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The Dynamics of Money Demand and Prices

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Abstract

The paper evaluates whether a monetary aggregate can serve as a useful predictor of inflation, using recent developments in the principle of cointegrated variables. M2 but not M1 is cointegrated with relevant price, transactions, and rate of return variables. However, deviations of M2 from its long-run equilibrium value do not significantly enhance inflation forecasts based on conventional output-gap models, a result that stands in contrast to the Federal Reserve's P* relationship. Nevertheless, changes in M2 do contain information about future inflation, consistent with the view that the demand for money reflects the forward-looking behavior of private agents.

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Contents

Summary

This paper evaluates whether a monetary aggregate can serve as a reliable predictor of movements in the price level. Interest in this possibility has been stimulated by recent research at the Federal Reserve pointing to an apparent stability in the long-run relationship between M2 and the price level--the so-called P* relationship.

The analysis by the Federal Reserve has been cast in the framework of the traditional quantity theory of money and concludes that deviations of the actual price level from its long-run equilibrium value (P*) are useful as predictors of changes in the rate of inflation. P* is defined as the price level that would prevail given the existing stock of M2, assuming that M2 velocity is at its trend level and the economy is operating at its estimated potential.

Specifically, the paper recasts the analysis by the Federal Reserve in a more general framework based on a modern theory of money demand and the principle of cointegrated variables. A dynamic optimization model of a representative household is developed to provide guidance in the search for a stable long-run relationship between, inter alia, some monetary aggregate and price level variable, and, more important, to illustrate how forward-looking behavior of private agents can reveal information about their expectations of future prices and expenditure plans.

The principal conclusion is that, although there is a well-defined money-demand function for M2, the empirical analysis indicates that deviations of money from its long-run equilibrium level do not significantly enhance inflation forecasts based on conventional output-gap models. This conclusion is in contrast to the Federal Reserve's research, which suggests that deviations of M2 velocity from its long-run value improve such inflation forecasts. However, changes in M2 do contain information about future inflation consistent with the view that the demand for M2 reflects forward-looking behavior of private agents.

I. Introduction

Through much of the 1980s the U.S. Federal Reserve System relied less on monetary aggregates and more on a broad range of economic and financial variables to guide the implementation of monetary policy. This trend culminated in 1987 when the Federal Reserve decided to cease specifying an annual growth range for M1, 1/ the variable that had been viewed historically as the most reliable monetary aggregate in indicating changes in nominal income growth. More recently, however, the apparent long-run relationship between M2 and the price level has raised interest within the Federal Reserve in this broader monetary aggregate, the so-called P* relationship. 2/

The analysis of Hallman et al. builds upon the traditional quantity theory of money and specifies the long-run equilibrium price level as $P^*_t = M2_t V2^*/Y^*_t$, where V2* is the average value of M2 velocity for the period 1955:1 to 1988:1 and Y^*_t is the Federal Reserve's measure of potential output. By definition, the actual price level is given by $P_t \equiv M2_t V2_t/Y_t$, where $V2_t$ is actual M2 velocity and Y_t is real GNP. Their empirical analysis finds that deviations of P_t from P^*_t, or equivalently $V2_t$ from V2* and Y_t from Y^*_t, are useful in predicting inflation.

This paper recasts the analysis of Hallman et al. in a more general framework based on a modern theory of money demand and the principle of cointegrated variables. Specifically, this paper undertakes an examination of whether a monetary aggregate can serve as a reliable predictor of movements in the price level. Most modern theories of money demand predict the existence of a relationship among a measure of money and such variables as the demand for goods and services, the corresponding price level, and the competing and own rates of return on money balances. More importantly, money demand theory can illustrate the forward-looking behavior of private agents that can reveal information about their expectations of future prices and expenditure plans. This aspect of the choice of how much money to hold also bears relevance to the forecasting of inflation.

The econometric methodology followed in this paper draws on recent developments in the theory of cointegrated variables and involves two basic steps. 3/ The first is to search for a long-run relationship among a monetary aggregate and appropriately defined transactions, price

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1/ The Federal Reserve publishes three official monetary aggregates. M1 consists of currency and checkable deposits; M2 includes in addition to M1 a variety of small-denomination savings-type instruments issued by depository institutions; and M3 consists of M2 plus certain large-denomination instruments, such as large certificates of deposit.

