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CROSS-SECTION ANALYSIS AND BANK DYNAMICS

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by

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Econometric studies of financial behavior have been produced in record numbers during the past five years. With few exceptions these studies have examined aggregative quarterly data of the United States from 1929 forward. They frequently are based on simultaneous equations models which may have as many as 80 stochastic relations. These studies have greatly increased our knowledge of and respect for the financial mechanism. In the present paper we have no intention of deprecating this very rewarding activity. Rather, we believe these contributions can be considerably enriched if they are supplemented with results from cross-section studies.

In this paper an aggregative model should be understood to consist of variables such as those appearing in the statistical series of The Survey of Current Business or The Federal Reserve Bulletin. A cross-section model consists of data concerning individual decision making units, households, banks, insurance companies,

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etc. Aggregative variables are measured only once each time period. Measurements on a decision making unit may refer to one or many individual time periods.

We shall argue that aggregative models of economic activity are seriously deficient if they are not capable of being represented in cross-section models. Tests of hypotheses and discrimination between hypotheses can be executed at very low power using aggregative data. More importantly information about the time path of a variable's response to a shock can be estimated only very inaccurately with aggregative data. If models are to prove useful for policy, accurate estimation of dynamic structural parameters is essential.

In section 1 some common problems of macro-econometric estimation are surveyed. The second section contains a partial review of recent macro-financial models of bank behavior and suggests where a less aggregative approach might have proved illuminating. Section 3 outlines a model of bank portfolio behavior which we are estimating with cross-section data. The last section reports estimates of the structure of this model and exhibits its macro-economic properties.

1. Common Problems of Macro-Econometric Estimation

In formulating macro-theories of finance, economists implicitly or explicitly think in terms of decision making units.[1/] There is, of course, an important difference between

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1/ Not everyone may agree that macro-models need have a corresponding micro-counterpart. Such persons skate on thin ice unless they specify what additional criteria they substitute for the logical foundations which describe micro-behavior. A "good fit" or statistical "significance" is not enough; the curse of macro-econometrics is that nearly all specifications fit well.

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modeling the behavior of, say, a single bank and modeling the behavior of an aggregate like the banking system. Micro-econometric studies are useless for macro-analysis unless a rigorously specified method of aggregation exists.[2/] Correspondingly, the application of

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2/ For discussions of the aggregation problem see H. Theil, Linear Aggregation of Economic Relations, Amsterdam: North-Holland Publishing Company, 1954 and H. A. John Green, Aggregation in Economic Analysis: An Introductory Survey, Princeton: Princeton University Press, 1964.

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economic theory to macro-economic model building is meaningless unless a bridge between micro-and macro-behavioral relations can be established. Therefore, the case for or against the use of micro-econometric results in model building does not hinge on the feasibility of aggregation. There are, of course, serious questions which can be raised about the feasibility of aggregation, but in this paper we shall assume that aggregation is possible. In passing we note that authors of macro-econometric studies discussed in the next section do not explain what assumptions they employ to insure that aggregation is possible. Nonlinearities abound in their equations.

Apart from aggregation, five principal hurdles are in the path of empirical macro-economic investigators: a) sparsity of observations, b) multicollinearity, c) auto-correlation of error terms, d) errors-in-variables, and e) misspecification. These hurdles also disturb cross-section investigators, but for the most part they are less disruptive. Errors-in-variables is a serious problem for both groups and will not be discussed further.

No doubt the most critical weakness is the small number of observations available to macro-investigators. As time passes, moreover, the appropriate specification of a model will change because of varying institutions, technology and regulations. Therefore the informational content of available macro time series is very limited. Researchers collectively appear to have responded to this problem in three ways. First, measure variables more frequently. This solution is only a partial cure which greatly increases the problem of auto-correlation of error terms discussed below.

Second, when a major structural change is known to have occurred, investigators often attempt to use data both before and after the change by introducing a "shift" dummy variable in the involved behavioral equations.[3/] This device will be successful only

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[3/] Eg. see S. Goldfeld, Commercial Bank Portfolio Behavior and Economic Activity, Amsterdam: North-Holland Publishing Company, 1966, p. 41.

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if it is correct to assume that a change caused a vertical shift in behavioral relationships. This assumption is clearly in error if lagged endogenous variables exist in these relationships; then the time path implied by coefficients estimated for lagged endogenous variables is some average of that recorded when shifts occurred and when they did not occur. Estimated speeds of adjustment will be unreliable.

Third, existing time series are used repeatedly by the same and more insidiously by different investigators. No new information exists in reworked time series. A very strong possibility exists that model builders fool themselves into attempting to explain pure stochastic variables with exogenous variables which happen by chance to be correlated with stochastic variables during the short period studied.

The fact that the United States has generated values of most economic measures which are highly intercorrelated over time makes the paucity of macro-economic observations all the more grievous. Most macro-econometric equations consist of comparatively few variables. In part this specification follows from the comparative simplicity of our models. Probably a more important explanation, however, is that standard errors of coefficients blow up to intolerable levels when the number of highly correlated variables rises. If intercorrelation is not perfect among variables, increasing the sample size will permit an investigator to obtain arbitrarily accurate estimates of a parameter. A promising approach to overcoming the effects of multicollinearity in macro models is to marry cross-section and time-series estimates of structural parameters.[4/]

[4/] An excellent example of the use of cross-section data in an aggregative model to overcome problems of multicollinearity is reported in J. Tobin, "A Statistical Demand Function for Food in the U.S.A.," Journal of the Royal Statistical Society, Volume CXIII, Part II (1950), pp. 113-141.

Even if no marriage is intended, single period cross-section studies are especially useful because they permit investigators to identify the relation between cross-section varying variables like income and cash balances when interest rates and other time varying variables are frozen.

Collectively, multicollinearity and the small number of available observations make estimation of macro-econometric models unavoidably inaccurate. Parameter estimates may be unbiased in single equation models or consistent in simultaneous equations models, but the power of statistical tests to discriminate among competing hypotheses is weak.

Autocorrelation of error terms, the third hurdle, also hampers accurate estimation because it implies that time-series observations are not independent. If no lagged endogenous variables are present, then the existence of autocorrelation implies that the number of degrees of freedom is less than the number of observations. The power of tests to discriminate among competing hypotheses is further weakened.

However, a principal feature of many recent macro-models has been the inclusion of lagged endogenous variables in structural equations. Investigators using this specification argue that a) formation of expectations and/or frictions of adjustment are important and b) optimal policy implementation must exploit this dynamic structure. Initially specifications were of a form which implied that the effects from a shock declined exponentially as time passed.[5/]

5/ L. M. Koyck, Distributed Lags and Investment Analysis, Amsterdam, North-Holland Publishing Company, 1954.

In recent years more intricate lagged operators which need not incorporate lagged endogenous variables have attracted many investigators.[6/]

6/ S. Almon, "The Distributed Lag Between Capital Appropriations and Expenditures," Econometrica, Vol. 33, No. 1 (January 1965), pp. 178-196.

It is easy to agree that dynamic behavioral characteristics of a model are important for policy formation. However, the popularity of these estimation methods is quite surprising in light of the fact that various authors have pointed out that with lagged endogenous variables estimates are biased and, in the presence of autocorrelation, inconsistent.[7, 8] Furthermore, conventional statis-

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7/ L. Hurwicz, "Least Squares Bias in Time Series," Statistical Inference in Dynamic Economic Models, edited by T. C. Koopmans, Cowles Commission Monograph 10,(New York: John Wiley and Sons, 1950,)pp. 365-383.

