A POLICY STRUCTURE
FOR MONETARY CONTROL DECISIONS

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ABSTRACT

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This thesis develops a system dynamics structure for monetary decision-making in the United States. The structure captures the process whereby information on the past and contemporary state of the economy is used to generate a stream of monetary control decisions. In the United States, this function is currently carried out by the Federal Reserve System. The structure is therefore a description of the Federal Reserve's policy structure. However, even before the inception of the Federal Reserve in 1913, monetary control was provided by a diversity of federal, state, and local agencies. The structure is designed to encompass the period before 1913 as well.

Development of the policy structure has been stimulated by a research program, conducted in the MIT System Dynamics Group, whose focus is the long-term socio-economic evolution of the United States.* A multi-sector model of the national economy is under construction for use in exploring both long-term (over a two-hundred-year span) economic growth issues, and shorter-term (over five to ten years) economic stabilization issues. The model must be capable of describing endogenously the monetary control function performed by the Federal Reserve and its predecessors. The structure presented in this thesis will serve the role of a monetary authority in the national model.

The thesis also contrasts the process orientation of a system dynamics policy structure with the typical treatment of monetary control decisions in macroeconometric models. In general, monetary control decisions are assumed to be exogenous to a macroeconometric model.

*The research described in this thesis, as well as the overall national socio-economic modeling project, is supported by a grant from the Rockefeller Brothers Fund.
model. Yet the Federal Reserve, or any monetary authority, does not act in a vacuum. Decisions are derived from perceptions of what monetary changes can be made to move the economy toward improved behavior. The process through which information is sorted, evaluated, and eventually translated into actions is not exogenous to the economy, nor is the process immediate or in any way optimal.

The structure developed in the thesis describes the decision-making process rather than the effect of decisions on the macroeconomy. One ultimate objective of the national socio-economic modeling project is the recommendation of monetary control decisions that could be more effective in managing the complex of economic problems facing the United States. New decisions, however, must be implemented within the existing framework of decision-making; recommended changes that are inconsistent with the decision-making process are unlikely to be either accepted or pursued with any vigor. The thesis uses the descriptive economics literature, past legislation, Federal Reserve publications, and econometric monetary studies to develop a dynamic model of monetary decision-making. The thesis should be helpful in illuminating the objectives of monetary control decisions, the performance measures by which the economy is judged, and the decision rules that govern the stream of actions taken by a monetary authority.

Thesis Supervisor: Jay W. Forrester
Title: Germeshausen Professor
ACKNOWLEDGEMENTS

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Few people could have lived with me for the past five years, sharing the good times and the deep depressions, and still think of me as a sane person. My wife Penny has provided the quiet strength that I needed each time the whole effort looked particularly hopeless and unmanageable. Now that it's done, we can look forward to many years as people instead of as students—there is, I expect, a big difference!
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CHAPTER ONE: INTRODUCTION

A. Objectives and Background

A.1. Principal Objective: A Monetary Authority Structure for the National Model

This study describes a system dynamics structure for monetary decision-making in the United States.¹ The structure captures the process whereby information on the past and contemporary state of the economy is used to generate a stream of monetary control decisions. Currently in the United States this function is carried out by the Federal Reserve System. Thus the structure is a description of the Federal Reserve's policy structure. However, even before the inception of the Federal Reserve in 1913, a monetary control function was served by a diversity of federal, state, and local agencies. The structure is designed to encompass the period before 1913 as well.²

Development of this structure has been stimulated by a research program, conducted in the MIT System Dynamics Group, whose focus is the long-term socio-economic evolution of the United States.³ A multi-sector

¹ System dynamics is a method of structuring social system models and analyzing their implications for policy design. See Section D.


³ The research reported in this study, as well as the overall national socio-economic modeling project, is supported by a grant from the Rockefeller Brothers Fund.
model of the national economy is under construction that will be used to
explore both long-term (over a two-hundred-year span) economic growth
issues, and shorter-term (over five to ten years) economic stabilization
issues. An important requirement of that model is a sector to describe
derendogenously the monetary control function performed by the Federal Reserve
and its predecessors. The structure presented in this study will serve
the role of a monetary authority in the national model.

A.2. Second Objective: A Comparison with Traditional Approaches to
Monetary Control Decisions.

A second objective of this study is to contrast the process
orientation of the structure described herein with the typical treatment
of monetary control decisions in macroeconomic models. In general, monetary
control decisions are assumed to be exogenous to a macroeconomic model. For
example, Foley and Sidrauski (Foley and Sidrauski 1971) explore the impact
of changes in the government-debt-to-money ratio, the variable affected by
Federal Reserve open-market operations, on a two-sector macroeconomic model.
They analyze changes in both equilibrium and aggregate growth conditions as
a result of a change in the debt-to-money ratio. They do not, however,
describe how a decision to change the ratio responds to the changing economy.

The Federal Reserve, or any monetary authority, does not act in
a vacuum. Decisions are derived from perceptions of what monetary changes
can be made to move the economy toward improved behavior. The process
through which information is sorted, evaluated, and eventually translated
into actions is not exogenous to the economy, nor is it immediate or in any
way optimal. As Maisel (Maisel 1973, p. 2) has noted, "...policy results from an interplay of history, personalities, and doctrine, all reacting to events in the economy and the Washington world."

The focus of the structure presented herein is the decision-making process, rather than the effect of decisions on the macro-economy. One ultimate objective of the national socio-economic modeling project is the recommendation of monetary control decisions that are more able to manage the complex of economic problems facing the United States. New decisions, however, must be implemented within the existing framework of decision-making; recommended changes that are inconsistent with the decision-making process are unlikely to be either accepted or pursued with any vigor. For example, new monetary controls designed to pursue only one objective, like controlling the Federal funds rate, offer little help to a Federal Reserve faced with competing goals and trying to satisfy among them. "Said an executive of one New York institution: 'The Fed has it in its power to arrest this rise [of prime rates] by keeping the federal funds rate at a more reasonable level. But it is trying to keep the money supply down, and the two things are diametrically opposed.'"\(^4\) Competition among goals is but one aspect of the policy structure that must be adequately understood before new and realistic decisions can be developed.

---

B. **Definitions of Terms**

B.1. **Policy Structure**

"Monetary policy" is usually understood as the stream of decisions made by the Federal Reserve, or some other monetary authority, designed to control monetary aggregates (bank reserves, money supply) and credit conditions (interest rates, availability of credit). Yet, a particular open market purchase is often referred to as a "policy." Similarly, a change in the discount rate or reserve requirements is often described as a "change in monetary policy." The Federal Reserve is thought of as pursuing a "tight money policy" during periods of credit restraint, and an "easy money policy" when credit is eased. The term "policy" is alternately applied to a single decision by the monetary authority, a stream of decisions, and a particular posture adopted by the authority in dealing with certain economic problems.

The inconsistent use of the term "policy" is confusing. Three separable concepts are subsumed in the common use of "policy." First, there are the "rules" that govern how information is processed to make decisions; in this study, the term **policy structure** will be applied to the rules of decision-making. In control theory the term "transfer function" is the equivalent of **policy structure**—the conversion of information inputs to decision outputs. Second, there are the specific "channels" used to transmit decisions, in this case open market operations, the discount rate, and reserve requirements; this study will employ the term **instruments** when referring to these channels. Third, there are individual "actions" taken by the monetary authority, such as to change the discount rate from six percent to seven percent; these actions will be referred to as **decisions**. Therefore, a monetary authority employs its **policy structure** to make **decisions** that are
implemented through its instruments of monetary control. In a particular example, the policy structure of the monetary authority dictates that a rise in inflation be countered by a decision to change the instrument of the discount rate.5

The policy structure of a monetary authority does not change through time. A single policy structure, when confronted by different information inputs, produces different decisions, but the policy governing the use of each instrument remains the same. A single policy structure produces both the decision to raise the discount rate in periods of inflation, and the decision to lower the discount rate in periods of deflation.

Figure I-1 summarizes these definitions. The policy structure receives information inputs. Through the application of its decision rules, it produces a stream of decisions with respect to each instrument of control. The information inputs may change, in which case the decisions change, but both the policy structure and the instruments remain unchanged.

---

5This use of terms is consistent with (Forrester 1961, pp. 93-94), with the replacement of policy by policy structure and the addition of instruments. Policy structure is used here to convey the notion that an ensemble of decision rules makes up a policy structure, whose output can be defined as encompassing a number of instruments. Therefore policy would refer to a single decision rule, with one instrument as its output. The use of the term decision is identical to that of (Forrester 1961).
Figure I-1: A Black Box Representation of the Monetary Policy Structure
B.2. Fractional Reserve Banking

Many of the information inputs to the policy structure for monetary control decisions come from the commercial banking system. To avoid later confusion regarding the form and origin of bank reserves and various ratios of quantities, this section provides some basic definitions of banking concepts.

Fractional reserve banking is the term applied to a banking system in which banks hold only a fraction of their demand deposits as reserves. Reserves are funds held by banks either to meet statutory requirements or for precautionary or speculative purposes. Demand deposits are obligations (liabilities) of the bank to the public. Reserves held to meet statutory requirements are required reserves; the level of required reserves is determined by a bank's demand deposits and the required reserve ratio, which is the fraction of demand deposits that the bank is required to hold as reserves. Reserves in excess of required reserves, held for precautionary or speculative purposes, are called excess reserves. The sum of required reserves and excess reserves, or total reserves, will be called reserves of the bank.

Reserves of the bank may come from two origins. They may be owned reserves, which result from currency or specie deposits, a bank's initial capital endowment, or a sale of a government security. Borrowed reserves are funds that have been borrowed from the Federal Reserve through the discount facility. Borrowed reserves can be held for only a short time; they must be repaid to the Federal Reserve. Owned reserves are held permanently by the bank, unless withdrawn as currency.
Fractional reserve banking allows a small amount of currency to support a large volume of transactions through the creation of deposits. Although the deposit-creation process is described in all introductory banking texts, it will be helpful to go through a simple example to identify a few new terms.

Suppose Mr. White finds $1000, in currency, in a mattress. Eager to protect his new wealth, he rushes to the First Bank to deposit the money. "I think," he says to himself, "I'll just keep $100 in cash just so that all of this money isn't lost by this bank's lousy computer." So saying, Mr. White goes home and puts the $100 back in the mattress.

The First Bank, meanwhile, has $900 in cash, and a $900 liability to Mr. White. Knowing that the Feds require them to hold 20% of Mr. White's deposit in reserve, they take $180 of the cash and put it in the vault. At the last moment, they hear that the Dow Jones has just dropped twenty points; they take an extra $20 and put that in the vault, too, just in case.

The First Bank then lends the remaining $700 cash to Mr. Blue. Eager to protect his new wealth, Mr. Blue rushes to the Second Bank. "I think," he says to himself, "I'll just keep $70 in cash. You never can be too sure with banks."

The Second Bank now has a $630 liability to Mr. Blue, and $630 in cash. By law, they have to keep $126 in reserve; they decide to keep $130, and lend the remaining $500 to Mr. Green.
This process obviously continues until the cash has been dispersed among a number of people and banks. Already, however, $500 has been used up. Yet Mr. White and Mr. Blue have deposits totalling $1530. The $500 in cash has been able to create $1530 in deposits; Mr. White holds $100 as currency, the First Bank holds $200 as reserves, Mr. Blue holds $70 as currency, and the Second Bank holds $130 as reserves. The injection of $500 in currency has been conserved as either currency or reserves, yet has created a much larger total of deposits. In fact, any injection of reserves or currency will have the same result. The total of reserves and currency held by the public is high-powered money; it is both conserved and can create several times its amount in deposits.

The amount of deposits that a given injection of high-powered money can create depends on how much is "siphoned off" into currency or reserves at each step of the process. When Mr. White withheld $100 in currency, he was subconsciously determining a currency-deposit ratio of one-ninth. Mr. Blue also observed a currency-deposit ratio of one-ninth. When both banks withheld a few dollars in excess reserves, in addition to their required reserves, they were establishing a ratio of reserves to deposits that was higher than the required reserve ratio.

These two ratios, the ratio of reserves to deposits and the currency-deposit ratio, determine the quantity of money that can be created by a given amount of high-powered money (assuming the process runs to completion). The money supply is defined (using the "M1" definition) as the sum of demand deposits and currency held by the public; the money supply is the amount of money available for transactions among producers and consumers.
C. The Monetary Authority Sector in the National Model

The national socio-economic model, when completed, will describe the principal interactions governing economic and social change in the United States over the time period from roughly 1800 to 2100. The model consists of fourteen interacting sectors: capital goods, consumer goods, resources, construction, agriculture, transportation, energy, knowledge, services, labor, household consumption, demographic, government, and financial. The first nine sectors listed engage in the direct production of goods or services. The labor sector allocates labor to the producing sectors, and determines industry and national unemployment rates and wages. The household sector allocates consumer time among employment direct (in the home) production of goods and services, and leisure, and determines household consumption and savings decisions. The demographic sector determines population birth, migration, and death rates within a population structure of four age groupings. The government sector determines fiscal policies of taxation and government expenditures, and issues debt during periods of deficit spending. Finally, the financial sector links together the other sectors through the banking system, extending short- and long-term credit and investing in government securities. The structure described in this study, called in the model the monetary authority sector and responsible for all functions of monetary control, resides within the financial sector.

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6 The current description of the project, including its objectives and the structure of the model, is "Understanding Social and Economic Change in the United States," by Jay W. Forrester, System Dynamics Group Memorandum D-2103.
The national model is intended to address a wide spectrum of issues. The long time horizon is necessary for a focus on the problems created by national transitions from an agricultural to an industrial and to a service economy. In addition, however, the detailed structure is intended to allow treatment of shorter-term issues such as economic stabilization over the business cycle and industry-specific unemployment problems. One important issue addressed by the model is the current widespread inflation and the potential contributions to inflation from short-term business and government-policy fluctuations, resource and energy shortages, and the long-term growth of a dominant service sector. As one of the principal channels of national economic control, the monetary authority sector plays a central role in all of these investigations.

In order to meet the needs of the overall national model, the monetary authority sector is designed within a few structural restrictions. Some of these restrictions are relatively insignificant. For example, because the model contains a single aggregate bank, the monetary authority is not required to interact with a diversity of banks as exists in the true economy. Other characteristics of the national model place more important constraints on the monetary authority sector. The four most important constraints are:

1.) The long time horizon of the model implies that the monetary authority sector must approximately generate monetary control decisions both before and after the organization of the Federal Reserve System (1913). This first constraint leads directly to the second.

2.) The monetary control structure must be functionally rather than institutionally defined. Monetary control existed
prior to the Federal Reserve; the structure cannot depend on the existence of a particular institution for its validity.

3.) The structure must be independent of the personalities involved in monetary decision-making. Although several individuals, such as Secretary of the Treasury Salmon P. Chase (during the Civil War), are reputed to have had a large impact on decisions, the structure must be sufficiently general to encompass that impact within a single causal structure.

4.) The structure must be valid under a wide variety of economic conditions, as has been exhibited by the US economy over the past 150 years. The monetary authority structure must contain decision rules sufficiently complex to generate monetary decisions under a diversity of potential economic patterns.
D. Description of Research Methodology

The policy structure for monetary control decisions has been developed through application of the system dynamics modeling technique. The technique of system dynamics has been developing during more than thirty years of continuous effort directed toward the analysis and control of complex system behavior. From its birth in the study of relatively simple mechanical systems, it has grown to provide a single framework for understanding the behavior of electronic, chemical, biological, and social systems whose elements interact through time to produce system changes. As an important advantage, system dynamics represents real-world relationships pictorially and mathematically in relatively simple terms. Although the creation of useful models is difficult, specialized mathematical ability is not a prerequisite for understanding and using the results of a system dynamics study.

System dynamics models are commonly described in three forms: as a causal diagram, showing the basic causal interactions among model variables; as a DYNAMO flow diagram, showing in addition to the causal interactions the forms of variables (described below); and as equations, giving the precise mathematical specification of each relationship. Examples of causal diagrams in this report are Figures III-1, IV-1, and V-2. Examples of DYNAMO flow diagrams are

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Much of this discussion has been adapted from (Meadows and Meadows 1973, pp. 33-39), with permission of the editors. For a complete description of system dynamics principles, see (Forrester 1961), (Forrester 1968).
Figures III-2, IV-2, and V-3. Equations can be found throughout Section C in Chapters Three, Four, and Five.

The equations of a system dynamics model are computer-simulated to generate the time-varying behavior of model variables. Using the computer to conduct studies of model behavior requires that each assumption be precisely expressed. According to the theory underlying system dynamics, only two types of variables, "levels" and "rates," are necessary to express any relationship in a system. Levels are the state variables or stocks of conserved quantities that characterize the system at any point in time. All levels are represented by rectangles. Model behavior depends on the variation in the quantity in each level over time. Levels that are dynamically unimportant (usually sources or sinks) are represented by clouds.

Rates are the system's action or policy variables that effect changes in the levels. Rates are represented as valves. Rates can control flows of people, money, goods, land, and other conserved quantities. These flows are represented by solid lines.

Since the rates acting on a level summarize all the factors that act to change that level, they are generally complex expressions. Often one or more components of a rate are sufficiently important to warrant individual attention. Called auxiliaries, these components are separated algebraically from the rate equations, assigned separate names, and represented pictorially as circles. System dynamics flow diagram symbols are summarized in Figure 1-2.
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Name and Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image" alt="Source or Sink" /></td>
<td><strong>Source or sink</strong></td>
</tr>
<tr>
<td><img src="image" alt="Level" /></td>
<td><strong>Level</strong>: the result of accumulation and depletion of flows, i.e., the result of an integration</td>
</tr>
<tr>
<td><img src="image" alt="Rate of Flow" /></td>
<td><strong>A rate of flow</strong></td>
</tr>
<tr>
<td><img src="image" alt="Physical Flow" /></td>
<td><strong>Physical flow</strong></td>
</tr>
<tr>
<td><img src="image" alt="Information Flow" /></td>
<td><strong>Information flow or functional dependence</strong></td>
</tr>
<tr>
<td><img src="image" alt="Auxiliary Variable" /></td>
<td><strong>A variable that is auxiliary to formulating a rate</strong></td>
</tr>
<tr>
<td><img src="image" alt="Exogenous Input" /></td>
<td><strong>Exogenous input</strong></td>
</tr>
</tbody>
</table>

| ![Constant](image) | **A constant** |

*Figure I-2: DYNAMO Symbols Glossary*

Whenever a sequence of causal influences leads back to its own starting point and thus forms a closed circuit, it constitutes a **feedback loop**. Figure I-3 illustrates a feedback loop taken from Chapter Three. The solid line represents the flow of bonds into the
level of bonds of the monetary authority BM. This flow is controlled by the rate of purchases of bonds PB M. The dotted lines indicate a causal link between two elements; they do not indicate the exact quantitative nature of the link.

**Figure I-3: Elements of One Feedback Loop Connecting the Level of Bonds with the Rate of Bond Purchases**

The sequence of influences in Figure I-3 is a positive feedback loop. In any positive loop a change in one element sets in motion a chain of events around the loop that eventually produces a reinforcing influence on that element. For example, if the level of bonds BM were to increase, desired purchases of bonds DPEM would increase (assuming
that the desired rate of expansion in bonds DREB remains constant). An increase in desired purchases DFBM, all else equal, will cause an increase in actual purchases of bonds PBM, thus increasing further the level of bonds BM.

Feedback loops may also be negative. In that case, a change in one element is propagated about the loop to result ultimately in a counteracting change in the same element. Usually, each element in a system will be influenced by several positive and negative loops simultaneously.

Feedback loops differ not only in their polarity, positive and negative, but also in the delay with which responses are propagated around the loop. It is in general very difficult to determine intuitively the direction, timing, and magnitude of the influence on one system element resulting from a change in some element elsewhere in the system. An initial increase in bonds BM might ultimately lead to either more or less bonds than if the increase had not occurred. The final direction of the response would depend on the strength and the delay of relationships inherent in each loop in which bonds are an element.

System dynamics models are continuous. Even though the actual decisions of the Federal Reserve are discrete (a discrete change in the discount rate, for example), the decisions respond to a continuous build-up of pressures for a change. Actual decisions are discrete only because of the institutional inability of banks to respond to a continuously changing required reserve ratio or discount rate. The system dynamics
model will create a continuous stream of decisions; the simulated discount rate, for example, will be a smooth curve.

The policy structure for monetary control decisions is actually only a part of a complete system dynamics model. There are few feedback loops internal to the policy structure itself. Most of the policy structure's dynamic behavior will result from its ultimate interaction with the rest of the national model. The policy structure translates inputs from the economy (as will be represented by the rest of the national model) into decisions to alter either the money supply or aggregate credit conditions. The other half of the feedback loops, connecting the monetary authority's decisions with the economy, will be provided by the structure of the national model.
E. Structural Overview

E.1. A Monetary Policy Structure in Simple Feedback Loops

A typical macroeconomic model treats monetary control decisions, often defined as the determination of the money supply, as exogenous to the economy. Discussions of monetary changes usually begin with an assumption of market equilibrium interrupted by an exogenous change in the money stock; for example, "Let us suppose the economy to be in full stock equilibrium and that the Government decides to expand the nominal supply of money. As we have noted, money is Government debt of a special kind, by assumption, and it can create any amount of it that it requires." (Ball 1964, p. 39)

This usual assumption of exogeneity is violated in the real economy. Monetary decisions can not be extracted from the economy's operation in any meaningful way, because those decisions both affect and are affected by economic performance. The current state of the economy (i.e., in terms of growth rate, unemployment rate, inflation rate, interest rates, etc.) depends on the prior history of monetary control. And in turn, the current decisions depend on the current economic condition.

Monetary control decisions are embedded in a feedback loop with the economy as sketched in Figure I-4. Information about the economy is used to derive the decisions that change the economy. The monetary decision-maker's perception of economic performance is delayed, perhaps biased by his own theoretical leanings, and distorted by the information-gathering process. The transmission of decisions to producers and consumers depends on the banking system and securities markets, which also introduce delays and distortion.
The concept of a monetary policy structure can be decomposed into three parts: a perception of the actual state of the economy, a perception of a desired state for the economy, and a set of decision rules to translate the perceived discrepancy between desired and actual states into decisions. Orcutt (Orcutt 1952, p. 195) describes some of the difficulties inherent in decision-making:

What is done is to observe the present discrepancy between the actual and the desired. This discrepancy is then used to guide or control the application of the instrument of adjustment. The action of the instrument of adjustment only takes place with some lag, and in this time interval the discrepancy between the actual and the desired may have changed due to the variation of uncontrolled, unpredicted, or even unknown factors. To the extent that the discrepancy between actual and desired does in fact change during the lag involved in the action of the instrument of adjustment, the action taken may turn out to be less appropriate or even inappropriate.
The decision-maker must know at least roughly what the impact of separate actions will be; that knowledge provides the rules leading to a decision from an observed discrepancy. The decision rules are derived largely from past experience. The apparent response of the economy to previous actions is observed, and that experience guides the development of decision rules.

The decision rules may also come from economic theory. Identities, such as the classical Equation of Exchange $MV = PT$ (the stock of money $M$ ($$) times its velocity $V$ (1/time period) must equal the price level $P$ ($$/good) times the volume of transactions $T$ (goods/time period)), provide a priori assumptions about the impact of a change in the money supply. But the theory itself is also modified by experience. For example, the neo-classical quantity theory has recognized that velocity tends to respond to interest rates—an observed phenomenon that alters the expected impact of a change in the stock of money (since interest rates are also affected).

The goals of monetary control, which define the desired economic condition, are also influenced by past experience. One aspect of a desired economic condition could be full employment. Yet from observation, most notably by Phillips (Phillips 1958), there appears to be a trade-off between full employment and price inflation. The goals of monetary control shift with experience; Maisel (Maisel 1973, pp. 63-64) provides a list of how goals were reevaluated in 1966 to reflect their dependence on previous observed behavior:

--There was a recognition that the choice of a monetary policy also involved a choice among competing goals. The traditional concept that fighting inflation was sufficient to guarantee accomplishing the other objectives for the economy became much harder to rationalize.
--The balance of payments had been playing a significant role in determining monetary policy since President Kennedy, early in his term and on the advice of Treasury Secretary Douglas Dillon, had designated it as a critical economic problem. But, as the need to pay for the war and to fight inflation became the dominating economic problems, the role of the balance of payments diminished.

--In 1966 it became apparent that the Federal Reserve could not neglect the side-effects of decreased money and credit, and higher interest rates. Three of these side-effects reached critical dimensions with relation to (a) the composition of demand and output, (b) the maintenance of viable financial markets, (c) the protection against large-scale failures of financial institutions.

--The markets in which monetary policy operated were examined with greater care and it became clear that these markets were not the idealized market of pure, perfect economic theory. Actual events occurred which differed widely from those in the abstract market of theoretical monetary policy.8

Figure I-5 captures this discussion of the dynamics of monetary decisions. Decisions evolve in response to the changing economy. The monetary decision-maker is faced with a variety of goals, instruments of change, and estimates of the expected effect of applying each instrument. Rather than pursuing some theoretically optimal path, he must respond to pressures to satisfice among competing goals without ever knowing unambiguously what the effects of his actions will be. Suggestions of new monetary control decisions must be reconciled with the dynamic process of decision-making—a process not yet fully understood nor adequately described by existing macroeconomic theory or practice.

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8 Maisel is unfortunately inconsistent in his use of "policy." Compare his first and second points with the fourth.
E.2. Functional Organization of the Structure

In defining the decisions to be made by the monetary authority sector, both the needs of the national model and the historical functions of monetary control must be considered. The overall purpose of monetary control is to ensure that money supplies are adequate for the volume of business transactions, but not excessive. Inadequate money supplies unnecessarily restrict business activity, and excessive supplies lead to speculation, financial instability, and raise the potential for price inflation.

Historically, the first function of monetary control was discounting—lending funds to business secured by discounted promissory notes,
the forerunner of modern commercial paper. Tucker records that the Bank of Amsterdam, established in 1609 as a bank of deposit,\(^9\) began in the mid-eighteenth century to make loans to the East India Company and several municipalities (Tucker 1839, p. 154). As commerce grew in the United States, larger banks adopted the habit of lending on discount to smaller banks, until the Federal Reserve as the central bank of the country, formalized lending to member banks through the discount window.\(^{10}\)

The second function of monetary control to develop in the banking system was the control of credit availability through restrictions on bank loans. Most early state bank charters constrained bank loans to some multiple of paid-in capital. Tucker (Tucker 1839, pp. 204-221) notes the gradual shift of loan restrictions from a multiple of capital to a multiple of bank specie reserves. As most loans are redeposited in the banks, from an aggregate view this early control of lending is identical to a reserve...

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\(^9\)A bank of deposit presumably holds 100% gold or silver deposit reserves against its demand deposits, as opposed to a bank of circulation, which issues paper money and makes loans. See Tucker (1839), pp. 145-160.

\(^{10}\)The Federal Reserve Act of 1913, sec. 13, par. 2: "Upon the endorsement of any of its member banks,...any Federal reserve bank may discount notes, drafts, and bills of exchange arising out of actual commercial transactions;...the Board of Governors of the Federal Reserve System to have the right to determine or define the character of the paper thus eligible for discount, within the meaning of this act. ...such definition shall not include notes, drafts, or bills covering merely investments or issued or drawn for the purpose of carrying or trading in stocks, bonds, or other investment securities, except bonds and notes of the Government of the United States. Notes, drafts, and bills admitted to discount under the terms of this paragraph must have a maturity at the time of discount of not more than 90 days, exclusive of grace." (F.R. Board 1956, pp. 43-44).
requirement against deposits, as formalized in the Federal Reserve Act of 1913. 11

A third function of monetary control performed by the Federal Reserve is the control of money supplies through open market buying and selling of securities. This function as well, though seemingly tied institutionally to the Federal Reserve, was carried out by state banks in the nineteenth century. On a national level, the Treasury had the power to deposit or withdraw funds from commercial banks (Friedman and Schwartz 1971, p. 150n), a power exactly analogous to the Federal Reserve's open market power.

Thus the three principal functions of Federal Reserve monetary control—setting the reserve ratio, setting the rate of discounting, and conducting open-market operations—were all exercised throughout the nineteenth century by state chartering authorities and the banks themselves. As described by Friedman and Schwartz (Friedman and Schwartz 1971, p. 9), the organiza-

11The Federal Reserve Act of 1913, sec. 19, as amended by Act of June 21, 1917: (par. 2) "Every member bank, banking association, or trust company which is or which becomes a member of any Federal reserve bank shall establish and maintain balances with its Federal reserve bank as follows: (par. 3) [for banks not in reserve or central reserve cities] ...an actual net balance equal to not less than seven per centum of the aggregate amount of its demand deposits and three per centum of its time deposits. (par. 4) [for reserve city banks] an actual net balance equal to not less than ten per centum of the aggregate amount of its demand deposits and three per centum of its time deposits... (par. 5) [for central reserve city banks] ...an actual net balance equal to not less than thirteen per centum of the aggregate amount of its demand deposits and three per centum of its time deposits... (par. 6) ...in order to prevent injurious credit expansion or contraction, may by regulation change the requirements as to reserves to be maintained against demand or time deposits or both..." (F.R. Board 1965, pp. 70-71).
tion of the Federal Reserve, though important, marked a change in the
degree of monetary control rather than a change in either its objectives
or the functional instruments through which it was pursued.

Accordingly, the monetary authority structure described in this
study is composed of three subsectors: a reserve ratio sector, a discount
rate sector, and an open-market operations sector. Each of the three sec-
tors continuously determines, on the basis of national economic conditions
and a decision structure, whether the previous decision (i.e., the reserve
ratio, discount rate, or volume of open-market purchases or sales) should be
changed or left the same. The focus of the entire structure is on specify-
ing, for each instrument, the inputs to which the decisions respond, the
criteria used to evaluate the inputs, and the process whereby a change in
the instrument is made.
F. Organization of the Study

This first chapter has introduced a number of concepts and characteristics of the policy structure that are explored in more detail throughout the study. Central among these is the notion of monetary decision-making as an endogenous dynamic process rather than an exogenous input. This concept underlies the entire study; Chapter Two will demonstrate, through a review of relevant monetary economics literature, the relative scarcity of formal structures for monetary decision-making. Chapter Two also shows that, despite the lack of formal policy structures, there exists a reasonable amount of (primarily informal) information regarding monetary goals, economic performance measures, and decision guidelines.

The primary characteristic of the policy structure for monetary control decisions is its division to represent the three instruments of monetary control—required reserve ratios, discount rate, and open-market operations. Chapters Three, Four, and Five are each devoted to one of these functional areas. Each describes the nature of the instrument both before and during the operation of the Federal Reserve System, provides an equation-by-equation justification of the structure and illustrates the dynamic characteristics of the structure by test simulations. These three chapters employ the informal information about the policy structure derived in Chapter Two, and add to it some detailed support for individual relationships.
Chapter Six contains a brief summary of the entire study, followed by suggestions for possible revisions in the structures of Chapters Three, Four, and Five. Finally, Chapter Six comments on the use of the structure for experiments within the complete national model, and suggests a few such experiments that would appear to be particularly helpful in understanding current national economic problems.
CHAPTER TWO: REVIEW OF MONETARY THEORY AND MODELS

A large body of literature exists on the role of money in a macro-economy, covering concepts of money demand, money supply, interest rate theory, optimal monetary control, and credit availability. As Monroe points out in his interesting historical summary, Monetary Theory Before Adam Smith, "Few aspects of modern economic discussion have their roots so deeply in the past as the theory of money." (Monroe 1966, p. vii).