2/ See Moore, Porter, and Small (1988) and Hallman, Porter, and Small (1989).

3/ For an introduction to the theory of cointegrated variables, see Granger (1986).

level, and interest rate variables in which a linear combination of these variables shares a common trend with the monetary aggregate. If such a relationship is found, the set of variables is said to be cointegrated. The second step relies on the existence of cointegration and formulates an error-correction model that represents the process of adjustment among the variables to their long-run relationship. 1/

The empirical analysis presented here finds that M2 but not M1 is cointegrated with relevant transactions, price, and rate of return variables. On that basis, the appendix proceeds to consider the short-run dynamics of M2 and price level variables. The analysis confirms the existence of a well-behaved demand equation for this broader monetary aggregate. However, the inflation equations collapse to simple autoregressive models. This result suggests that M2 rather than the price level adjusts in the short run to restore the long-run relationship among these variables. Thus, relatively little information about the inflation process is gained by analyzing changes in M2 alone.

While a long-run relationship exists among M2, the price level and other determinants of money demand, the inflation process may be better represented by considering developments in both the goods and money markets rather than by those in the money market alone. Empirically, this is achieved by substituting for the transactions variable in the long-run relationship a measure of potential output. This substitution is made because the real demand for goods and services is not expected to deviate persistently from its potential supply in view of the economy's tendency to close any output gap over time and its intertemporal budget constraint. Deviations from the long-run relationship between money, potential output, price level, and interest rate variables thus reflect the process of adjustment in both the goods and money markets. Dynamic price equations based on this long-run relationship indicate that, when the deviations from this long-run relationship are decomposed into a term related to the velocity gap in the Federal Reserve's analysis and an output gap, the velocity gap term is insignificant and the traditional Phillips curve approach to inflation based on an output gap remains useful--that is, contrary to the Federal Reserve's analysis, deviations of M2 from its long-run relationship to the determinants of money demand do not enhance inflation forecasts. However, changes in M2 do contain some information about future inflation, consistent with the view that the demand for M2 reflects forward-looking behavior by households and businesses.

The remainder of the paper is organized as follows: Section 2 outlines the basic principles of money demand theory and highlights their relevance to forecasting inflation. The third section searches for long-run relationships among monetary aggregates and the measurable

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1/ The relationship between cointegration and the error-correction representation of time-series variables is developed in Engle and Granger (1987).

determinants of money demand. Section 4 examines the short-run adjustment in the money market by estimating dynamic equations for M2 and the level price variables. The fifth section extends the analysis of inflation to include developments in the goods and money markets which substantially improves the dynamic price equations. Section 6 offers some conclusions.

II. Theoretical Considerations

While the objectives of this paper are primarily empirical, economic theory provides an important foundation for the econometric methodology based on cointegration used below by providing guidance concerning the variables to use in the search for a long-run relationship between, inter alia, a monetary aggregate and price level variable. More importantly, money demand theory can illustrate the forward-looking behavior of private agents that can reveal information about their expectations of future prices and expenditure plans. This aspect of the choice of how much money to hold is particularly relevant to the forecasting of inflation.

Most modern theories of money demand predict a relationship among a measure of money and such variables as the demand for goods and services, price level, and certain interest rates. Moreover, money demand theory serves to identify other factors that influence money demand and to clarify which assets yield monetary services. In general, monetary assets are distinguished by the yield of a nonpecuniary return arising from their role as a medium of exchange or the relatively low cost at which they can be converted to a medium of exchange. These characteristics explain why monetary assets are held even though they are clearly dominated in their rates of return by some financial assets. Thus, changes in factors such as regulations and payments technology, by altering the monetary services of assets, influence both the quantity of money demanded and potentially the appropriate measure of money.

The basic principles of money demand theory can be derived from a dynamic optimization model of a representative household. The demand for money fundamentally reflects choice at the margin between holding an additional unit of money and the alternative uses of wealth (e.g., spending on goods and services or holding a financial asset). At an optimal intertemporal plan for consumption expenditures, portfolio allocations and money balances, the household is indifferent to small changes in its plan. This condition yields predictions about money demand that can be tested empirically.