8/ Z. Griliches, "A Note on Serial Correlation Bias in Estimates of Distributed Lags," Econometrica, Vol. 29, No. 1 (January 1961),pp. 65-73.

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tical tests appear to be very weak in discriminating among quite different lagged operators.[9] Feasible techniques for consistently

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9/ Z. Griliches, and N. Wallace, "The Determinants of Investment Revisited," International Economic Review, Vol. 6, No. 3 (September 1965), pp. 319-325.

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estimating such operators place a heavier demand on economic theory than presently seems justified.[10]

10/ Cf. L. D. Taylor and T. A. Wilson, "Three-pass Least Squares: A Method for Estimating Models with a Lagged Dependent Variable," Review of Economics and Statistics, Vol. XLVI, No. 4 (November 1964), pp. 329-346 and K. F. Wallis, "Lagged Dependent Variables and Serially Correlated Residuals: A Reappraisal of Three-pass Least Squares," mimeographed, 1966.

In the third section of the present paper we argue that, at a micro level, economic theory leads to rather specific descriptions of the timing of bank portfolio adjustment. Estimating the implied behavioral relation from cross-section data does not require the use of either lagged endogenous variables or other arbitrary lagged operators.

The final hurdle for macro econometricians concerns the specification of a model. If model specification were, as in principle it should be, dependent solely upon theory then both micro and macro quantitative studies would be equally vulnerable to misspecification. In practice most investigators admit that they experiment with alternative specifications when estimating models. It is trite, but important, to observe that this form of experimentation dissipates the value of data in discriminating among competing models. It is perfectly legitimate for an investigator to report his prior belief's about behavioral parameters or to estimate equations repeatedly with small changes in specification until the data yield results which conform to his prior beliefs. On the other hand it borders on fraud for an author to suggest that his estimated standard errors or tests of hypotheses are not seriously contaminated by experimentation. It matters little whether the experimentation was performed consciously by one investigator or unconsciously by several!

The main control against incorrect inferences in classical statistical theory is the possibility of replicating results from independent evidence. Precisely this replication is not possible with macro data. If theories are capable of being tested with cross-section data, the possibility of safeguarding our common analytical framework is vastly enhanced. Cross-section samples of decision making units can in practice often be replicated repeatedly.

Of course, cross-section models must be carefully specified if they are to prove useful. For example, Professor Kuh has suggested that it may be quite risky to use cross-section results in time-series applications.[11/] To protect against misspecifica-

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11/ E. Kuh, "The Validity of Cross-Sectionally Estimated Behavior Equations in Time Series Applications," Econometrica, Vol. XXVII, No. 3 (April 1959) pp. 197-214.

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tion owing to the existence of "firm effects" he recommends that rectangular arrays of data be collected which record the value of a firm's variables in a number of different time periods. Professor Kuh surely is right in stating that misspecified models yield inconsistent estimators of parameters in the true structure. However, he did not conclude and should not be misinterpreted to be saying that investigators should emphasize macro-economic time series at the expense of other data.

Orcutt and Watts have reported performing Monte Carlo experiments on a model of a primitive economy at different levels of disaggregation.[12/] They considered samples of rectangular arrays

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[12/] G. H. Orcutt and H. W. Watts, "Consequences of Data Aggregation over Components for Prediction of the Effect of Policy on Economic Aggregates," mimeographed preliminary paper read at the First World Congress of the Econometric Society, September, 1965.

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of consumers and generated data for each observation with an assumed set of structural parameters. They considered a number of different assumptions about the stochastic terms in their model and reported that it was quite difficult to obtain reliable estimates of the assumed structure when data were highly aggregated. Less aggregative data yielded more satisfactory results. In their paper and in earlier papers by Orcutt a very persuasive argument against relying on aggregative data was developed.[13/] It may not be feasible in

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[13/] G. H. Orcutt, "Micro Analytic Models of the United States Economy: Need and Development," American Economic Review, Supplement, Vol. LII, No. 2 (May 1962), pp. 229-240.

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the near future to estimate full-blown micro structures, but greater reliance on micro data has much to offer researchers.

2. Some Remarks on Recent Macro Monetary Research

The discussion in section 1 suggests that it is often difficult to learn about aggregate behavior from aggregative time-series data. Recent attempts to obtain quantitative information on the role of the commercial banking system in the monetary mechanism provide excellent examples of the difficulties involved. We will indicate where micro-econometric models can eliminate some of the problems.

Aggregate bank behavior has been analyzed directly in empirical studies of money supply functions and in analyses of bank demand for major earning assets. Bank behavior is also implicit in indirect "market equations" such as term structure relations. We shall confine our attention to those published studies concerned directly with bank behavior.

There is no general agreement in the literature about the nature of the lag structure for money supply models. de Leeuw finds evidence of a long lag between an initial reserve injection and subsequent bank holdings of desired earning assets.[1] His re-

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1/ Frank de Leeuw, "A Model of Financial Behavior," The Brookings Quarterly Model of the U.S., edited by Duesenberry, J., et.al., (Chicago: Rand McNally, 1965), pp. 476-482.

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sults indicate that banks achieve only 4.6% of their total excess reserve adjustment within one quarter and only 27% of their total borrowing response within that quarter. Goldfeld's estimates on the other hand indicate that for reserve city banks there is no lag in adjustment to desired excess reserve positions and that for these same banks some 40% of total borrowing response is achieved in one quarter.[2/] For country banks, 60% and 30% of the total response of

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2/ Stephen Goldfeld, Commercial Bank Behavior and Economic Activity, (Amsterdam: North-Holland, 1966), Chap. 5.

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excess reserves and borrowing respectively are achieved in the first quarter. The studies by Teigen, Rangarajan and Severn found no evidence from quarterly data of a lag in the response of the money supply to a permanent change in unborrowed reserves.[3, 4/] Brunner and Meltzer have not stressed the role of lags in their recent econometric analyses of the money supply function.[5/]

3/ R. Teigen, "Demand and Supply Functions for Money in the U.S.," Econometrica, October 1964, and "A Structural Approach to the Impact of Monetary Policy," Journal of Finance, Vol. XIX, No. 2 (May 1964), pp. 284-308.

4/ C. Rangarajan and A. Severn, "The Response of Banks to Changes in Aggregate Reserves," Journal of Finance, Vol. XX, No. 4, December, 1965), pp. 651-664.

5/ K. Brunner and A. Meltzer, "Some Further Investigations of Demand and Supply Functions for Money," Journal of Finance, Vol. XIX, No. 2 (May 1964), pp. 240-83.

As noted in the previous section, a basic difficulty of aggregate studies of the money supply function is that the existence of multicollinearity induces researchers to construct bank portfolio equations which have very few variables. A bank is often assumed to be concerned only with the allocation of its assets between excess reserves and earning assets.[6] Borrowing from the Federal Reserve is the principal endogenous liability. This is clearly a gross simplification of behavior. At any point in time, a commercial bank will be observed to hold many kinds of assets other than excess reserves. If either relative rates of return on available assets or relative costs of liabilities are relevant to portfolio decisions, the parameter estimates of money supply models are suspect.

Studies which examined aggregate bank portfolio decisions have generally found evidence of long lags in bank portfolio adjustments. For example, Goldfeld using a Koyck-type distributed lag formulation, estimated that banks achieve only 16% of their total commercial loan response in the first quarter following a shock.[7]

6/ For an explicit and detailed treatment of a micro economic basis for an aggregate money supply function see K. Brunner, "A Schema for the Supply Theory of Money," International Economic Review, Vol. 2 (January 1961), pp. 79-109.