A review of all aspects of monetary theory is beyond the scope of this study. This chapter concentrates on particular areas and particular authors that provide some insights into the decision-making process of monetary control, in terms of either goals for monetary control, performance measures of the economy, or decision guidelines. Few authors focus directly on the monetary decision-making process; those that do are reviewed in Section C of this chapter. Section A reviews the fundamental theories of the economic impact of monetary control decisions. Chapter One noted that a monetary authority's choice of policy goals and decision rules depends in part on a priori monetary theories and their justification or revision through empirical observation. All monetary theories are attempts to explain the response of the macro-economy to a monetary control decision (e.g., a change in the money supply). Section A, therefore,
discusses monetary theories as they relate to the dominant mechanisms, or channels, through which changes in the money supply can affect aggregate spending and prices.

The most complete formalizations of monetary theories are incorporated in the several existing econometric models of macroeconomic behavior. One of these models, the MPS model, is reviewed in Section B.\textsuperscript{12} The purpose of this review is to compare an econometric model of monetary control with the system dynamics approach taken in this study. Because the MPS model is used for forecasting by the Federal Reserve, the model also defines to some extent the Fed's view of monetary interactions. The MPS model is therefore helpful in deriving some of the decision rules for the monetary policy structure of this study.

\textsuperscript{12}The MPS (MIT-Pennsylvania-SSRC) model is chosen over other models because its creators explicitly focused on structural specification at the possible expense of high $R^2$'s. This characteristic makes the MPS model potentially more useful to the current system dynamics study than other econometric models. See (Cooper 1972, p. 13).
A. The Economic Influence of Monetary Control: Theory

A.1. Overview of Monetary Channels

Spencer provides a diagram, redrawn in Figure II-1, of the influences of a disequilibrium between money supply and demand on aggregate spending (Spencer 1974, p. 9). An action by the Federal Reserve altering the money supply sets in motion two kinds of economic reactions—changes in relative prices, and changes in wealth. Relative prices are taken here to include, in addition to prices of goods and services, the rates of return on real capital and financial assets. Changes in

![Diagram](image)

Figure II-1: The Monetary Transmission Process [redrawn from (Spencer 1974, p. 9)]
wealth encompass changes in real cash balances (nominal cash balances adjusted for price inflation) and changes in equity values.\(^{13}\)

The relative price channel assumes that both consumption and investment depend on both interest rates and the price of real capital relative to the aggregate price level. A rise in the stock of money induces a fall in interest rates and a rise in the relative price of real capital, encouraging increased investment to produce additional real capital. Furthermore, increased lending (stimulated by higher bank reserves and lower interest rates) raises consumption, so that both investment and consumption are initially stimulated by a rise in the money supply. In the long run, as more production factors (labor, equipment, financing) are demanded, interest rates and the general price level rise, at least partially offsetting the effect of the initial rise in the money stock.

\(^{13}\)None of these money-spending linkages has enjoyed a continuous development over the past seventy-five years. Both Fisher and Wicksell explored these monetary channels at the beginning of this century, with interest rates relied upon for short-term adjustments and real balances adjusting in the long-run. However, attention was diverted from these considerations, probably unintentionally, by Keynes, and, perhaps intentionally, by Keynes's interpreters. Hicks took a relatively minor part of Keynes's analysis, the so-called "liquidity trap," and popularized it as Keynes's principal contribution to monetary theory. Not until the late 1940's did considerations of money-spending linkages return to the fore of economic analysis. "Relative price and wealth changes were viewed as major elements of monetary transmission mechanisms around the turn of the century (in rudimentary fashion) and in recent years, but in much of the intervening period their role was subjected to considerable question." (Spencer 1974, p. 21). See (Fisher 1963), (Wicksell 1962), (Keynes 1936, p. 207), and (Hicks 1937).
The wealth channel assumes that an increase in the money stock, for example through a Federal Reserve open-market purchase, increases public wealth, which is assumed to increase consumption expenditures (the real balance effect). In addition, the rise in the market value of securities (price of real capital times capital stock) induces a shift in the public's portfolio out of government securities and into equities, inducing a rise in equity prices. The resulting capital gains to equity holders is assumed to increase spending. As in the relative price channel, these wealth-induced effects on spending are at least partially offset in the long run by a rise in the general price level.

A.2. Relative Price Theory

On the surface, relative price theory states that a change in the money stock induces changes in interest rates and therefore in relative prices of real and financial assets, causing a change in spending behavior. Underlying this surface are theories of choice in asset portfolios. Portfolio theory also supports, to a lesser degree, the wealth channel through equity values, but its main contribution is to theories of relative price changes induced by monetary control decisions.

Portfolio choice theory depends on two relatively simple, yet extremely powerful assumptions of economic behavior: (1) an increase in the supply of any one asset lowers its price relative to other assets in the portfolio and reduces its marginal returns.
per unit of asset; (ii) all else equal, the portfolio-holder tries to equate the marginal returns on all assets in his portfolio, allowing for risk and transactions costs.

Pigou's simple portfolio model distinguished only money and real capital (Pigou 1917). Keynes added government and private debt, but assumed perfect substitutability between them and real capital, focusing on the relative returns between money and one other asset, bonds (Keynes 1935). Modern portfolio theory derives mainly from the work of Tobin (Tobin 1961) and Brunner and Meltzer (Brunner and Meltzer 1963, 1972), and somewhat informally from Friedman (Friedman 1961, 1957). Tobin, using a portfolio model with six assets, draws the important conclusion that an increase in the supply of money does not unambiguously raise the demand for real capital, but may affect instead the demand for financial assets. Brunner and Meltzer, however, argue that because financial assets are closer substitutes for money than is real capital, an increase in the stock of money lowers not only the relative price of money but also the relative prices of its close substitutes as well. The result is an increase in the desired stock of real capital.

The incorporation of portfolio theory into a standard IS-LM framework has lent additional theoretical support for the relative price channel of monetary influence. Laidler shows informally that portfolio theory is consistent with the classical LM curve (Laidler 1969, p. 34). Foley and Sidrauski develop a complete formal model of portfolios containing money, bonds, and real capital, and combine this
stock equilibrium sector with a flow equilibrium description of income and expenditures to produce a two-sector macro-economic model (Foley and Sidrauskis 1971). Their model, while more complex than a basic IS-LM structure, nevertheless can be reduced to an IS-LM and again shows the general consistency of portfolio choice theory with traditional macro-economics (Foley and Sidrauskis 1971, pp. 92-94).

A.3. Wealth Theory

The influence of monetary control decisions on public non-human wealth, and through wealth on consumption, constitutes the wealth channel of monetary influence. Included in this channel are two effects—the real balance effect, and the equity effect. The real balance effect essentially describes the increase in consumption resulting from an increase in the real money stock $M/P$ ($M = \text{nominal money stock}, \ P = \text{general price level}$). Pigou (1943) revived the concept of real cash balances in the 1940's, and Patinkin formalized the concept in a period model of macro-economic behavior (Patinkin 1965). It is interesting that the real balance effect has also been tied to traditional IS-LM analysis, with both Friedman (1970, p. 206) and Brunner and Meltzer (1972, p. 847) agreeing that the real balance effect is one explanation of long-run shifts in the IS curve.

The equity effect captures the impact of monetary actions on the equity component of total wealth and thus on spending. An open market purchase by the Federal Reserve raises security prices relative
to equity prices, forcing up equity demand and thus equity prices. The rising equity prices yield capital gains to equity owners, raising
their wealth and (presumably) increasing consumption. This channel of
monetary influence plays a major role in the MPS econometric model; over
sixteen quarters, fully forty-five percent of the impact of an increase in
the money stock on aggregate spending can be attributed to this channel

A.4. Implications of These Theories for a Monetary Policy Structure

Both the relative price theory and the wealth theory imply
a short-run stimulative effect of an increase in the money stock.
Therefore, one of the principal decision rules for monetary control is
that an economy below full-capacity production can be stimulated by
an expansion of the money stock. This guideline, however, must be reconciled
with the long-run inflationary effect of a rise in the money supply.
It is generally recognized that money is neutral in the long run;
increases in the money supply might possibly bring an economy to full
capacity production, but further increases will result only in price
inflation (Patinkin 1965). Money neutrality can be traced to the
Equation of Exchange, \( MV = PT \) (\( M \) = money stock ($), \( V \) = velocity of
money (1/time), \( P \) = price level ($/unit), \( T \) = transactions volume
(units/time)), where \( T \) is assumed constrained by production capacity
and \( V \) is constant in the long run.

Short-run changes in velocity, however, are recognized as an
important element in the economy's reaction to a monetary decision.
Velocity's observed tendency to resist monetary control, that is, to increase when the money supply becomes restrictive (Garvey 1959), cushions the impact of a sharp change in the money supply. "Changes in velocity, along with other mechanisms built into our monetary system, serve to spread the effects of a flexible monetary policy." (Eastburn 1965, pp. 55-6)

Relative price and wealth theories also provide some of the indicators of economic performance. Changes in interest rates can be used as a rough gauge of the degree of monetary restrictiveness. If interest rates are rising, the money supply is likely to be insufficient for current money demand. The monetary authority, under these conditions, must decide whether satisfying the excess money demand would be beneficial to the economy. If prices are also rising, the monetary authority may decide that satisfying money demand is not worth the risk of exacerbating inflation by raising the money supply. On the other hand, if the economy is also faltering (rate of growth of real output is declining), the monetary authority may feel that added inflation is less important than stimulating output. These three indicators, interest rates, rate of inflation, and rate of growth in output, are all incorporated in the policy structure described in Chapters Three, Four, and Five.
B. Monetary Control in the MPS Econometric Model

The MPS (MIT-Pennsylvania-SSRC) model is a large-scale macro-econometric model of the United States. The model is an ambitious attempt to capture in a single econometric structure the complexity of the macro-economy. It incorporates (in 1972) sixty-six stochastic equations and 105 non-stochastic equations divided into six main areas: final demand, distribution of income, taxes and transfers, the labor market, prices, and a financial sector. The money market, a subsector of the financial sector, represents roughly five percent of the total model (Cooper 1972, pp. 24-28). The overall objective of the model is to provide a framework for analysis of the macro-economic impacts of fiscal and monetary control decisions.

The MPS model is an important milestone in econometric research, because of its heavy emphasis on justifying structural equations from economic theory. In this respect, the MPS model is more easily compared to a system dynamics model than reduced-form models of the St. Louis type (Christ 1969). A review of the MPS monetary sector should provide some useful insights for the design of a monetary sector in the national model currently under development.

14 Equations for the MPS model are given in (FRS 1973).

15 Like any model, the MPS model contains some of its creators' biases. For example, it is difficult to detect any real balance channel from money control to spending. However, its completeness relative to other existing models makes it most appropriate for the purpose of this study.
B.1. A Brief Description of the MPS Monetary Subsector

The monetary subsector of the MPS model performs two functions: the determination and balancing of money (demand deposit) supply and demand, and the determination of the short-term rate of interest. The causal structure for the subsector is shown in Figure II-2, redrawn from (Modigliani et al. 1970, p. 204). Money demand depends endogenously on the short-term (Treasury bill) rate, an internal distributed lag structure, and exogenously on gross national product and the time deposit rate. Money supply depends exogenously on government deposits and a seasonal, and endogenously on the level of demand deposits (at member banks). Demand deposits, in turn, depend endogenously on the banking system's demand for free reserves, and exogenously on unborrowed reserves, time deposits, and reserve requirements. Demand for free reserves depends endogenously on the bill rate, and exogenously on unborrowed reserves, reserve requirements, the discount rate, time deposits, commercial loans, and a seasonal. Finally, the Treasury bill rate is endogenously determined by the balancing of money supply and demand.

The heart of this subsector is the equation for the demand for free reserves (excess reserves - borrowed reserves), a structural equation based on bank maximization of portfolio profit. Allowance is made for gradual readjustment of bank asset holdings to exogenous changes; in the case of an increase in unborrowed reserves, portfolios adjust over a period of three quarters.
Figure II-2: The Monetary Subsector of the MPS Model [redrawn from (Modigliani et al. 1970, p. 204)]

The structure of Figure II-2 is basically two coupled negative feedback loops, acting to balance money supply with money demand. An important contribution of this monetary structure is the explicit representation of the lags in this balancing process, replacing the usual assumption of immediate adjustment with a more realistic gradual process.

B.2. Exogeneity of Policy Instruments in the MPS Monetary Subsector

The MPS model takes as exogenous the discount rate, reserve requirements, and unborrowed reserves (basically controlled by open-market operations). That these variables are endogenous in the true economy can hardly be questioned; the Federal Reserve responds to money market and general economic conditions in making decisions.
Modigliani recognizes this shortcoming (Modigliani et al 1970, p. 212), and defends the MPS structure as appropriate for the analysis of the impacts of monetary decisions as opposed to a description of current decision-making. Moreover, the econometric simulation technique employed in analyzing the MPS model requires the specification of some exogenous, time-dependent variables. Given the objective of the MPS model, the choice of policy instruments as exogenous variables seems more useful than, for example, taking as exogenous demand deposits and the bill rate.

The objective of this study, in contrast to the objective of the MPS model, is to derive a structure for monetary decision-making. The structure described in the following three chapters treats as exogenous the level of demand deposits, excess reserves of the banking system, and the bond rate (comparable to the bill rate of the MPS model), as well as other variables not addressed in the MPS monetary subsector (the rate of inflation, for example). Open-market operations, the discount rate, and reserve requirements are the principal endogenous elements of the policy structure. The structure describes the process whereby decisions to change these instruments are derived from the (sectorally) exogenous inputs, including relevant internal lags and adjustment mechanisms. The policy structure of a monetary authority presented in Chapters

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16 In the entire national model, the monetary authority sector intersects with the banking sector and other parts of the overall model, so that variables exogenous to the monetary authority sector are endogenous to the entire model.
Three, Four, and Five determines open-market decisions, the discount rate, and the required reserve ratio, and, allowing for an interface between system dynamics and econometrics, could potentially provide these three inputs required by the MPS monetary subsector.
C. Formal and Informal Models of Monetary Decision-Making

Despite the large number of theoretical and empirical macro-economic models, there exists only one prior attempt to model the decision-making behavior of a monetary authority (Wood 1967). Wood develops a statistical model of the Federal Reserve's open-market decisions by hypothesizing a preference function that the Fed tries to optimize. The Fed is assumed to have objectives relating to GNP, unemployment, balance of payments, inflation, and interest rates (Wood 1967, p. 139). Wood then estimates his model's parameters on the basis of data from 1952 to 1963, and concludes that the Fed's behavior was reasonably consistent with his hypothesis of multi-goal optimization.

Only one prior system dynamics study treats monetary decisions as endogenous (Shaffer 1974). That study focuses on the macro-economic effects of attempts to control the money supply. In two of his test simulations, the money supply is first assumed to change only in response to endogenously generated unemployment, then to both unemployment and inflation (Shaffer 1974, pp. 43-45). The policy structure of the Shaffer model, however, is quite simplistic—no formal distinction is made among the instruments of monetary control (reserve requirements, open-market operations, discount rate) to be used in controlling the money supply, and control is assumed to be undelayed. These deficiencies are remedied in the structure presented in Chapters Three, Four, and Five. 17

17 The Shaffer model produces the interesting result that monetary control based on the unemployment rate is destabilizing (Shaffer 1974, p. 45). This result is somewhat similar to the results of simulations performed with the MPS econometric model, in which control proportional to deviations from target unemployment and inflation rates was introduced and found to be slightly destabilizing (Cooper 1972, p. 254). Neither of these results, however, provide conclusive evidence that monetary control in the true economy is destabilizing, because neither model adequately represents the monetary policy structure. Experiments with the completed national model will allow a better assessment of the stability characteristics of a macro-economy.
Informal descriptions of monetary decisions fall into two categories: historical descriptions by economists, and essentially personal accounts by past or acting Federal Reserve officials. Friedman and Schwartz provide the most exhaustive account of the period 1867 to 1960 (Friedman and Schwartz 1963). Their chronological reconstruction highlights the pressures that come to bear on monetary authorities, and the hesitation that seems to accompany monetary decisions. As an example, they describe the 1937 increase in reserve requirements as the result of debate beginning in 1934 (Friedman and Schwartz 1963, p. 520ff).

Although restricted to a fifty-year period, the historical review of Eastburn is also quite helpful in understanding the policy structure of a monetary authority (Eastburn 1965). He provides a chronological listing of all decisions made by the Federal Reserve from 1919 to 1964, together with a brief summary of the economic conditions prevailing at the time of each decision (Eastburn 1965, pp. 68-96).

Other historical accounts, including (Reed 1930), (Mitchell 1903), (Andrew 1907), and (Andersen 1965), provide similar insights into the pressures on a monetary authority and the sluggishness with which an authority tends to respond. All of these accounts support Eastburn's content that the three principal objectives of monetary control are: "(a) price stability; (b) avoidance of instability in production, employment, and income; and (c) sustained economic growth" (Eastburn 1965, p. 17). None, however, describes in any detail the actual process that leads from a perception of a problem to a monetary decision.
The second category of descriptive literature, the personal accounts of Federal Reserve officials, is more useful in defining a monetary policy structure. Maisel, an ex-Governor of the Federal Reserve Board, describes in detail how decisions are made by the Board of Governors (Maisel 1973). Reproduced in Figure II-3 is Maisel's view of the process through which the Federal Reserve decides to change its instruments of control (Maisel 1973, pp. 31-34).

The first section of the chart shows the starting point for policy decisions. The state of the economy is examined and a forecast of economic and financial developments is made based on existing policy. As the decision making starts, the first two boxes on the upper left of the table show current operating instructions for monetary policy reflected in specific settings for the monetary instruments....

Based on studies of how the propensities to spend and to finance are developing and shifting, a forecast is made of the status of the economy and of the monetary variables if monetary policy remains unchanged. The two-way lines between the propensities to spend and lend and the monetary variables show that their interactions mutually bring about a particular level of spending and financing....

The next section of the chart depicts the choice of goals and objectives. They are compared (as indicated by dotted lines) with the economic developments expected to result from current policy. If a gap between desired and forecast spending and financial outcomes appears probable, the Federal Reserve must then determine whether changing the monetary variables is likely to bring the economy closer to the nation's goals. The monetary variables influence many spending decisions. The relationships which depend upon money must be estimated and a path or target for money must be chosen which will bring the economy as close to its goals as possible. The Fed must also weigh the costs compared to the hoped for gains from such a change.

At the same time, decisions must be made as to what settings for the monetary instruments will keep the monetary variables moving along the desired path in the light of all the other forces interacting in the economy and
Figure II-3: The Federal Reserve Decision-Making Process from (Maisel 1973, pp. 32-33)
financial markets. Operating instructions or guides are selected to adjust the instruments in order that the movements in the monetary variables can be properly controlled.

The third section depicts the period of operations. As a result of the chosen settings for the monetary instruments and the constantly shifting decisions of households, businesses, governments, and financial institutions, spending occurs, with its related economic, financial, and monetary consequences. Our data-gathering system estimates what is happening. The reported economic data are compared to the chosen targets for the monetary variables and the desired goals for the economy. If, as is usually the case, the actual data diverge from the targets and goals, the possible causes for the divergence must be analyzed.... Depending on this analysis, decisions may be made to change operating instructions in an attempt to move the monetary variables closer to their previously set target; or the monetary targets may be revised to accord with actual events. On the other hand, the decision may be to accept the new developments and maintain existing operations while revising the goals for the economy and financial markets. These revised decisions, shown in the fourth section of the chart, interact again with new spending desires to bring about an altered and hopefully more desirable level of spending, output, prices, and financial impacts.

Maisel describes a monetary policy structure of the same general form as that of (Orcutt 1952), as mentioned in Chapter One. Missing from Maisel's description are the delays inherent in the structure, and the magnitude of change in each instrument in response to observed economic problems. These delays and sensitivities of instruments are the subject of the following three chapters.

Other personal accounts, such as (Harding 1925), are less informative than Maisel because they fail to extract from specific cases the general structure of decision-making. Nevertheless, a very useful account of Open-Market Committee operations over one year is
provided by (FRBNY 1972), a review of the decisions made by the Open-Market Desk Manager during 1971. The paper reveals quite clearly the shifts in goals that occur as a result of changing economic conditions, and the resulting gradual but continual alteration of Federal Reserve decisions.
CHAPTER THREE: POLICY STRUCTURE FOR OPEN-MARKET OPERATIONS

First of all, it should be remembered that the [Open Market] Committee's decisions do not take place in a vacuum, but are made against the background of recent experience in the money and credit markets. I should like to emphasize this ever-present element of continuity. Quite often policy can be summarized in terms of creating somewhat more or somewhat less pressure in the money market and on member bank reserve positions, or in terms of maintaining about the same conditions that prevailed in an earlier period.


A. Background

Open-market buying and selling of securities constitutes the Federal Reserve System's most powerful instrument of control over aggregate money and credit conditions. Through their open-market operations, the Federal Reserve continually adjusts the availability of bank reserves in attempting to control inflation, unemployment, and financial liquidity conditions.

As compared to discount operations, which loan reserves to member banks, open-market operations provide or absorb reserves on a permanent basis.\(^{18}\) In the case of a Federal Reserve open-market purchase, the banking system exchanges a negotiable security for liquid reserves, which reserves can then be used to meet reserve requirements or to make

\(^{18}\) Permanent in the sense that a specific decision is required to reverse the effect of a previous decision.
further investments. Since the Federal Reserve cannot force the banking system to sell its financial assets, however, the price of these assets will be bid up by an intended open-market purchase until banks are willing to sell. A single open-market transaction, therefore, affects both the amount of bank reserves and the prices (or inversely, yields) of financial assets. Open-market operations can thereby influence both aggregate money-supply and credit conditions.

Open-market operations, however, are not pursued independently of ongoing financial conditions. As Rouse indicated, open-market operations are in general responding to changes in the banking system's need for funds, to movements in security yields, as well as to operational goals for the economy. The Federal Reserve cannot pursue for very long a particular open-market stance that is counter to the needs of the banking system (and the overall economy), without being pressured, by Congress, bankers, and the public, into changing their position. Open-market decisions must respond to objectives that may often be in conflict. Restraining inflation, for example, may often be traded-off against providing for real or apparent liquidity needs. Providing reserves for expansion may induce added inflation.

In the narrowest sense, open-market operations originated with the formation of the Federal Reserve System in 1913. In a broader sense, however, the ability to affect aggregate bank reserves existed before 1913, and various early monetary authorities attempted control over monetary aggregates through quite similar mechanisms. In the final
decades of the 19th century, the "central-banking activities of the Treasury were being converted from emergency measures to a fairly regular and predictable operating function" (Friedman and Schwartz 1963, p. 149). The Treasury could, and did on many occasions, purchase and sell government bonds in the open-market to release or absorb reserves; in addition, the Treasury used its tax receipts to influence monetary aggregates by alternately depositing and withdrawing large amounts in national banks.

Earlier monetary authorities used somewhat less similar, but no less powerful, instruments to affect monetary aggregates. From 1816 to 1836, the Second Bank of the United States received in payment of taxes a continual stream of state bank notes that were redeemable at the issuing banks for specie. "Thus, as a creditor of the state banks, it could at its discretion loosen the money market by following a lenient policy of redemption or, conversely, tighten the market by applying pressure to the redemption vise." (Krooss 1969, p. 353). The National Banking Act of 1864 gave the Treasury, under the control of the Comptroller of the Currency, the authority to issue bonds that could be used by the national banks to support expansion in the supply of national bank notes (Krooss 1969, pp. 1383-1395). The Treasury could therefore control the supply of national bank notes by controlling the amount of bonds issued to the national banks.

It was thus against a long background of attempted control over the money supply that the Federal Reserve Act authorized System operations in the open market. The act in essence confined aggregate control
activities to the security market, supplanting earlier note issue, redemption, bond issue, and deposit transfer schemes with a single mechanism for aggregate monetary control.
B. Causal Hypotheses of the Policy Structure for Open-Market Operations

The policy structure for open-market operations captures the forces leading to a decision by the monetary authority to buy or sell securities in the securities market. In the national model, securities traded by the monetary authority are represented by a bond with a fixed maturity, a fixed face value (price at maturity), and a variable current market price. A bond market (Behrens et al. 1974) determines both the actual number of bonds transacted and the current price of a bond. The policy structure for open-market operations determines a volume of bond transactions that the monetary authority would like to achieve in the bond market. On the other side of the market, a substructure within the aggregate bank determines the banking system's desired bond transactions. These two volumes of desired transactions are compared in the bond market substructure to determine the actual volume of bonds transacted and the current bond price. If total desired purchases exceed total desired sales, then the bond price will rise; conversely, if total desired sales exceed total desired purchases, the bond price will fall.

Figure III-1 shows the causal relationships leading to the desired net open-market purchases by the monetary authority. Desired net open-market purchases, expressed as a volume of bonds per year, is the rate at which the monetary authority would like to purchase bonds from the bond market (negative net purchases indicate net sales). Whether or not the monetary authority's desired purchases (sales) are
Figure III-1: Causal Relationships Underlying Desired Net Open-Market Purchases by the Monetary Authority
realized depends on whether there exist in the bond market willing sellers (buyers) at the current bond price. Figure III-1 shows only the relationships leading to desired net open-market purchases. Additional relationships, whose equations are described later in this chapter, translate desired net open-market purchases into separate desired purchases and sales of bonds. Desired purchases and sales are then used in the bond market to determine actual purchases and sales.

The most important element of Figure III-1 is the desired rate of growth in the money supply, in the center of the figure. This element is the rate of growth in the money supply that the monetary authority would like to achieve in order to meet its goals for inflation, unemployment, and availability of financial capital (as measured by the bond yield). This desired rate of growth (fraction per year) is first converted to a desired increase in the money supply (dollars per year) by multiplication with the current money supply (dollars). The desired increase in the money supply (dollars per year) is then converted to the volume of desired net open-market purchases (bonds per year) by dividing by the current bond price and multiplying by the money multiple, which is the ratio between the supply of high-powered money (currency and bank reserves) and the total money supply. The derivation of the money multiple is explained in connection with its equation in Section C of this chapter.

---

19 The money supply is defined here as the sum of currency and demand deposits, commonly called the "M1" definition of money supply.
The desired rate of growth in the money supply is the sum of four separate growth rates—the rate of growth in gross national product (GNP), and the three rates of growth indicated by inflation, unemployment, and liquidity. The latter three rates of growth reflect the pursuit of goals for inflation, unemployment, and financial liquidity. If all of these three goals were satisfied, then all three indicated rates of growth would be zero, and the desired rate of growth in the money supply would equal the rate of growth in GNP. Under those circumstances, the monetary authority would be attempting through its open-market operations to match the growth in the money supply to the growth in the dollar volume of output, GNP.\(^{20}\)

In general, the performance of the economy, as measured by the rate of inflation, the rate of unemployment, and the bond yield, does not meet the goals of the monetary authority. A positive gap between current and desired inflation, for example, will lead the monetary authority to attempt to restrain growth in the money supply with the expectation of thereby restraining inflation. The current spread in inflation (unemployment, bond yield) measures the difference between current and desired inflation (unemployment, bond yield). If the current spread in inflation is positive, then the rate of growth indicated by inflation is negative, leading to a desired rate of growth in the money supply that is below the rate of growth in GNP. Conversely,

\(^{20}\)The monetary authority would, in effect, be trying to keep the velocity of circulation at its current value. Velocity is defined as the ratio of nominal GNP to the money supply.
a positive current spread in unemployment, indicating current unemployment above the goal, leads to a positive rate of growth indicated by unemployment, presumably stimulating the economy through money supply growth that is faster than growth in GNP. Finally, bond yield above desired bond yield leads to a positive rate of growth indicated by liquidity, and vice versa for bond yield below desired bond yield. The exact form of each of these nonlinear relationships is presented in Section C.

This type of "reactive decision-making" is in direct contrast to proposed schemes of unalterable monetary control such as a fixed rate of money supply growth (Friedman 1970). Actual monetary authorities, such as the Federal Reserve, are better described as reactive in the sense that decisions change in reaction to changes in the economy. It will be possible to test with the entire national model the effect of a fixed money supply growth rule. Previous tests with econometric models have proven to be largely inconclusive (Cooper 1972, pp. 245-281). It is hoped that the national model, with its emphasis on dynamics, might shed some light on the essentially dynamic question of whether a fixed rule would improve aggregate economic behavior over current reactive, adaptive decision-making.

Desired bond yield, desired unemployment, and desired inflation are the three goals of the monetary authority for open-market operations. The goals are assumed to be variable, depending on the past history of inflation, unemployment, and bond yield. Each goal gradually adapts to ongoing inflation, unemployment, and bond yield.
For example, if 5% inflation persists for decades despite the monetary authority's best attempts at its control, then desired inflation approaches 5% and the rate of growth indicated by inflation approaches zero. Alternative goal structures are discussed in Chapter Six.

In summary, the monetary authority attempts through its open-market operations to control the growth in the money supply. The monetary authority is assumed to pursue four objectives: first, to accommodate growth in nominal GNP by allowing the money supply to grow at the same rate as nominal GNP; second, to resist inflation by reducing the growth rate of the money supply whenever inflation is above desired inflation; third, to resist unemployment by increasing the growth rate of the money supply whenever unemployment is above desired unemployment; and fourth, to resist swings in financial liquidity conditions by increasing (decreasing) the growth rate of the money supply whenever the bond yield is above (below) the desired bond yield.
C. Equations of the Policy Structure for Open-Market Operations

Figure III-2 is the DYNAMO flow diagram for the policy structure for open-market operations. Inputs exogenous to this structure include the bond yield BY, the rate of inflation RI, the rate of unemployment RU, the rate of growth in output RGO, demand deposits DD, reserves of the bank RB, the currency-deposit ratio CDR, and the money supply M.