The specific formulation of the representative household's dynamic optimization problem used here emphasizes the forward-looking aspect of its choice of how much money to hold. Consider a hypothetical household that seeks to maximize

$$E\left[\sum_{t=0}^{\infty} \delta^t U(c_t, \ell_t) | \Omega_0\right], \tag{1}$$

where c_t and ℓ_t are the household's consumption and leisure during t, δ is the rate of time preference, and Ω_0 is the set of available information when the intertemporal plan is formed. 1/ The utility function, U(.,.), is assumed to be quasiconcave and thus to yield unique, positive values for c_t and ℓ_t. For simplicity, labor is taken to be supplied inelastically.

Money indirectly enters the optimization problem. Real money balances enable the household to increase its leisure by reducing the amount of "shopping" time, s_t, required to purchase c_t. 2/ The units of time are chosen so that there is one unit of time per period available for shopping and leisure together, $\ell_t = 1 - s_t$. Given prevailing regulations and payments technology the time required for undertaking transactions increases with the amount of consumption and decreases with the quantity of real balances held by the household (up to a satiation level). Specifically,

$$s_t = \Psi(c_t, m_{t-1}), \tag{2}$$

where $\Psi(.,.)$ has partial derivatives $\Psi_1 > 0$ and $\Psi_2 \leq 0$. M_{t-1} is the nominal stock of money held at the beginning of period t, and $m_{t-1} = M_{t-1}/P_t$ where P_t is the money price of the consumption good. 3/ In addition to services from its role as the medium of exchange, money held at the beginning of period t can yield a pecuniary return of $(1 + RM_t)$ at the beginning of period t+1.

As an alternative to consumption or holding real money balances, the household can assemble a portfolio of bonds. These securities can be purchased at par in period t and be redeemed for $(1 + RB_t)$ units of money in period t+1. B_{t-1} denotes the number (possibly negative) of

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1/ A similar treatment of money demand theory is provided by McCallum and Goodfriend (1986).

2/ Uncertainty in the exchange process provides one explanation of why money holdings facilitate transaction (i.e., save shopping time). See Brunner and Meltzer (1971) and King and Plosser (1986).

3/ By requiring money balances to be held in advance of expenditures, the demand for money necessarily becomes forward looking in nature. In this regard, the model outlined above is related to those incorporating a cash-in-advance constraint. See Lucas (1987), Chapter 6, and Lucas and Stokey (1987).

bonds held by the household at the beginning of period t, while $b_{t-1} = B_{t-1}/P_t$.

In the above setting, the household's budget constraint is

$$y_t \geq c_t + (1 + \pi_t)^{-1}m_t - (1 + RM_t)m_{t-1} \tag{3}$$

$$+ (1 + \pi_t)^{-1}b_t - (1 + RB_t)b_{t-1}.$$

Here y_t is real labor income and π_t is the inflation rate, $(P_{t+1} - P_t)/P_t$.

At the optimal intertemporal plan for c_t, m_t, and b_t, the household is indifferent to small changes in this plan. 1/ Two such perturbations are considered. First, consumption is reduced by one unit and real money balances are raised by one unit during period t. As a result, utility changes by

$$U_1(c_t,\ell_t) + U_2(c_t,\ell_t)\Psi_1(c_t,m_{t-1}). \tag{4}$$

During period t+1, more leisure results from the $(1 + \pi_t)^{-1}$ increase in real money balances at the beginning of the period. In addition, consumption is raised during period t+1 by $(1 + \pi_t)^{-1}(1 + RM_t)$ to restore real money balances to their original paths. These changes in utility are given by

$$\delta E\left[(1 + \pi_t)^{-1}U_2(c_{t+1},\ell_{t+1})\Psi_2(c_{t+1},\ell_{t+1})\Omega_t\right] \tag{5}$$

$$+ \delta(1 + RM_t)\ E\{(1 + \pi_t)^{-1}[U_1(c_{t+1},\ell_{t+1})$$

$$+ U_2(c_{t+1},\ell_{t+1})\Psi_1(c_{t+1},m_t)|\Omega_t\}.$$

At the optimal plan, (4) and (5) must be equal.

1/ A transversality condition is assumed to hold at the end of the household's planning horizon that rules out explosive paths for these variables.