7/ Goldfeld, op.cit., p. 133.

Bank holdings of U.S. Government securities and municipal securities have been estimated to respond even more slowly than loans.8/

8/ Ibid., p. 132, and de Leeuw, op.cit., p. 477.

It is clearly important to obtain accurate estimates of the dynamic properties of bank portfolio equations. In practice for various reasons macro-investigators have imposed simple specifications to obtain estimates of the lag structure. The existence of a large body of individual bank data makes this research strategy unnecessary. With a sufficiently large sample, lag structures can be estimated empirically without employing indefensible, *a priori* specifications.9/

9/ The means by which these direct estimates are obtained are discussed in sections 3 and 4.

In section 4 an individual bank is found to adjust its cash position within a few months. Interest earning liquid assets are a sufficiently close substitute for cash that the bank shifts rapidly out of excess reserves and into these assets after a reserve injection. It then gradually sells off part of these liquid assets to obtain more profitable investments. In short, we are able to estimate parameters of a bank portfolio model which are consistent with micro-theory.

A common assumption of macro-models is that all assets are gross substitutes. An increase in the expected rate of return of one asset will induce an investor to hold less or at least no more of other available assets. This assumption is not readily verifiable but it is frequently used in macro portfolio studies to judge the plausibility of empirical results.

There is no way for theory to tell us whether or not assets are gross substitutes. The application of the concept of gross substitutability to model testing as a maintained hypothesis may lead to serious misspecification. These specification problems need not arise in micro-econometric analysis. For a single cross section, market rates of interest are constant across banks and need not be explicitly accounted for. When micro bank data are analyzed over time, micro-econometric analysis encounters the same problems from interest rate multicollinearity and underidentification that macro-analysis does.

Micro-econometric analysis enjoys a further advantage over its macro counterpart because it provides a direct means of testing for differences of behavior among banks according to their size, location, reserve classification, etc.[10/] These difference

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10/ To the extent to which there are behavioral differences among banks, the results of the macro-models are biased. Goldfeld attempts to account for some of the differences by distinguishing between reserve city and country banks in his analysis. See Goldfeld, op.cit., pp. 131-136.

can have important implications for monetary policy; the speed and magnitude of the banking system's response is likely to be influenced by such differences.

Concern over behavioral differences among banks leads us to a central problem for micro-investigators, that of aggregation. What may be true for an individual bank may not be true for the banking system. A single bank may be able to adjust its cash position quickly but the banking system may not. A reduction of excess reserves for one bank will produce an increase in reserves for another bank; long lags may in fact exist because of the way that single banks interact.

Simulation experiments provide a convenient means of determing the consequences of aggregation across banks. Given reliable micro estimates and specific assumptions about the interrelations among elements in the banking system, simulation techniques can be used to improve our knowledge of the monetary mechanism. The results of some simple but illuminating simulation experiments are reported in section 4.

3. A Model of Bank Portfolio Behavior

In this section a theoretical structure is advanced which leads to a rather specific description of the timing of bank portfolio adjustments. These dynamic considerations are then embedded in a verifiable model of bank portfolio behavior.

A typical commercial bank holds a large number of different assets in its portfolio ranging from cash to term loans and conventional mortgages. Each asset has a unique set of characteristics, e.g., its liquidity, reversibility, predictability of return, etc.[1/] It is convenient initially to focus the analysis on the

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1/ The treatment of asset characteristics is essentially an elaboration of that provided by James Tobin, in his unpublished book on monetary theory, Ch. II, "Properties of Assets." For an application of asset liquidity characteristics to commercial banks see J. Pierce, "Commercial Bank Liquidity," Federal Reserve Bulletin, Vol. 52, No. 8 (August 1966), pp. 1093-1101.

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ease with which assets can be bought or sold under the assumption that the expected rates of return and covariances of return for these assets, exclusive of trading costs, are given.

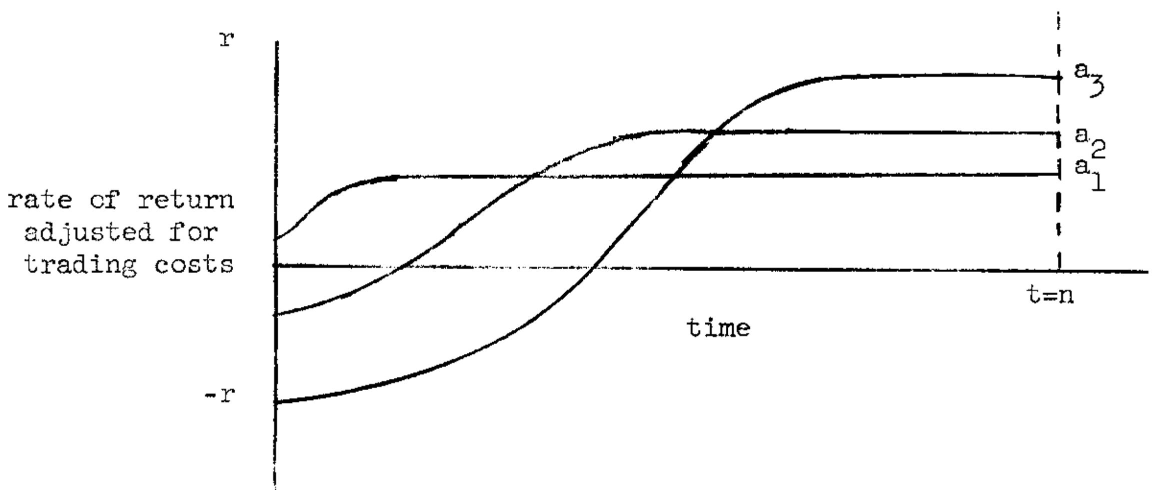
Each asset has a "full value" determined by its own and competing market yields. The speed and ease with which this full value price can be realized is assumed to be a continuous function of (1) the amount of time available between the decision to sell (buy) it and the actual sale (purchase) and (2) the number of units to be bought or sold. In general, the less time available between decision and action and the greater the number of units to be traded, the greater will be the deviation between realized price and full value price. In the present paper attention is restricted to the first argument of this full value realization function.

The ease of purchase and sale clearly differs among assets. Cash can be exchanged for cash instantaneously at zero cost. Treasury bills can be purchased or sold quickly at low cost. Within wide limits, the dealer's fee for bills is insensitive to both the size of the transaction and the time available between order and delivery. Transaction fees for other U.S. Government securities are higher than those of bills. In general, the longer the maturity of the security, the greater is the dependence of the dealer's fee on the time available for delivery and on the size of the transaction.

Mortgages can be acquired quickly and in volume only if a bank is willing to incur high promotional expenses and/or make rate concessions. A secondary market exists for some types of mortgages but the prices in these markets are sensitive to the timing and volume of mortgage sales. While the purchase of other loans involves the same sort of costs of rapid and extensive acquisition as mortgages, there is no organized secondary market for these assets. Prior to maturity, the current realizable value of these assets is essentially zero. They can, of course, be used as collateral for borrowing.

Consider now the expected rate of return on an asset, r , which is adjusted to include trading costs. The relationship between r and calender time is shown in Figure 3-1 for three hypothetical assets. Specifically the figure shows what rate of return an investor would realize if in period zero he decided to acquire an asset for delivery in period t to be held until period n . The value of n represents the bank's planning horizon, i.e., the maximum number of periods into the future which it considers when formulating portfolio plans.