Bonds of the Monetary Authority BM

\[
BM_i = BM_{i-1} + (BM_{i-2} - BM_{i-3}) + (BM_{i-1} - BM_{i-2}) + (BM_{i-2} - BM_{i-3}) \\
BM = IBAM/BPR \\
IBAM = 30E9
\]

- BM - BONDS OF THE MONETARY AUTHORITY (BONDS)
- DT - SOLUTION TIME INTERVAL (YEARS)
- PBM - PURCHASES OF BONDS BY THE MONETARY AUTHORITY (BONDS/YEAR)
- SBM - SALES OF BONDS BY THE MONETARY AUTHORITY (BONDS/YEAR)
- MBM - MATURATIONS OF BONDS AT THE MONETARY AUTHORITY (BONDS/YEAR)
- IBAM - INITIAL BOND ACCOUNT OF THE MONETARY AUTHORITY ($)
- BPR - BOND PRICE ($/BOND)

The level of bonds held by the monetary authority BM, corresponding to the Federal Reserve System Open-Market Account, is increased by the monetary authority's purchases of bonds PBM and is decreased by the sales of bonds SBM and the maturations of bonds MBM. The initial value for the level given above roughly corresponds to the 1960 security holdings of the Federal Reserve System.
Figure III-2: DYNAMO Flow Diagram
for the Open-Market Operations Policy Structure
BAM, K = BM, K * BPR, K

BAM - BOND ACCOUNT OF THE MONETARY AUTHORITY (\$)
BM - BONDS OF THE MONETARY AUTHORITY (BONDS)
BPR - BOND PRICE (\$/BOND)

The bond account of the monetary authority BAM is a supplementary equation determining the approximate dollar value of the bonds held by the monetary authority BM. The variable is used only for plotting a rough dollar value of the monetary authority's bond holdings. This rough value will differ slightly from the actual value whenever the bond price BPR is changing, since bonds actually enter and leave the bond account at their purchase price rather than at the current price. However, since each bond is held on average for only six or seven months (see discussion of Equation 8), the current price will usually be quite close to the purchase price. This approximation is sufficiently accurate for the purpose of providing a rough dollar value for the bonds held by the monetary authority BM.
Net Purchases of Bonds by the Monetary Authority NPBM

\[ NPBM.K = PBM.JK - SBM.JK - MBM.JK \]

NPBM  - NET PURCHASES OF BONDS BY THE MONETARY AUTHORITY (BONDS/YEAR)
PBM  - PURCHASES OF BONDS BY THE MONETARY AUTHORITY (BONDS/YEAR)
SBM  - SALES OF BONDS BY THE MONETARY AUTHORITY (BONDS/YEAR)
MBM  - MATURATIONS OF BONDS AT THE MONETARY AUTHORITY (BONDS/YEAR)

The net purchases of bonds by the monetary authority NPBM is calculated as a supplementary equation for plotting the net open-market purchases of the monetary authority. Net purchases NPBM is equal to the purchases of bonds PBM minus the sales of bonds SBM and the maturations of bonds MBM.

Sales of Bonds by the Monetary Authority SBM

\[ SBM.KL = (DSBM.K/DSB.K)(RT.K) \]

SBM  - SALES OF BONDS BY THE MONETARY AUTHORITY (BONDS/YEAR)
DSBM  - DESIRED SALES OF BONDS BY THE MONETARY AUTHORITY (BONDS/YEAR)
DSB  - DESIRED SALES OF BONDS (BONDS/YEAR)
RT  - BONDS TRANSACTED (BONDS/YEAR)

The sales of bonds by the monetary authority SBM is determined by comparing the monetary authority's desired sales DSBM to the total desired sales in the bond market DSB, and allocating to the monetary
authority the corresponding fraction of the total bonds transacted BT. The bond market, which is part of the structure describing commercial banking in the national model, matches bond-sellers with bond-purchasers, acting as the security brokers in the true financial system. If total desired purchases exceed total desired sales, then the number of bonds actually transacted is set equal to slightly more than desired sales to represent temporary adjustments in brokers' inventories and "pulling" of bonds in reaction to high demand. The bond market equations also define the bond yield BY, which changes as a result of imbalance between desired purchases and desired sales.²¹

\[
PBM_{KL} = \frac{DPBM_{K}}{DPB_{K}}(BT_{K})
\]

PBM - PURCHASES OF BONDS BY THE MONETARY AUTHORITY (BONDS/YEAR)
DPBM - DESIRED PURCHASES OF BONDS BY THE MONETARY AUTHORITY (BONDS/YEAR)
DPB - DESIRED PURCHASES OF BONDS (BONDS/YEAR)
BT - BONDS TRANSACTED (BONDS/YEAR)

The purchases of bonds by the monetary authority PBM is determined in a manner exactly analogous to the sales of bonds SBM, dependent upon the desired purchases of bonds DPB and the bond market.

Maturations of Bonds at the Monetary Authority MBM

\[
MBM_{KL} = BM_{K}/AMB
\]

AMB=1

MBM - MATURATIONS OF BONDS AT THE MONETARY AUTHORITY (BONDS/YEAR)
BM - BONDS OF THE MONETARY AUTHORITY (BONDS)
AMB - AVERAGE MATURITY OF BONDS (YEARS)

²¹ Equations of the bond market are presented and described briefly in (Behrens et al. 1974, pp. 69-73).
The maturations of bonds at the monetary authority MBM is determined by dividing the current monetary authority bond holdings BM by the average maturity of bonds AMB. The average maturity of bonds AMB is assumed to be equal to one year, as it is throughout the national model.

Desired Purchases of Bonds by the Monetary Authority DPBM

\[
DPBM, k = (NBT, k + BM, k / AMB) + (BM, k \times DREB, k / 2)
\]

\[
\begin{align*}
DPBM & \quad - \text{DESIRED PURCHASES OF BONDS BY THE MONETARY AUTHORITY (BONDS/YEAR)} \\
NBT & \quad - \text{NORMAL BOND TRANSACTIONS (BONDS/YEAR)} \\
BM & \quad - \text{BONDS OF THE MONETARY AUTHORITY (BONDS)} \\
AMB & \quad - \text{AVERAGE MATURITY OF BONDS (YEARS)} \\
DREB & \quad - \text{DESIRED RATE OF EXPANSION IN BONDS (FRACTION/YEAR)}
\end{align*}
\]

Desired purchases of bonds by the monetary authority DPBM is the rate at which the monetary authority would like to purchase new bonds from the bond market (expressed in terms of bonds per year). Desired purchases are composed of two elements. The first, the sum of normal bonds transacted NBT and maturations of bonds, expressed as bonds BM divided by average maturity of bonds AMB, represents the normal flow of bond purchases that keep the level of bonds BM constant. Maturations of bonds appear in this equation because maturations are normally
exactly offset by additional new purchases. The monetary authority automatically replaces any bonds that mature by purchasing an equal amount of additional bonds. Normal bond transactions NBT, the product of the normal rate of bond transactions NRBT and current bond holdings BM, represents the rate at which the monetary authority normally turns over its bond holdings. This term appears symmetrically in the equation for desired sales of bonds by the monetary authority DSBM, Equation 9.

The second term, bonds BM times one-half of the desired rate of expansion in bonds DREB, captures the monetary authority's desires to expand or contract its bond holdings to influence the rate of growth of the money supply. The negative of this term appears in the equation for desired sales of bonds by the monetary authority DSBM, Equation 9. The formulation is designed to accomplish a desired increase (decrease) in bonds by simultaneously raising (lowering) purchases of bonds and lowering (raising) sales of bonds by equal amounts. For example, if the desired rate of expansion in bonds DREB were twenty percent per year and bond holding BM were one thousand bonds, then this formulation would increase desired purchases DPBM by one hundred bonds per year and decrease desired sales DSBM by one hundred bonds per year, yielding a net desired change of two hundred bonds per year, or twenty percent per year. Equal pressure on both desired purchases DPBM and desired sales DSBM is therefore exerted by any desired rate of expansion in bonds DREB.
Normal Bond Transactions NBT

\[
NBT, K = NRBT \times BM, K \\
NRBT = .84
\]

\[
NBT \quad - \quad \text{NORMAL BOND TRANSACTIONS (BONDS/YEAR)} \\
NRBT \quad - \quad \text{NORMAL RATE OF BOND TRANSACTIONS (FRACTION/YEAR)} \\
BM \quad - \quad \text{BONDS OF THE MONETARY AUTHORITY (BONDS)}
\]

Normally the monetary authority does not hold its securities to maturity, but instead turns over its holdings at a rate equal to the normal rate of bond transactions NRBT. NRBT enters symmetrically into the equation for desired bond sales, Equation 9, yielding a normal bond-holding time of six to seven months:

\[
\text{Normal bond-holding time} = \frac{\text{Bonds}}{(\text{Bond maturities} + \text{normal sales})} \\
= \frac{\text{Bonds}}{(\text{Bonds/AMB} + \text{Bonds} \times \text{NRBT})} \\
= \frac{\text{Bonds}}{(\text{Bonds/1} + (\text{Bonds} \times .84))} \\
= 1/1.84 = .54 \text{ years} \approx 6-7 \text{ months.}
\]

Desired Sales of Bonds by the Monetary Authority DSBM

\[
DSBM, K = NBT, K - (BM, K \times DREB, K/2) \\
DSBM \quad - \quad \text{DESIRED SALES OF BONDS BY THE MONETARY AUTHORITY (BONDS/YEAR)} \\
NBT \quad - \quad \text{NORMAL BOND TRANSACTIONS (BONDS/YEAR)} \\
BM \quad - \quad \text{BONDS OF THE MONETARY AUTHORITY (BONDS)} \\
DREB \quad - \quad \text{DESIRED RATE OF EXPANSION IN BONDS (FRACTION/YEAR)}
\]
Desired sales of bonds by the monetary authority DSBM is formulated analogously to desired purchases DPBM. The first term, normal bond transactions NBTr, is the rate at which the monetary authority normally turns over its bond holdings BM. The second term reflects the monetary authority's desires to increase or decrease its bond holdings BM.

Desired Rate of Expansion in Bonds DREB

\[
\text{DREB}_K = \text{TABHL} (\text{TDREB}, \text{IREB}_K, -2, 2, .5) \\
\text{TDREB} = -1 / .95 / .8 / .5 / 0 / .5 / .8 / .95 / 1
\]

DREB - DESIRED RATE OF EXPANSION IN BONDS (FRACTION/YEAR)
TDREB - TABLE FOR DESIRED RATE OF EXPANSION IN BONDS
IREB - INDICATED RATE OF EXPANSION IN BONDS (FRACTION/YEAR)

Figure III-3: Table Function for Desired Rate of Expansion in Bonds DREB
The desired rate of expansion in bonds DREB is the rate, in terms of a fraction per year, at which the monetary authority would like to expand its bond holdings. The monetary authority will attempt to expand (contract) its bond holding BM whenever it feels that the money supply M should be growing at a positive (negative) rate. The indicated rate of expansion in bonds IREB, the argument for the table function of Figure III-3, is the rate of expansion in bonds that would fully accommodate any expansion in bonds indicated by considerations of growth, inflation, unemployment, and liquidity. The dashed line in Figure III-3 shows the table values that would equate the desired rate of expansion DREB with the indicated rate of expansion IREB. The actual table values, given by the solid line in Figure III-3, constrain the magnitude of DREB to be in general less than IREB. The desired rate of expansion in bonds DREB is constrained to be greater than -1.0 because the monetary authority is assumed to be unwilling to contract its bond holdings at a rate faster than one hundred percent per year. Similarly, the monetary authority is assumed to be unwilling to expand its bond holdings at a rate faster than one hundred percent per year. The desired and indicated rates of expansion are equal for rates of expansion between plus-and-minus fifty percent per year. For moderate changes in bond holdings, therefore, the monetary authority attempts to purchase or sell in the bond market the full volume of transactions indicated by growth, inflation, unemployment, and liquidity. Rapid changes in bond holdings, however, are constrained.
Indicated Rate of Expansion in Bonds IREB

\[ \text{IREB}_k = \frac{\text{DNOP}_k}{\text{BM}_k} \]

- **IREB** \( \text{INDICATED RATE OF EXPANSION IN BONDS (FRACTION/YEAR)} \)
- **DNOP** \( \text{DESIRED NET OPEN-MARKET PURCHASES (BONDS/YEAR)} \)
- **BM** \( \text{BONDS OF THE MONETARY AUTHORITY (BONDS)} \)

The indicated rate of expansion in bonds IREB translates the volume of desired net open-market purchases, expressed in terms of bonds per year, into a fractional rate of expansion in bonds, expressed in terms of a fraction per year. Normally, it would be appropriate to enter the desired net open-market purchases DNOP directly into the equations for desired purchases and sales of bonds, DPBM and DSBM respectively. The translation into the indicated rate of expansion IREB, and the table function for the desired rate of expansion DREB, prevent excessively large or small desired net open-market purchases DNOP from either rapidly exhausting the bond holding BM or imposing very large desired purchases of bonds on the bond market. The monetary authority is assumed to be unwilling to exhaust rapidly their bond holdings, realizing that such an action would impair their ability to accomplish future open-market operations. The monetary authority is also assumed to be unwilling to cause a rapid rise in the bond price BPR by attempting very large purchases
of bonds. For these reasons, this policy structure first translates desired net open-market purchases DNOP into an indicated rate of expansion in bonds IREB before calculating desired purchases and sales of bonds, DPBM and DSBM.

Desired Net Open-Market Purchases DNOP

\[ DNOP, K = DIMS, K \times MM, K / BPR, K \]

- **DNOP** - DESIRED NET OPEN-MARKET PURCHASES (Bonds/Year)
- **DIMS** - DESIRED INCREASE IN MONEY SUPPLY ($/YEAR)
- **MM** - MONEY MULTIPLE (DIMENSIONLESS)
- **BPR** - BOND PRICE ($/BOND)

Desired net open-market purchases DNOP are the net purchases of bonds the monetary authority would like to make to meet its objectives in open-market operations. The desired increase in money supply DIMS, the first term in the above equation, is the increase in the money supply, expressed in terms of dollars per year, that would achieve its open-market objectives. The money multiple MM translates a change in the total money supply M into a dollar volume of open-market purchases. Therefore, the desired increase in the money supply DIMS times the money multiple MM yields the dollar volume of net open-market purchases that the monetary authority would like to make. Division by the bond price BPR yields the volume in bonds of desired net open-market purchases DNOP.
Money Multiple $\MM$

$$\MM \cdot k = \frac{(\RRD \cdot k + \text{CDR} \cdot k)}{(1 + \text{CDR} \cdot k)}$$

$\MM$ - MONEY MULTIPLE (DIMENSIONLESS)

$\RRD$ - RATIO OF RESERVES TO DEPOSITS (DIMENSIONLESS)

$\text{CDR}$ - CURRENCY-DEPOSIT RATIO (DIMENSIONLESS)

The money multiple $\MM$ translates a change in the total money supply $M$ into the appropriate dollar value of reserves to be provided by open-market operations. The money multiple $\MM$ is derived from the relationships that define the money supply and the supply of "high-powered" money. High-powered money is the sum of currency and bank reserves, and is called "high-powered" because "one dollar of such money held as bank reserves may give rise to the creation of several dollars of deposits" (Friedman and Schwartz 1963, p. 50).

$$M \equiv C + D$$

where $M \equiv$ money supply ($\$)

$C \equiv$ currency ($\$)$

$D \equiv$ demand deposits ($\$)$

$$H \equiv R + C$$

where $H \equiv$ high-powered money ($\$)$

$R \equiv$ bank reserves ($\$)$

$C \equiv$ currency ($\$)$

Therefore $$\frac{H}{M} = \frac{R + C}{D + C} = \frac{R/D + C/D}{1 + C/D}.$$
High-powered dollars are conserved. A dollar provided by the monetary authority in an open-market operation will remain as part of either bank reserves or currency. A dollar provided by an open-market purchase can lead to several dollars in demand deposits, yielding the multiple expansion in the money supply as indicated by the money multiple MM. For example, if the ratio of reserves to deposits RRD is .15, and the currency-deposit ratio CDR is .1, then the money multiple MM will be roughly .33, implying that a desired increase in the money supply DIMS of 100 dollars per year can be accomplished by an increase in open-market purchases of 33 dollars per year.

The currency-deposit ratio CDR is the ratio between the public's currency and deposit holdings. This ratio is determined outside of the monetary authority sector.

Ratio of Reserves to Deposits RRD

\[
RRD.K = \frac{RB.K}{DD.K}
\]

 RRD - RATIO OF RESERVES TO DEPOSITS (DIMENSIONLESS)
 RB - RESERVES OF THE BANK ($)
 DD - DEMAND DEPOSITS ($)
The ratio of reserves to deposits RRD is the ratio between the reserves of the bank RB and the total demand deposits DD. If the bank held no excess reserves, so that their reserve holdings were exactly equal to required reserves, then this ratio would equal the required reserve ratio RRR. Because of excess reserves, the ratio of reserves to deposits RRD will be in general slightly higher than the required reserve ratio RRR.

Desired Increase in Money Supply DIMS

\[ \text{DIMS} \times \text{M} \times \text{DRGM} \]

\[ \text{DIMS} \times \text{M} \times \text{DRGM} \]

- **DIMS**: DESIRED INCREASE IN MONEY SUPPLY ($/YEAR)
- **M**: MONEY SUPPLY ($)
- **DRGM**: DESIRED RATE OF GROWTH OF MONEY (FRACTION/YEAR)

The desired increase in money supply DIMS is the annual dollar increase in the money supply M that the monetary authority would like to accomplish. The desired increase in the money supply DIMS is formulated as the product of the current money supply M ($) and the desired rate of growth in money DRGM (fraction per year).
Desired Rate of Growth in Money $\text{DRGM}$

\[ \text{DRGM}_{K} = \text{RGG}_{K} + \text{RGIL}_{K} + \text{RGIU}_{K} + \text{RGII}_{K} \]

$\text{DRGM}$ - Desired Rate of Growth of Money (Fraction/Year)

$\text{RGG}$ - Rate of Growth in GNP (Fraction/Year)

$\text{RGIL}$ - Rate of Growth Indicated by Liquidity (Fraction/Year)

$\text{RGIU}$ - Rate of Growth Indicated by Unemployment (Fraction/Year)

$\text{RGII}$ - Rate of Growth Indicated by Inflation (Fraction/Year)

The desired rate of growth in money $\text{DRGM}$ is the rate of growth in the money supply $M$ that the monetary authority would like to achieve through its open-market operations. The desired rate of growth in money $\text{DRGM}$ is the sum of four components: the rate of growth in gross national product $\text{RGG}$, representing the rate of growth in nominal output (output at current prices); the rate of growth indicated by liquidity $\text{RGIL}$, representing adjustments to desired growth in the money supply to control bond yield $\text{BY}$; the rate of growth indicated by unemployment $\text{RGIU}$, reflecting increases in the desired growth of money to control unemployment; and the rate of growth indicated by inflation $\text{RGII}$, reflecting decreases in the desired growth of money to control inflation.

The desired rate of growth in money $\text{DRGM}$ is the central element in the policy structure for open-market operations. It captures the pressures that cause the monetary authority to force the growth rate of
the money supply to deviate from the growth rate in GNP. These pressures arise from three sources—the bond yield BY, the rate of unemployment RU, and the rate of inflation RI. If the economy were able to maintain consistently a stable bond yield BY, a rate of unemployment RU equal to the desired rate of unemployment DRU, and a rate of inflation equal to the desired rate of inflation DRI, then the monetary authority would allow the money supply M to grow at the same rate as GNP. Deviations from the desired bond yield DBY, from the desired rate of unemployment DRU, or from the desired rate of inflation DRI, will in general cause the desired rate of growth in money DRGM to be different from the rate of growth in GNP RGG.

The use of a desired rate of growth in money DRGM does not imply that this policy structure uses a "money-supply target" as opposed to an "interest-rate target," a distinction often made in describing Federal Reserve operations. The policy structure described here attempts to control both interest rates on securities (the bond yield BY) and the rate of growth of money. At any particular point in time, under a specific set of economic circumstances, it might be appropriate to describe the monetary authority as ignoring interest rates (perhaps because they are stable) and concentrating solely on making the money supply grow at the rate indicated by economic activity. However, their policy is to try to control both financial liquidity (interest rates) and the rate of

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22Chapter 6, Section B, discusses the possibility of explicitly including a growth objective in DRGM.
growth in the money supply, as well as trying to control inflation and unemployment. All of these control objectives must appear in the policy structure for the monetary authority.

Appendix III-A, at the end of this chapter, contains parts of a list of Federal Reserve Decisions compiled by Eastburn (Eastburn 1965, pp. 68-96). In the second column of the appendix are open-market decisions made between 1921 and 1964, followed in the third column by a brief summary of the economic conditions that preceded the decision. Liquidity, inflation, and unemployment are mentioned repeatedly as the rationale for open-market decisions. For example, an open-market sale in 1924 is described as responding to "Business at high level, prices rising." An open-market sale in 1939 came as the result of "Strong market demand, which resulted in rapid advances in Government security prices [yields declining]." An open-market purchase in 1957 is defined as an action "To increase the availability of bank reserves and thereby cushion adjustments and mitigate recessionary tendencies in the economy."

All of these influences are embodied in the formulation of the desired rate of growth of money DRGM. The influences are captured by the three indicated rates of growth from unemployment, inflation, and liquidity, to be described in the equations that follow.
Rate of Growth in Gross National Product RGG

\[ RGG \cdot K = RGO \cdot K + RI \cdot K \]

\[ RGG = \text{RATE OF GROWTH IN GNP (FRACTION/YEAR)} \]
\[ RGO = \text{RATE OF GROWTH IN OUTPUT (FRACTION/YEAR)} \]
\[ RI = \text{RATE OF INFLATION (FRACTION/YEAR)} \]

The first element in the desired rate of growth in money DRCM is the rate of growth in gross national product RGG. This rate of growth is the fraction by which nominal output is expanding per year. Nominal output is defined as the product of real output (goods per year) and the price level (dollars per good). The rate of growth in nominal output RGG, therefore, is equal to the sum of the rate of growth in real output RGO and the rate of inflation RI.\(^{23}\)

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\(^{23}\)If \( \text{GNP} = O \cdot P \) (where \( O \equiv \text{real output} \), \( P \equiv \text{price level} \)), then

\[
\frac{\dot{\text{GNP}}}{\text{GNP}} = \frac{\dot{O}}{O} + \frac{\dot{P}}{P}. 
\]
Rate of Growth Indicated by Liquidity RGIL

\[ RGIL.K = \text{TABLE}(TRGIL, CSBY.K, -0.05, 0.05, 0.01) \]
\[ TRGIL = \frac{-1}{-0.04/-0.015/-0.01/-0.005/0/0.005/0.01/0.015/0.04/1} \]

RGIL  - RATE OF GROWTH INDICATED BY LIQUIDITY (FRACTION/YEAR)
TRGIL  - TABLE FOR RATE OF GROWTH INDICATED BY LIQUIDITY
CSBY  - CURRENT SPREAD IN BOND YIELD (FRACTION/YEAR)

The Federal Reserve regards as one of its principal functions the avoidance of liquidity crises in the financial community. A high aggregate demand for funds will result in high loan interest rates, high
yields on securities, and a high federal funds rate (the rate at which individual banks will lend reserves to each other). The Federal Reserve Board uses the federal funds rate as an index of liquidity, and one of the objectives of open-market operations is to maintain the federal funds rate at some desired level by providing or withholding reserves through its open-market decisions. In the aggregate bank structure of the national model, there is no federal funds market. Implicit in the bank structure is the assumption that all possible interbank lending takes place. As a measure of funds availability, this structure uses instead the current spread in bond yield CSBY, defined as the difference between the current and the desired bond yields. When funds are scarce, the bond yield BY will be bid up because bond holders will want to sell bonds and reinvest the funds in loans. This action will drive down the bond price BPR (and thus force up the bond yield BY). The monetary authority will respond by raising its desired rate of growth in money DRGM, which will increase its open-market purchases to provide additional reserves to the bank.

The rate of growth indicated by liquidity RGIL is the mechanism through which control of the bond yield BY takes place. Figure III-4 graphs its dependence on the current spread in bond yield CSBY. The function is relatively insensitive to small deviations from desired bond yield DBY, such that variations of ±3% or less change the desired rate of growth of money DRGM by at most ±1.5% per year. However, larger deviations in the bond yield BY away from the desired bond yield DBY
result in progressively larger changes in the desired rate of growth of money DRGM. For example, a difference of 5% between current and desired bond yields results in a 10% per year addition to the desired rate of growth in money DRGM.

Current Spread in Bond Yield CSBY

\[ \text{CSBY}, k = \text{BY}, k - \text{DBY}, k \]
\[ \text{CSBY} \quad - \quad \text{CURRENT SPREAD IN BOND YIELD (FRACTION/YEAR)} \]
\[ \text{BY} \quad - \quad \text{BOND YIELD (FRACTION/YEAR)} \]
\[ \text{DBY} \quad - \quad \text{DESIRED BOND YIELD (FRACTION/YEAR)} \]

The current spread in bond yield CSBY is simply the difference between the current bond yield BY and the desired bond yield DBY. This spread measures the gap between actual financial liquidity conditions and the monetary authority's objective for liquidity conditions.

Desired Bond Yield DBY

\[ \text{DBY}, k = \text{SMOOTH(BY}, k, \text{TABY}) \]
\[ \text{TABY} = 5 \]
\[ \text{DBY} \quad - \quad \text{DESIRED BOND YIELD (FRACTION/YEAR)} \]
\[ \text{BY} \quad - \quad \text{BOND YIELD (FRACTION/YEAR)} \]
\[ \text{TABY} \quad - \quad \text{TIME TO AVERAGE BOND YIELD (YEARS)} \]
The desired bond yield DBY is the monetary authority's objective against which the current bond yield BY is compared. The desired bond yield DBY is formulated as a first-order exponential average of the actual bond yield BY, with a time constant, time to average bond yield TABY, equal to five years. A first-order exponential average is identical to a continuous Koyck-distributed lag with a coefficient of adjustment equal to the reciprocal of the time constant (Koyck 1954). This formulation provides the monetary authority with an objective for bond yield that gradually adjusts to the actual bond yield BY. Their objective is therefore not fixed, but will adapt to sustained changes in the bond yield BY. This type of formulation for goal-setting is currently employed throughout the financial sector of the national model.\footnote{A discussion of alternative goal-setting formulations appears in Section B of Chapter Six.}
Rate of Growth Indicated by Unemployment RGIU

RGIU.K = TABHL(TRGIU, CSU, K, 0, 0.2, 0.02)  
TRGIU = 0/01/025/045/07/1/15/0.25/4/475/5  
RGIU - RATE OF GROWTH INDICATED BY UNEMPLOYMENT (FRACTION/YEAR)  
TRGIU - TABLE FOR RATE OF GROWTH INDICATED BY UNEMPLOYMENT  
CSU - CURRENT SPREAD IN UNEMPLOYMENT (FRACTION)

Figure III-5: Table Function for Rate of Growth Indicated by Unemployment RGIU
The second principal function of the monetary authority is to attempt to control unemployment. The monetary authority responds to high unemployment by increasing the desired rate of growth of money DRGM above the rate of growth of GNP RGG. The form of this response, as embodied in the rate of growth indicated by unemployment RGIU, is graphed in Figure III-5. The figure shows that small values for the current spread in unemployment CSU, which is the difference between the actual and desired rates of unemployment, elicit little response from the monetary authority. As the current spread in unemployment CSU increases, however, the rate of growth indicated by unemployment RGIU increases more than proportionately. If, for example, the current rate of unemployment RU is ten percent above the desired rate of unemployment DRU, then the monetary authority will try to force the money supply M to grow at an annual rate that is ten percent higher than the rate of growth in GNP RGG (assuming all else equal).

Whenever the rate of unemployment RU is below the desired rate of unemployment DRU, the rate of growth indicated by unemployment RGIU is equal to zero. The monetary authority, therefore, responds to unemployment only when current unemployment is above their objective.
Current Spread in Unemployment CSU

\[ CSU_K = RU_K - DRU_K \]

- CURRENT SPREAD IN UNEMPLOYMENT (FRACTION)
- RATE OF UNEMPLOYMENT (FRACTION)
- DESIRED RATE OF UNEMPLOYMENT (FRACTION)

The current spread in unemployment CSU is simply the difference between the current rate of unemployment RU and the desired rate of unemployment DRU. This spread measures the gap between actual unemployment and the monetary authority's objective for unemployment.

Desired Rate of Unemployment DRU

\[ DRU_K = \text{SMOOTH}(RU_K, TARU) \]

- DESIRED RATE OF UNEMPLOYMENT (FRACTION)
- RATE OF UNEMPLOYMENT (FRACTION)
- TIME TO AVERAGE RATE OF UNEMPLOYMENT (YEARS)

The desired rate of unemployment DRU is the monetary authority's standard against which the current rate of unemployment RU is compared. The desired rate of unemployment DRU is formulated as a first-order exponential average of the actual rate of unemployment RU, with a time constant,
time to average the rate of unemployment TARU, equal to ten years. The desired rate of unemployment DRU adjusts quite slowly to ongoing changes in the rate of unemployment RU. Changes in the rate of unemployment RU over the business cycle, for example, will have little effect on the desired rate of unemployment DRU. Changes that persist over several business cycles, however, will result in a shift of the monetary authority's unemployment standard.

Rate of Growth Indicated by Inflation RGII

RGI\textsubscr{\text{I},K}=\text{TABHL}(\text{TRGII},\text{CSI},K,0,.2,.02) \quad 24, A
TRGII=0/-,.01/-,.025/-,.05/-,.09/-,.15/-,.24/-,.33/-,.42/-.47/-,.5 \quad 24,1, T

RGII  - RATE OF GROWTH INDICATED BY INFLATION (FRACTION/YEAR)
TRGII  - TABLE FOR RATE OF GROWTH INDICATED BY INFLATION
CSI    - CURRENT SPREAD IN INFLATION (FRACTION/YEAR)

The third principal function of the monetary authority is to attempt to control inflation by regulating growth in the money supply. The monetary authority responds to high inflation by reducing the desired rate of growth of money DRGM below the rate of growth of GNP RGG. The form of this response, as embodied in the rate of growth indicated by inflation RGII, is graphed in Figure III-6. The dashed line of Figure III-6 indicates values for RGII that would completely offset inflation. For example, if the current spread in inflation CSI is assumed equal to the actual rate of inflation RI (implying that the desired rate of in-
flation DRI, Equation 26, is zero), and the rate of growth in GNP RGG is 4%, of which 2% is inflation, then the rate of growth indicated by inflation RGII would be -2% (on the dashed line of Figure III-6) yielding a desired rate of growth in money DRGM of 2%. The actual values for the table function, shown by the solid line of Figure III-6, gives a nonlinear response to inflation. For values of the current spread

Figure III-6: Table Function for Rate of Growth Indicated by Inflation RGII
inflation CSI of less than seven percent, some inflation in the economy is accommodated. For values of the current spread in inflation SCI greater than seven percent, inflation is resisted more and more strongly. Figure III-7 gives some sample economic conditions and the desired rate of growth of money DRGM that would result in each case from this structure.