The second perturbation to the plan is similar to the first except that bonds are used to substitute consumption intertemporally rather than money balances. The change in utility in period t is again given by (4), while that in period t+1 is

$$\delta(1 + RB_t)\ E\{(1 + \pi_t)^{-1}[U_1(c_{t+1},\ell_{t+1}) + u_2(c_{t+1},\ell_{t+1})\Psi_1(c_{t+1},m_t)|\Omega_t\}. \tag{6}$$

At the optimal plan, (4) and (6) must be equal, and thus so must be (5) and (6).

The two perturbations when combined determine a portfolio-balance relationship among $E(m_t|\Omega_t)$, $E(c_{t+1}|\Omega_t)$, $E(\pi_t|\Omega_t)$, RB_t, and RM_t. 1/ The equality between (5) and (6) can be expressed as the implicit function

$$(RB_t - RM_t) - E[(1 + \pi_t)^{-1}U_2(c_{t+1},\ell_{t+1})\psi_2(c_{t+1},m_t)|\Omega_t]/ \\ E\{(1 + \pi_t)^{-1}[U_1(c_{t+1},\ell_{t+1}) + U_2(c_{t+1},\ell_{t+1})\psi_1(c_{t+1},m_t)|\Omega_t]\} = 0 \tag{7}$$

The second term is simply the ratio of the expected marginal utility of the transactions services of money to the expected marginal utility of consumption. If (7) is solvable for m_t, the demand for money balances satisfies the relationship.

$$M_t = E[F(c_{t+1},\pi_t,RB_t,RM_t)\ P_{t+1}|\Omega_t], \tag{8}$$

since $\ell_{t+1} = 1 - \Psi(c_{t+1},m_t)$. Strictly speaking, (8) is not a money demand function, but rather a first order condition that the demand for money must satisfy at an optimal holding of money balances.

Several difficulties obviously exist in generalizing from a money demand theory for a representative household to that for the economy as a whole, including the problem of aggregating over households and the existence of other types of economic agents. While the former problem

1/ The higher order moments of the distributions of these variables also enter the relationship.

generally is not addressed in macroeconomics, a model of a representative firm's demand for money analogous to that above could be developed. In that case, an expression similar to (7) would relate the difference between the competing and own rates of return on holding money balances to the monetary services of the assets. This consideration implies that the relevant transactions variable for the economy as a whole is much broader than consumption.

Two basic conclusions about money demand are derived from the above model and its qualifications. First, the demand for a stock of money at a point in time reflects real expenditure plans, expectations about the price level, and the competing and own rates of return on money balances. The appropriate transactions variable and corresponding price level go well beyond household consumption. Therefore, the amount of money private agents choose to hold may contain information useful in predicting movements in price level variables such as the GNP deflator or that for total domestic demand. Second, changes in such factors as regulations and payments technology (represented by shifts in $\Psi(.,.)$ in the above model) alter the monetary services of assets, influencing both the quantity of money demanded and potentially the set of assets that yield a monetary return.

III. Testing for Cointegration

The potentially measurable determinants of money demand include real transactions and price level variables, as well as competing and own rates of return. However, the precise empirical quantities that correspond to the theoretical concepts are not clearcut, as is indeed the case for money. The search for a long-run relationship that includes a monetary aggregate and price level variable thus covers, in addition to two monetary aggregates (M1 and M2), several measures of real transactions and corresponding price levels. These latter variables are real GNP (GNP82), real domestic demand excluding federal government expenditures (DDXGF82), real total domestic demand (DDT82), and the implicit deflators associated with these variables (PGNP, PDDXGF, PDDT). Two competing rates of return are used, the three-month Treasury bill rate (RTB) and six-month commercial paper rate (RCP). The own rate of return on M1 (RM1) is a moving weighted average of the nominal yields of the components of M1, where the weights reflect component shares in the aggregate. Two own rates of return on M2 are considered, one corresponds to that for M1 (RM2) while the other is a moving weighted average of the yields on the non-M1 components of M2 (RM2NM1). Finally, a time trend serves as a rough proxy for technological progress in the payments system. 1/

1/ The definition and sources of the various data series are described further in the annex.