Figure 3-1



In terms of the previous discussion, a_1 , a_2 , and a_3 may be considered to be Treasury bills, bonds, and long maturity loans, respectively.

The costs associated with rapid placement of new funds is an important element in analyzing bank portfolio behavior. These costs are important for two reasons. First, as Figure 3-1 suggests it simply is not profitable to acquire illiquid assets the moment funds are deposited in a bank. Second, because deposit flows are uncertain, banks must be prepared to experience withdrawals. A simple Bayesian argument suggests that the longer a deposit stays in a bank the lower is the probability that it will be withdrawn in the next time period. As the probability of withdrawal declines, the importance of asset liquidation costs lessens. Both reasons provide a solid basis for relating individual bank assets to a sequence of previous deposit levels.

The analysis which follows presents a dynamic portfolio model which is consistent with the framework developed above. A bank is considered to have two categories of deposit liabilities: demand balances, d , and time deposits, s . The level of each is defined over the previous $t - i$ periods $(i = o, \ldots, n-1)$. The bank's deposit history is given by the two $1xn$ vectors $D_t = (d_t, d_{t-1}, \ldots, d_{t-n+1})$ and $S_t = (s_t, s_{t-1}, \ldots, s_{t-n+1})$. For later reference, the following notation is used for changes in deposit levels: $\bar{d}_t = (d_t - d_{t-1})$, $\bar{s}_t = (s_t - s_{t-1})$ where lower case letters refer to matrix elements.

Let A_t be a $kx1$ vector of the values of the k assets held by the bank at the end of period t , $A_t' = (a_{1t} \ldots a_{kt})$. Finally let C_t be a scalar which measures the level of the bank's other liabilities plus capital and reserves at the end of period t . The balance sheet identity requires that

$$\sum_{i=1}^{k} a_{it} = d_t + s_t + C_t \ . \tag{3-1}$$

Given this budget constraint, banks are assumed to operate in a world in which:

(a) they are price takers;

(b) they are subject to Government regulation;

(c) they all face the same expected rates of return and covariances of asset returns at a given point in time;

(d) their deposits are subject to random variation.

Given these conditions and the vectors D_t and S_t , the desired composition of the asset portfolio is a function of expected rates of return on the k assets and of their covariances of return.

The hypothesis to be tested is that at a point in time t :

$$A_t = \alpha \bar{\bar{D}}_t + \beta \bar{\bar{S}}_t + \gamma C_t + E_t \tag{3.2}$$

where

α is a kxn matrix of coefficients

β is a kxn matrix of coefficients

$\bar{\bar{D}}_{it}$ is a nxl vector of demand deposits of the form $(\bar{d}_{it}, \bar{d}_{it-1}, \ldots, \bar{d}_{it-n+2}, d_{it-n+1})'$. It describes the changes in demand deposits over the previous n-1 periods and the level of accounts in period t-n+1 .

$\bar{\bar{S}}_{it}$ is a nxl vector of saving and time accounts of the same form

γ is a kxl vector of coefficients[2/]

E_t is a kxl vector of error terms with expected value zero.

2/ Note that the sum of coefficients in each column of α and β is necessarily unity. The sum of elements in γ is also unity. These restrictions are a consequence of the balance sheet identity.

An important assumption of this model is that banks make no effort to forecast or anticipate future deposit levels.[3/] They

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3/ We are also working on a second model which represents banks as attempting to forecast future deposit flows. This model will be described in a forthcoming monograph.

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receive new funds, simultaneously hold them in liquid form, and then gradually allocate them to higher yielding, less liquid assets.

The behavior depicted in equation (3-2) can be conveniently exhibited by considering a bank's demand for loans. For simplicity, assume that the bank's only liability is demand deposits, and that three periods are required for full adjustment of the portfolio.

Then:

$$(3\text{-}3)\quad L_t = b_1(d_t - d_{t-1}) + b_2(d_{t-1} - d_{t-2}) + b_3\, d_{t-2} + b_4\, C_t + \epsilon_t$$

$$= b_1\, \bar{d}_t + b_2\, \bar{d}_{t-1} + b_3\, d_{t-2} + b_4\, C_t + \epsilon_t\ .$$

The coefficient b_3 represents the "steady state" fraction of demand deposits held in the form of loans. If demand deposits should rise to a new level in period $t + 1$ and remain there, the change in loans will be b_1 of the increase in period $t + 1$, b_2 of the increase in $t + 2$, and b_3 of the increase in period $t + 3$, and thereafter. This behavior is best thought of as a strategy which maximizes some function of discounted future net income.

The basic rationale for this behavior lies in the discussion of the ease and speed of asset acquisitions and sales. If a bank were to receive an increase in the level of its deposits, and even if it knew with certainty that the funds would not be withdrawn, it would not attempt to place them immediately in illiquid form. Figure 3-1 implies that a rapid shift of funds into certain assets can be very expensive. In the three asset world of this figure, a bank would first hold all its funds in a_1 , then shift all the funds into a_2 at some value of $i = i^*_2$, and finally shift the funds into a_3 at $i = i_3^*$. If the size of these transactions did not affect the asset yields there would be three discrete movements in the portfolio.4/

4/ This discussion assumes that there are unique optimal rates of asset sales and purchases which are functions of time and of the size of transactions. The derivation of these optimal rates and of the implied optimal portfolio is difficult. We hope to obtain a partial solution for this problem in our larger study.

The rate at which nonmarketable assets can be liquidated is determined by the rate at which they mature. For our model to represent a stable relationship between A_t and $\bar{\bar{D}}_t$, it is necessary to assume that bank response to rises in deposit levels is the same as to declines. This assumption will be tested in subsequent research.

At any given point in time, α and β are assumed to be constant across banks. It cannot be assumed reasonably that they are constant over time, however. Variations in interest rates, conventions of portfolio management, etc. will influence the allocation of deposit liabilities among the k assets. It is conceptually possible to modify the model by specifying α and β as a function of interest rates. In this more general form we have:

(3-4)
$$\alpha_t = f_t(r_1, \ldots, r_k)$$
$$\beta_t = g_t(r_1, \ldots, r_k) \ .$$

The estimation of f_t and g_t is difficult. The relevant interest rates are unobserved expected rates of return on the k assets. However, in empirical work shifts in portfolio composition over time can be studied in a rough sort of way by pooling successive cross sections and then allowing a separate intercept for all but the last cross section.

4. Estimation and Simulation of the Micro Model

In this section, an application of our micro-model to a sample of New England commercial banks is described. We shall very summarily report and interpret the resulting parameter estimates, but emphasize their significance for understanding macro-behavior. Five simple simulation experiments are reported which shed light on the timing of bank portfolio adjustments in response to open market purchases of securities from the public.

The sample of 187 banks is drawn from a population of approximately 270 member banks in the First Federal Reserve (Boston) District. Data concerning individual banks were collected from daily deposit reports and quarterly call reports over the period January 6, 1960 through July 7, 1964.[1] Eleven consecutive call

1/ Data were coded to prevent identification of individual banks. We are indebted to John Arena of the Boston Federal Reserve Bank for help in effecting the transfer of data. Transfer and coding operations were performed at the Computation Center at Massachusetts Institute of Technology, Cambridge, Massachusetts. We are grateful to the Center for providing technical assistance and financial support in the form of computor time.

reports beginning with the April 12, 1961 call are analyzed below. Deposit information was converted into weekly and "monthly" averages of daily deposit levels.[2]

2/ Throughout this section for obvious reasons a "month" refers to a period of 4 consecutive weeks and not calendar months.