<table>
<thead>
<tr>
<th>Rate of Inflation (RI)</th>
<th>Rate of Growth Indicated by Inflation (RGII)</th>
<th>Rate of Growth in GNP (RGG)</th>
<th>Desired Rate of Growth of Money (DRGM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0%</td>
<td>4%</td>
<td>4%</td>
</tr>
<tr>
<td>2%</td>
<td>-1%</td>
<td>6%</td>
<td>5%</td>
</tr>
<tr>
<td>4%</td>
<td>-2.5%</td>
<td>8%</td>
<td>5.5%</td>
</tr>
<tr>
<td>7%</td>
<td>-7%</td>
<td>11%</td>
<td>4%</td>
</tr>
<tr>
<td>8%</td>
<td>-9%</td>
<td>12%</td>
<td>3%</td>
</tr>
<tr>
<td>10%</td>
<td>-15%</td>
<td>14%</td>
<td>-1%</td>
</tr>
</tbody>
</table>

Figure III-7: The Desired Rate of Growth of Money DRGM under Sample Inflationary Conditions

The monetary authority is assumed not to respond to relative deflation alone. When the current spread in inflation CSI is less than zero, the rate of growth indicated by inflation RGII is zero. The desired rate of growth of money DRGM will reflect the actual rate of
inflation or deflation through the rate of growth of GNP RGG, but no separate responses will be transmitted through RGII.

Current Spread in Inflation CSI

\[ CSI, K = RI, K - DRI, K \]

- **CSI**: CURRENT SPREAD IN INFLATION (FRACTION/YEAR)
- **RI**: RATE OF INFLATION (FRACTION/YEAR)
- **DRI**: DESIRED RATE OF INFLATION (FRACTION/YEAR)

The current spread in inflation CSI is simply the difference between the current rate of inflation RI and the desired rate of inflation DRI. This spread measures the gap between actual inflation and the monetary authority's objective for inflation.

Desired Rate of Inflation DRI

\[ DRI, K = SMOOTH(RI, K, TARI) \]

- **DRI**: DESIRED RATE OF INFLATION (FRACTION/YEAR)
- **RI**: RATE OF INFLATION (FRACTION/YEAR)
- **TARI**: TIME TO AVERAGE RATE OF INFLATION (YEARS)
The desired rate of inflation DRI is the monetary authority's standard against which the current rate of inflation RI is compared. The desired rate of inflation DRI is formulated as a first-order exponential average of the actual rate of inflation RI, with a time constant, time to average the rate of inflation TARI, equal to ten years. The desired rate of inflation DRI adjusts quite slowly to ongoing changes in the rate of inflation RI. Changes in the rate of inflation RI over the business cycle, for example, will have little effect on the desired rate of inflation DRI. Changes that persist over several business cycles, however, will result in a shift of the monetary authority's inflation standard.
D. Test Simulations of the Policy Structure for Open-Market Operations

D.1. Scope and Purpose of the Simulations

The equations of Section C, defining the policy structure for open-market operations, translate a set of inputs into a stream of open-market decisions. The stream of decisions determines a continuous flow of purchases and sales of bonds by the monetary authority. The inputs are of essentially two types: parameters, or constants, that remain unchanged over time; and variables, which would normally change through time. When the policy structure for the monetary authority is combined with the national model, these variables inputs will be provided by the overall model. Each of the variables will be generated by a dynamic structure of its own; the bond yield BY, for example, will be generated by the structure that defines the interactions in the bond market.

The policy structure of the monetary authority, therefore, does not generate its behavior solely from internal interactions, as is usually the case with system dynamics models. This policy structure depends on a specification of its variable inputs in order for any behavior to be generated. In the entire national model, the monetary authority will be embedded in a variety of feedback loops that will generate behavior from their own internal interactions. The variable inputs to the monetary authority will then be endogenous elements of a feedback structure. When taken separately, the monetary authority requires that its variable inputs be provided by a set of
test functions. These test functions supplant the feedback relations of the national model that would normally provide the monetary authority with its variable inputs.

Figure III-8 enumerates both the parameters and the variable inputs that must be provided to the policy structure for open-market operations. Three types of parameters are identified as constant inputs: constants (C), initial values (N), and table functions (T). The equations of Section C have already defined representative values for all of these parameters. The variable inputs must be defined by test functions of their own.

<table>
<thead>
<tr>
<th>Parameters (type)</th>
<th>Variable Inputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Initial bond account of the monetary authority IBAM (C)</td>
<td>- Money supply M</td>
</tr>
<tr>
<td>- Average maturity of bonds AMB (C)</td>
<td>- Reserves of bank RB</td>
</tr>
<tr>
<td>- Normal rate of bond transactions NRBT (C)</td>
<td>- Desired purchases of bonds DPB</td>
</tr>
<tr>
<td>- Table for desired rate of expansion in bonds TDREB (T)</td>
<td>- Desired sales of bonds DSB</td>
</tr>
<tr>
<td>- Table for rate of growth indicated by liquidity TRGIL (T)</td>
<td>- Bonds transacted BT</td>
</tr>
<tr>
<td>- Time to average bond yield TABY (C)</td>
<td>- Bond price BPR</td>
</tr>
<tr>
<td>- Table for rate of growth indicated by unemployment TRGIU (T)</td>
<td>- Demand deposits DD</td>
</tr>
<tr>
<td>- Time to average rate of unemployment TARU (C)</td>
<td>- Rate of growth in output RGO</td>
</tr>
<tr>
<td>- Table for rate of growth indicated by inflation TRGII (T)</td>
<td>- Rate of inflation RI</td>
</tr>
<tr>
<td>- Time to average rate of inflation TARI (C)</td>
<td>- Bond yield BY</td>
</tr>
<tr>
<td></td>
<td>- Currency-deposit ratio CDR</td>
</tr>
<tr>
<td></td>
<td>- Rate of unemployment RU</td>
</tr>
</tbody>
</table>

Figure III-8: Parameters and Variable Inputs for the Policy Structure for Open-Market Operations
The money supply $M$ is defined as the sum of demand deposits $DD$ and currency, or, using the currency-deposit ratio $CDR$, as $(DD)(1 + CDR)$. The currency-deposit ratio $CDR$ is defined to be constant with a value of 0.1. Demand deposits $DD$ are then defined as a level equation, increased (or decreased) by the flow of new deposits that could be created by the open-market operations of the monetary authority. A nine-month third-order delay is incorporated between net purchases of bonds by the monetary authority $NPBM$ and the increase in demand deposits, representing the delay in the deposit-creation process.

Open-market operations, therefore, are assumed to accomplish fully the desired increase in the money supply $DIMS$ after a nine-month delay. Reserves of the bank $RB$ are defined as a constant fraction of demand deposits $DD$, that fraction being equal to 0.15. Desired purchases of bonds $DPB$, desired sales of bonds $DSB$, and bonds transacted $BT$ are all defined so that the monetary authority is allowed to realize the full amount of its desired purchases and sales of bonds, $DPBM$ and $DSBM$ respectively. The bond market, therefore, is presumed to exert no constraint on the monetary authority's open-market operations. The bond price $BPR$ depends mechanically on the bond yield $BY$; a static formula, given in Appendix I, converts any value of bond yield $BY$ into the current bond price $BPR$.

25 The precise equations for all these variable inputs appear as "Interface Equations" in Appendix I.
The bond yield BY, the rate of growth in output RGO, the rate of inflation RI, and the rate of unemployment RU are all defined by exogenous test functions of a common form. The test functions allow the variables to take any one (or any combination) of three dynamic patterns: a constant value, a step of specifiable height, or a sinusoid of specifiable amplitude and period. These four test functions allow for examination of the response of the policy structure to various input conditions.

The purpose of the test simulations described in this section is to explore the dynamic characteristics of the policy structure. The dynamic characteristics of this type of open-loop policy structure can be defined as the time-forms of its response to specified input time-forms. For example, one dynamic characteristic of the policy structure would be its response over time to a step increase in the rate of inflation RI. Exploration of the policy structure's dynamic characteristics includes examining the sensitivity of its response to alterations in its parameters. The policy structure's response to a step in inflation, for example, will be sensitive to some degree to the value given to the time to average the rate of inflation TARI.

Exploring the dynamic characteristics of this policy structure does not include a comparison of its output to time-series data. Eventually, the performance of the national model, with the monetary authority included, will be compared to observed real-world behavior to judge the model's ability to reproduce conditions as they actually
occurred in the true economy. However, that comparison could be misleading if attempted with the policy structure for the monetary authority in isolation. Suppose, for example, that time-series data were provided for all of the variable inputs to the policy structure for open-market operations, rather than having those inputs generated by the national model. If the open-market purchases generated by the policy structure began to diverge slightly from the actual open-market purchases, this divergence would not be reflected by any alteration in the inputs away from their time-series values (in the bond yield BY, for example). The divergence could be compounded through time, and the simulated volume of open-market purchases could become widely different from the actual time-series. In the full national model, however, the bond market would have altered the bond yield BY, which would have changed open-market purchases, possibly counteracting the initial divergence.

It is of course possible to provide the policy structure with time-series for all its variable inputs, and compare the open-market operations as generated by the policy structure with those generated by the Federal Reserve. However, the phenomenon described in the preceding example could possibly take place. One might then be tempted to reject a policy structure whose output did not correspond to time-series data, even though the policy structure might perform quite well when embedded in the national model. Conversely, a policy structure whose output matched closely the time-series data may be incapable of operating realistically in the full national model. The simulation tests presented here, therefore, concentrate on the
dynamic characteristics of the policy structure, and no comparison to
time-series data is attempted.\footnote{These paragraphs do not imply that this policy structure is incapable of reproducing time-series data. Its ability to do so, however, is simply not a meaningful indication of the policy structure’s correspondence with the true decision-making process.}

Figure III-9 outlines the test simulations performed on the policy structure for open-market operations. The figure provides a brief description of the economic conditions being simulated, followed by an abbreviated accounting of the dynamic characteristics that each simulation illustrates. The figure shows, for example, that one dynamic characteristic explored by the simulations is the response of the policy structure to cyclic variations in GNP, inflation, and unemployment.

D.2. Test Simulations

Figure III-10 illustrates the response of the policy structure for open-market operations to a constant 3%-per-year rate of growth of output RGO. Inflation, unemployment, and the bond yield are all assumed constant. The monetary authority sets its desired rate of growth in money DRGM equal to the rate of growth in gross national product RGG, which, in the absence of inflation, is equal to the rate of growth in output RGO. The resulting rate of growth of money RGM is 3%-per-year, so that GNP and the money supply exhibit identical rates of growth. Velocity V is thereby held constant. In order to maintain a constant fractional rate of growth in the money supply, the monetary authority
<table>
<thead>
<tr>
<th>Figure</th>
<th>Conditions Simulated</th>
<th>What the Simulation Shows</th>
</tr>
</thead>
<tbody>
<tr>
<td>III-10</td>
<td>GNP growing at 3% per year; inflation, unemployment, and bond yield are stable.</td>
<td>The monetary authority keeps the money supply growing at the same rate as GNP.</td>
</tr>
<tr>
<td>III-11</td>
<td>Growth in GNP steps from 3% to 6%; inflation, unemployment, and bond yield are stable.</td>
<td>The monetary authority immediately raises the growth in the money supply in response to faster growth in real output.</td>
</tr>
<tr>
<td>III-12</td>
<td>Various step increases in inflation; other conditions stable.</td>
<td>Compares the response to different gaps between actual and desired inflation; shows the adjustment of desired to actual inflation.</td>
</tr>
<tr>
<td>III-13</td>
<td>Step increase in inflation; various values for TARI; other conditions stable.</td>
<td>The response to inflation depends on how quickly the goal for inflation adjusts to actual conditions.</td>
</tr>
<tr>
<td>III-14</td>
<td>Various step increases in unemployment; other conditions stable.</td>
<td>Compares the response to different gaps between actual and desired unemployment; shows the adjustment of desired to actual unemployment.</td>
</tr>
<tr>
<td>III-15</td>
<td>Various step changes in the bond yield; other conditions stable.</td>
<td>Compares the response to different gaps between actual and desired bond yield; shows the adjustment of desired to actual bond yield.</td>
</tr>
<tr>
<td>III-16</td>
<td>Sinusoidal rate of growth in output; other conditions stable.</td>
<td>The monetary authority responds immediately to cyclic growth, but the money supply lags behind GNP.</td>
</tr>
<tr>
<td>III-17</td>
<td>Various cyclical fluctuations in unemployment and inflation; other conditions stable.</td>
<td>Depending on the relative magnitudes, the monetary authority responds more to either inflation or unemployment.</td>
</tr>
</tbody>
</table>

Figure III-9: Outline of the Test Simulations, Giving Conditions Simulated and Their Results
Figure III-10: Response to a Constant 3% per-year Rate of Growth of Output

- Net Purchases of Bonds
- Velocity
- Desired Rate of Growth of Money
- Bonds of the Monetary Authority
must purchase bonds at an ever-increasing rate. Net purchases of bonds NPBMB, therefore, increases over the entire 30-year period. Bonds of the monetary authority BM are thereby also increased throughout the period, and more than double over 30 years.

This test simulation illustrates that in the absence of any adverse economic conditions, the monetary authority tries to control the money supply so that its rate of growth is the same as that of GNP. The absence of inflation, unemployment, and fluctuations in the bond yield imply that the economy has the proper amount of money in proportion to its output, and that economic activity is neither inflated nor restrained by the money supply.

Figure III-11 shows on the same scales the response of the policy structure to a step increase in the rate of growth of output RGO. In year 10, RGO is increased from 3% per year to 6% per year. Because this higher rate of growth is due entirely to growth in real output, the desired rate of growth of money DRGM also rises immediately to 6% per year. The actual rate of growth of money RGM, however, lags behind, due to the assumed nine-month delay between open-market operations and the money supply. This slight delay causes a minor increase in velocity V, since the lagged response of the money supply forces the economy to economize slightly in the use of money. Net purchases of bonds NPBMB must double in year 10 in order to release twice the prior amount of reserves per year. Thereafter, net purchases NPBMB continue to increase but with a rate of growth twice as high as before the change. The step change has resulted in both a one-time
Figure III-11: Response to a Step Increase in the Rate of Growth of Output
doubling and a doubling of the rate of increase of net purchases of bonds NPBM.

The rate of growth of output RGO, as used in the function for the desired rate of growth of money DRGM, is the rate of growth that the monetary authority can perceive in making its open-market decisions. In all simulations it is presumed that the monetary authority can immediately perceive the rate of growth in GNP (in output, inflation, unemployment, and bond yield). If there is any delay between changes in actual economic conditions and the monetary authority's measurement of those changes, then the response of the money supply would be even more sluggish than that shown in Figure III-11. Whether or not the monetary authority sector will require separate perception delays on these inputs will depend on how the inputs are defined and generated by the rest of the national model. For example, if the rate of inflation RI is defined in the model as the measured rate of inflation (measured, perhaps, by the monetary authority itself), then this sector should have immediate access to the measured rate of inflation and no perception delay would be necessary.

Figure III-12 plots on a single graph the results of four different changes in the inputs to the policy structure. Each line plots the response of the policy structure to a different step increase in the rate of inflation RI. The rate of growth of money RGM is the

27 Employs "comparative plotting," a new feature of DYNAMO II.
Figure III-12: Response to Various Step Increases in the Rate of Inflation
plotted variable in each case. The rate of inflation RI starts at 1% per year, then is increased in year two to 2% per year, 4% per year, 8% per year, and 12% per year. Because inflation is fully reflected in the rate of growth of GNP RGG, RGG thereby also increases from 1% per year to 2%, 4%, 8%, and 12% per year.

The initial response of the monetary authority in each case is to resist inflation by holding the desired rate of growth of money DRGM below the rate of growth of GNP RGG. However, the desired rate of inflation DRI gradually adjusts to the actual rate of inflation RI as the monetary authority, faced with an apparently uncontrollable increase in inflation, adjusts its goal for inflation to actual conditions. In equilibrium, therefore, the rate of growth of money RGM approaches the rate of inflation RI (rate of growth of output RGO is assumed to be zero).

The transient response to inflation, however, is quite different in each case. The rate of growth indicated by inflation RGII, a component of the desired rate of growth of money DRGM, is the relationship controlling the transient response. When the rate of inflation RI steps from 1% per year to 2% per year, RGII takes a value of -0.5% per year, so that the desired rate of growth of money DRGM takes a value of 1.5% per year, even though the rate of growth in GNP RGG is 2% per year. The monetary authority thereby attempts to resist half of the 1% increase in inflation. As the desired rate of inflation DRI adjusts to the actual rate of inflation RI, the
desired rate of growth of money DRGM approaches 2% per year, as the rate of growth indicated by inflation RGII approaches zero.

The response becomes more severe as the step in inflation increases. When inflation steps from 1% per year to 4% per year, RGII takes a first value of -1.75% per year, so that DRGM has a first value of 2.25% per year. When inflation steps to 8% per year, RGII changes to -7% per year, so that the desired rate of growth of money DRGM remains at 1% per year even though inflation has increased by 7% per year. The monetary authority thereby attempts to resist initially the full amount of the increase in inflation. When inflation increases to 12% per year, the rate of growth indicated by inflation RGII takes a value of -19.5% per year, so that the desired rate of growth of money DRGM is actually -7.5% per year. In this manner, the monetary authority resists a very large increase in inflation by forcing the money supply to decline. In Figure III-12, the rate of growth of money RGM is negative for roughly 2-3 years as the monetary authority tries to restrain severe inflation. Gradually, however, the goal for inflation, the desired rate of inflation DRI, adjusts to the higher and unyielding rate of inflation RI. The rate of growth of money RGM approaches 12% per year. In all these cases, the speed with which the monetary authority adjusts its goal to actual conditions is governed by the time to average the rate of inflation TARI, given a value of ten years.

Figure III-13 examines the sensitivity of the policy structure's response to changes in the time to average the rate of inflation
Figure III-i3: Sensitivity of the Response to Changes in the Time to Average the Rate of Inflation
TARI. Four different values for TARI, of 3 years, 10 years, 30 years, and 1000 years, are used. The rate of inflation RI is increased in year two from 1% per year to 6% per year. When the time to average the rate of inflation TARI is set equal to 1000 years, the monetary authority's desired rate of inflation DRI remains essentially constant at its first value of 1% per year. This case represents a goal that does not respond to actual conditions. Even though inflation has increased by 5% per year, the monetary authority will allow only a 1.25%-per-year increase in the rate of growth of money RGM. RGM stays essentially constant at 2.25% per year, even though GNP (which includes inflation) is growing at 6% per year.

For other, smaller values of the time to average the rate of inflation TARI, the desired rate of inflation DRI adjusts to the actual rate of inflation RI. A shorter time constant implies that the monetary authority adjusts its goals more quickly to actual conditions. For any of the curves of Figure III-13, the difference between the rate of growth of GNP RGG (the discrete step in the figure) and the rate of growth of money RGM (the four curved lines) is the amount of inflation that the monetary authority is resisting. For example, in year 10, with TARI equal to three years, RGM is roughly 0.5% below RGG; with TARI equal to ten years, RGM is roughly 1.5% below RGG; and with TARI equal to thirty years, RGM is roughly 2.5% below RGG. The time to average the rate of inflation TARI therefore determines how reluctant the monetary authority is to allow their goals to adjust to ongoing conditions.
The time to average the bond yield TABY and the time to average the rate of unemployment TARU perform similar functions for the goals for liquidity and unemployment. The values for all three of these time constants, as chosen in Section C of this chapter, yield inflation and unemployment goals that would remain relatively stable over a six-year business cycle, but the shorter value for TABY (five years as compared to ten years for TARI and TARU) allows the goal for liquidity to adjust quite significantly over a typical business cycle. The monetary authority is thereby assumed willing to adapt to changes in liquidity conditions more quickly than to changes in unemployment or inflation conditions.

Figure III-14 shows the monetary authority's response to various step increases in the rate of unemployment RU. The rate of inflation RI and the rate of growth in output RGO are both assumed to be equal to zero. The time to average the rate of unemployment TARU is assigned its original value of ten years. The rate of unemployment RU is alternately increased from 1% to 2%, 4%, 8%, and 12%. In each case, the monetary authority attempts to combat the increase in unemployment by raising the desired rate of growth of money DRGM above the rate of growth of GNP RGG (which is 0% per year). As unemployment persists, however, the monetary authority adapts to a higher rate of unemployment RU and the rate of growth of money RGM is allowed to fall gradually back to zero.

The response to different increases in unemployment, however, is nonlinear. A 1% increase in unemployment causes only a minor increase
Figure III-14: Response to Various Steps in the Rate of Unemployment
in the rate of growth of money RGM. When unemployment steps to 4% (a net increase of 3%), RGM reaches a peak of roughly 1.5%. When unemployment increases to 8%, the rate of growth of money RGM peaks at 4.5%, a response that is proportionately much stronger than the response to smaller changes. When unemployment rises to 12%, RGM reaches a high value of nearly 9%, an even stronger response. These different responses are all governed by the rate of growth indicated by unemployment RGIU, Equation 21 as described in Section C. The table function shown in Figure III-5 illustrates the nonlinearity of the response to unemployment. For example, for a 2% increase in unemployment, Figure III-5 shows a rate of growth indicated by unemployment RGIU of only 1%, while an 8% increase gives RGIU a value of 7%, much more than four times as strong.

Figure III-15 illustrates the response to various step changes in the bond yield BY, with other conditions held stable. The time to average bond yield TABY is assigned its original value of five years. The bond yield is alternately changed from 4% per year to 5% per year, 7% per year, 9% per year, and 0% per year. In all three cases of an increase in the bond yield BY, the rate of growth of money RGM is increased above zero. When the bond yield is decreased, however, the rate of growth of money RGM is forced negative. In all four cases, RGM gradually returns to zero as the desired bond yield DBY adjusts to the bond yield BY.

In a full model, actions taken like those shown in Figure III-15 would be intended to control the bond yield BY. With the
Figure III-15: Response to Various Step Changes in the Bond Yield
monetary authority uncoupled from the bond market, the bond yield BY does not respond to the corrective action. The step changes in bond yield BY are unaltered by the increase (or decrease) in net purchases of bonds by the monetary authority NPBM that results from an increase (or decrease) in the desired rate of growth of money DRGM. Figure III-15 illustrates the monetary authority's response to sustained changes in bond yield BY, much as Figure III-12 and Figure III-14 illustrate the response to sustained changes in inflation and unemployment, respectively. All three of these figures are responses to artificial changes in the inputs. They are intended to convey an impression of the dynamics of the monetary authority's response to economic conditions. The behavior of the monetary authority in conjunction with a fully-reacting economy will necessarily have to await its combination with the rest of the national model.

Figure III-16 is the first of two illustrations of the policy structure's response to cyclical inputs. The rate of growth of output RGO is assumed to vary sinusoidally between 0% per year and 6% per year with a period of six years, as duplicated by the desired rate of growth of money DRGM in the figure. The actual rate of growth of money RGM, however, lags behind DRGM because of the assumed delay between open-market operations and the money supply. Increases in the money supply M, therefore, lag behind increases in gross national product GNP, with the result that velocity V varies over the cycle. Friedman and Schwartz document that velocity usually
declines during business contractions and usually rises during business expansions (Friedman and Schwartz 1963). Figure III-16 shows that this typical behavior of velocity may arise from a lag between the GNP and the money supply. In other words, pro-cyclical variations in velocity may at least partially result from the inability of the monetary authority (Federal Reserve) to exert immediate control over the money supply. There is, of course, little reason to expect that variations in velocity originate entirely from this source. However, the lag between open-market operations and the money supply is quite clearly a contributing factor to the behavior of velocity.

Figure III-17 contrasts three forms of cyclical variation in both inflation and unemployment. The figure illustrates how the relative magnitudes of inflation and unemployment can shift the attention of the monetary authority from one to the other.

Curve A is the response to pro-cyclical variation in inflation between 0% per year and 4% per year, and counter-cyclical variation in unemployment between 4% and 0%. Both inputs have a period of six years.

Curve B is the response to pro-cyclical variation in inflation between 0% per year and 4% per year, and counter-cyclical variation in unemployment between 10% and 0%.

Curve C is the response to pro-cyclical variation in inflation between 0% per year and 8% per year, and counter-cyclical variation in unemployment between 4% and 0%.
Curve C illustrates how large symmetrical fluctuations in inflation can contribute to asymmetrical fluctuations in the rate of growth of money RGM. The asymmetry of curve C (different amplitudes above and below the 4% line) is due to the nonlinear response of the monetary authority to inflation. Very high inflation causes a proportionately more severe response than low inflation. The monetary authority, therefore, allows the rate of growth of money RGM to exceed 4% per year by only 1.5%, but is willing to allow RGM to drop almost 3% below the average 4%-per-year line when inflation is low. The rate of growth of money RGM, therefore, is not a smooth sinusoid, even though a smooth sinusoid in the rate of inflation RI was employed as the input.

A comparison of curves A and B illustrates the shift between two objectives. In curve A, the monetary authority is relatively insensitive to the fluctuation in unemployment, and attempts to resist inflation by allowing the money supply to fluctuate relatively evenly, but with a smaller amplitude than inflation. Curve B, however, shows that larger changes in unemployment, with the same variation in inflation, cause the monetary authority to shift its focus from inflation to unemployment. From year 3 to year 7, curve B shows a rate of growth of money RGM higher than that in curve A. This higher rate of growth comes from an attempt to counteract higher unemployment by raising the rate of growth of money RGM. As unemployment subsides, the monetary authority returns to its prior objective of controlling inflation.
Figure III-18 shows in more detail the conditions underlying curve B of Figure III-17. Near the bottom of Figure III-18 are plotted the rates of inflation and unemployment, RI and RU respectively. Near the top of the figure are plotted the rate of growth of gross national product RGG, the desired rate of growth of money DRGM, and the rate of growth of money RGM. The change from inflation control to unemployment control can be seen in roughly year three, as DRGM departs widely from RGG to try to stimulate the economy in the face of rising unemployment. The resulting RGM shows fluctuations with a frequency that is twice that of the input time-forms, as the monetary authority resists inflation over the first half of the cycle and resists unemployment over the second half.