The theory of cointegrated variables provides tests for the existence of a long-run relationship among a monetary aggregate and the determinants of money demand. To implement these tests, long-run equations (i.e., equations in level terms only) are estimated for the various sets of variables. The residuals of these equations are then examined to determine whether deviations from the long-run relationship tend to persist or to diminish over time. Specifically, the equations' residuals are tested for their order of integration. 1/ If the null hypothesis that the residuals are integrated or order zero cannot be rejected, the set of variables is said to be cointegrated. 2/

1. Time series properties of data

An important preliminary to the tests for cointegration is to examine the order of integration of each time series to be included in the long-run relationship, and in particular to test for the presence of a unit root. 3/ The tests for cointegration used in this paper are appropriate only if each time series (or linear combination of two series) is integrated of order one.

The tests to detect the presence of unit roots in the individual time series presented forthwith include the Augmented Dickey-fuller (ADF) test and two associated with Phillips and Perron, $z(\alpha)$ and $z(t_\alpha)$. 4/ The former is well known. The latter two are the autoregressive coefficient and corresponding t-statistic both corrected for serial correlation in the regression's error term. Moreover the Phillips-Perron tests are based on several alternative hypotheses about the time series properties of the variables, which permit testing for inter alia the presence of a non-zero drift and non-zero mean in the time series

1/ Denote a stationary series as I(0) (integrated of order zero); then another series Z_t, for example, is I(k) (integrated of order k) if $\Delta^k Z_t$ is I(0).

2/ See Granger (1986), Engle and Granger (1987), and Phillips and Ouliaris (1990). Briefly, take the example of two series $X1_t$, $X2_t$, both integrated of order 1 (I(1)). If there exists a non-zero constant A such that $Z_t = X1_t - AX2_t$ is I(0), $X1_t$ and $X2_t$ are said to be cointegrated. In other words, if both series move together then even though the series themselves are trended the difference between them could be stationary, implying that the error term in a regression between those variables has well defined first and second moments.

3/ To say that a variable has a unit root is equivalent to stating that the variable is integrated of order one, I(1). A variable X_t is integrated of order one if it is nonstationary and can be written as $X_t = \beta + X_{t-1} + u_t$ where u_t has mean zero, variance σ_u, and is stationary. Unit root refers to the coefficient on X_{t-1}.

4/ See Dickey and Fuller (1979, 1981), Phillips (1987), and Phillips and Perron (1988) and Perron (1986).

under consideration. 1/ The testing methodology is amplified in Perron (1986).

The strategy begins with the regression equation

$$x_t = \mu + \beta(t - T/2) + \alpha x_{t-1} + u,$$

which permits testing the null hypothesis of a unit root with drift against the alternative hypothesis of a stationary series with a deterministic trend. 2/ The results for selected variables are presented in Table 1, which includes in addition to the ADF, $z(\alpha)$ and $z(t\alpha)$ tests, a modified F-test, $z(\phi_3)$, of the null hypothesis H_0: $(\mu \neq 0, \beta = 0, \alpha = 1)$. 3/ The tests statistics indicate that the null hypothesis of a unit root cannot be rejected at the 5 percent significance level for any series. However, the inability to reject the null hypothesis could reflect the low power of these tests.

A second regression equation,

$$x_t = \mu^* + \alpha^* x_{t-1} + u_t^*$$

yields more powerful tests than those presented in Table 1. Before considering the test statistics based on this regression, however, it must be determined that μ^* is zero, since the test statistics are not invariant with respect to this parameter. The modified F-test, $z(\phi_2)$, of the null hypothesis H_0: $(\mu = \beta = 0, \alpha = 1)$ that is reported in Table 1 can be used to make this determination. With the exception of the three interest rate variables, the null hypothesis can be rejected leading to the conclusion that the other time series tested appear to have a unit root with drift.

1/ Referring to the previous footnote characterizing an I(1) series, non-zero drift arises β is non-zero.

2/ Following Nelson and Plosser (1982), with the exception of the rate of return variables, the tests are run on the logarithms of the various series to account for the fact that the dispersion of series tends to increase with their absolute levels. The tests are based on quarterly data for the time period 1959:1 to 1989:4.

3/ The ADF tests are based on the regression equation

$$\Delta x_t = \alpha + \beta x_{t-1} + \sum_{i=1}^{4} \partial_i \Delta x_{t-i}.$$

The $z(\alpha)$, $z(t_\alpha)$, and $z(\phi_3)$ tests are presented for a range of Newey-West lag windows, which serve to correct these test statistics for heteroskedasticity in the regression's error terms. See Newey and West (1987).

