements), seasonally adjusted.	FRED
DR	Discount Rate (quarterly average of monthly data).	FRB, Various Issues
FFR	Federal Funds Rate (quarterly average of monthly data).	FRB, Various Issues
$\frac{y - y^*}{y^*}$	Percentage Deviation of Real GDP (SAAR) from Trend; Trend is forecast value obtained from the following estimating equation: $y_t = \alpha + \beta t + \epsilon_t$ where t = time, sample period = 1971:I - 1993:I.	Author's calculations; method follows Mehra (1994).

Abbreviations: See End of Table.

TABLE 7 (con't)**DEFINITIONS AND SOURCES OF DATA**

Variable	Definition	Source
RAM	Reserve Adjustment Magnitude, seasonally adjusted.	FRED
UR	Unemployment Rate, seasonally adjusted.	FRED
b - $\dot{P}$	Real 10 Year Bond Rate.	Bond Rate (b): FRB, Various Issues.
M1	Growth Rate of M1, SAAR.	FRED
M2	Growth Rate of M2, SAAR.	FRED

Abbreviations:

SAAR = Seasonally Adjusted Annual Rate.

FRED = Federal Reserve Economic Data, electronic data transfer system, Federal Reserve Bank of St. Louis.

FRB = Federal Reserve Bulletin.

APPENDIX B

DATA STATIONARITY: UNIT ROOT TESTS

The empirical model used developed in this study assumes that the data is stationary when expressed in first-difference form. This appendix reports results of unit root tests for stationarity of the data used in this study. Results indicate that first-differencing of the data is sufficient to induce stationarity.

One of the core assumptions of the classical regression model is that the data have constant means and finite variances. If so, the data are said to be "stationary," or mean-reverting. If the data violate this property, they are referred to as nonstationary variables, or integrated processes. A nonstationary variable may be made stationary through successive differencing, in which case the series is said to be integrated of order d --i.e., $I(d)$ --where d is the number of times the variable must be differenced for it to achieve stationarity. Consequently, a data series that is stationary without differencing is referred to as an $I(0)$ variable. If the raw data--the "levels"--used in a regression are in fact $I(1)$, or integrated of an even higher order, then relationships between variables may be inferred that are in reality spurious.

This "spurious regression" phenomenon was largely ignored until it was reemphasized in an influential article by Granger and Newbold (1974), who warned that "[t]he fact that many economic 'levels' are near random walks or integrated processes means that considerable care has to be taken in specifying one's equations" (p.117). They observed that the problem may be alleviated in many cases if the data are first-differenced. More specifically, if differencing of nonstationary "white noise" data series produce stationary series, then "classical regression yields satisfactory results, since the error series will be white noise and least squares fully efficient" (Granger and Newbold, 1974, p.117). Consequently, it has been common practice in macroeconomics to estimate models using first-differenced data. However, since first-

differencing may not always result in stationarity series (i.e., the series may be integrated of an order higher than one), it is possible that first differencing may not avoid the spurious regression problem. Thus, to shed light on whether first-differencing adequately transforms the data used in the present study into stationary series, the data is analyzed using conventional "unit root" tests.

Dickey and Fuller (1979, 1981) developed the following test for the stationarity of data series Y_t . First, express Y_t as a stochastic function of Y_{t-1} , i.e.,

$$(1) \quad Y_t = \alpha + \rho Y_{t-1} + \epsilon_t .$$

When $\rho = 1$ the variable is said to be nonstationary. In this case, random disturbances (ϵ_t) are not transitory, but instead are permanently embedded in the series.¹ When $\rho < 1$, disturbances "die out" over time. Thus, Dickey and Fuller suggested a test for $\rho = 1$ (i.e., a test of the hypothesis that Y possesses a "unit root"). However, the statistic for such a test does not have the conventional t distribution (i.e., the distribution does not approach a standard normal distribution in the limit). Consequently, the critical values for the test statistic are not the same. In practice, unit root tests usually rely on critical values constructed by Fuller (1976).²

The unit root tests conducted herein are Augmented Dickey-Fuller (ADF) tests, based upon the following regression equation:

$$(2) \quad \Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{j=1}^k \gamma_j \Delta Y_{t-j} + \epsilon_t ,$$

where $\Delta Y_t = Y_t - Y_{t-1}$, $\beta = (\rho-1)$, and k autoregressive terms are included to improve the fit of the equation. In this form, the test is of the null hypothesis $H_0: \beta = 0$. Determining the proper specification of equation (2) is somewhat problematic, since theory does not specify number of autoregressive terms to include (Said and Dickey, 1984, p.606). Frequently, k is chosen so that ϵ_t

¹If $\rho = 1$ and $\alpha \neq 0$, the series is said to be a "random walk with drift."