The Appendix that follows describes many of the open-market decisions made by the Federal Reserve over the period 1920-1964, giving the economic rationale offered by the Fed at the time of the decision.
Figure III-18: Further Details of Figure III-17
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<tr>
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<tbody>
<tr>
<td>1921: April</td>
<td>Bought $400 million of Government securities (January-March 1922).</td>
<td>Commodity and agricultural values and business activity at low level; gradual contraction in credit; gold reserves strengthened.</td>
</tr>
<tr>
<td>-1922: August</td>
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<tr>
<td>1922: June</td>
<td>Sold $525 million of Government securities.</td>
<td>Production in basic industries at highest level on record; labor fully employed; prices rising; renewed expansion in credit; heavy gold inflow.</td>
</tr>
<tr>
<td>-1923: July</td>
<td></td>
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<tr>
<td>1923: December</td>
<td>Bought $510 million of Government securities (December 1923-September 1924).</td>
<td>Business and prices receded; attitude of business community hesitant; European countries undertaking to stabilize currencies and considering return to gold standard; easy money here a check on the inflow of foreign capital and gold and a factor encouraging American foreign investment.</td>
</tr>
<tr>
<td>-1924: October</td>
<td></td>
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<tr>
<td>1924: November</td>
<td>Sold $260 million of Government securities.</td>
<td>Business at high level; prices rising; some speculation in stocks and real estate; rapid expansion in credit.</td>
</tr>
<tr>
<td>-1925: March</td>
<td></td>
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<tr>
<td>1926: April</td>
<td>Bought $65 million of Government securities. Buying rate on bankers' acceptances reduced.</td>
<td>Liquidation of bank loans in New York City; decline in open market money rates; apparent slowing down in some lines of business activity; decrease in stock prices and brokers' loans.</td>
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<tr>
<td>1926: August</td>
<td>Sold $80 million of Government securities.</td>
<td>Rapid growth in bank loans; high business activity; advance in open-market money rates; increase in Reserve Bank credit outstanding.</td>
</tr>
<tr>
<td>-1926: September</td>
<td>Buying rate on bankers' acceptances raised.</td>
<td></td>
</tr>
<tr>
<td>1927: May</td>
<td>Bought $230 million of Government securities.</td>
<td>Moderate recession in business; lower level of prices, especially farm products; relatively heavy indebtedness of member banks; and a tendency toward firmer conditions in the money market. Also serious credit stringency and threat of renewed foreign exchange depreciation and instability in Europe, which it was feared would interfere with marketing abroad of farm products, especially cotton.</td>
</tr>
<tr>
<td>-1927: November</td>
<td>Buying rate on bankers' acceptances reduced</td>
<td></td>
</tr>
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<td></td>
<td>(July-August).</td>
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<tr>
<td>1928: January</td>
<td>Sold $405 million of Government securities</td>
<td>Industrial production expanding rapidly, particularly for durable goods; prices of stocks increasing sharply; huge growth in security loans and new security issues; action aimed at checking speculative activity and making member banks scrutinize loan applications more carefully.</td>
</tr>
<tr>
<td>-1929: May</td>
<td>(January 1928-April 1929).</td>
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<td></td>
<td>Buying rate on bankers' acceptances raised</td>
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<td>(January 1928-March 1929).</td>
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<tr>
<td>1929: August</td>
<td>Buying rate on bankers' acceptances reduced. Restrictive effect of discount operations moderated by free purchases of banker's acceptances during autumn to assist seasonal financing of agriculture and trade.</td>
<td>Industrial production, factory employment, and payrolls at high levels; earnings of corporations at record volume; capital issues numerous and large; speculative credit at banks increasing rapidly; rates charged by banks higher than at any time since 1921; loans to brokers and dealers in securities and stock prices at unprecedented levels.</td>
</tr>
<tr>
<td>1929: October -1930: December</td>
<td>Bought $560 million of Government securities, of which $120 million were bought in 2 days at most critical phase of stock market crash.</td>
<td>Recession in industry; commodity and stock prices dropped sharply; private lenders called loans to brokers; bank credit liquidation started. Actions aimed at preventing complete collapse of security markets and money panic, and at making credit easy to facilitate business recovery.</td>
</tr>
<tr>
<td>1931: January -1931: August</td>
<td>Bought $130 million of Government securities (June-August). Buying rate on bankers' acceptances reduced (January-May).</td>
<td>Production declining sharply after partial recovery; stock, speculative bond, and commodity prices declining further; credit liquidation increased and currency hoarding developing; increasing bank failures in United States and beginning of banking crises in Europe.</td>
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<tr>
<td>1932: January -1932: August</td>
<td>Bought $1,110 million of Government securities (mainly in March-June, smaller amounts in July and August). Buying rate on bankers' acceptances reduced (February-June).</td>
<td>Production and stock and bond prices reach depression lows; commodity prices still declining; renewed gold outflow; further credit liquidation and bank failures. Glass-Steagall Act permitting Federal Reserve Banks to use United States securities as collateral for notes enabled Federal Reserve Banks to buy large amounts of securities; member banks reduced indebtedness and acquired excess reserves.</td>
</tr>
<tr>
<td>1933: April -1933: November</td>
<td>Bought $595 million of Government securities. Buying rate on bankers' acceptances reduced sharply, but purchases of Government securities partly offset by decline in acceptance portfolio.</td>
<td>Action taken to ease the position of banks and promote recovery after bank &quot;holiday.&quot; Production and commodity prices advanced sharply, as well as prices of stocks and speculative bonds, from low levels reached in March.</td>
</tr>
<tr>
<td>1937: April</td>
<td>Bought $96 million of Treasury bonds; also bought bills to offset decline in notes.</td>
<td>To maintain orderly conditions in the Government bond market and in money market and to facilitate member bank adjustments to the increased reserve requirements.</td>
</tr>
<tr>
<td>1937: August -1938: April</td>
<td>Bought $38 million of Government securities (November 1937). Treasury released $300 million of sterilized gold at Federal Open Market Committee request.</td>
<td>To ease credit situation and security markets in view of decline in business activity and commodity and security prices, following business inventory accumulation and inflationary tendencies.</td>
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<tr>
<td>1939: October - 1940: January</td>
<td>Strong market demand, which resulted in rapid advances in Government security prices late in 1939, partly met by System sales; gold inflow, business active, prices rising, money easy, credit expanding.</td>
</tr>
<tr>
<td>1940</td>
<td>Partial offset to gold inflow; increased excess reserves; large amounts of funds seeking investment; Government security prices rose to new high levels. System sales also to maintain orderly market conditions.</td>
</tr>
<tr>
<td>1942-1945</td>
<td>To maintain the structure of prices and yields of Government securities and to supply banks with adequate reserves to enable them to meet the drains on their reserves caused by rapid increase in currency in circulation and other factors, and to enable them to purchase such amounts of Government securities as they were called upon to take.</td>
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<tr>
<td>1946: January</td>
<td>Reduced total holdings of Government securities by more than $2 billion.</td>
<td>Restrained growth in member bank reserves (due chiefly to gold inflow) by redeeming maturing United States securities as Treasury retired securities using accumulated balances in war loan accounts and budget surplus. Business active; inflationary pressures were strong.</td>
</tr>
<tr>
<td>October</td>
<td>Retirements of about $7 billion of maturing securities. Buying rate on bankers' acceptances raised (July-August 1946).</td>
<td></td>
</tr>
<tr>
<td>1947: November</td>
<td>Bought $5 billion Treasury bonds.</td>
<td>Bought large amounts of Treasury bonds in November and December to stem decline in bond prices. Dropped buying prices in late December to levels slightly above par. Bought bonds thereafter to maintain these price levels.</td>
</tr>
<tr>
<td>-1948: March</td>
<td>Sold or redeemed over $6 billion of short-term Government securities. Buying rate on bankers' acceptances raised (December 1947-January 1948).</td>
<td>Sold or redeemed short-term Treasury securities, partly to offset effect on bank reserves of bond purchases and continued gold inflow, in the effort to restrain the growth in bank credit. Inflationary pressures continued strong. Short-term rates rose further.</td>
</tr>
<tr>
<td>1949: November</td>
<td>Bought a net of $1.6 billion of short-term Government securities. Little change in total portfolio.</td>
<td>Operations designed to allow money market to firm moderately in response to increased demand for funds, as business recovery gained momentum and signs of inflationary pressures reappeared, and at the same time to aid Treasury refunding. Slight rise in yields on both short-term and long-term securities.</td>
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<td>-1950: June</td>
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<tr>
<td>1951: mid-April</td>
<td>Bought $300 million of long-term bonds through June, and $1.5 billion of short-term securities during refunding periods.</td>
<td>Purchased restricted bonds to aid in readjustment of bond market; purchased short-term securities to aid in Treasury refundings.</td>
</tr>
<tr>
<td>-1952: November</td>
<td>Sold or redeemed $1.7 billion of short-term Government securities at other times.</td>
<td>Sales to absorb reserves created by above purchases.</td>
</tr>
<tr>
<td>1951: December</td>
<td>Increased holdings of securities in late December by about $600 million, net.</td>
<td>To meet seasonal reserve needs.</td>
</tr>
<tr>
<td>1952: February</td>
<td>Increased holdings by about $200 million, net.</td>
<td>Large purchases of securities made in February and June to facilitate market adjustments to Treasury financings. Most of those purchases were offset by sales of other securities.</td>
</tr>
<tr>
<td>-1952: June</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1953: January</td>
<td>Sold in open market or redeemed $800 million net of U.S. Government securities.</td>
<td>To offset seasonal changes in factors affecting reserves and thus to maintain pressure on member bank reserve positions.</td>
</tr>
<tr>
<td>-1953: April</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1954: June</td>
<td>Sold in open market or redeemed U.S. Government securities totaling about $1 billion in July and August.</td>
<td>Reductions in reserve requirements were offset in part by temporary sales of securities in order to prevent excess reserves from increasing unduly at the time, but security purchases were resumed as need for funds developed.</td>
</tr>
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<td>-1954: August</td>
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<tr>
<td>1954: September</td>
<td>Made net purchases in open market of approximately $850 million.</td>
<td>To supply the banking system with reserves to meet expected growth and seasonal demands for credit and money.</td>
</tr>
<tr>
<td>-1954: November</td>
<td>Made net purchases of U.S. Government securities in open market of less than $50 million, all under repurchase agreements with dealers and brokers.</td>
<td>To meet part of the temporary end-of-year needs of banks for reserve funds, but in view of rising credit demands, to permit these needs to be reflected in part in slightly less easy reserve positions.</td>
</tr>
<tr>
<td>1955: January</td>
<td>Sold in the open market or redeemed U.S. Government securities totaling $1.3 billion.</td>
<td>To offset effects of seasonal factors affecting bank reserve positions and, in view of strong credit demands, to bring about somewhat greater member bank borrowing from Federal Reserve Banks.</td>
</tr>
<tr>
<td>-1955: June</td>
<td>Made outright purchase of Treasury bills in the open market totaling $700 million net and increased repurchase agreements with dealers and brokers by $300 million.</td>
<td>To meet part of reserve needs associated with seasonal factors, thus requiring banking system to meet needs in part by further increasing indebtedness. This action was taken with a view to providing for seasonal needs while limiting undue expansion of bank credit.</td>
</tr>
<tr>
<td>1956: April</td>
<td>System holdings of U.S. Government securities reduced by $350 million.</td>
<td>To increase restraint on credit expansion, in view of sharp increase in bank credit in March and indications of broad increase in spending, growing demands for credit, and upward pressures on prices and costs.</td>
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<tr>
<td>1956: December</td>
<td>System holdings of U.S. Government securities and bankers' acceptances increased by over $550 million, including substantial repurchase agreements with dealers.</td>
<td>To supply reserve funds in recognition of additional pressures in money, credit, and capital markets resulting from seasonal factors and international conditions at a time when lower liquidity ratios of banks were themselves exerting restraint on bank lending.</td>
</tr>
<tr>
<td>1957: mid-Oct. -1957: December</td>
<td>System holdings of U.S. Government securities increase by $1 billion, including substantial amounts of securities held under repurchase agreement.</td>
<td>To increase the availability of bank reserves and thereby cushion adjustments and mitigate recessionary tendencies in the economy.</td>
</tr>
<tr>
<td>1959: March -1959: mid-July</td>
<td>Increased System holdings of U.S. Government securities by about $1.1 billion.</td>
<td>To offset partially the absorption of reserves due mainly to a decline of $780 million in gold stock and an increase of about $1 billion in currency in circulation and to keep credit expansion under restraint.</td>
</tr>
<tr>
<td>1960: late March -1960: July</td>
<td>Increased System holdings of Government securities by nearly $1.4 billion.</td>
<td>To promote further reduction in the net borrowed reserve positions of member banks and, beginning in May, to provide reserves needed for moderate bank credit and monetary expansion.</td>
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<tr>
<td>1961: February -1961: August</td>
<td>Bought substantial amounts of U.S. Government securities with maturities over 1 year, following February 20 announcement that system open market operations would include securities outside the short-term area. These purchases were partly offset by net sales of short-term securities. Total System holdings of Governments increased about $700 million.</td>
<td>To encourage bank credit and monetary expansion while avoiding direct downward pressure on short-term interest rates, thereby moderating pressures on the U.S. balance of payments from outflow of short-term capital attracted by higher interest rates abroad.</td>
</tr>
<tr>
<td>1962: mid-June -1962: late October</td>
<td>Increased System holdings of U.S. Government securities by about $200 million with net sales and redemptions of Treasury bills of about $700 million being more than offset by purchases of coupon issues, of which two-thirds were issues maturing in more than 1 year.</td>
<td>To permit moderate increase in bank credit and money supply while avoiding redundant bank reserves that would encourage capital outflows, taking into account gradual improvement in domestic economy and possibilities for further advance, while recognizing the bank credit growth of past year and continuing adverse balance of payments.</td>
</tr>
<tr>
<td>1963: mid-May -1963: late July</td>
<td>Reduced the degree of reserve availability slightly further. System holdings of U.S. Government securities increased nearly $1.2 billion, about one-fifth representing net purchases of issues maturing in more than 1 year.</td>
<td>To achieve a slightly greater degree of firmness in the money market in order to minimize the outflow of capital while continuing to provide reserves for moderate monetary and credit growth.</td>
</tr>
</tbody>
</table>


(Eastburn 1965, pp. 68-96) (continued)
<table>
<thead>
<tr>
<th>DATE OF DECISION</th>
<th>UNDERLYING ECONOMIC CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1964: January -1964: mid-August</td>
<td>Increased the System's holdings of U.S. Government securities, after having reduced them seasonally early in the year. On balance, total holdings rose about $1.1 billion, $300 million of which represented net purchases of securities with maturities of over 1 year.</td>
</tr>
<tr>
<td>1964: mid-August -1964: late November</td>
<td>Increased the System's holdings of U.S. Government securities by about $1.5 billion, of which $600 million represented net purchases of securities with maturities of more than 1 year.</td>
</tr>
<tr>
<td>To provide for moderate growth in the reserve base, bank credit, and the money supply for the purpose of facilitating continued expansion of the economy while fostering improvement in the capital account of U.S. international payments, after offsetting seasonal downward pressures on short-term interest rates early in the period.</td>
<td></td>
</tr>
<tr>
<td>To maintain slightly firmer conditions in the money market with a view to minimizing the outflow of funds attracted by higher short-term interest rates abroad while offsetting reserve drains and providing for growth needs of the domestic economy.</td>
<td></td>
</tr>
</tbody>
</table>


(Eastburn 1965, pp. 68-96)
CHAPTER FOUR: POLICY STRUCTURE FOR THE DISCOUNT RATE

Their immediate and principal operations consist in discounting promissory notes and bills of exchange not yet due, that is, in lending money on the credit of these negotiable papers, after deducting or discounting the interest.

---George Tucker (Tucker 1839, p. 161)

A. Background

When George Tucker described the operations of a bank of circulation in 1839, one of his principal objectives was to show how such banks contributed to economic activity more than simple banks of deposits. The most important function singled out by Tucker was that of discounting—lending on the security of (discounted) negotiable paper. Discounting allows liabilities of an individual or corporation to circulate almost as easily as deposits, the only penalty being the rate of discount applied. The practice originated in the trading countries of Europe, notably in Amsterdam and in Italy, where bills of exchange on foreign banks were allowed to circulate at a discount because of the transaction costs involved in redeeming them. Discounting has gradually evolved to the current practice of central banks lending to commercial banks on the security of discounted obligations of either corporations or the banks themselves.

As intended by the original Federal Reserve Act, lending through the discount window was to be for short-term purposes only. As Anderson notes (Anderson 1968, p. 4),
The philosophy embodied in the Federal Reserve Act contemplated that Reserve Bank credit should be extended for a short term only and that it should be confined to financing the production and the distribution of goods from producer to consumer. It should not be used to finance investment or speculative activity of any kind—securities, commodities, or real estate. Confining bank credit to productive purposes, it was believed, would result in an automatic response of supply to the expanding and contracting needs of commerce, industry, and agriculture.

The purpose of discounting is therefore to provide for short-term flexibility in the supply of credit. Federal Reserve credit is not intended to provide overall expansion or contraction in reserves, as may be associated with open-market operations. As Roosa notes, "...even though any individual bank can temporarily, in effect, cause the creation of reserves by borrowing at the discount window, that same bank simultaneously takes on an obligation to find ways of extinguishing those reserves." (Roosa 1959, p. 334). Most borrowing from the Federal Reserve, or "borrowing at the discount window," as reserve borrowing has come to be called, is limited to meeting short-term required reserve deficiencies, although there is some evidence of member banks taking advantage of a low discount rate to expand their operations (Turner 1938).

As early as 1781, with the chartering of the Bank of North America, the country had a discount mechanism controlled by a central authority. Pelatiah Webster, in discussing the operations of the Bank of North America in an essay of 1786, notes that "they may accomodate their citizens with discounts or loans on interest, to the great increase of the bank-stock or reserve, as well as doing great favor to individuals,
and increasing the trade, manufactures, and husbandry of the State" (Krooss 1969, p. 224). With the establishment of the First Bank of the United States in 1791, offices of discount from a central bank began to appear in various cities "wheresoever they [the bank directors] shall think fit," forerunners of the regionalized reserve bank system (Krooss 1969, p. 312).28

The Act of 1816 chartering the Second Bank of the United States established a maximum discount rate of six percent per year (Krooss 1969, p. 469). Changes in the rate generally tended to follow changes in general credit conditions, but the rate appears to have remained fairly stable in the range from three to six percent, until the Bank's charter expired in 1836.

The period between 1836 and 1863, when the National Bank Act was passed, saw the rise of state banking regulation. Although the several states had different schemes, Krooss notes their common features as

1) any person or persons could form a bank without a special act of the state legislature; 2) note issues had to be supported by some security, usually bonds and mortgages; 3) each bank was required to maintain a specie reserve equal to a specific percentage (usually 25 percent) of deposits; and 4) each bank had to be examined periodically by a state bank examiner. (Krooss 1969, p. 1058).

28 By 1809, offices of discount had been established in Boston, New York, Baltimore, Norfolk, Charleston, Savannah, Washington, and New Orleans (Krooss 1969, pp. 362-363). All but Norfolk were designated as reserve cities in 1914 (FRBOARD 1943, p. 401).
During this period there was no central, national authority that could provide temporary excess reserves through a discount function. At the state level, however, smaller banks continued to obtain temporary reserves through discounting their bills at larger, urban banks such as existed in New York, Philadelphia, Boston, and Washington. The difference between this kind of discount activity and that maintained by a central bank is that with a central bank, the reserves of the entire banking system can be temporarily expanded through discounts. This restriction apparently placed no great burden on the state banks since the banks were free to issue paper money.29

The National Bank Act of 1863 reestablished a degree of national control over the banking system. As in the earlier Second Bank of the United States, offices of deposit and discount were set up in major urban centers, in the hope of stabilizing general credit conditions through major banks backed by government bonds. National banks were restricted in their note issues to their deposits of government bonds with the Comptroller of the Currency. The period until 1907, however, was far from stable. A serious controversy arose among

29The origin of the term "free banking," as applied to this historical period, comes from the lack of restrictions placed on issuing paper money. Even though banks were required to maintain specie reserves against circulation, in many states these requirements were loosely interpreted and even more loosely observed. In Michigan, for example, specie reserves were transferred from bank to bank one day ahead of the state bank examiner (Krooss 1969).
defenders of a gold standard, a silver standard, and a bimetallic standard. The National Bank Act was soon recognized as incapable of providing the degree of monetary control required in a rapidly industrializing economy. The money market panic of 1907, culminating roughly a decade of alternating credit crises and inflation, crystallized objection to the Act and forced legislative action to complete the centralization of monetary control, a trend that had been progressing for over a century. The Aldrich-Vreeland Act of 1908 allowed national banks to issue additional notes on the security of commercial paper or government (including all municipal) bonds deposited with the Treasury. This clear forerunner of the discount facility established six years later by the Federal Reserve Act allowed short-term flexibility in aggregate circulation. The invention of a central discount facility, as embodied in the Aldrich-Vreeland Act, was without doubt a result of the previous inability of the banking system to provide the credit flexibility necessary in a geographically large and economically complex country.

For roughly ten years following the creation of the Federal Reserve, both System officials and economists thought that the discount rate could be used to control aggregate credit conditions. By 1923, however, they had realized that because of its inherent inequities of credit distribution among banks, and because of the apparent lack of a strong link between the discount rate and bank use of the discount facility, the discount rate was not an effective instrument of aggregate credit control. "The new policy stressed what has since been called 'leaning against the wind.' This meant that the System was supposed
to encourage business expansion and to discourage speculation. It was to lean equally against the winds of inflation and the winds of deflation." (Krooss 1969, p. 2087).

With the exception of the period 1913-1923, the discount rate has therefore been a relatively reactive element of monetary control. In general, the rate changes in response to, rather than in anticipation of, member bank borrowing, inflation, and unemployment. This reactive nature of the discount rate is the overriding characteristic of the pol: structure described in the following two sections of this chapter.
B. Causal Hypotheses of the Policy Structure for the Discount Rate

The policy structure for the discount rate captures the forces leading to a decision by the monetary authority to set the value of the discount rate. In the national model, the aggregate bank may borrow reserves from the monetary authority. The rate it pays for these borrowed reserves is the discount rate. The monetary authority can attempt to discourage bank borrowing either by raising the discount rate, or by exerting "moral suasion" over the bank. In the true economy, the Federal Reserve exerts moral suasion over banks by "inviting bank officials to lunch" and encouraging them to curtail their borrowing through the discount facility. The policy structure for the discount rate includes a representation of moral suasion.

Figure IV-1 shows the causal relationships underlying the policy structure for the discount rate. The indicated discount rate, in the top-center of the figure, represents the discount rate that the monetary authority would like to impose, given the current borrowings of the bank, current inflation, current unemployment, and the current bond yield. The bond yield in the national model represents the market rate on securities. The indicated discount rate is formulated as a multiple of the current bond yield; for example, if the current bond yield is 5% per year, and the borrowing, unemployment, and inflation conditions indicate that the discount rate should be 20% higher than current market rates (bond yield), then the indicated discount rate will have a value of 6% per year. The actual discount rate adjusts exponentially to the indicated discount rate with a time constant of one year.
Figure IV-1: Causal Diagram of the Policy Structure for the Discount Rate
The multiplier from unemployment on the discount rate represents the monetary authority's response to unemployment in determining the discount rate. The current spread in unemployment, as described in Chapter Three, is the argument for this relationship. All else equal, an increase in unemployment will cause the monetary authority to push the discount rate below the bond yield in order to encourage the bank to increase its reserves through borrowing from the discount window.

The multiplier from inflation on the discount rate represents the monetary authority's response to inflation in setting the discount rate. Its argument is the current spread in inflation as described in Chapter Three. All else equal, an increase in inflation will lead to a discount rate above the bond yield, as the monetary authority attempts to restrain growth in bank reserves by restraining reserve borrowing.

The multiplier from borrowing on the discount rate captures the reaction of the monetary authority to the reserve-borrowing practices of the aggregate bank. Borrowing is measured by the ratio of borrowed reserves to owned reserves; owned reserves are the total reserves of the bank minus its borrowed reserves. The policy structure uses the concept of a desired ratio of borrowed to owned reserves to represent the level of borrowing that the monetary authority expects the bank to maintain. All else equal, if actual bank borrowing rises above this desired ratio, then the monetary authority will raise the discount rate in order to discourage bank borrowing. Similarly, if bank borrowing falls below the desired ratio, the monetary authority will lower the discount rate in order to ease the conditions on borrowing and encourage further expansion in bank reserves.
In the true economy, commercial banks generally have an impression of the level of reserve borrowing that is considered acceptable by the Federal Reserve. The policy structure for the discount rate develops a concept of "acceptable borrowing" that is used by the bank structure in making its borrowing decision. Acceptable borrowing is defined as the desired ratio of borrowed-to-owned-reserves, modified by the pressure on bank borrowing. The pressure on bank borrowing is the representation of moral suasion. If the indicated discount rate is above the actual discount rate, then borrowing, inflation, and unemployment conditions indicate that the discount rate should be raised (assuming that the bond yield has remained constant). Under these conditions, the monetary authority will attempt to reduce bank borrowing by exerting pressure, or moral suasion, on the bank. Acceptable borrowing will be depressed below the desired ratio of borrowed to owned reserves. Whenever the discount rate is equal to the indicated discount rate, implying that the discount rate is in accordance with that indicated by bank borrowing, inflation, and unemployment, then the pressure on bank borrowing is neutral, and acceptable borrowing is equal to the desired ratio of borrowed to owned reserves.
C. Equations for the Policy Structure for the Discount Rate

Figure IV-2 is the DYNAMO flow diagram of the policy structure for the discount rate. Inputs exogenous to this structure include the bond yield BY, borrowed reserves BR, reserves of the bank RB, the current spread in inflation CSI, and the current spread in unemployment CSU.

Discount Rate DR

\[
\begin{align*}
\text{DR,} & = \text{DR,} + (\text{DT/TADR}) (\text{IDR,} - \text{DR,}) \\
\text{DR} & = \text{DRN} \\
\text{DRN} & = .04 \\
\text{TADR} & = 1
\end{align*}
\]

\[
\begin{align*}
\text{DR} & \quad \text{DISCOUNT RATE (FRACTION/YEAR)} \\
\text{DT} & \quad \text{SOLUTION TIME INTERVAL (YEARS)} \\
\text{TADR} & \quad \text{TIME TO AVERAGE DISCOUNT RATE (YEARS)} \\
\text{IDR} & \quad \text{INDICATED DISCOUNT RATE (FRACTION/YEAR)} \\
\text{DRN} & \quad \text{DISCOUNT RATE INITIAL (FRACTION/YEAR)}
\end{align*}
\]

The discount rate DR is formulated as a first-order exponential average of the indicated discount rate IDR. The indicated discount rate IDR represents the value for the discount rate that is indicated by the current bond yield BY, the current rate of inflation RI, the current rate of unemployment RU, and current reserve-borrowing by the bank. The actual discount rate DR adjusts exponentially to the indicated discount rate IDR with a time constant, the time to average the discount rate TADR, equal to one year.
Figure IV-2: DYNAMO Flow Diagram of the Policy Structure for the Discount Rate
If the monetary authority were capable of immediately adjusting the discount rate to bond yield, inflation, unemployment, and borrowing conditions, then the delay between the indicated discount rate IDR and the discount rate DR would be unnecessary. However, the monetary authority is assumed to be unwilling to make rapid and immediate adjustments in the discount rate. In the true economy, the discount rate is traditionally considered by the financial community as an easily-identifiable indicator of the Federal Reserve's degree of monetary restraint (Beckhart 1972, p. 487). Too-frequent changes in the discount rate would reduce its psychological impact as an indicator of Federal Reserve opinion. Also, Federal Reserve officials, of both the Board of Governors and the member banks, seldom agree about the need for, or the desirability of, a change in the discount rate; the decision must be debated, and staff studies must be prepared, until credit conditions clearly warrant a change (Maisel 1973, pp. 69-72). The time to average the discount rate TADR is given a value of one year to reflect this sluggishness in the monetary authority's decision-making process.
Indicated Discount Rate IDR

\[ \text{IDR}_k = \text{BY}_k \times \text{MBDR}_k \times \text{MUDR}_k \times \text{MIDR}_k \]

- INDICATED DISCOUNT RATE (FRACTION/YEAR)
- BOND YIELD (FRACTION/YEAR)
- MULTIPLIER FROM BORROWING ON DISCOUNT RATE (DIMENSIONLESS)
- MULTIPLIER FROM UNEMPLOYMENT ON DISCOUNT RATE (DIMENSIONLESS)
- MULTIPLIER FROM INFLATION ON DISCOUNT RATE (DIMENSIONLESS)

The indicated discount rate IDR is formulated as the product of the bond yield BY, the multiplier from borrowing on the discount rate MBDR, the multiplier from unemployment on the discount rate MUDR, and the multiplier from inflation on the discount rate MIDR. The monetary authority attempts to keep the discount rate in line with other market rates of interest, represented in the national model by the bond yield BY. The indicated discount rate IDR, therefore, is expressed as a multiple of the bond yield BY; if inflation, unemployment, or borrowing conditions indicate that the discount rate DR should be set above other market rates, then one or more of the three multipliers will have a value greater than unity, and the indicated discount rate IDR will be set above the bond yield BY.

This formulation suggests that the monetary authority is less concerned about the absolute value of the discount rate than it is about...
the relation between the discount rate and other market rates. The monetary authority will set the discount rate DR above the bond yield BY if economic conditions dictate restraint of bank borrowing and the resulting restriction of expansion in bank reserves. Similarly, conditions warranting a loosening of credit will lead the monetary authority to set the discount rate DR below the bond yield BY.

Appendix IV-A, at the end of this chapter, contains parts of a list of Federal Reserve decisions compiled by Eastburn (Eastburn 1965, pp. 68-96). In the second column of the appendix, are discount rate decisions made between 1934 and 1960, followed in the third column by a brief summary of the economic conditions that preceded the decision. Bank borrowing, inflation, stagnant employment, and the desire to maintain approximate parity between the discount rate and other market rates are mentioned repeatedly as the rationale for changes in the discount rate. For example, a 1942 reduction in the discount rate was "to encourage member banks subject to temporary reserve deficiencies to borrow from the Reserve Banks." A 1948 increase in the discount rate is described as "Part of an anti-inflationary program designed to keep pressure on member bank reserves." A 1955 increase in the discount rate was "to keep discount rates in an appropriate relationship with market rates of interest." A 1957 decrease was designed to "eliminate any undue restraint on bank borrowing in view of the decline in business activity and evidences of economic recession." All of these influences on the discount rate are embodied in the formulation for the indicated discount rate IDR. The forms of the three multipliers that
reflect attempts to control inflation, unemployment, and bank borrowing are presented in the following three equations.

Multiplier from Inflation on Discount Rate MIDR

\[ \text{MIDR} = \text{TABHL}(\text{TMIDR}, \text{CSI}, 0, 0.2, 0.02) \]

\[ \text{TMIDR} = 1/1.01/1.025/1.045/1.07/1.1/1.15/1.25/1.4/1.475/1.5 \]

MIDR - MULTIPLIER FROM INFLATION ON DISCOUNT RATE (DIMENSIONLESS)

TMIDR - TABLE FOR MULTIPLIER FROM INFLATION ON DISCOUNT RATE

CSI - CURRENT SPREAD IN INFLATION (FRACTION/YEAR)

Figure IV-3: Table Function for Multiplier from Inflation on Discount Rate MIDR
The multiplier from inflation on the discount rate MIDR captures the impact of inflation on the indicated discount rate IDR. The multiplier takes as its argument the current spread in inflation CSI (Equation 25, as described in Chapter Three), which measures the difference between the current rate of inflation RI and the monetary authority's desired rate of inflation DRI. The nonlinear form of the table for the multiplier from inflation on the discount rate TMIDR is shown in Figure IV-3. For small values of the current spread in inflation CSI the table shows only a minor response, as the monetary authority is willing to allow the discount rate DR to stay close to the bond yield BY. As the current spread in inflation CSI increases, however, the response of the monetary authority becomes progressively more severe. For example, the table shows that where current inflation exceeds desired inflation by 15% per year, the monetary authority will set the discount rate DR at roughly 1.33 times the bond yield BY (all other influences assumed inactive). At very high values for the current spread in inflation CSI the multiplier saturates; the monetary authority is assumed to be unwilling to impose on financial markets a very large discrepancy between the discount rate DR and the bond yield BY, even if inflation is very high.

If the rate of inflation RI falls below the desired rate of inflation DRI, then the current spread in inflation CSI takes on a negative value. Under these circumstances, the multiplier from inflation on the discount rate MIDR takes the extreme left-hand value in Figure IV-3, in this case unity. Inflation below desired inflation, therefore, produces
(by itself) no alteration in the discount rate DR away from the bond yield BY. Deflation, then, is assumed not to produce any change in the discount rate DR, if both unemployment and borrowing are at their respective desired levels.

Multiplier from Unemployment on Discount Rate MUDR

\[ \text{MUDR, K} = \text{TABHL (TMUDR, CSU, K, 0, 2, 02)} \]
\[ \text{TMUDR} = 1.99, .995, .95, .91, .85, .75, .67, .58, .53, .5 \]

MUDR - MULTIPLIER FROM UNEMPLOYMENT ON DISCOUNT RATE (DIMENSIONLESS)
TMUDR - TABLE FOR MULTIPLIER FROM UNEMPLOYMENT ON DISCOUNT RATE
CSU - CURRENT SPREAD IN UNEMPLOYMENT (FRACTION)

The multiplier from unemployment on the discount rate MUDR captures the impact of unemployment on the indicated discount rate IDR. The formulation of this multiplier is similar to, but opposite in its effect on the discount rate DR, the multiplier from inflation MIDR. The multiplier takes as its argument the current spread in unemployment CSU (Equation 22, as described in Chapter Three), which measures the difference between the current rate of unemployment RU and the monetary authority's desired rate of unemployment DRU. The nonlinear form of the table for the multiplier from unemployment on the discount rate TMUDR is shown in Figure IV-4. For small values of the current spread in
unemployment CSU the table shows only a minor response, as the monetary authority is willing to allow the discount rate DR to stay close to the bond yield BY. As the current spread in unemployment CSU increases, however, the response of the monetary authority becomes progressively more severe. For example, the table shows that where current unemployment exceeds desired unemployment by 15%, the monetary authority will set the discount rate DR at roughly .625 times the bond yield BY (all other
influences assumed inactive). At very high values for the current spread in unemployment CSU the multiplier saturates; the monetary authority is assumed to be unwilling to impose on financial markets a very large discrepancy between the discount rate DR and the bond yield BY, even if unemployment is very high.

Multiplier from Borrowing on the Discount Rate MBDR

MBDR,K=TABLE(TMBDR,RCDB,K,0,2,.2) 31.1
TMBDR=.75/.86/.92/.95/.98/1/1.02/1.05/1.08/1.14/ 31.1, T
1.25
MBDR  - MULTIPLIER FROM BORROWING ON DISCOUNT RATE (DIMENSIONLESS)
TMBDR  - TABLE FOR MULTIPLIER FROM BORROWING ON
        DISCOUNT RATE
RCDB  - RATIO OF CURRENT-TO DESIRED-BORROWING (DIMENSIONLESS)

The multiplier from borrowing on the discount rate MBDR defines the monetary authority's reaction to the bank's borrowing at the discount window. The function, as graphed in Figure IV-5, depends upon the ratio of current- to desired-borrowing RCDB. Borrowing by the bank at the discount window is measured by the ratio between the bank's borrowed reserves BR and owned reserves (total reserves of the bank RB minus borrowed reserves BR). The ratio of current- to desired-borrowing RCDB is therefore a comparison between the current borrowed-to owned-reserves ratio and the desired ratio that the monetary authority would like the bank to maintain.
Figure IV-5: Table Function for Multiplier from Borrowing on Discount Rate MBDR

The monetary authority is reluctant to allow the banks to borrow a major proportion of their reserves at the discount window; if the ratio of current-to-desired-borrowing RCDB exceeds unity, then the multiplier from borrowing on the discount rate MBDR rises above unity, increasing the indicated discount rate IDR. The form of this relationship, as shown in Figure IV-5, is nonlinear. As the ratio of current-to-desired-borrowing RCDB increases above unity, the multiplier from borrowing on the discount rate MBDR increases more than proportionately.
The monetary authority, therefore, is assumed willing to allow small variations around unity in the ratio of current--to desired-borrowing RCDB without making large changes in the discount rate DR. As the ratio increases, however, the monetary authority will make larger and larger changes in the discount rate DR.