The sample of 1,926 bank-call observations was drawn in a quite complicated manner which will be fully described in a forthcoming monograph by the present authors. Briefly, bank observations were deleted 1) for all calls after a merger in which a bank participated, 2) if a bank had no demand deposits in a week, 3) if a bank had zero time deposits in a week and then subsequently received time deposits, 4) if irreconciliable discrepencies arose when merging deposit and call report tapes, and 5) in the cases of about ten banks when permanent tape read redundencies resulted or other nonrecoverable tape handling errors occurred.

Several further remarks are necessary to appreciate the results below. First, to avoid "firm"effects, all variables are measured about individual bank means. When bank means were not deleted, the model yielded quite plausible results, but some individual parameter values were erratic. An analysis of variance revealed that bank means were very significant in all regressions.

Second, because individual bank means have been removed, coefficients in individual regression equations are unique only up to an additive transformation. For purposes of exposition, coefficients have been standardized to go through the mean value of one bank in the sample. Subject to the balance sheet constraints noted in the previous section, additive transformations of coefficients are possible and reflect different individual bank portfolio preferences.

Third, while the model in section 3 suggested that a bank's call report asset variables should be regressed on a sequence of previous deposit changes, it did not specify how long the sequence should be. The sequence should be long enough so that addition of more distant lagged deposit changes do not greatly improve the fit of individual regressions or, equivalently, so that the coefficient on the most distant change equals the coefficient of the level of deposits existing before that change. No sharp test of the cut-off time is obvious for the criterion depends entirely upon what asset or assets are considered. In practice we found that, with the possible exception of mortgage loans, most change coefficients were oscillating about equilibrium levels after about 45 weeks. To be safe, in Tables 4-1 and 4-2 one full year of deposit histories are reported.

Fourth, in a small number of banks massive deposit changes were observed in a few scattered weeks. For example, a bank may find its demand deposits have grown 300% in one week and declined by 250% in the following week. These large changes are unlikely to be viewed by banks in the same way as smaller changes. A crude adjustment procedure was devised to account for this heterogeneity of deposit changes. If a weekly percentage deposit change, X, fell outside the range $-20\% \leq X \leq 25\%$ the bank's deposit change for that week was assumed to be its average weekly deposit change during 1960. The difference between this imputed value and the observed value was returned to the regression in a dummy "overflow" variable. If a bank experienced no large change or the large change disappeared the overflow variable's value was zero. To conform with the notation in the previous section the overflow variable was added to capital as well. Therefore, the portfolio impact of such deposit overflows is the sum of the overflow coefficient and the capital coefficient in each regression. This procedure worked satisfactorily for the majority of large change situations, but for a small number of banks the overflow variables were nonzero over a long string of consecutive weeks. This procedure will be further refined in subsequent work.

Finally, to avoid inefficiency resulting from heteroskedasticity all variables for a bank were deflated by the bank's total assets on ~~April 12, 1961~~ each call.

The results of this analysis are reported in Tables 4-1, 4-2, and 4-3. Columns of these tables must be read together because the coefficients come from the same regression. In Tables 4-1 and 4-2 the first three coefficients refer to recent weekly changes, the next twelve coefficients refer to previous monthly changes, and the last coefficient concerns deposit levels at the bank one year earlier. Given the objectives of this paper we have not bothered to report standard errors or t-values in the tables; an asterisk indicates only that the value of an estimated coefficient is two or more standard errors from zero. No asterisk or F values are reported for "other assets" because these coefficients were obtained from an identity or, equivalently, by pooling a number of regression coefficients of some other minor bank assets. A very brief discussion of the major conclusions from these tables follows:

1) The percentage of demand deposits reaching the bank at different dates held as cash conforms to the expected pattern but is larger than our a priori expectations. Almost all banks in the sample are small country banks which had a reserve requirement of 12%; estimated marginal excess reserves against demand deposits are about 13%. The percentage of time deposits reaching the bank on different dates held as cash is erratic as expected, but in the long run appears quite unexpectedly to be negative for this bank. The estimated marginal negative excess reserves against time deposits is also about 13%.[3/] The surprising feature of these results

[3/] The use of the term marginal should be stressed. When no bank means were estimated, the implied cash holdings against time deposits were about 6% as expected.

is that the difference between the marginal "desired reserve requirement" for demand and time deposits is estimated to be about 33% or five times the difference in the legal reserve requirements. Two promising interpretations of this finding involve the existence of a size aggregation effect and/or a liquidity effect.

Table 4-1

Demand Deposit Changes and Portfolio Composition

	CASH	ST&LOCS	MORTS	C&I	CONSUM	BILLS	1-5's	OTHER
$\bar{d}_w$	.495*	.033	-.034*	.092*	.105*	.221*	-.103*	.191
$\bar{d}_{w-1}$	.302*	.009	-.035*	.153*	.135*	.293*	.032	.111
$\bar{d}_{w-2}$	.311*	.020	-.026*	.160*	.125*	.197*	.060	.153
$\bar{d}_{m-1}$	.370*	.029	-.045*	.123*	.128*	.256*	.052	.087
$\bar{d}_{m-2}$	.287*	.034*	-.054*	.158*	.143*	.326*	-.029	.135
$\bar{d}_{m-3}$	.226*	.001	-.028*	.125*	.137*	.338*	.026	.175
$\bar{d}_{m-4}$	.196*	.036*	-.036*	.189*	.141*	.341*	.090*	.043
$\bar{d}_{m-5}$	.239*	-.003	-.044*	.128*	.164*	.334*	.010	.172
$\bar{d}_{m-6}$	.216*	.002	-.011	.154*	.186*	.284*	.027	.142
$\bar{d}_{m-7}$	.239*	.049*	-.024*	.182*	.177*	.186*	.121*	.070
$\bar{d}_{m-8}$	.253*	.015	-.020	.157*	.188*	.175*	.060	.172
$\bar{d}_{m-9}$	.253*	.042*	-.016	.157*	.202*	.211*	.008	.143
$\bar{d}_{m-10}$	.238*	-.000	.009	.169*	.216*	.102*	.108*	.158
$\bar{d}_{m-11}$	.283*	.087*	-.021	.155*	.251*	.010	.109*	.126
$\bar{d}_{m-12}$	.275*	.080*	-.006	.169*	.240*	.021	.109*	.112
~~d_{w-51}~~ d_{m-13}	.248*	.059*	.013*	.174*	.256*	.053*	.064*	.133

TABLE 4-2

Time Deposit Changes and Portfolio Composition

	CASH	ST&LOCS	MORTS	C&I	CONSUM	BILLS	1-5's	OTHER
$\bar{s}_{w}$	.190	.188*	-.003	.124	.020	.456*	-.180	.205
$\bar{s}_{w-1}$	.009	.190*	-.073	.129	.147	.447*	.104	.047
$\bar{s}_{w-2}$	.131	-.060	.016	.204	.300*	.160	.068	.181
$\bar{s}_{m-1}$	.305*	-.058	-.020	.206*	.208*	.191	.080	.088
$\bar{s}_{m-2}$	.064	.068	.025	.161*	.173*	.185	.024	.300
$\bar{s}_{m-3}$	-.094	.162*	-.040	.277*	.054	.107	.246	.288
$\bar{s}_{m-4}$	-.020	.065	.051	.182*	.214*	.654*	-.126	-.020
$\bar{s}_{m-5}$	.088	.108	.056	.156*	.180*	.216	-.069	.265
$\bar{s}_{m-6}$	-.078	.037	.086	.257*	.182*	.041	.149	.326
$\bar{s}_{m-7}$	.155	-.014	.063	.257*	.080	.182	-.096	.373
$\bar{s}_{m-8}$	.063	.058	.167*	.274*	.129	.191	-.071	.189
$\bar{s}_{m-9}$	-.043	.147	.065	.026	.262*	.068	.014	.461
$\bar{s}_{m-10}$	-.007	.081	.179*	.287*	.288*	.043	-.057	.186
$\bar{s}_{m-11}$	-.006	.085	.167*	.139	-.004	.148	-.009	.480
$\bar{s}_{m-12}$	-.188*	.097	.187*	.182*	.283*	.041	-.005	.403
~~s_{w-51}~~ S_{m-12}	-.081*	.087*	.195*	.191*	.184*	.038	.026	.360