²It should also be noted that unit root tests of the Dickey-Fuller variety have low power, in the sense that the tests are not good at distinguishing between the presence of unit roots (which imply the need to difference the data) and "near unit roots" (eg., $\rho = 0.95$, which imply stationary data) (Maddala, 1992, p.584).

in equation (2) is approximately white noise. However, this often involves the inclusion of numerous autoregressive terms. As noted by Maddala (1992, p.584), long autoregressions may bias β toward zero and lead one to erroneously accept the null hypothesis of the presence of a unit root.

Table 8 reports results for unit root tests conducted for the data series used in this study. The tests are conducted on the full data period 1972:I-1993:I. The form of unit root test is given by equation (2), with k chosen to be equal to 2. Since $k=2$ may not be sufficient to induce white noise errors, Table 8 also reports Durbin's alternative test (Durbin's m) for the presence of first order serial correlation when regressors include a lagged dependent variable. This will help the reader to judge the overall adequacy of the unit root test.

Evidence recorded in Table 8 suggests very strongly that nearly all of the variables are nonstationary in levels. Only three variables--the deviation of real GDP from trend, log unemployment, and the M2 growth rate for period 1982:IV-1993:I--appear to be $I(0)$. In turn, almost all variables appear to be $I(1)$, as evidenced by significant Dickey-Fuller t -statistics for ADF tests in first-differences. The glaring exception is real (M1) money demand. The ADF(2) statistic for real M1 is -2.391, which is not significant at even the 10 percent level. (The 10 percent critical value cut-off for the relevant t -distribution is -2.59.) Thus, real M1 may be borderline $I(2)$. An examination of the autocorrelation function for this variable, however, suggests that real M1 may be adequately characterized as $I(1)$. When expressed in level form, the autocorrelations of real M1 do not quickly die out. When expressed in first difference form, the autocorrelations decline relatively quickly, and, when expressed in second-differences, the pattern of autocorrelations are not very different. Thus, it is likely that treating real M1 as $I(2)$ may constitute overdifferencing of the series. Consequently, although the unit root test suggests that

real M1 may be $I(2)$, for purposes of this study it will be assumed that stationarity is induced after first-differencing.³

³With respect to the other suspect variable, $D2M1$, the sample size is so small (12 observations) that it is unwise to draw any particular conclusions regarding order of integration from the unit root test. It is assumed that the data is, like most macroeconomic data, $I(1)$ over this period.

TABLE 8
UNIT ROOT TESTS

Variable	Levels		First Differences	
	ADF(2)	m(1)	ADF(2)	m(1)
$\ln \frac{M}{P}$	-0.015	-1.421	-2.391	2.316**
$\ln M$	0.286	-0.454	-3.451**	1.710*
$\ln y$	-0.960	-0.072	-4.353***	-0.212
$\ln i_s$	-1.068	1.703*	-4.721***	-0.826
$\ln \dot{P}$	-1.176	-0.143	-7.412***	1.280
$\ln NBR^a$	0.950	0.596	-5.463***	0.252
$\ln DR$	-1.361	-1.210	-3.544***	-0.736
$\ln FFR$	-1.405	2.204**	-4.310***	-0.618
RAM	1.781	-0.431	-4.642***	-1.985*
$\ln (y - y^*)$	-3.020**	-1.046	-4.353***	-0.211
$\ln UR$	-2.711*	0.698	-3.920***	-1.205
$\ln (b - \dot{P})$	-1.264	-0.116	-6.932***	0.452
D1 M1	-2.394	0.768	-5.383***	-1.484
D2 M1	-1.629	0.695	-2.311	0.483
D3 M2	-2.712*	-1.494	-5.334***	-2.336**

Notes: See below.

TABLE 8 (con't)

UNIT ROOT TESTS

Notes: The estimating equation for the augmented Dickey-Fuller test is

$$\Delta Y_t = \alpha + \beta Y_{t-1} + \sum_{j=1}^k \gamma_j \Delta Y_{t-j} + \epsilon_t,$$

where $k=2$. ADF(2) is the t-statistic obtained from the estimate on β . The relevant critical values are from Table 8.5.2 in Fuller (1976, p.373). The estimating equation for Durbin's m test is

$$\hat{\epsilon}_t = \alpha + \rho \hat{\epsilon}_{t-1} + \beta Y_{t-1} + \sum_{j=1}^2 \gamma_j \Delta Y_{t-j} + \mu_t,$$

where $m(1)$ in the table represents the t-statistic associated with the estimate for ρ . A significant $m(1)$ indicates the presence of first order serial correlation. All data series are estimated for period 1972:I-1993:I except for D1 M1, D2 M1, and D3 M2, which are estimated for periods 1972:I-1979:III, 1979:IV-1982:III, and 1982:IV-1993:I, respectively.

*denotes significant at the 10 percent level

**denotes significant at the 5 percent level

***denotes significant at the 1 percent level.

VITA

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