If bank borrowing falls below desired borrowing, as indicated by the ratio of current--to desired-borrowing RCDB falling below unity, then the monetary authority will reduce the discount rate DR below the bond yield BY. The monetary authority thereby attempts to encourage bank borrowing at the discount window.

Ratio of Current--to Desired-Borrowing RCDB

\[ \text{RCDB}, k = \text{RBOR}, k / \text{DRBOR}, k \]

RCDB       - RATIO OF CURRENT-- TO DESIRED-BORROWING
(DIMENSIONLESS)
RBOR       - RATIO OF BORROWED-- TO OWNED-RESERVES
(DIMENSIONLESS)
DRBOR      - DESIRED RATIO OF BORROWED-- TO OWNED--
RESERVES (DIMENSIONLESS)

The ratio of current-- to desired-borrowing RCDB is the monetary authority's index of bank borrowing as compared to desired borrowing.

The ratio of borrowed-- to owned-reserves RBOR is the ratio between the current value of borrowed reserves BR and the current value of owned
reserves (reserves of the bank RB minus borrowed reserves BR). Borrowed reserves BR is the dollar value of the bank's indebtedness to the monetary authority. Owned reserves are the reserves that the bank has obtained from other sources (paid-in capital, currency deposits, sales of securities in the open market). Borrowed reserves BR are usually on the order of one-tenth of owned reserves or less.

The desired ratio of borrowed- to owned-reserves DRBOR is the proportionality between borrowed- and owned-reserves that the monetary authority would like to see the banks maintain. Its derivation is explained in connection with Equation 34 below.

Ratio of Borrowed- to Owned-Reserves RBOR

\[
RBOR, K = BR, K / (RB, K - BR, K)
\]

\[
\begin{array}{ll}
RBOR & \text{RATIO OF BORROWED- TO OWNED-RESERVES} \\
& \text{(DIMENSIONLESS)} \\
BR & \text{BORROWED RESERVES ($)} \\
RB & \text{RESERVES OF THE BANK ($)}
\end{array}
\]

The ratio of borrowed- to owned-reserves RBOR is the index used by the monetary authority to measure bank borrowing. A ratio index is used, as opposed to an index of the absolute value of borrowed reserves BR, so that overall expansion in the bank's reserve holdings, and a corresponding increase in borrowing, is not mistaken as excessive borrowing.
Desired Ratio of Borrowed- to Owned-Reserves DRBOR

DRBOR.K = DRBOR.J + (DT/TAB)(RBOR.J - DRBOR.J)
DRBOR = DRBori
DRBori = .1
TAB = 3

DRBOR = DESIRED RATIO OF BORROWED- TO OWNED-RESERVES (DIMENSIONLESS)
DT = SOLUTION TIME INTERVAL (YEARS)
TAB = TIME TO AVERAGE BORROWING (YEARS)
RBOR = RATIO OF BORROWED- TO OWNED-RESERVES (DIMENSIONLESS)
DRBori = DESIRED RATIO OF BORROWED- TO OWNED-RESERVES INITIAL (DIMENSIONLESS)

The desired ratio of borrowed- to owned-reserves DRBOR, the standard against which current bank borrowing is compared, is formulated as a long-term exponential average of the actual ratio of borrowed- to owned-reserves RBOR. The time constant, time to average borrowing TAB, determines how quickly the standard changes in response to changes in actual borrowing habits. The chosen value of three years implies a response to borrowing quicker than the monetary authority's response to either inflation or unemployment. The monetary authority's borrowing standard DRBOR will partially adapt to changes in borrowing habits that occur over the business cycle, to accommodate changes in borrowing needs over the cycle. The inflation standard DRI and the unemployment standard DRU, however, will remain nearly constant over a business cycle.
Acceptable Borrowing AB

\[ AB_{K} = DRBOR_{K} \times PBB_{K} \]

**AB** - ACCEPTABLE BORROWING (DIMENSIONLESS)
**DRBOR** - DESIRED RATIO OF BORROWED-TO-OWNED-RESERVES (DIMENSIONLESS)
**PBB** - PRESSURE ON BANK BORROWING (DIMENSIONLESS)

The ratio of borrowed-to-owned-reserves RBOR acceptable to the monetary authority, called acceptable borrowing AB, is used by the bank sector to assess the monetary authority's position on bank borrowing. It is formulated as the product of the desired ratio of borrowed-to-owned-reserves DRBOR and the pressure on bank borrowing by the monetary authority PBB. Pressure on bank borrowing PBB is the representation of "moral suasion" in this policy structure.

Pressure on Bank Borrowing PBB.

\[ PBB_{K} = TABHL(TPBB_{K}, IDR_{K}/DR_{K}, .8, 1.2, .05) \]

**TPBB** = 1.1/1.05/1.02/1.01/1/.975/.95/.9/.75
**PBB** - PRESSURE ON BANK BORROWING (DIMENSIONLESS)
**TPBB** - TABLE FOR PRESSURE ON BANK BORROWING
**IDR** - INDICATED DISCOUNT RATE (FRACTION/YEAR)
**DR** - DISCOUNT RATE (FRACTION/YEAR)
Figure IV-6: Table Function for Pressure on Bank Borrowing PBB.

Because the Federal Reserve is often reluctant to make sudden changes in the discount rate, even when a change is warranted by the economic conditions, the Federal Reserve exerts "moral suasion" on bank borrowing. They will recommend that the banks reduce their borrowing at the window before they will actually raise the discount rate. This moral suasion is represented in the policy structure by the pressure on bank borrowing by the monetary authority PBB, as graphed in Figure IV-6. The table is drawn as a function of the ratio between the indicated discount rate IDR and the actual discount rate DR, and is asymmetrical about the point where no discrepancy exists. This asymmetry reflects the assumption that the monetary authority is better able to reduce bank borrowing
than to increase it; thus the magnitude of the pressure is higher when the indicated discount rate IDR is above the discount rate DR than when it is below the discount rate DR.

It is through the pressure on bank borrowing PBB that the monetary authority attempts to control borrowed reserves BR by moral suasion. Figure IV-7 illustrates the negative feedback loop between borrowed reserves BR in the bank sector and moral suasion in the monetary authority sector. If borrowed reserves BR increase, then the indicated discount rate IDR increases immediately through the link of Equations 31 (MBDR), 32 (RCDB),

---

**Figure IV-7:** Negative Feedback Loop
Coupling Borrowed Reserves BR in the Bank Sector with the Pressure on Bank Borrowing PBB in the Monetary Authority Sector
and 33 (RBOR). Through the pressure on bank borrowing PBB, an indicated discount rate IDR above the discount rate DR immediately reduces acceptable borrowing AB, which is in turn used by the bank sector in making its borrowing decision. A decreased acceptable borrowing AB reduces borrowed reserves BR, thereby counteracting the initial increase in borrowed reserves BR.
D. Test Simulations of the Policy Structure for the Discount Rate

D.1. Scope and Purpose of the Simulations

The equations of Section C have defined the policy structure determining the discount rate. The monetary authority is described as setting the discount rate DR equal to the bond yield BY, unless bank-borrowing habits, the rate of inflation, and/or the rate of unemployment dictate a deviation from the bond yield. The equations also define the level of borrowing that is acceptable to the monetary authority. Acceptable borrowing includes moral suasion exerted by the monetary authority on bank borrowing, and is used by the bank structure of the national model in determining its desired amount of borrowed reserves.

Chapter Three, Section D.1, discussed some of the problems associated with testing the policy structure for open-market operations when it is uncoupled from the full national model. In particular, the discussion noted that much of the dynamic behavior of open-market operations will come only when they are linked with a fully reactive economy. These same comments apply to testing of the policy structure for the discount rate. Test inputs must be provided to the policy structure in order for any behavior to be generated. Figure IV-8 enumerates the constant and variable inputs that are required by the policy structure for the discount rate.

The parameters have all been given representative values by the equations of Section C. The bond yield BY is defined by the same
### Parameters (type)
- Discount rate initial DRN (C)
- Time to average discount rate TADR (C)
- Table for multiplier from inflation on discount rate TMIDR (T)
- Table for multiplier from unemployment on discount rate TMUDR (T)
- Table for multiplier from borrowing on discount rate TMBDR (T)
- Time to average borrowing TAB (C)
- Table for pressure on bank borrowing TPBB (T)

### Variable Inputs
- Bond yield BY
- Current spread in inflation CSI
- Current spread in unemployment CSU
- Borrowed reserves BR
- Reserves of the bank RB

Figure IV-8: Parameters and Variable Inputs for the Policy Structure for the Discount Rate

test function used in Chapter Three. Similarly, the equations generating the current spreads in inflation and unemployment, CSI and CSU respectively, as defined in Chapter Three, are also employed here. The same test functions for the rate of inflation RI and the rate of unemployment RU are used here. Finally, borrowed reserves BR and reserves of the bank RB are both defined so that the operator can specify a constant, a step function, or a sinusoid for the ratio of borrowed-to owned-reserves RBOR.

Figure IV-9 outlines the test simulations used to explore the dynamic characteristics of the policy structure for the discount rate. The figure provides a brief description of the economic conditions being simulated, followed by an abbreviated accounting of the dynamic characteristics that each simulation illustrates.
<table>
<thead>
<tr>
<th>Figure</th>
<th>Conditions Simulated</th>
<th>What the Simulation Shows</th>
</tr>
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<tr>
<td>IV-10</td>
<td>Step increase in bond yield; sinusoidal bond yield; other conditions stable.</td>
<td>The discount rate follows the bond yield with a delay.</td>
</tr>
<tr>
<td>IV-11</td>
<td>Various step increases in inflation; other conditions stable.</td>
<td>Compares the response to different gaps between actual and desired inflation; shows the adjustment of desired to actual inflation.</td>
</tr>
<tr>
<td>IV-12</td>
<td>Step increase in unemployment; various values for TARU; other conditions stable.</td>
<td>The response to unemployment depends on how quickly the goal for unemployment adjusts to actual conditions.</td>
</tr>
<tr>
<td>IV-13</td>
<td>Cyclical fluctuation in bond yield; step in RBOR; other conditions stable.</td>
<td>Shows the adjustment to higher borrowing superimposed on a cycle.</td>
</tr>
<tr>
<td>IV-14</td>
<td>Cyclical fluctuation in RBOR; other conditions stable.</td>
<td>Illustrates changes in moral suasion over a cycle.</td>
</tr>
</tbody>
</table>

Figure IV-9: Outline of the Test Simulations, Giving Conditions Simulated and Their Results
D.2. Test Simulations

Figure IV-10 shows the response of the discount rate DR to two different test inputs for the bond yield BY. In the top half of the figure, the bond yield BY is increased in year two from 5% per year to 7% per year. The discount rate DR adjusts to the higher level over a period of roughly three years. The speed of adjustment is determined by the time to average the discount rate TADR. Its present value of one year implies that the discount rate DR will cover roughly 63% of the difference from the indicated discount rate IDR in one year. In Figure IV-10, therefore, the discount rate DR has reached a value of roughly 6.25% per year after one year.

In the lower half of Figure IV-10 is shown the response of the discount rate DR to a sinusoidal variation in bond yield BY with a period of six years. Oscillations in the discount rate DR lag behind the bond yield BY by roughly nine months, and exhibit a slightly smaller amplitude.

This simulation illustrates the impact of the time to average the discount rate TADR on the behavior of the discount rate DR. A smaller value for the time constant would quicken the response of the discount rate DR to a change in the bond yield BY, and diminish the degree of attenuation (loss of amplitude) in response to a fluctuating bond yield BY. A larger value for the time to average the discount rate TADR would result in a slower response to bond yield BY, and would increase the degree of attenuation. The absolute value for the time to average the discount rate TADR will be less important
Figure IV-10: Response of the Discount Rate to a Step and a Sinusoid in Bond Yield
to the behavior of the completed national model than its value in proportion to typical frequencies in its inputs. The discount rate DR should, for example, reflect frequencies in bond yield BY corresponding to those of typical business cycles, as is shown in Figure IV-10. A much larger value for TADR, of perhaps five to ten years, would result in too much attenuation in response to bond yield BY rising and falling over six years. On the other hand, a much shorter value for TADR would result in responses to input changes that would be clearly more rapid than the Federal Reserve's response. The chosen value of one year for the time to average the discount rate TADR reflects this kind of consideration of the bounds within which the true value must lie. Within those bounds, there will be the possibility of experimentation with the total model to see if any particular value leads to behavior that is more consistent with observed behavior.\textsuperscript{30}

\textbf{Figure IV-11} is a comparative plot of the response of the discount rate DR to four different step increases in the rate of inflation RI. In year two, the rate of inflation RI is alternately increased from 1\% per year to 4\% per year, 8\% per year, 12\% per year, and 20\% per year. The discount rate DR is plotted in each case.

\textsuperscript{30}In this researcher's opinion, the behavior of the total model can be expected to be relatively insensitive to the value given to TADR, as long as it is chosen in the proper range. Its assigned value of one year is a compromise between a lower bound of roughly one-quarter year and an upper bound of roughly two years.
Figure IV-11: Response of the Discount Rate to Various Step Increases in Inflation
The figure illustrates four dynamic characteristics of the policy structure. First, the monetary authority increases the discount rate DR above the bond yield BY when inflation increases (bond yield BY remains constant at 4% per year). Second, its response is nonlinear; its response to the increase to 20% per year, for example, is more than three times as vigorous than its response to the increase to 12% per year. This nonlinearity is embodied in the table for the multiplier from inflation on the discount rate TMIDR, graphed in Figure IV-3. Third, in each case, as the desired rate of inflation DRI adjusts to the actual rate of inflation RI, the discount rate DR declines back toward the bond yield BY. The speed with which this accommodation to a higher rate of inflation RI occurs is governed by the time to average the rate of inflation TARI, given a value of ten years. Fourth, and finally, even in the face of very high inflation, the monetary authority is unwilling to impose a very large gap between the discount rate DR and the bond yield BY. The monetary authority's major response to inflation comes through its open-market operations, as described in Chapter Three. The authority realizes that the discount rate offers little leverage in controlling inflation or unemployment, as its total area of control is over borrowed reserves. The monetary authority, therefore, uses the discount rate, and its position relative to other market rates, more as an indicator of monetary ease or restraint than as the instrument through which that ease or restraint will be effected.

Figure IV-12 illustrates the response of the discount rate DR to a step increase in year two in the rate of unemployment RU from 1% to 15%, and with three different values for the time to average the
Figure IV-12: Sensitivity of the Response to Unemployment to the Time to Average the Rate of Unemployment
rate of unemployment TARU. The top curve employs a value for TARU of three years; in the center curve TARU equals its normal value of ten years; in the lower curve TARU equals one thousand years. The bottom curve illustrates the situation in which there is essentially no adjustment in the desired rate of unemployment DRU, representing an unchanging unemployment goal. The discount rate DR in this case is forced down from 4% per year to roughly 2.7% per year and then remains constant. In the other two cases, in which the goal for unemployment adjusts to actual conditions, the discount rate DR gradually returns to the bond yield BY (assumed constant at 4% per year). As the time to average the rate of unemployment TARU decreases, both the maximum gap between the discount rate DR and the bond yield BY, and the time over which the discount rate DR differs from the bond yield BY, decrease. The time to average the rate of unemployment TARU, therefore, exerts an influence on both the magnitude and the duration of the response to unemployment.

The time to average the rate of inflation TARI, and the time to average borrowing TAB, have similar effects on the responses to inflation and bank borrowing. These time constants can change the formulation of goals from a quick adaptation to current conditions to no adaptation. A discussion of alternative methods for goal formulation appears in Chapter Six.

Figure IV-13 illustrates how the monetary authority exerts moral suasion over a cycle, superimposed on an adjustment to higher
Figure IV-13: Moral Suasion Exerted over a Cycle
borrowing. The bond yield BY is allowed to vary sinusoidally with a period of six years. In addition, in year four, the ratio of borrowed-to owned-reserves RBOR is increased from 0.1 to 0.15. The change in bank borrowing is not sufficiently great to cause any significant alteration in the discount rate DR; the discount rate DR follows the bond yield BY in much the same manner as in Figure IV-10. The standard for bank borrowing, the desired ratio of borrowed- to owned-reserves DRBOR, adjusts to the higher ratio of borrowed- to owned-reserves RBOR over a period of roughly nine years, as governed by the time to average borrowing TAB.

Acceptable borrowing AB is the ratio of borrowed-to owned-reserves that the monetary authority would like the bank to hold. The difference between AB and DRBOR is the degree of moral suasion that the monetary authority is exerting on the bank. For example, between years five and eight, acceptable borrowing AB is below the desired ratio of borrowed- to owned-reserves DRBOR. During this period, the monetary authority is trying to constrain bank borrowing below what would normally be acceptable (as indicated by DRBOR) through moral suasion.

Moral suasion is exerted when there is a difference between the indicated discount rate IDR and the discount rate DR. When the indicated discount rate IDR is above the discount rate DR, implying that the discount rate DR should be raised, the pressure on bank borrowing PBB will constrain acceptable borrowing AB below the desired ratio of borrowed- to owned-reserves DRBOR.
Figure IV-13 illustrates how moral suasion changes over a cycle. Between years five and eight, the discount rate DR is increasing, because the indicated discount rate IDR (in this case, equal to the bond yield BY) is above the actual discount rate DR. Acceptable borrowing AB is below DRBOR during this period as the monetary authority supplements the restraining effect of a rising discount rate with moral suasion. Between years eight and eleven, the discount rate DR is falling. Acceptable borrowing AB is above DRBOR during this period as the monetary authority supplements the ease of a falling discount rate by encouraging higher-than-normal bank borrowing. Moral suasion, therefore, is used alternately to discourage and to encourage bank borrowing around a normally-acceptable level; restricting borrowing as part of a generally restrictive posture, and encouraging borrowing as part of a generally lenient posture.

Figure IV-14, the last test simulation presented in this chapter, illustrates the effect of fluctuations in bank borrowing. The ratio of borrowed-to-owned-reserves RBOR is fluctuating sinusoidally between 0% and 20%, with a period of six years. The lower curve of Figure IV-14 shows the response of the discount rate DR. The discount rate DR does not exhibit smooth oscillations because of the nonlinearity of its response to borrowing. The multiplier from

31 Years 0 to 15 have been removed from this simulation so a stable cycle would be exhibited. The early years had minor transients.
Figure IV-14: Response to Fluctuations in the Ratio of Borrowed- to Owned-Reserves
borrowing on the discount rate MBDR, as graphed in Figure IV-5, determines this response.

The upper curves in the figure illustrate the relation between acceptable borrowing AB and the desired ratio of borrowed-to-owned-reserves DRBOR. DRBOR is following smoothly the changes in actual borrowing. At the bottom of the cycle, acceptable borrowing AB diverges significantly from DRBOR. In this period, the discount rate DR is increasing most rapidly, implying that the monetary authority is vigorously tightening its posture regarding bank borrowing. Acceptable borrowing AB is therefore kept low until the pressures on the discount rate abate, at which point AB rises.

The following Appendix describes many of the Federal Reserve's discount rate decisions for the period 1934-1960.
<table>
<thead>
<tr>
<th>DATE OF DECISION</th>
<th>DECISION</th>
<th>UNDERLYING ECONOMIC CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1934: February -1935: May</td>
<td>Reduced from range of 2 - 3 1/2 percent to 1 1/2 - 2 percent at all Banks</td>
<td>To promote business recovery and to correspond with the general decline in money rates resulting from beginning of heavy gold inflow and increased member bank excess reserves</td>
</tr>
<tr>
<td>1942: February -1942: April</td>
<td>Reduced from 1 1/2 to 1 percent at 10 Banks making rate 1 percent at all Banks</td>
<td>To encourage member banks subject to temporary reserve deficiencies to borrow from the Reserve Banks, rather than to sell Government securities in the open market, as an aid to the financing of the war.</td>
</tr>
<tr>
<td>1942: October</td>
<td>Preferential rate of 1/2 percent on advances secured by short-term Governments</td>
<td>To encourage member banks to utilize their excess reserves to buy Government securities and to assure them of adequate reserves at low cost when needed.</td>
</tr>
<tr>
<td>1946: April -1946: May</td>
<td>Removal of preferential rate of 1/2 percent on advances secured by short-term Government securities</td>
<td>Required borrowing banks to pay regular discount rate of 1 percent and thereby made it less easy for member banks to obtain Federal Reserve credit on the basis of which to expand loans. Indicated that the Federal Reserve System did not favor a further decline in interest rates in the circumstances then prevailing.</td>
</tr>
</tbody>
</table>

Appendix IV-A: Decisions to Change Discount Rate, and Underlying Economic Conditions, 1934-1960

(Eastburn 1965, pp. 68-96) (continued)
<table>
<thead>
<tr>
<th>DATE OF DECISION</th>
<th>DECISION</th>
<th>UNDERLYING ECONOMIC CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1948: January</td>
<td>Raised from 1 to 1 1/2 percent at all Banks</td>
<td>Part of an anti-inflationary program designed to keep pressure on member bank reserves and thereby to restrain expansion of bank credit and at the same time continue the policy of stabilizing the long-term rate on Government bonds.</td>
</tr>
<tr>
<td>1948: August</td>
<td>Raised from 1 1/2 to 1 3/4 percent at all Banks.</td>
<td></td>
</tr>
<tr>
<td>1950: August</td>
<td>Increased discount rates from 1 3/4 to 2 1/4 percent. This increase was made in 2 steps at all Reserve Banks except Cleveland.</td>
<td>Output and employment close to peacetime record levels; accelerated expansion of credit; prices rising; prospective increases in Government expenditures for military purposes. System announced it was prepared to use all means at its command to restrain further bank credit expansion consistent with policy of maintaining orderly conditions in Government securities market.</td>
</tr>
<tr>
<td>1955: August</td>
<td>Increased discount rates from 2 1/4 to 2 1/2 percent.</td>
<td>To keep discount rates in an appropriate relationship with market rates of interest and thus maintain a deterrent on excessive borrowing by individual banks at the Reserve Banks.</td>
</tr>
<tr>
<td>1955: September</td>
<td>Increased discount rates from 1 3/4 to 2 1/4 percent.</td>
<td></td>
</tr>
</tbody>
</table>

Appendix IV-A: Decisions to Change Discount Rate, and Underlying Economic Conditions, 1934-1960

(Eastburn 1965, pp. 68-96) (continued)
<table>
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<tr>
<th>DATE OF DECISION</th>
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<th>UNDERLYING ECONOMIC CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1956: April -1956: May</td>
<td>Discount rates raised from 2 1/2 percent to 2 3/4 percent at 10 Reserve Banks and to 3 percent at 2 Banks around middle of April.</td>
<td>To increase restraint on credit expansion, in view of sharp increase in bank credit in March and indications of broad increase in spending, growing demands for credit, and upward pressures on prices and costs.</td>
</tr>
<tr>
<td>1956: August -1956: November</td>
<td>Discount rates raised late in August to 3 percent at the 10 Reserve Banks with rates of 2 3/4 percent.</td>
<td>Discount rates increased in conformity with rise in market rates resulting from vigorous credit demands. Policies designed to increase and maintain restraint on undue credit expansion while covering seasonal and other temporary variations in reserve needs, including effects of frequent Treasury financing operations.</td>
</tr>
<tr>
<td>1957: August</td>
<td>Raised discount rates from 3 to 3 1/2 percent at all Reserve Banks.</td>
<td>To bring discount rates into closer alignment with open market money rates and maintain the restrictive effect of member bank borrowing.</td>
</tr>
<tr>
<td>1957: November -1957: December</td>
<td>Reduced discount rates from 3 1/2 to 3 percent at all Reserve Banks</td>
<td>To reduce the cost of borrowing from the Reserve Banks and eliminate any undue restraint on bank borrowing in view of the decline in business activity and evidences of economic recession.</td>
</tr>
</tbody>
</table>

Appendix IV-A: Decisions to Change Discount Rate, and Underlying Economic Conditions, 1934-1960

(Eastburn 1965, pp. 68-96) (continued)
<table>
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<tr>
<th>DATE OF DECISION</th>
<th>DECISION</th>
<th>UNDERLYING ECONOMIC CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1958: January</td>
<td>Reduced discount rates from 3 to 2 3/4 percent at 11 Reserve Banks.</td>
<td>To reduce further the cost of borrowing from the Reserve Banks and increase further the availability of bank reserves in order to encourage bank credit and monetary expansion conducive to resumed growth in economic activity.</td>
</tr>
<tr>
<td>1958: February</td>
<td>Reduced discount rates from 2 3/4 to 2 1/4 percent at 11 Reserve Banks and from 3 to 2 1/4 percent at one Reserve Bank.</td>
<td>Do.</td>
</tr>
<tr>
<td>1959: March</td>
<td>Raised discount rates from 2 1/2 to 3 percent at all Reserve Banks.</td>
<td>To keep discount rates in an appropriate relationship with the rise in market rates resulting from vigorous credit demands and to restrain undue credit expansion.</td>
</tr>
<tr>
<td>1959: June</td>
<td>Raised discount rates from 3 to 3 1/2 percent at all Reserve Banks.</td>
<td>Do.</td>
</tr>
<tr>
<td>1959: September</td>
<td>Raised discount rates from 3 1/2 to 4 percent at all Reserve Banks.</td>
<td>[Do.]</td>
</tr>
</tbody>
</table>

Appendix IV-A: Decisions to Change Discount Rate, and Underlying Economic Conditions, 1934-1960

(Eastburn 1965, pp. 68-96)
CHAPTER FIVE: POLICY STRUCTURE FOR THE REQUIRED RESERVE RATIO

And the Bankers always reserving Money in hand to answer more than the common Run of Demands (and some People constantly putting in while others are taking out) are able besides to lend large Sums, on good Security, to the Government or others, for a reasonable Interest, by which they are paid for their Care and Trouble; and the Money which otherwise would have lain dead in their Hands, is made to circulate again thereby among the People: And thus the Running Cash of the Nation is as it were Doubled; for all great Payments being made in Bills, Money in lower Trade becomes much more plentiful: And this is an exceeding great Advantage to a Trading Country, that is not over-stock'd with Gold and Silver.


A. Background

Benjamin Franklin identified in 1729 the then principal reason underlying reserve holdings—"to answer more than the common Run of Demands." Early banking history contains numerous accounts of bank failures brought on by reserve holdings insufficient to meet withdrawal demand. The first bank to fail in the United States, the Farmers' Exchange Bank of Gloucester, Rhode Island, had at the time of its failure (1809) eighty-six dollars and forty-six cents in reserves to back six hundred forty-eight thousand and forty-three dollars of issued noted (Krooss 1969, p. 352).
The First Bank of the United States, chartered in 1791 as the first bank created by the national government, was more responsible than most state banks in its operations. When its charter expired in 1809, its ratio of reserves to deposits (including issued notes) was nearly 0.40. Figure VI-1 records, for various years in the early 1800's, the reserve positions for reporting state banks and for the first ten years of the Second Bank of the United States. With the exception of only a few years, reserve ratios were in general less than 0.30; one might also expect the banks not reporting, whose capital in 1815 totaled seventy-five percent of that of the reporting banks, to maintain even narrower reserve margins.

Until 1824, the reserve holdings of individual banks were voluntary. As a result, many banks issued notes in such volume that their reserves quickly became insufficient to meet redemption requests. States were faced with the combined problems of depreciating currencies and loss of public confidence in banks because of failures. In 1824, several of the large Boston banks, in an attempt to restrict the note-issuing activities of several unstable banks, organized the "Suffolk System," one of the first steps in banking reform. In exchange for a

32"Treasury Report on the Bank," submitted to Congress on March 2, 1809, by Secretary of the Treasury Albert Gallatin. As recorded in (Krooss 1969, pp. 362-368). Calculated as the ratio of specie in the vaults to the sum of deposits and outstanding notes. Outstanding notes are included since they are liabilities of the issuing bank payable on demand, identical to deposits.
permanent two-thousand-dollar reserve deposit, the Boston banks would redeem at par the notes of the "country" banks. Since the country bank notes, because of their large supply, had been previously redeemed at a discount, the Boston banks were offering currency guarantees in exchange for permanent required reserve holdings.
Faced with similar problems, the State Legislature of New York established in 1829 the New York Safety Fund. The Fund collected specie reserves from all the operating banks, to be used to cover the debts of insolvent banks. This early bank control, although more of a deposit insurance scheme than a reserve requirement, was intended to convince banks that a state authority maintained an interest in their operations and would try to restrain any attempts to issue more notes than their reserve holdings could support. New York thus became the first state with a centralized monetary authority.

The final centralization of a reserve requirement against deposits came with the National Banking Act of 1864.

SEC. 31. And be it further enacted, That every association in the cities hereinafter named shall, at all times, have on hand, in lawful money of the United States, an amount equal to at least twenty-five per centum of the aggregate amount of its notes in circulation and its deposits; and every other association shall, at all times, have on hand, in lawful money of the United States, an amount equal to at least fifteen per centum of the aggregate amount of its notes in circulation, and of its deposits. And whenever the lawful money of any association in any of the cities hereinafter named shall be below the amount of twenty-five per centum of its circulation and deposits, and whenever the lawful money of any other association shall be below fifteen per centum of its circulation and deposits, such associations shall not increase its liabilities by making any new loans or discounts otherwise than by discounting or purchasing bills of exchange payable at sight, nor make any dividend of its profits until the required proportion between the aggregate amount of its outstanding notes of circulation and deposits and its lawful money of the United States shall be restored. . . .

---National Banking Act of 1864, as recorded in (Krooss 1969, p. 1396.)
The National Banking Act contains the distinction between city and country banks, later incorporated (and even later discarded from) the Federal Reserve System. The reserve requirement provisions of the Federal Reserve Act are primarily a reaffirmation of the necessity of controlling bank activities. That control had been gradually evolving over the 1800's from individual bank control of reserves, through local and state authorities, and for fifty years before the Federal Reserve Act, had actually been a part of national legislation. The Federal Reserve Act, in its provisions for reserve requirements, represented only one more step in the use of a monetary control instrument that had become basic to banking over the prior one hundred years.
B. Causal Hypotheses of the Policy Structure for the Required Reserve Ratio

The policy structure for the required reserve ratio captures the forces leading to a decision by the monetary authority to set the value of the required reserve ratio. The required reserve ratio is the ratio between reserves and demand deposits that the monetary authority requires the bank to hold. Given the level of deposits, the bank must hold reserves that are at least as great a fraction of demand deposits as the required reserve ratio. In the national model, demand deposits correspond to all immediately-transferable deposits, regardless of form. The required reserve ratio, therefore, applies to a composite of deposits, which may include certificates of deposit as well as what are normally considered as demand deposits.33

Figure V-2 shows the causal relationships underlying the policy structure for the required reserve ratio. The indicated required reserve ratio is the reserve ratio that the monetary authority would like to require, given conditions of deposit turnover and the excess reserve position of the bank. The indicated required reserve ratio is formulated by a nonlinear weighting of the two reserve ratios indicated by turnover and excess reserves; the form of the weighting,

---
33 The Federal Reserve applies different required reserve ratios against CD's and demand deposits. The required reserve ratio described here incorporates both reserve ratios into the same conceptual structure.
Figure V-2: Causal Diagram of the Policy Structure for the Required Reserve Ratio
described in detail in Section C, allows for variable emphasis to be put on either turnover or excess reserves. The actual required reserve ratio exponentially adjusts to the indicated required reserve ratio with a time constant of three years.