TABLE 4-3

Dummy Values, "Capital" and Portfolio Composition

	CASH	ST&LOCS	MORTS	C&I	CONSUM	BILLS	1-5's	OTHER
Time Dummies								
4-12-61	.015*	-.005*	-.009*	-.004	-.016*	.017*	.020*	-.018
6-30-61	.011*	.001	-.007*	.002	-.011*	.012*	.021*	-.029
9-27-61	.014*	.003	-.008*	-.004	-.014*	.014*	.025*	-.030
12-30-61	.034*	-.008*	-.006*	-.003	-.015*	.005	.016*	-.023
3-26-62	.016*	-.002	-.007*	.003	-.012*	.014*	.004	-.016
6-30-62	.011*	.003	-.006*	.004	-.006*	.011*	-.002	-.015
9-28-62	.011*	.005*	-.006*	-.001	-.010*	.013*	-.006	-.006
12-28-62	.025*	-.008*	-.005*	-.004	-.011*	.002	.003	-.002
3-18-63	.023*	-.002	-.005*	.002	-.012*	.004	-.004	-.006
6-29-63	.008*	.005*	-.004*	.003	-.005*	-.002	-.000	-.005
Overflow								
Demand	-.010	-.006	.003	-.002	-.001	.029*	-.008	-.005
Time	-.002	-.004	.025*	-.011	.013	.030*	-.007	-.044
C_t	.204*	.037*	.045*	.196*	.242*	.064*	.100*	.112
R^2	.242	.135	.239	.051	.174	.178	.153	
S_ϵ	.023	.016	.010	.019	.016	.036	.030	
F	12.003*	5.874*	11.847*	2.006*	7.909*	8.139*	6.773*	

The first interpretation is a consequence of the facts that small banks in our sample have larger percentages of their deposits as time deposits that they have distinctly less predictable demand deposits than larger banks.[4] If correct this interpretation

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4/ The statement about deposit predictability refers to unpublished results we have obtained when estimating autoregressive deposit forecasting equations for individual banks.

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may partly account for the inability of Goldfeld and investigators working on preliminary versions of the FRB-MIT aggregative model to explain the distribution of deposits and assets among reserve city banks, country banks, and nonmember banks.[5]

5/ Cf. Goldfeld, op.cit., pp. 147-148.

The second interpretation rests on the fact that bank assets, whether financed by demand or time deposits yield a sizable, predictable cash flow. It is quite possible that the cash flow from assets financed by new time deposits is sufficient to permit a bank to reduce its marginal cash holdings without increasing its "liquidity risk" exposure.

If correct, this interpretation suggests that time deposit reserve requirements do not directly constrain the volume of bank deposits, but merely act as a tax on bank profits. A conclusion for research on banks seems to be that excess reserves is a quite inadequate measure of bank liquidity protection; gross cash flow variables must be incorporated in models of bank behavior. Further research on this result is clearly important.

2) The percentage of a bank's assets invested in state and local securities, intermediate maturity (1-5 year United States Treasury obligations) securities, and other residual assets was not very regularly related to either demand or time deposits flowing into the bank on different dates. After about 44 weeks, however, a bank's share of these assets was not particulary affected by deposit flows. Apparently banks purchase these assets when the market seems "right" but typically within about eleven months.

3) Among loan variables, mortgages were only slightly related to demand deposit flows. Specifically, the equation in Table 4-1 suggests that no appreciable relationship exists between mortgage holdings and deposit flows for approximately 23 weeks and then a gradual, somewhat erratic investment in this asset which perhaps continues for more than the reported number of time periods. Time deposit flows begin to affect mortgage holdings after about 15 weeks and by about the 40th week have reached near equilibrium levels. A very similar mortgage adjustment pattern was reported by one of us when this model was applied to a sample of mutual savings banks.6/

6/ D. Hester, "A Model of Portfolio Behavior Applied to Mutual Savings Banks," mimeographed paper read at the First World Congress of the Econometric Society, 1965.

4) Flows of demand and time deposits affect commercial and industrial loans quite rapidly with near equilibrium percentages of each type of deposit being obtained in about 19 weeks. Demand deposits flow increasingly into consumer loans with equilibrium levels being reached only after about 45 weeks. Time deposits appear as consumer loans both earlier and much less regularly than demand deposits.

5) Demand deposits flow into treasury bills increasingly until about the 19^{th} week. After 19 weeks the percentage of demand deposit flows appearing as treasury bills declines to a long run equilibrium of about 5% for this bank. Time deposits are again less regularly related to treasury bill holdings with peaks occurring in the first two weeks and between the 16^{th} and 19^{th} weeks.

6) Table 4-3 shows the values of coefficients of dummy time variables; each coefficient should be read as measuring the difference between a bank's portfolio on the call of the indicated date and the "Saxon" call of December 20, 1963. We interpret these coefficients as measuring the collective effect of interest rates and other nondeposit flow determinants on portfolio composition. Apart from some conspicuous seasonal variations, the interesting and statistically significant changes in this period appear to be: 1) a shift into mortgages, 2) a shift out of bills, 3) a shift out of intermediates, and 4) a shift into other assets. During the same period, interest rates, with the important exception of mortgages were steady or rising; short and intermediate term rates rose

relative to long term rates. It is remarkable that in every case the First District banks were moving against interest rates; that is, they were shifting into assets when rates paid on these assets were falling. Superficially it appears that bank portfolios were better characterized as determining rather than determined by interest rates.[7/] If this interpretation is accepted then the spe-

7/ The statement is superficial because Tobin and Brainard have persuasively argued that in theory one must be very cautious in predicting how movements in interest rates affect portfolio composition. Furthermore, our mapping of dummy variable coefficient values with interest rate movements is surely not isomorphic; the specification of the model is incomplete. See J. Tobin and W. C. Brainard, "Financial Intermediaries and the Effectiveness of Monetary Controls," American Economic Review, Vol. LII, No. 2 (May 1963), pp. 383-400.

cification of bank portfolio equations in some macro models is defective, for such equations are characterized as demand equations with quantities as dependent variables.[8/] Whether rates of interest

8/ Cf. Goldfeld, op.cit., pp. 131-133.

are dependent or independent variables, it should be clear that macro-models which require that bank portfolios respond with some time pattern to changes in demand deposits, time deposits, and interest rates are missing important behavioral elements.[9]

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[9] We interpret Morrison to be saying something similar when he introduces his concept "transitory potential deposits." Cf. G. R. Morrison, Liquidity Preferences of Commercial Banks, (Chicago: University of Chicago Press, 1966), pp. 16-19.