The reserve ratio indicated by turnover reflects the need to hold reserves in order to cover the normal flow of payments through deposits. The principal, and earliest-recognized purpose for requiring banks to hold reserves is to guarantee that banks will be able to meet the normal flow of withdrawals by their depositors. Early banks failed primarily because they allowed their reserves to decline too far in proportion to their deposits, and were therefore unable to meet common withdrawal demand. The desired coverage of reserves expresses the coverage over the withdrawal stream that the monetary authority would like the banks to hold in reserves. Coverage is expressed as a ratio between reserves and withdrawals, or alternatively, the number of years worth of withdrawals to be held as reserves. Coverage of reserves for a commercial bank is on the order of a few days. Desired coverage of reserves is formulated as the product of a constant normal coverage of reserves and an index of money coverage in nation, a variable used throughout the national model to express the impact of computer-processing and other developments on the need to hold money balances. Turnover in deposits is a measure of the number of times a typical deposit is used in a year; deposit turnover is on the order of twenty times a
year. The product of turnover in deposits and the desired coverage of reserves yields a desired ratio of reserves to deposits, or the reserve ratio indicated by turnover. This formulation is derived from the simple relations among deposits, withdrawals, and reserves in a single bank:

Let \( D = \) deposits ($),
\( W = \) withdrawals ($/year),
\( R = \) reserves ($)

Since withdrawals (from a single bank) must be met from reserves,

\[
\frac{W}{D} = \text{turnover in deposits} = \text{TD (times per year)}
\]

\[
\frac{R}{W} = \text{coverage of reserves} = \text{CR (years)}
\]

from first equation,

\[ W = \text{TD} \times D \]

thus,

\[
\frac{R}{TD \times D} = \text{CR}
\]

or alternatively,

\[
\frac{R}{D} = \text{CR} \times \text{TD}
\]

Given TD,

\[
(\text{desired } \frac{R}{D}) = (\text{desired CR}) \times \text{TD}.
\]

Turnover in deposits for a single bank includes checks drawn on one bank and immediately redeposited in another bank. The
single bank must meet this withdrawal from its reserves (in modern banking, from its own deposits with the Federal Reserve). An aggregate bank, like that used in the national model, would not reflect such a transfer. In order to approximate the actual turnover in deposits of single banks, turnover in deposits for this policy structure is calculated as a weighted average of the turnover in the deposits of all the individual production and household sectors. This derivation is explained in more detail in Section C.

The reserve ratio indicated by turnover, and its resulting impact on the required reserve ratio, captures the evolution of the required reserve ratio as a guarantee that banks will be able to meet withdrawals. To a large extent, the required reserve ratio plays no role in ongoing monetary control. Its existence, however, and its approximate magnitude, arises out of the need to protect depositors against banks reducing their reserves below the point where they are able to meet withdrawal demand. The reserve ratio indicated by turnover accomplishes this objective in the policy structure.

To the extent that the required reserve ratio is used at all in ongoing monetary control, it is used to control excess reserves. Since excess reserves can potentially create expansion in the money supply outside of the control of the monetary authority, large amounts of excess reserves are regarded as destabilizing. An increase in the required reserve ratio can effectively absorb excess reserves.

The reserve ratio indicated by excess reserves is the ratio of required-reserves to deposits that would maintain excess reserves
at the desired level. Desired required reserves are derived from the desired excess reserve fraction and the current reserves of the bank. The desired excess reserve fraction is the fraction of reserves that the monetary authority would like the bank to hold in excess of required reserves. The monetary authority, for example, may want the bank to hold one-tenth of their reserves as excess reserves; desired required reserves, therefore, would be nine-tenths of the reserves of the bank.

The desired excess reserve fraction is formulated as a long-term average of the actual excess reserve fraction. This goal formulation process is identical in form to those employed by the other two subsectors in deriving goals for inflation, unemployment, borrowing, and bond yield. The goal for excess reserves, therefore, gradually adjusts to the actual excess reserve holdings of the bank.
C. Equations of the Policy Structure for the Required Reserve Ratio

Figure V-3 is the DYNAMO flow diagram of the policy structure for the required reserve ratio. Inputs exogenous to this structure include the turnover in demand deposits TDD, the index of money coverage in nation IMCN, reserves of the bank RB, excess reserves ER, and demand deposits DD.

Required Reserve Ratio RRR

\[
\begin{align*}
RRR & = RRR_1 = (DT/TARR) (IRR_1 - RRR_1) + RRR_1 \\
RRR & = RRR_1 \\
RRR_1 & = 0.2 \\
TARR & = 3
\end{align*}
\]

- **RRR** - REQUIRED RESERVE RATIO (DIMENSIONLESS)
- **DT** - SOLUTION TIME INTERVAL (YEARS)
- **TARR** - TIME TO AVERAGE REQUIRED RESERVE RATIO (YEARS)
- **IRR** - INDICATED REQUIRED RESERVE RATIO (DIMENSIONLESS)
- **RRR_1** - REQUIRED RESERVE RATIO INITIAL (DIMENSIONLESS)

The required reserve ratio RRR is formulated as a first-order exponential average of the indicated required reserve ratio IRRR. A first-order exponential average is a continuous Koyck-distributed lag with a coefficient of adjustment equal to the reciprocal of the time constant, time to average required reserve ratio TARR (Koyck 1954). In this formulation, the indicated required reserve ratio IRRR reflects the pressures to change the reserve ratio, and the actual required reserve ratio RRR exponentially adjusts to the indicated required reserve ratio IRRR with a time
Figure V-3: DYNAMO Flow Diagram of the Policy Structure for the Required Reserve Ratio
constant of three years, the time to average required reserve ratio TARRR. This formulation reflects the delay between a rise in the pressure to change the reserve requirement and an actual change. This delay exists for a number of reasons: a desire to be confident that changes in excess reserves or in deposit turnover are persistent; a reluctance to make frequent changes in the reserve ratio; and especially under the National Banking Act and the Federal Reserve, the institutional sluggishness of a central monetary authority reaching decisions by committee. The time to average required reserve ratio TARRR is given the value of three years to reflect observed delays in monetary authority decisions.\(^{34}\) Friedman and Schwartz report that the New York Reserve Bank began in 1934 to pressure the System to increase reserve requirements, a change not made until over two years later in 1936-1937 (Friedman and Schwartz 1963, p. 520). The 1951 change in reserve requirements followed pressures for a change that began in 1949 (Eastburn 1965, pp. 76-77).

\(^{34}\) As an exponential time constant, TARR represents the time required for RRR to follow 63% of any change in IRRR. For example, if IRRR suddenly changed from .10 to .20 in year 0, RRR would move from .10 to .163 by year 3 (presuming RRR equal to IRRR before year 0).
Indicated Required Reserve Ratio IRRR

\begin{align*}
\text{IRRR} & : \text{Indicated Required Reserve Ratio} \\
\text{RRIT} & : \text{Reserve Ratio Indicated by Turnover (Dimensionless)} \\
\text{WIRR} & : \text{Weighting of Indicated Reserve Ratios (Dimensionless)}
\end{align*}

The indicated required reserve ratio IRRR is formulated as the product of the reserve ratio indicated by turnover RRIT and the weighting of indicated reserve ratios WIRR. This formulation yields an indicated required reserve ratio IRRR that is a compromise between the reserve ratio indicated by turnover RRIT and the reserve ratio indicated by excess reserves RRRIER. For example, if RRIT takes a value of 0.2 and RRRIER takes a value of 0.3, then the indicated required reserve ratio IRRR will have a value somewhere between the two. The weighting of indicated reserve ratios WIRR determines whether that value will be closer to RRIT or to RRRIER; in other words, the relative importance of turnover compared to excess reserves in determining the required reserve ratio RRR. In the example, if both were given equal weight, then the indicated required reserve ratio IRRR would have a value of 0.25.
Weighting of Indicated Reserve Ratios WIRR

\[ WIRR = \text{IndRIR} \times \text{RIRR} \times \text{Kv} \times 2 \times 2 \]

\[ TWIRR = 0.75 \times 0.75 \times 0.75 \times 0.75 \]

WIRR - WEIGHTING OF INDICATED RESERVE RATIOS (DIMENSIONLESS)
TWIRR - TABLE FOR WEIGHTING OF INDICATED RESERVE RATIOS
RIRR - RATIO OF INDICATED RESERVE RATIOS (DIMENSIONLESS)

Figure V-4: Table Function for Weighting of Indicated Reserve Ratios WIRR
The weighting of indicated reserve ratios WIRR determines how heavily the two objectives of covering deposit turnover and controlling excess reserves are weighted in determining the indicated required reserve ratio IRRR. The weighting function, shown in Figure V-4, takes as its argument the ratio of indicated reserve ratios RIRR, which is equal to the reserve ratio indicated by excess reserves RRIER divided by the reserve ratio indicated by turnover RRIT.

On Figure V-4, three lines, in addition to the actual table function values, are drawn to illustrate the extremes and the median of the weighting function. The horizontal line, if used as the weighting of indicated reserve ratios WIRR, would make the indicated required reserve ratio IRRR equal to the reserve ratio indicated by turnover RRIT. The $45^\circ$ line, if used as WIRR, would make the indicated required reserve ratio IRRR equal to the reserve ratio indicated by excess reserves RRIER. These two lines, therefore, define the extremes of the weighting function; either line would make the indicated required reserve ratio IRRR completely independent of one of the objectives. The line bisecting the two extremes would result in a weighting function making the indicated required reserve ratio IRRR equal to the average of the two indicated reserve ratios.

The actual function for the weighting of indicated reserve ratios WIRR, the heavy line in Figure V-4, is quite close to the average when the two indicated reserve ratios are nearly equal (ratio of indicated reserve ratios RIRR near 1.0). However, when the ratio of indicated reserve ratios RIRR is either quite small or
quite large, the weighting function diverges from the average. The function as used in the policy structure is more responsive to the reserve ratio indicated by turnover RRIT than to the reserve ratio indicated by excess reserves RRIER. To use the earlier example, if RRIT were .2 and RRIER were .3, the indicated required reserve ratio IRRR would be .24.

Another way of considering the weighting of indicated reserve ratios WIRR is as the fraction by which the monetary authority is willing to have the required reserve ratio RRR deviate from the reserve ratio indicated by turnover RRIT. The function in Figure V-4 maintains the indicated required reserve ratio IRRR within ±25% of the reserve ratio indicated by turnover RRIT, even in the face of very high or very low excess reserves. The reserve ratio indicated by turnover RRIT represents the fundamental purpose of requiring reserves, the capacity to meet withdrawal demand. The reserve ratio indicated by excess reserves RRIER represents the less fundamental objective of controlling excess reserves. The monetary authority is therefore willing to use the required reserve ratio RRR to control excess reserves only if such use does not force required reserves to deviate too far from the level needed to meet withdrawal demand.

Test simulations in Section D will illustrate the sensitivity of the required reserve ratio RRR to alterations in the weighting of indicated reserve ratios WIRR.
Ratio of Indicated Reserve Ratios RIRR

\[ \text{RIRR}_k = \text{RRIER}_k / \text{RRIT}_k \]

- **RIRR** - Ratio of Indicated Reserve Ratios
  - Dimensionless
- **RRIER** - Reserve Ratio Indicated by Excess Reserves
  - Dimensionless
- **RRIT** - Reserve Ratio Indicated by Turnover
  - Dimensionless

The ratio of indicated reserve ratios RIRR is the argument for the weighting function described above. It is defined as the reserve ratio indicated by excess reserves RRIER divided by the reserve ratio indicated by turnover RRIT.

Reserve Ratio Indicated by Turnover RRIT

\[ \text{RRIT}_k = \text{DCR}_k \times \text{TDD}_k \]

- **RRIT** - Reserve Ratio Indicated by Turnover
  - Dimensionless
- **DCR** - Desired Coverage of Reserves (Years)
- **TDD** - Turnover in Demand Deposits (1/Year)

The reserve ratio indicated by turnover RRIT is the ratio between reserves of the bank RB and demand deposits DD that would make the coverage of reserves in a single bank equal to the desired coverage of reserves DCR, given current turnover in demand deposits TDD. The derivation of the reserve ratio indicated by
turnover RRIT was given by the simple equations in Section B. If turnover in demand deposits TDD increases, banks should hold on average a higher amount of reserves for the same amount of deposits, in order to meet the higher withdrawal demand.

Figure V-5 shows turnover in demand deposits in the United States for the years 1920-1957 (Garvy 1959, p. 21). Turnover has varied from a maximum of roughly thirty-six times per year in 1929 to a minimum of roughly thirteen times per year in 1945.

![Turnover of Demand Deposits in the United States, 1920-1957](image)

*Figure V-5: Turnover in Demand Deposits in the United States, 1920-1957 (Garvy 1959, p. 21)*

Turnover in demand deposits TDD is derived (external to this sector, as an interface equation) as a weighted average of deposit turnover in all of the production and household sectors. In the true economy, turnover in demand deposits TDD would be a weighted average of turnover in the deposits of all commercial
banks. Because the national model uses one aggregate bank, which will not reflect the turnover in deposits of an individual bank, an approximation is required in order to calculate TDD. Using deposit turnovers from the sectors is equivalent to assuming that each sector has a bank associated with it, and turnover in demand deposits TDD is a weighted average of turnover in the "consumer goods bank," "transportation bank," etc.

Each of the sectors has an internal money level, out of which payments are made. These money levels include both currency and demand deposits. Turnover in their demand deposits will be equal to turnover in their money levels only if the currency-deposit ratio remains constant, and if both receipt and payment streams are apportioned between currency and deposits by the currency-deposit ratio. If the currency-deposit ratio is increasing, deposit turnover will be higher than money turnover because of the transfer from deposits into currency. In general, deposit turnover can be related to money turnover by the following relationship:35

\[
\text{let } TM = \text{turnover in money (1/year)} \\
\text{TD} = \text{turnover in deposits (1/year)} \\
C = \text{currency-deposit ratio (dimensionless)} \\
\text{TD} = TM + \frac{dC}{dt} \cdot \frac{1}{1 + C}
\]

35 This relationship is derived from the assumptions previously noted, with the additional assumption that changes in C can be described as a net flow from currency to deposits.
Changes in the currency-deposit ratio, however, are quite small in comparison to turnover in money. For example, if C were to change from .1 to .2 in one year, a change which is an order of magnitude above the normal variation, the second term above would be roughly 0.09 times per year. Turnover in money, however, is on the order of 20 times per year. Turnover in demand deposits TDD, therefore, is approximated by a weighted average of money turnover in the production and household sectors, ignoring changes in the currency-deposit ratio.

Desired Coverage of Reserves DCR

\[ DCR, K = NCR \times IMCN, K \]

\[ NCR = .01 \]

DCR - DESIRED COVERAGE OF RESERVES (YEARS)
NCR - NORMAL COVERAGE OF RESERVES (YEARS)
IMCN - INDEX OF MONEY COVERAGE IN NATION (DIMENSIONLESS)

The desired coverage of reserves DCR is the coverage that the monetary authority would like the bank to maintain to meet withdrawal demand. Normal coverage of reserves NCR has a value of 0.01 years, implying that the monetary authority would like the bank to hold roughly three-and-a-half days' worth of withdrawals as reserves. The index of money coverage in nation IMCN is a dimensionless multiplier that will reduce the desired coverage of reserves DCR as improvements in check-cashing and other deposit-handling techniques allow
banks to economize on reserve holdings. This multiplier is derived outside of the monetary authority sector. It is used similarly by the production and household sectors in formulating their desired money coverage.

Reserve Ratio Indicated by Excess Reserves RRIER

\[ \text{RRIER}_k = \text{DRR}_k / \text{DD}_k \]

- \( \text{RRIER} \) = Reserve Ratio Indicated by Excess Reserves (dimensionless)
- \( \text{DRR} \) = Desired Required Reserves (\$)
- \( \text{DD} \) = Demand Deposits (\$)

The reserve ratio indicated by excess reserves RRIER represents the value for the required reserve ratio RRR that would meet the monetary authority's objective of controlling excess reserves. Desired required reserves DRR is the value of required reserves that would meet the excess reserve objective. Dividing by the reserves of the bank RB yields the reserve ratio indicated by excess reserves RRIER.

To a large extent, reserve requirement changes in the past fifty years have been for the purpose of controlling excess reserves. Reproduced in Appendix V-A are parts of a list of Federal Reserve decisions compiled by Eastburn (Eastburn 1965), pp. 68-96). In the second column are reserve requirement decisions made by the Federal Reserve, followed in the third column by a brief summary of the
economic circumstances that preceded the decision. In all but a very few cases, the excess reserve positions of member banks are mentioned as one of the prime reasons for a change in reserve requirements. The increases of 1936-37, the largest increases over the period, were for the direct purpose of absorbing excess reserves to avoid "injurious credit expansion." Similarly, the 1954 reductions in requirements were intended "to supply the banking system with reserves to meet expected growth." The policy structure defined here is designed to capture this dependence of reserve requirements on the excess reserve position of the banking system.

Desired Required Reserves DRR

\[
DRR_K = (1 - DERF_K)(RB_K)
\]

- **RR** = DESIRED REQUIRED RESERVES ($)
- **DERF** = DESIRED EXCESS RESERVE FRACTION (DIMENSIONLESS)
- **RB** = RESERVES OF THE BANK ($)

Desired required reserves DRR is the value of required reserves that would equate actual excess reserves held by the bank with the monetary authority's excess reserve goal, given the current total reserves of the bank RB. The desired excess reserve fraction DERF captures the monetary authority's excess reserve goal. For example, if the monetary authority would like the bank to hold 10%
of its total reserves as excess reserves (DERF = .1), then desired required reserves DRR would be 90% of the reserves of the bank RB.

Desired Excess Reserve Fraction DERF

\[
DERF, K = \text{SMOOTH}(ERF, K, TAERF)
\]

\[
TAERF = 10
\]

**DERF** - DESIRED EXCESS RESERVE FRACTION (DIMENSIONLESS)

**ERF** - EXCESS RESERVE FRACTION (DIMENSIONLESS)

**TAERF** - TIME TO AVERAGE EXCESS RESERVE FRACTION (YEARS)

The desired fraction of total reserves held as excess reserves, or the desired excess reserve fraction DERF, is formulated as a long-term exponential average of the actual ratio between excess and total reserves ERF. This variable represents the excess reserve standard of the monetary authority. The standard gradually shifts with the bank's excess reserve position. If excess reserves as a fraction of total reserves are declining over time, then the monetary authority's expectation, or standard, or excess reserve holdings will also decline. The goal of this policy structure is therefore variable. It responds gradually to changes in the banking structure by adjusting over time to actual conditions. Conditions that persist for a number of years are accepted as "desirable," partially because no apparent ill consequences have resulted, and partially because an apparently unchangeable condition becomes defined as a performance standard.
The time to average the excess reserve fraction TAERF represents the speed of adjustment between the actual ratio ERF and the desired ratio DERF. Its chosen value of ten years, a first-order exponential time constant, implies that changes in the goal for excess reserves will lag changes in the actual excess reserve position by roughly ten years. This period reflects the time required to adjust attitudes toward the banking system, and to translate the changed attitudes into decision-making guidelines. The time to average excess reserve fraction TAERF is given a value of ten years so that the monetary authority's goal for excess reserves, as embodied in the desired excess reserve fraction DERF, adjusts to actual conditions with the same time constant as its goals for inflation and unemployment, as described in Chapters Three and Four. A test simulation in Section D illustrates the sensitivity of the required reserve ratio RRR to different values for the time to average excess reserve fraction TAERF.

Excess Reserve Fraction ERF

\[
ERF_k = \frac{ER_k}{RB_k}
\]

- **ERF** = EXCESS RESERVE FRACTION (DIMENSIONLESS)
- **ER** = EXCESS RESERVES ($)
- **RB** = RESERVES OF THE BANK ($)
The excess reserve fraction ERF is the fraction of total reserves of the bank RB that the bank holds as excess reserves ER. The excess reserve fraction ERF is the measure of the bank's actual excess reserve position to which the monetary authority's goal adjusts. A fractional measure ensures that overall expansion in banking activity, with a corresponding proportional increase in both excess reserves ER and total reserves of the bank RB, is not interpreted by the monetary authority as a change in the bank's excess reserve position.
D. Test Simulations of the Policy Structure for the Required Reserve Ratio

D.1. Scope and Purpose of the Simulations

The equations of Section C have defined the policy structure determining the required reserve ratio. In setting the required reserve ratio, the monetary authority responds to both turnover in demand deposits and the excess reserve position of the bank. Higher turnover in demand deposits leads to a higher required reserve ratio to maintain desired coverage of reserves over withdrawals. An increase in the fraction of bank reserves held as excess reserves leads to an increase in the required reserve ratio to absorb excess reserves.

Chapter Three, Section D.1, discussed some of the problems associated with testing the policy structure for open-market operations when it is uncoupled from the full national model. In particular, the discussion noted that much of the dynamic behavior of open-market operations will come only when they are linked with a fully reactive economy. These same comments apply to testing of the policy structure for the required reserve ratio. Test inputs must be provided to the policy structure in order for any behavior to be generated. Figure V-6 enumerates the constant and variable inputs that are required by the policy structure for the required reserve ratio.

The parameters have all been given representative values by the equations of Section C. Turnover in demand deposits TDD is provided by a test function allowing for a constant, a step function, and/or a sinusoid. The index of money coverage in nation IMCN is held constant.
### Parameters (type)
- Time to average required reserve ratio TARRR (C)
- Required reserve ratio initial (N)
- Table for weighting of indicated reserve ratios TWIRP (T)
- Normal coverage of reserves NCR (C)
- Time to average excess reserve fraction TAERF (C)

### Variable Inputs
- Turnover in demand deposits TDD
- Index of money coverage in nation IMCN
- Demand deposits DD
- Reserves of the bank RB
- Excess reserves ER

**Figure V-6:** Parameters and Variable Inputs for the Policy Structure for the Required Reserve Ratio

at 1.0. Demand deposits DD are held constant at one hundred billion dollars. Reserves of the bank RB are defined in two ways. In the first three test simulations, Figures V-8, V-9, and V-10, reserves of the bank RB vary to permit step changes in the excess reserve fraction ERF (Figure V-8 shows the behavior of RB when defined as a variable). In the final two test simulations, reserves of the bank RB are held constant. Excess reserves ER are defined as the difference between reserves of the bank RB and required reserves.

Figure V-7 outlines the test simulations used to explore the dynamic characteristics of the policy structure for the required reserve ratio. The figure provides a brief description of the economic conditions being simulated, followed by an abbreviated accounting of the dynamic characteristics that each simulation illustrates.
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<th>What the Simulation Shows</th>
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<td>V-8</td>
<td>Step increase in excess reserve fraction; variable reserves of the bank.</td>
<td>Required reserve ratio rises, then falls as the monetary authority adjusts to higher excess reserves.</td>
</tr>
<tr>
<td>V-9</td>
<td>Various step increases in excess reserve fraction.</td>
<td>Compares the response to different changes in the bank's excess reserve position.</td>
</tr>
<tr>
<td>V-10</td>
<td>Step increase in excess reserve fraction; various values for TAERF</td>
<td>The response to excess reserves depends on how quickly the monetary authority adjusts to actual conditions.</td>
</tr>
<tr>
<td>V-11</td>
<td>Reserves of the bank constant; various step changes in turnover of demand deposits.</td>
<td>Compares the response to different changes in deposit turnover.</td>
</tr>
<tr>
<td>V-12</td>
<td>Step change in turnover; various forms of the weighting of indicated reserve ratios WIRR</td>
<td>Illustrates the impact of different weighting functions.</td>
</tr>
</tbody>
</table>

Figure V-7: Outline of the Test Simulations, Giving Conditions Simulated and Their Results
D.2. Test Simulations

Figure V-8 shows the response to a step increase in the excess reserve fraction ERF. In year two, ERF steps from .05 to .20. Reserves of the bank RB increase in order to accommodate the rise in excess reserves ER. The reserve ratio indicated by excess reserves RRIER initially increases to nearly .24 in an attempt to absorb the increase in excess reserves. The required reserve ratio RRR, therefore, also begins to rise.

As the desired excess reserve fraction DERF begins to adjust to the higher excess reserve fraction ERF, the reserve ratio indicated by excess reserves RRIER begins to fall. The required reserve ratio RRR peaks in year nine, then declines toward its initial value of .20. As RRR declines, the reserves of the bank RB also decline as required reserves decline. Equilibrium will be re-established with the required reserve ratio RRR equal to .20, both the desired and the actual excess reserve fractions, DERF and ERF, equal to .2, and reserves of the bank RB at a higher level to accommodate the higher excess reserves.

Figure V-9 illustrates the response of the required reserve ratio RRR to four different step increases in the excess reserve fraction ERF. The top curve, in which ERF steps from 0.05 to 0.20, represents the same conditions as in Figure V-8. In each case, the required reserve ratio RRR begins to adjust to a higher (or lower) value, then adjusts back to its initial value as the desired excess reserve fraction DERF adjusts to the excess reserve fraction ERF.
Figure V-8: Response to a Step Increase in the Excess Reserve Fraction
Figure V-9: Response to Various Step Increases in the Excess Reserve Fraction
This test simulation illustrates how the monetary authority attempts initially to counteract a change in excess reserves, then gradually adapts its goal to the new conditions as the conditions remain unchanged. The time to average the required reserve ratio TARRR governs how quickly the required reserve ratio RRR adjusts to the indicated required reserve ratio IRRR. A longer value for TARRR, for example, would reduce the amount of adjustment accomplished per year. With a higher TARRR, the required reserve ratio RRR would not increase as rapidly as in Figure V-9; the peaks in RRR would not be as high because RRR would not have reached as high a level as in Figure V-9 before the indicated required reserve ratio IRRR began to decline.

**Figure V-10** illustrates the effect of changing the time to average the excess reserve fraction TAERF. This time constant determines how quickly the desired excess reserve fraction DERF adjusts to the actual excess reserve fraction ERF. In each of the simulations, ERF increases from 0.05 to 0.20 in year two and remains at the higher value. This top curve illustrates a situation in which the desired excess reserve fraction DERF does not adjust, but remains at its initial value of 0.05. Under these conditions, the required reserve ratio RRR stabilizes at a value slightly less than .23. The equilibrium is determined by the balancing between the reserve ratio indicated by excess reserves RRIER and the reserve ratio indicated by turnover RRIT. RRIT has remained constant at 0.20, and RRIER has
Figure V-10: Response to Changes in the Time to Average Excess Reserve Fraction

\( \text{RRR} \cdot T1 = 0, \text{RRR} \cdot T2 = 1, \text{RRR} \cdot T3 = 2, \text{RRR} \cdot 3 \)
stabilized at a value of roughly 0.28. The weighting of indicated reserve ratios WIRR then determines the equilibrium value of the required reserve ratio RRR.

The other three curves of Figure V-10 illustrate three values of the time to average the excess reserve fraction TAERF. For TAERF equal to three years, the lowest curve, the desired excess reserve fraction DERF adjusts quite quickly to ERF, so that RRR rises for only four years before declining back to 0.20. As TAERF increases, the required reserve ratio RRR rises longer and declines more slowly; with TAERF equal to thirty years, RRR peaks in year twelve before beginning a slow decline.

Figure V-11 shows the response of the required reserve ratio RRR to changes in the turnover of demand deposits TDD. In year two, TDD is alternately changed from 20 times per year to 30 times per year, 25 times per year, and 18 times per year. In each case, the required reserve ratio RRR adjusts to a new equilibrium value over a period of roughly ten years. However, because of the weighting of indicated reserve ratios WIRR, the new RRR does not fully compensate for the change in deposit turnover (RRIER has remained at 0.20). For example, in the top curve the reserve ratio indicated by turnover RRIT has risen to 0.30, but the required reserve ratio RRR rises only to roughly 0.26. The monetary authority balances the need to provide for reserve coverage with the need to control excess reserves; the balancing is accomplished in the policy structure by the weighting of indicated reserve ratios WIRR.
Figure V-11: Response to Various Step Increases in Turnover of Demand Deposits
Figure V-12 illustrates the same conditions as in the top curve of Figure V-11, but with different forms for the weighting of indicated reserve ratios WIRR. The insert on the lower right corner of the figure shows the three forms simulated. Curve A uses a weighting function that completely ignores the excess reserve position of the bank; under these conditions, the required reserve ratio RRR rises to 0.30. Curve B, on the other hand, represents the effect of equal weighting between the reserve ratio indicated by turnover RRIT and the reserve ratio indicated by excess reserves RRIER. With equal weighting, RRR equilibrates at 0.25. Curve C shows the effect of a weighting function that puts most emphasis on controlling excess reserves. Since the reserve ratio indicated by excess reserves RRIER remains at 0.20, the required reserve ratio RRR deviates only slightly from its initial value.

The following Appendix describes many of the reserve requirement decisions made by the Federal Reserve over the period 1936-1962.
Figure V-12: Sensitivity to the Weighting of Indicated Reserve Ratios
<table>
<thead>
<tr>
<th>DATE OF DECISION</th>
<th>DECISION</th>
<th>UNDERLYING ECONOMIC CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1936: August</td>
<td>Raised by 1/2</td>
<td>To reduce large volume of excess reserves created by gold inflow so that the Federal Reserve would be in a better position to influence credit if necessary at some future time. No change in Federal Reserve policy to influence business and credit situation at the time intended by action.</td>
</tr>
<tr>
<td>1937: March-May</td>
<td>Raised by 1/3 to legal maximum, effective March 1 and May 1.</td>
<td>To reduce member bank excess reserves &quot;which would result in an injurious credit expansion if permitted to become the basis of a multiple expansion of bank credit.&quot; Action not designed to be restrictive at time but for preparedness. Distinct tendencies toward inflationary developments in business and prices at beginning of year.</td>
</tr>
<tr>
<td>1937: August-April</td>
<td>Reduced by 1/4 of legal minimum requirements (April 1938).</td>
<td>To ease credit situation and security markets in view of decline in business activity and commodity and security prices, following business inventory accumulation and inflationary tendencies.</td>
</tr>
<tr>
<td>1941: November</td>
<td>Raised to legal maximum.</td>
<td>To restrain inflationary credit expansion by absorbing about $1.2 billion of excess reserves. Business expanding, prices rising; strong credit demands.</td>
</tr>
</tbody>
</table>


(Eastburn 1965, pp. 68-96) (continued)
<table>
<thead>
<tr>
<th>DATE OF DECISION</th>
<th>DECISION</th>
<th>UNDERLYING ECONOMIC CONDITIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1942: August -1942: October</td>
<td>Reduced from 26 to 20 percent at central reserve city banks.</td>
<td>To assist New York City and Chicago banks in meeting persistent outflow of funds to other parts of the country caused by heavy Government borrowing in the financial centers and disbursements in other areas, and to supply funds for banks to purchase Treasury securities.</td>
</tr>
<tr>
<td>1948: February -1948: September</td>
<td>Raised on demand deposits from 20 to 26 percent at central reserve city banks; 20 to 22 percent at reserve city; and 14 to 16 percent at country banks; on time deposits from 6 to 7 1/2 percent at all banks.</td>
<td>Reserve requirement action to help additional reserves made available by gold inflow and by Federal Reserve purchases in support of the market for Government securities. Congress provided authority (until June 30, 1949) for increases in reserve requirements above those otherwise authorized. Securities purchased in open market to maintain the stability of the market and to assist temporarily in the adjustment of member banks to increased reserve requirements.</td>
</tr>
<tr>
<td>1949: May -1949: September</td>
<td>Reduced on demand deposits by 4 percentage points; on time deposits by 2 1/2 percentage points. Changes in several steps.</td>
<td>Recession in business and prices. Credit policy aimed at encouraging a high level of business activity, but avoiding conditions of such ease as would prevent needed adjustments or encourage undue expansion.</td>
</tr>
</tbody>
</table>


(Eastburn 1965, pp. 68-96) (continued)
<table>
<thead>
<tr>
<th>DATE OF DECISION</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1951: January -1951: February</td>
<td>Raised by 2 percent on demand deposits; 1 percent on time deposits; maximum limits except at central reserve city banks.</td>
<td>Continued expansion of bank credit. Action taken to absorb about $2 billion of funds, largely from seasonal return of currency and System purchases of bonds, and generally to reduce the ability of banks to expand credit that would add to inflationary pressures. At central reserve city banks requirements were raised to a level considerably above those that prevailed during most of the war period.</td>
</tr>
<tr>
<td>1953: July</td>
<td>Reduced reserve requirements on net demand deposits by 2 percentage points at central reserve city banks and by 1 percentage point at reserve city and country banks, thus freeing an estimated $1.2 billion of reserves.</td>
<td>To free additional bank reserves for meeting expected seasonal and growth credit demands, including Treasury financing needs, and to further reduce the pressure on member bank reserve positions.</td>
</tr>
<tr>
<td>1954: June -1954: August</td>
<td>Reduced reserve requirements on net demand deposits by 2 percentage points at central reserve city banks and by 1 percentage point at reserve city and country banks, and requirements on time deposits by 1 percentage point at all member banks, thus freeing about $1.5 billion of reserves in the period June 16 to August 1.</td>
<td>To supply the banking system with reserves to meet expected growth and seasonal demands for credit and money, including Treasury financing needs.</td>
</tr>
</tbody>
</table>


(Eastburn 1965, pp. 68-96) (continued)
DATE OF DECISION | DECISION | UNDERLYING ECONOMIC CONDITIONS
--- | --- | ---
1958: January | -1958: February | 
1958: February | Reduced reserve requirements on demand deposits from 20 to 19 1/2 percent at central reserve city banks; from 18 to 17 1/2 percent at reserve city banks; and from 12 to 11 1/2 percent at country banks, thus freeing an estimated $500 million of reserves. | Do.
1958: March | Reduced reserve requirements on demand deposits from 19 1/2 to 19 percent at central reserve city banks; from 17 1/2 to 17 percent at reserve city banks; and from 11 1/2 to 11 percent at country banks, thus freeing an additional $500 million of reserves. | Do.
1958: February | -1958: mid-April | To supplement reserve requirement actions in further increasing the availability of bank reserves.


(Eastburn 1965, pp. 68-96) (continued)
DATE OF DECISION | DECISION | UNDERLYING ECONOMIC CONDITIONS
--- | --- | ---
1958: April | Reduced reserve requirements on demand deposits from 19 to 18 percent (in two stages) at central reserve city banks and from 17 to 16 1/2 percent at reserve city banks, thus freeing a total of about $450 million of reserves. | To supplement previous actions to encourage bank credit and monetary expansion and resumed growth in economic activity and to offset current gold outflow.
1960: August | Authorized member banks to count about $500 million of their vault cash as required reserves, effective for country banks August 25 and for central reserve and reserve city banks September 1. Reduced reserve requirements against net demand deposits at central reserve city banks from 18 to 17 1/2 percent, effective September 1, thereby releasing about $125 million of reserves. | To provide mainly for seasonal needs for reserve funds, and to implement 1959 legislation directed in part toward equalization of reserve requirements of central reserve and reserve city banks.
1960: late November -1960: December | Authorized member banks to count all their vault cash in meeting their reserve requirements and increased reserve requirements against net demand deposits for country [cont'd next page] | To provide, on a liberal basis, for seasonal reserve needs, to complete implementation of legislation directed in part toward equalization of reserve requirements of central reserve and reserve city banks, and to offset the effect of [cont'd next page]

Appendix V-A: Decisions to Change Reserve Requirements, and Underlying Economic Conditions, 1936-1962
(Eastburn 1965, pp. 68-96) (continued)
bonds from 11 to 12 percent. The net effect of these two actions, effective November 24, was to make available about $1,050 million of reserves. Reduced reserve requirements against net demand deposits at central reserve city banks from 17 1/2 to 16 1/2 percent, effective December 1, thereby releasing about $250 million of reserves.

1962: October

Reduced reserve requirements against time deposits from 5 to 4 percent, effective October 25 for reserve city banks and November 1 for other member banks, thereby releasing about $780 million of reserves.

To help meet seasonal needs for reserves, while minimizing downward pressures on short-term interest rates, and to provide for the longer-term growth in bank deposits needed to facilitate the expansion in economic activity and trade.


(Eastburn 1965, pp. 68-96)
CHAPTER SIX: SUMMARY AND DIRECTIONS FOR FUTURE RESEARCH

A. A Brief Summary of the Study

The principal objective of this study has been to develop a system dynamics model of monetary control decisions. The structure will be used in the national socio-economic model to endogenously generate the response of monetary authorities to changing economic conditions. The long time horizon of the national model has dictated that the structure be relevant to the entire period from 1800 to the present. To meet this requirement, the monetary authority structure has been presented and defended as independent of any particular agency of monetary control, and as sufficiently general to encompass the control activities of both individual banks and state and federal institutions.

Readers of Chapters Three, Four, and Five, which describe the details of the monetary authority structure, will realize that the structure corresponds more closely to the Federal Reserve than to earlier monetary authorities. This intentional bias is to enable more realistic and detailed analysis of current and future policy options available to the United States. The national socio-economic model will be used to evaluate many alternative policies to deal with contemporary problems of inflation, unemployment, rising energy and material costs, and societal dissatisfaction with economic progress (or lack thereof). Those explorations will require a structure that accurately describes the policies of the current
monetary control agents, The Federal Reserve, in responding to economic conditions.

Chapters Three, Four and Five also indicated, however, that the same functions served by the Federal Reserve were present to a remarkable extent during the nineteenth century. This study has argued that the history of monetary control has been more of a coalescing of power rather than of drastic changes in either the objectives or instruments of monetary control. Reserve requirements, as described in Chapter Five, served the same objective of stability in banking, whether administered by the individual banks, the National Bank, or the Federal Reserve. Chapter Four noted the use of discounts for temporary reserve expansion long before the Aldrich-Vreeland Act set the stage for a central discount facility. Finally, open market operations, in precisely their current form, were employed by the Treasury decades before the Federal Reserve, for the same general purpose of controlling aggregate money; and throughout the nineteenth century, slightly different mechanisms were used to achieve the same objectives.

Chapter Two reviewed much of the existing literature in monetary theory with two objectives in mind: first, to identify any previous descriptions of the policy process underlying monetary control decisions; second, to obtain some insights into the intended effect of control decisions. With the exception of a few optimization models, no formalized models of a monetary policy structure exist. There are, however, several informal, verbal descriptions of how decisions are
made. These descriptions were used to provide some of the structural assumptions made in Chapters Three, Four, and Five. The theoretical literature provided some of the inputs to the policy structure, and identified the equilibrium conditions that could be expected to obtain after a monetary control decision was implemented.

The most difficult part of the policy structure to quantify has been the response of each of the instruments to a change in its inputs. The nine table functions in the current policy structure are approximate at best. They reflect the general characteristics of response, but are difficult to quantify precisely. In a dynamic model, such as the full national model, precise quantification is less important than identifying the form and direction of table functions; specific function values are often derived from experiments with the model, observing its reaction to input changes and comparing that reaction to known behavior. Much of the behavior of a monetary policy structure will come from its interaction with a completed macroeconomic model. Further validation of the table functions proposed in this study must await its combination with the entire national model.
B. Suggestions for Structural Changes

B.1. Alternative Goal Formulations

Chapters Three, Four, and Five contained formulations of goals for monetary control decisions. The goals were the desired bond yield DBT, the desired rate of inflation DRI, the desired rate of unemployment DRU, the desired ratio of borrowed-to-owned-reserves DRBOR, and the desired excess reserve fraction DERF. All of these goals were formulated by identical processes: actual conditions were averaged over a period of years to derive the desired conditions. How the choice of a very long time constant for the averaging process converted these variable goals to fixed goals. The simulations also illustrated how a short time constant, on the order of three years, allowed the goal to vary over a typical business cycle. A longer time constant, on the order of ten years, allowed the goals to respond only to changes that persisted over several cycles.

Despite both the simplicity and the flexibility of this kind of goal formulation, it is incapable of representing a goal that is a mix of both a fixed and a variable component. A more flexible, but also less simple, structure would allow both an absolute goal and a variable goal to be weighted and combined to form the operational goal. This type of goal formulation has been described in (Forrester 1964), from which Figure VI-1 below has been reproduced.
Figure VI-1: Formulation of a Mixed Goal

from (Forrester 1964, p. 38)

Although the structure of Figure VI-1 was developed in the context of goals for a corporation, the concepts are equally valid for a monetary authority. The wavy line in the figure encloses the variables that do not appear in the current goal structure for the monetary authority. The absolute goal is the long-term, fixed goal for decisions. In the case of an inflation-goal, the absolute goal may be 0% per year inflation. The weighting factor determines the
relative importance of the absolute and the variable (traditional performance) goals in determining the operational goal. The weighting factor depends first on the ability of management (the Board of Governors, perhaps) to project onto the rest of the organization the need to adhere to the absolute goal, even though the organization's past performance may indicate that the absolute goal is unattainable. Second, the weighting factor is assumed to depend on the effective size of the organization; in other words, on the complexity and sheer magnitude of the organization over which management must exert its influence. As an organization grows larger and more complex, it becomes more difficult to project an absolute goal over the diverse components of decision-making, and past performance becomes more easily accepted as the operational goal.

If used in the policy structure for monetary control decisions, this type of goal formulation would provide a more flexible, and perhaps more realistic, description of the process whereby a monetary authority derives its goals for inflation, unemployment, liquidity, and borrowed and excess reserves of the bank. There is a great deal of evidence, however, mostly in the current press, that the Federal Reserve is more conscious of past performance than of any absolute goals for performance. The continuing debate over whether an economy is capable of achieving both full employment and price stability highlights the reactive nature of goals. For example, Maisel states without qualification that "There is a trade-off
between idle men and a more stable value for the dollar. A conscious
decision must be made as to how much unemployment and loss of output
is acceptable in order to get smaller price rises" (Maisel 1973, p. 14).
A Federal Reserve Bank President has testified before Congress, "So I
would want immediately to concede that central banking cannot create
perfect stability . . ." (US Congress 1952, p. 415; testimony of
Malcolm Byran, President, Federal Reserve Bank of Atlanta). Academic
economists also recognize how performance goals adapt to ongoing
economic conditions. Ten years ago, five percent per year inflation
would have seemed unacceptable. Yet, with recent inflation rising
above ten percent per year, Paul Samuelson writes, ". . . suppose that
somehow the OPEC oil monopoly were to weaken and real energy prices
come down a bit. Suppose good crops all over the world were to
replenish our low food reserves and depress prices of food and fiber.
There would still probably remain a true, balanced inflation to the tune
of say 6 or 7 percent a year."\textsuperscript{36}

It has been with this kind of evidence in mind that a reactive
goal formulation has been used in this policy structure.


Chapter Three defined four goals for open-market operations:
holding the rate of growth of money equal to the rate of growth of GNP;

\textsuperscript{36}Paul A. Samuelson, "Inflation Fallacies," \textit{Newsweek,} July 29, 1974,
p. 66. Emphasis added.
controlling inflation; controlling unemployment; and controlling liquidity, as reflected by the bond yield. It may be appropriate to incorporate a fifth goal in the desired rate of growth in money DRGM -- a goal of maintaining the rate of growth in real output RGO at its historic level. There is some evidence that the Federal Reserve regards monetary control decisions as being capable of stimulating growth in real output, and that they would attempt to raise the rate of growth of the money supply if real growth falters.

The desired rate of growth of money DRGM could be expanded to include an influence from the rate of growth of output RGO. A desired rate of growth of output DRGO could be defined as a long-term average of the actual rate of growth of output RGO. If RGO fell below DRGO, an additional term in the desired rate of growth of money DRGM could raise money growth above current GNP growth, all else equal.

It is not clear, however, that a goal of controlling real growth would be distinct from the goal of controlling unemployment. To some extent, the rate of unemployment is indicative of the degree to which potential real output is being realized. In order to include an explicit goal for real growth, the interdependence between employment and real output would necessarily have to be considered.
C. **Suggestions for Experiments with the National Model**

Inclusion of the monetary authority structure in the entire national model will allow for some experiments that have been impossible in other system dynamics or econometric models. These experiments will be substantially different in character from traditional approaches. For example, in traditional models a usual procedure is to exogenously impose an open market purchase and analyze the model's response. In the national model, open market purchases are generated endogenously. The kinds of monetary questions that might be experimentally explored with the national model are outlined below.

1. What happens if the monetary authority responds more or less quickly to inflation (bank borrowing, changing velocity, changing bond yield, real growth rate, deposit instability)? Many argue that the Federal Reserve's response to the economy is either too sluggish, or too aggressive, or both in differing circumstances (Maisel 1973). The time constants explicit in the monetary authority structure could be varied to see how the dynamics of the total economy would change.

2. Does the Federal Reserve contribute to or resist the fluctuations over the business cycle? Friedman and Schwartz present the paradoxical evidence that fluctuations in the money supply have been more severe since the arrival of the Federal Reserve than before 1914 (Friedman and Schwartz 1963, pp 9-10). One could impose on the national model a fixed supply of money and judge whether business
cycles were more or less severe than with an "elastic" currency.

(3) Will the Federal Reserve, following traditional policies in response to current economic problems, be able to control either inflation or unemployment? A contemporary argument is that inflation, when at least partially rooted in material and fuel scarcity, implies that traditional monetary control responses will be ineffective, and might contribute to future inflationary problems. This question is the monetary part of a more general issue of whether traditional governmental programs are proper for addressing current problems.
REFERENCES
REFERENCES


ANDREW 1907  A. Piatt Andrew, "The Treasury and the Banks under Secretary Shaw," Quarterly Journal of Economics, August 1907.


CMA 1969
Controlling Monetary Aggregates,
Federal Reserve Bank of Boston, 1969.

CMA 1972
Controlling Monetary Aggregates II:
The Implementation, Federal Reserve

CMC 1964
Commission on Money and Credit,
Inflation, Growth and Employment,
Prentice-Hall, Inc., Englewood Cliffs,

COOPER 1972
Jerome Phillip Cooper, "Essays on the
Federal Reserve Board-MIT-Pennsylvania
Model: Development of the Monetary
Sector, Production and Policy Analysis,"
unpublished doctoral dissertation, MIT
Department of Economics, 1972.

DELEEuw & GRAMLICH 1969
Frank deLeeuw and Edward Gramlich,
"The Channels of Monetary Policy,"

EASTBURN 1965
David P, Eastburn, The Federal Reserve
on Record, Federal Reserve Bank of

EASTBURN 1970
David P, Eastburn, (ed.), Men, Money,
and Policy, Federal Reserve Bank of

FISHER 1963
Irving Fisher, The Purchasing Power
of Money: Its Determination and Rela-
tion to Credit Interest and Crises,
rev. ed. New York, Reprints of
Economic Classics, 1963.

FOLEY & SIDRAUSKI 1971
Duncan K Foley & Miguel Sidrauski,
Monetary and Fiscal Policy in a
Growing Economy, the MacMillan Co.,
FORRESTER 1961  

FORRESTER 1964  

FORRESTER 1968  

FRBOARD 1943  

FRBOARD 1956  

FRBOARD 1961  

FRBOARD 1971  

FRIEDMAN 1956  

FRIEDMAN 1957  

FRIEDMAN 1961  
FRIEDMAN 1970

FRIEDMAN & SCHWARTZ 1963

FRBNY 1972

FRS 1973

GARVY 1959

HARDING 1925

HICKS 1937

HOLLAND & GARVY 1968

HORWICH 1967
JOHNSON 1972


JONES 1968


KEYNES 1935


KNIGHT 1970


KOCHIN 1972


KOYCK 1954


KROOSS 1969


LAIDLER


MAISEL 1973


MEADOWS AND MEADOWS 1973


MEEK 1968

MITCHELL 1903


MODIGLIANI*


MODIGLIANI ET AL 1970


MONROE 1966


ORCUTT 1952


ORMSBY 1966


PATINKIN 1965


PHILLIPS 1958

PIGOU 1917

PIGOU 1943

RANDERS 1973

REED 1930

ROOSA 1959

SHAFFER 1974

SPENCER 1974

TOBIN 1961

TUCKER 1839

TURNER 1938
Robert C. Turner, Member-Bank Borrowing, The Ohio State University, Columbus, Ohio, 1938.
U. S. CONGRESS 1952
Joint Committee on the Economic Report, Monetary Policy and the Management of the Public Debt, Hearings before the Subcommittee on General Credit Control and Debt Management, 82nd Cong., 2nd Session, March 10-31, 1952.

U. S. CONGRESS 1961

WICKSELL 1961

WILLIS 1915

WOOD 1967
APPENDIX A

LISTING OF EQUATIONS FOR THE MONETARY AUTHORITY
MONETARY AUTHORITY SECTOR

OPEN-MARKET OPERATIONS SUBSECTOR

BM, K = BM, J + (DT) (PBM, JK - SBM, JK - MBM, JK)

BM = IABM * BFR
C IABM = 30E.9

BM, K = (NBT, K + BM, K / AMB) + (BM, K * DREB, K / 2)
NBT = NRBT * BM, K
NRBT = 0.4

DSBM, K = NBT, K * (BM, K * DREB, K / 2)
DREB, K = TABHL (TDEB, IREB, K - 2, 2, 5)
TDEB = .1 / .95, .08 / .5, 0, .5, .8 / .95, 1
IREB, K = UNOF, K / BM, K
dNIP, K = DIMS, K * MM, K * BFR, K
MM, K = (RRD, K + CDR, K) / (1 + CDR, K)
RRD, K = F3, K / DD, K
DIMS, K = M, K * DSGM, K
DSGM, K = RGG, K * RGIL, K + RGII, K
RGIL, K = TABLE (TGLIL, CSBY, K, -, .05, .05, .01)
TGLIL = -.4 / -.1, -.04 / -.015 / -.01 / -.005 / .005 / .01 / .015 / .04 / 1
CSBY, K = BY, K - DBY, K
DBY, K = SMOOTH (BY, K, TABY)

TARY = 5
RGII, K = TABHL (TGGII, CSII, K, 0, 2, .02)
TGGII = 0, .01 / .025, .05 / .09 / .15 / .25 / .35 / .475 / .5
CSII, K = F1, K - DRI, K

DRI, K = SMOOTH (RI, K, TARI)

TARI = 10
RGII, K = TABHL (TGGII, CSII, K, 0, 2, .02)
TGGII = 0, .01 / .025 / .05 / .09 / .15 / .24 / .33 / .42 / .47 / .5
CSII, K = F1, K - DRI, K

DRI, K = SMOOTH (RI, K, TARI)

TARI = 10

NOTE
DISCOUNT RATE SUBSECTOR

DR.K=DR.J + (DT/TABDR) (IDR.J-DR.J)
DR=DRN
DRN=.04
TADDR=1
IDR.K=BY.K*MIBDR.K*MUDR.K*MIDR.K
MIDR.K=TABHL(TMIDR,CST.K,0,2,02)
TMIDR=1/1.01/1.025/1.045/1.071/1.1/1.15/1.2/1.25/1.4/1.475/1.5
MUDR.K=TABHL(TMUDR,CST.K,0,2,02)
TMUDR=1/1.99/1.975/1.95/1.92/1.85/1.76/1.67/1.58/1.53/1.5
MBDR.K=TABLE(TMBDR,RCDR.K,0,2,2)
RCDR.K=RBOR.K/DRBOR.K
RBOR.K=BR.K*(RB.K-BR.K)
DRBOR.K=DRBOR.J + (DT/TAB) (RBOR.J-DRBOR.J)
DRBOR=DRBORI
DRBORI=.1
TAB=3
AB.K=DRBOR.K*PBK.K
PBK.K=TABHL(TPBK,DR.K/DR.K,8,1.2,05)
TPBK=1/1.01/1.02/1.01/1/1.975/1.95/1.9/1.75
REQUIRED RESERVE RATIO SUBSECTOR
RRR.K=RRR.J + (DT/TARRR) (IRR.J-RRR.J)
RRR=RRRI
RRRI=.2
TARRR=3
IRR.K=IRRIT.K*IRR.K
IRRIT.K=TABHL(TIRR,KIRR.K,0,2,25)
TIRR=.75/.75/.8/.9/1.1/1.2/1.25/1.25
IRR.K=IRRER.K/IRRIT.K
IRRER.K=DRR.K/IRR.K
DRR.K=(1-DERF.K) (RB.K)
DERF.K=SMOOTH(ERF.K,TAERF)
TAERF=10
ERF.K=ER.K/RB.K
NOTE
INTERFACE EQUATIONS

IMCN,K=1
TDD.K=TDDO(1+STEP(TDDS,ST))(1+TDDA* SIN(6.28*TIME.K/TDDP))
TDDO=25
TDDS=0
TDDA=0
TDDP=6
RGM,K=CDDEN.JK/DDEN.K
M.K=(DD.K)(1+CDR.K)
RB,K=R1*RB1.K+R2*RB2.K
RB1.K=(.15)(DD.K)
RB2.K=(ERR.K*DD.K)(1+FRE.K)
R1=0
R2=1
FRE.K=FER.K/(1-FER.K)
FER.K=FER0(1+STEP(FERS,ST))(1+FERA* SIN(6.28*TIME.K/FERP))
FERP=1.05
FERA=0
FER=0
ER.K=RB.K-(RRR.K*DD.K)
BR.K=RB.K* BREX.K/(1+BREX.K)
BREX.K=BREXO(1+STEP(BRS,ST))(1+BRA* SIN(6.28*TIME.K/BRP))
BREXO=.1
BRS=0
BRA=0
BRP=6
DPB.K=BT.K
DSB.K=BT.K
BT.K=DPBM.K
BPR.K=FVB/(1+(BY.K)(AMB/1))
FVB=1000
DD.K=S1*DDEX.K+S2*DDEN.K
S1=0
S2=1
DDEN,K=DDEN.J+(DT)(CDDEN.JK)
DDEN=DDENO
DDENO=100E9
CDDEN.K=DELAY3(ICDD.JK,TCDD)
TCDD=.75
ICDD.K=(BM.K*DREB.K)(BPR.K)/(RRD.K+CDR.K)
DDEX.K=DDENO(1+STEP(DDS,ST))(1+DDA* SIN(6.28*TIME.K/DPD))
ST=2
DDS=0
DDA=0
DPD=6
RGO,K=RGO(1+STEP(GRS,ST))(1+GRA* SIN(6.28*TIME.K/GRP))
GRO=0
GRS=0
GRA=0
GRP=6
RIK=RI0+1+STEP(RIS,ST)(1+RI1*SIN(6.28*TIME,K/R1^2))
RIO=0
RIS=0
RI1=0
RIF=6
BYK=BY0+1+STEP(BYS,ST)(1+BYA*SIN(6.28*TIME,K/R1^2))
BY0=0
BYS=0
BYA=0
BYF=6
VK=GNP.K/M.K
GNP.K=0,K*F.K
O,K=O,J+D(T)(O,J*RG0,J)
O=275E9
P=1
CDR,K=CDR0
CDR0=.1
RU.K=RU0+1+STEP(RUS,ST)(1+RUA*SIN(6.28*TIME,K/R1^2))
RU0=0
RUS=0
RUA=0
RUP=6
NOTE CONTROL CARDS
NOTE
PLOT NPBM=F/DRGM=RGM=R00,RG0=0,RGIL=L,RGIU=U,RGII=I
SAVE DRGM,RGM,RG0,DR,BY,AB,DRB0R
SPEC DT=.0625/LENGTH=30/PLTFER=0/SAVPER=1
NOTE
THIS MODEL USES COMPARATIVE PLOTS

NOTE
USE THE NEW DYNAMO-II COMPILER

NOTE
IF IT'S WORKING

NOTE

PLOT BM=B(0,80E6)/N=PB=M(0,4E6)/RGM=++,DRGM=\*(0,06)/V=/V(0,6)
C FLTTER=1
CP R1=1
T R2=0
C GRO=.03
RUN FIGURE III-10
C FLTTER=1
C GRO=.03
C GRS=1
C ST=10
RUN FIGURE III-11
PLOT RGM
CP FLTTER=0
CP RIO=.01
C RIS=1
RUN I1
C RIS=3
RUN I2
C RIS=7
RUN I3
C FLTTER=1
C RIS=11
CP RGM,I1,RGM,I2,RGM,I3,RGM(-.05,.15)
RUN FIGURE III-12
CP RIS=5
C TARI=3
RUN T1
C TARI=30
RUN T2
C TARI=1000
RUN T3
C FLTTER=1
CP RGM,T1,RGM,T2,RGM,T3,RGM(0,.08)
RUN FIGURE III-13
C RIO=0
C RIS=0
CP RUO=.01
C RUS=1
RUN U1
C RUS=3
RUN U2
C RUS=7
RUN U3
01262 C PUS=11
01272 C PLTPER=1
01282 C PLOT RGM.U1,RGM.U2,RGM.U3,RGM(0,.1)
01292 RUN FIGURE III-14
01302 C P LENGTH=15
01322 C P SAVPER=.5
01332 C RUO=0
01342 C BYS=.25
01352 RUN B1
01362 C BYS=.75
01372 RUN B2
01382 C BYS=1.25
01392 RUN B3
01402 C BYS=-1
01412 C PLTPER=.5
01422 C PLOT RGM.B1,RGM.B2,RGM.B3,RGM(-.08,.08)
01432 RUN FIGURE III-15
01442 C GRO=.03
01452 C GRA=1
01462 C CP PLTPER=.25
01472 C P LENGTH=10
01482 PLOT DRGM=*,RGM=+(0,.08)/V=(2.4,2.6)/M=M,GNP=6(0,400)
01492 RUN FIGURE III-16
01502 C P SAVPER=.25
01512 C PLTPER=0
01522 PLOT RGM
01532 C RIO=.02
01542 C RIA=1
01552 C RUO=.02
01562 C RUA=-1
01572 RUN S1
01582 C RIO=.02
01592 C RIA=1
01602 C RUO=.05
01612 C RUA=-1
01622 RUN S2
01632 C RIO=.04
01642 C RIA=1
01652 C RUO=.02
01662 C RUA=-1
01672 C PLTPER=.25
01682 C PLOT RGM.S1,RGM.S2,RGM(0,.08)
01692 RUN FIGURE III-17
01693 C PLTPER=.25
01694 C PLOT RU.S2,RI.S2(0,.4)/RGG.S2,RGM.S2,DRGM.S2(-.015,.45)
01695 RUN*FIGURE III-18
01702 C R1=0
01712 C R2=1
01722 CP LENGTH=7.5
01732 C DRN=.05
01742 C BYO=.05
01752 C BYS=.4
01762 PLOT BY,DR
01772 RUN D1
01782 C BYO=.02
01792 C DRN=.02
01802 C BYA=1
01812 C PLTPER=.25
01822 CPLOT BY, D1, DR , D1, BY, DR (0,.08)
01832 RUN FIGURE 1V-10
01842 CP RIO=.01
01852 C RIS=1
01862 RUN A1
01872 C RIS=7
01882 RUN A2
01892 C RIS=11
01902 RUN A3
01912 C RIS=19
01922 C PLTPER=.5
01932 CP LENGTH=15
01942 CPLOT DR, A1,DR, A2, DR, A3,DR (.04,.06)
01952 RUN FIGURE 1V=11
01962 C RIO=0
01972 CP RUO=.01
01982 CP RUS=14
01992 C TARU=3
02002 RUN C1
02012 C TARU=1000
02022 RUN C2
02032 C PLTPER=.25
02042 CPLOT DR, C1,DR, C2,DR (.02,.04)
02052 RUN FIGURE 1V-12
02062 C RUO=0
02072 C RUS=0
02082 C BYA=1
02092 C BRS=.5
02102 C ST=4
02112 C PLTPER=.5
02122 PLOT BY, DR (.02,.1)/DRBOK, AB (0,.16)
02132 RUN FIGURE 1V-13
APPENDIX B

LISTING OF DEFINITIONS FOR THE MONETARY AUTHORITY
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>Acceptable Borrowing (Dimensionless)</td>
</tr>
<tr>
<td>AMB</td>
<td>Average Maturity of Bonds (Years)</td>
</tr>
<tr>
<td>BAK</td>
<td>Bond Account of the Monetary Authority ($/Bond)</td>
</tr>
<tr>
<td>BM</td>
<td>Bonds of the Monetary Authority (Bond)</td>
</tr>
<tr>
<td>BRP</td>
<td>Bond Price ($/Bond)</td>
</tr>
<tr>
<td>BR</td>
<td>Borrowed Reserves ($)</td>
</tr>
<tr>
<td>BRA</td>
<td>Test BR Amplitude</td>
</tr>
<tr>
<td>BRLX</td>
<td>Test BR Exogenous</td>
</tr>
<tr>
<td>BREXO</td>
<td>Test BR Exogenous Initial</td>
</tr>
<tr>
<td>BKP</td>
<td>Test BR Period</td>
</tr>
<tr>
<td>BRS</td>
<td>Test BR Step Height</td>
</tr>
<tr>
<td>BT</td>
<td>Bonds Transacted (Bonds/Year)</td>
</tr>
<tr>
<td>BY</td>
<td>Bond Yield (Fraction/Year)</td>
</tr>
<tr>
<td>BYA</td>
<td>Test BY Amplitude</td>
</tr>
<tr>
<td>BYO</td>
<td>Test BY Initial</td>
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