The coefficients reported in Tables 4-1 and 4-2 correspond quite well to theoretical expectations about the behavior of a single bank. What is the macro-counterpart of this micro-structure? For brevity, throughout the remainder of this paper attention is restricted to the demand deposit coefficients. Our discussion therefore is conditional and explicitly ignores potentially important shifts between demand and time deposits. The analysis is conditional in a second sense in that possibly important interest rate effects which may accompany monetary policy operations are ignored. Finally, to make the analysis more compact only four bank assets will be studied: cash; bills; the sum of mortgages, commercial and industrial loans, and consumer loans; and all other bank assets.

To examine the macro-structure, a monetary sector consisting of up to three banks was studied with a series of simulation experiments. Bank portfolio equations were constructed for the four asset model from coefficients reported in Table 4-1. The experiments were designed to show how different assumptions about the organization and operation of the banking system affected the time path of the system's response to an exogenous deposit injection of $1 billion. It is assumed that bank purchases of investments and loans are paid for with currency. Specific experiments are, of course, quite arbitrary and a number of interesting structures remain to be studied.10/

10/ One minor inelegancy appears in the experimental results reported in Tables 4-4 and 4-5. In Table 4-1 the first three coefficients refer to weekly changes, the next twelve refer to monthly changes. An existing macro-simulation computer program could be employed for all experiments only if coefficients referred to monthly changes. Therefore the first three weekly change coefficients were averaged and called a "month." The story in Table 4-4 is not affected by this approximation.

Experiment 1 considers a primitive system consisting of an isolated bank which has no contact directly or indirectly with other banks. Apart from a transitory, predictable flowback from bank loans and investments which is implicit in the estimated parameters, all funds lent or invested by the bank leak out into currency hoards, foreign countries, or nonbank intermediaries. No money multiplier exists. The simulation merely traces through the structural parameters and the system is in equilibrium after 13 months. The injection produced an equilibrium increase in loans of $443 million and a $248 million increase in bank cash.

The second experiment considers a sophisticated highly bank-oriented system where a single multibranch bank serves the

Table 4-4

Simulated Response of the Banking System to an Injection of $1 Billion in Demand Deposits

Calendar time	Experiment 1		Experiment 2		Experiment 3		Experiment 4 Small Bank		Experiment 4 Large Bank	
(in 4 week months)	△ CASH (millions)	△ LOANS (millions)	△ CASH (millions)	△ LOANS (millions)	△ CASH (millions)	△ LOANS (millions)	△ CASH (millions)	△ LOANS (millions)	△ CASH (millions)	△ LOANS (millions)
1	369	225	369	225	369	225	0	0	369	225
4	226	234	677	547	504	421	113	78	451	390
7	216	329	807	872	629	695	148	136	511	601
10	253	343	917	1115	760	900	166	193	585	729
13	275	403	996	1356	862	1131	180	238	636	879
16	248	443	983	1563	888	1339	184	280	616	1003
19	248	443	988	1668	921	1472	185	306	618	1055
22	248	443	990	1723	942	1565	186	320	619	1083
25	248	443	992	1749	958	1628	186	326	620	1096
28	248	443	997	1762	970	1672	187	330	622	1102
31	248	443	998	1771	979	1705	188	332	623	1107
34	248	443	999	1777	985	1728	188	333	624	1110
37	248	443	999	1781	989	1744	188	334	624	1112
40	248	443	1000	1783	992	1756	188	335	624	1113
43	248	443	1000	1784	994	1765	188	335	624	1114
46	248	443	1000	1785	996	1771	188	336	624	1114
49	248	443	1000	1786	997	1775	188	336	624	1114
Equilibrium	248	443	1000	1787	1000	1787	188	336	624	1115

entire economy. All funds lent or invested by the bank in one month are redeposited with it in the next period; no leakage of cash exists except into bank vaults. In equilibrium the injection produced a $1,787 million increase in loans. The response is slower than in the first experiment; seventeen months pass before loans reach 90% of their equilibrium value. Bank cash adjusts to 90% of its equilibrium value in about 10 months. In equilibrium the money supply will have increased by $4,033 million; 90% of this change will occur in approximately 14 months. All estimated lags are probably positively biased (too long); a monopoly bank can largely ignore deposit unpredictability. Lags in bank portfolio adjustment are partly attributable to the existence of deposit unpredictability.

Figure 4-1 shows the values of the components of the banking system's portfolio on different dates resulting from experiment 2. The diagram suggests that aggregate system time paths need not be monotonic, but perhaps could be approximated quite well with relatively simple lagged operators.

The third experiment considers a sophisticated, less bank-oriented system where a single large bank again serves the economy. It differs from experiment 2 because only 50% of incremental currency in the nonbanking sectors finds its way back into the bank during the subsequent month.[11/] An interpretation is that incremental

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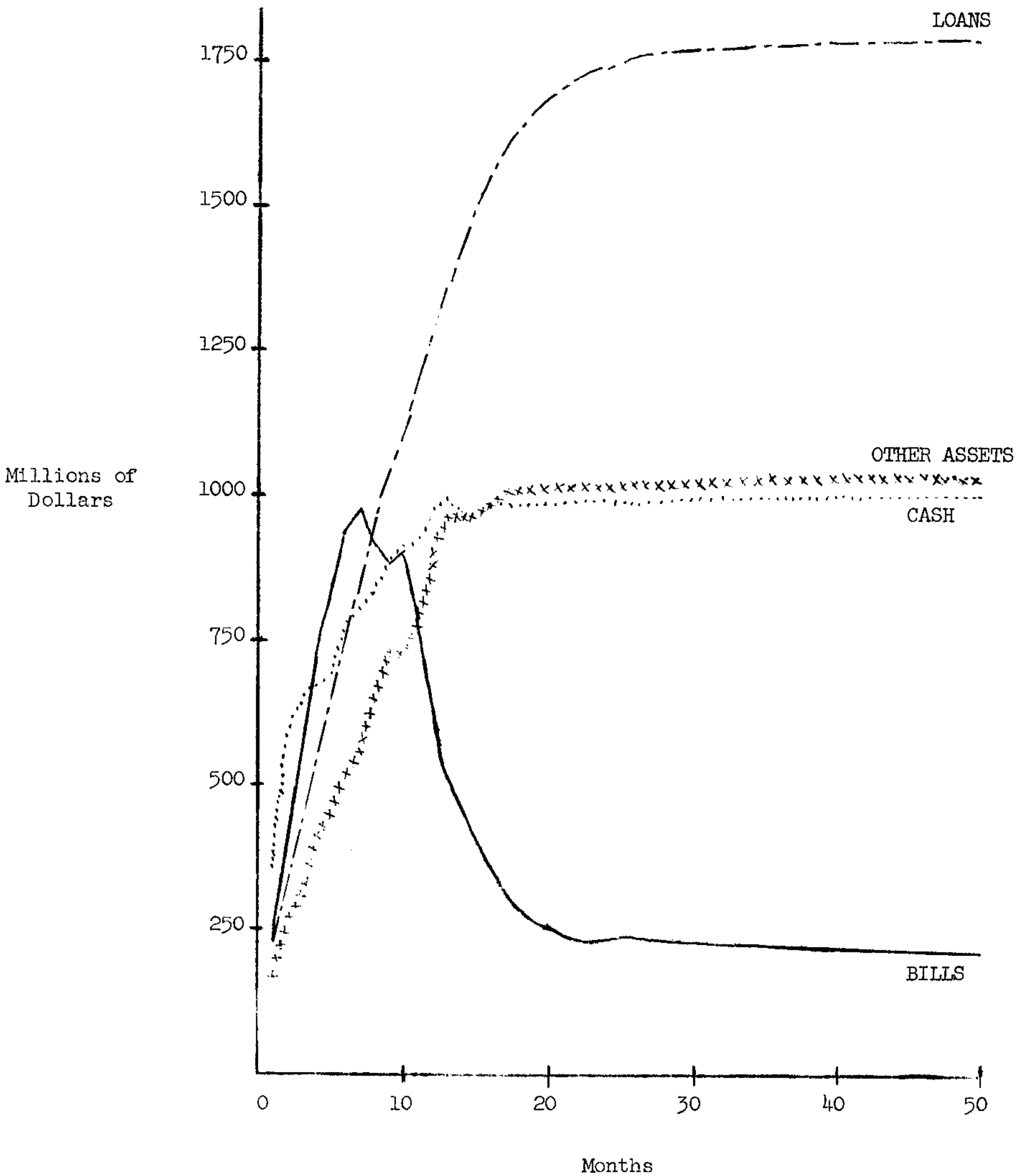
11/ "Incremental" in this paper refers to the difference between the level of currency held by the nonbanking sectors on some date and the level observed immediately before the injection occurred.

Figure 4-1

The Simulation of Experiment 2



currency flows back and forth among nonbank intermediaries or individuals for some time before being redeposited in the bank. The long run equilibrium properties of this experiment are identical to those of experiment 2; however, the timing of portfolio adjustments differs. In this regime bank cash takes 16 months and bank loans take 24 months to adjust to 90% of their respective equilibrium values. It appears therefore that as the degree of nonbank intermediation increases, the speed and sharpness of bank response to monetary policy actions are diminished.

The fourth experiment considers a banking system consisting of three banks, all characterized by the same portfolio equations. One bank receives the deposit injection and also receives 50% of all secondary deposits which the banking system creates. The other two banks receive no initial injection but each receives 25% of the secondary deposits. This hypothetical distribution of secondary deposits is assumed to reflect the location of economic activity and to be invariant over the simulation. An interpretation of this arrangement is that the first bank is a large money market bank and the other two are hinterland institutions. As in experiment 2 all funds lent or invested by the system are redeposited during the following month. The long run equilibrium properties are again identical to those of experiment 2.

Increasing the number of banks does not affect the timing of the response of the banking system _in this model_. In reality, of course, it would tend to slow down adjustment relative to experiment 2 because the risk of deposit drain to an individual bank is an increasing function of the number of banks. Because the structure used in the simulation experiments was estimated from actual banks, we think that results are an unbiased representation of the banking system. To be sure the average bank in the sample is small; it is possible that a sample of large banks would yield different parameter estimates.[12/] We also have made no allowance for the

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[12/] At one point we broke the sample into two groups depending upon whether banks had more than 25 million dollars of deposits on January 6, 1960. The estimated parameters from the two samples were not appreciably different. In an analysis of covariance, of ten assets studied only state and local securities, long term bonds, and residual miscellaneous assets were significant of the .05 level.

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geographic distribution of banks across the country.

However, as shown in Table 4-4 the timing of the response of the money market bank differs from that of the hinterland banks. The big bank has reached 90% of its long run loan position after 16 months and 90% of its long run cash position after 9 months. Hinterland banks reach 90% of their equilibrium loan position after 19 months and 90% of their equilibrium cash after 11 months. This suggests why model builders have such difficulty in describing deposit flows among reserve city, country, and nonmember banks.[13/]

[13/] Cf. Goldfeld, op.cit., pp. 147-148.

Simple lagged operators will not capture this complex interbank adjustment.

Until this point, simulation experiments have explicitly identified deposit flows with portfolio changes in a given month. This identification is tenuous if the average maturity of loans and investments is less than one month or if loans are partially repaid within a month. In such instances a bank may make two or more loans within a month; presumably funds lent a number of times within a month will be redeposited with other banks in the system during that month. Such "quick turnover" of assets will speed up the rate at which the system moves toward an equilibrium. An approximation to this process can be studied with simulation experiments if one assumes that deposit flows are some multiple of increments to nonbank public currency holdings. In a sense quick turnover is the opposite of experiment 3 above where nonbank intermediation was assumed to keep funds temporarily out of the banking system. Experiment 5 reported in Table 4-5 shows how quick turnover will affect the timing of bank portfolio responses.

The three bank system of experiment 4 is studied with three different specifications, a nine-day turnover, a two-week turnover, and a one-month turnover. The nine-day and two-week cases exhibit "overshooting" which is a consequence of the deposit flow approximation. In the nine-day case, system loans reach a 90% adjustment to equilibrium after 15 months; cash adjusts by the second month although overshooting causes it to fluctuate outside of the

Table 4-5

Experiment 5

Calendar Time (in 4 week months)	a) Nine Day Turnover Δ CASH (millions)	a) Nine Day Turnover Δ LOANS (millions)	b) Two Week Turnover Δ CASH (millions)	b) Two Week Turnover Δ LOANS (millions)	c) One Month Turnover Δ CASH (millions)	c) One Month Turnover Δ LOANS (millions)
1	369	225	369	225	369	225
4	791	739	802	669	677	547
7	1002	1021	952	1009	807	872
10	1013	1254	1002	1252	917	1115
13	1107	1511	1057	1484	996	1356
16	1095	1735	1008	1682	983	1563
19	999	1808	984	1747	988	1668
22	968	1820	989	1772	990	1723
25	960	1785	992	1772	992	1749
28	958	1753	1000	1772	997	1762
31	991	1752	1004	1778	998	1771
34	1019	1765	1001	1783	999	1777
37	1024	1784	1000	1786	999	1781
40	1018	1800	999	1787	1000	1783
43	1004	1803	999	1786	1000	1784
46	990	1795	1000	1786	1000	1785
49	986	1785	1000	1786	1000	1786
Equilibrium	1000	1787	1000	1787	1000	1787

90% range occasionally until the fourteenth month. In the two week case system loans also reach a 90% adjustment to equilibrium after 15 months; system cash reaches 90% of its equilibrium after 6 months. In the one month case, which is identical to experiment 2, system loans require 17 months and system cash requires about 10 months to reach 90% of equilibrium values. Quick turnover greatly accelerates the movement of the system toward cash equilibrium, but the timing of loan response is quite unaffected.

In conclusion, this paper has argued that while aggregate financial econometric studies have been very useful, micro-financial model building is a particularly promising research area. In the last two sections a micro-model of bank portfolio behavior has been reported which sheds considerable light on a number of current issues. This model is presently incomplete and does not yet incorporate interest rates satisfactorily. Two points raised in this paper deserve reemphasis here.

1. One of the most disturbing findings in a number of recent macro-financial models is the extremely slow response of banks and money markets to policy induced shocks. Biased and inconsistent estimates of lag structures are a consequence of the use of lagged operators in the presence of autocorrelation. Using the micro-structure reported in this section, a number of simulation experiments indicated that unless the economy is not bank-oriented (experiment 3) it is very unlikely that banks take more than 68 weeks to reach a 90% adjustment of all components of their portfolios.

Bank cash adjusts considerably faster. Moreover a number of other institutional features, CD's, the federal funds market, and interest rates, were not explicitly examined in the model. Because these features tend to increase the speed of bank adjustment to shocks, we conclude that a conservative upper bound for the time necessary for banks to respond to policy actions is on the order of five quarters.

2. Micro-studies are uniquely fortunate in being able to incorporate information from both portfolio and interviews directly in formulating verifiable hypotheses. Consequently correct specifications of stochastic relations are more likely to result than in the case of macro-models. Most importantly, the danger of contamination from reanalyzing a given set of data is greatly reduced because replication of samples is usually possible in micro studies.