Since the null hypothesis of μ equal to zero cannot be rejected for the three rate of return variables, these time series were tested for the presence of a unit root using the second regression equation. The results are presented in Table 2 and again the null hypothesis of a unit root cannot be rejected in each case.

Finally, a more powerful test of the null hypothesis of a unit root is possible for the own rate of return on M1, since the null hypothesis of a zero mean cannot be rejected for this series. A modified F-test, $z(\phi_1)$, of the null hypothesis H_0: $(\mu^* = 0, \alpha^* = 1)$ is reported in Table 2. A third regression equation

$$x_t = \hat{\alpha} x_{t-1} + \hat{u}_t$$

affords more powerful tests for the presence of a unit root in RM1 than those presented in Table 2. However, as seen in Table 3, the null hypothesis of a unit root still cannot be rejected.

To summarize, the Phillips-Perron tests presented in this subsection indicate one cannot reject the hypothesis that all of the basic time series variables considered in this appendix have unit roots. In contrast to the other variables, there is no evidence of drift in the rate of return variables--and in the case of the own rate of return on M1 the mean is zero (Chart 1). A further conclusion is that since price level measures are integrated of order one, the corresponding inflation measures are integrated of order zero.

2. Cointegration tests

The tests for cointegration used in this paper are the ADF, $z(\alpha)$ and $z(t_\alpha)$ tests applied to the residuals from the estimated long-run relationships. These relationships are derived from vector autoregressions (VARs) with lags over three quarters. 1/ The choice of variables to include in the VARs was guided by the theoretical framework above and the statistical properties of the individual time series. The residuals from the long-run relationships were then calculated for use in the cointegration tests.

The results in Table 4 indicate that, for a selection of transactions and price level variables, M1 is not cointegrated with these variables and the own and competing rates of return. The absence of cointegration in the case of M1 may stem from the regulatory reforms implemented in the late 1970s and 1980s. In light of this evidence, no attempt was made to estimate a dynamic money demand equation for this aggregate.

1/ On quarterly data from 1959:4 to 1989:4.

Tables 5 and 6 present test statistics for two types of long-run relationships that include M2. In the first, the cointegrating regressions relate M2 to a selection of transactions and price level variables. These long-run relationships are consistent with the velocity approach to the demand for M2 that underlies the P* relationship of Hallman et al.. In this case, it is not possible to reject the null hypothesis of no cointegration. The second relationship includes in addition to those variables in the first the own and competing rates of return. 1/ The addition of these variables to the long-run relationships leads to the rejection of the null hypothesis of no cointegration.

The above results, which suggest that it would be inappropriate to include residuals from a velocity-based long-run relationship in a dynamic equation that represents the demand for M2, appears to reflect two factors. First, as is well known, empirical estimates of the speed with which money balances adjust to gaps between the desired or "long-run" demand and actual holdings is typically very slow. Second, in the early years of the sample period, the own rate of return on M2 was subject to regulation while in more recent years it has exhibited inertia with the result that throughout the period there has been significant movements in the opportunity cost of holding M2. 2/ These opportunity cost movements, some of which persisted, resulted in offsetting movements in velocity. When these two factors are taken together, the power of the statistics presented here is such that the data is interpreted as being consistent with the absence of a tendency for money demand to revert to a long-run equilibrium value. The inclusion of the own and competing rates of return in the cointegrating regression incorporates the second factor and the statistical tests then point to the rejection of the hypothesis of no cointegration.

Two representative long-run relationships derived from the VARs for M2 are presented below, one for the case in which the transactions variable is real GNP and the other in which it is real total domestic demand. These relationships are:

$$\log M2 = -1.863 + 1.18 \log GNP82_{-1} + 0.901 \log PGNP_{-1} + 0.042RM2NM1 - 0.040RTB \qquad (9)$$

1/ A rationale for presenting these alternatives is that although the evidence indicates the likelihood that both the own- and competing-rates of return on M2 are I(1), the opportunity cost of holding M2, which is the difference of these rates of return, is likely I(0) and therefore stationary.

2/ The relaxation of regulatory controls in the form of deposit ceilings on components of M2 began in 1982. The complete abolition of such ceilings did not take place until more recently--rates on all NOW accounts could not be freely priced until January 1986, while those on passbook savings accounts were not freed until April 1986.

$$\log M2 = -1.640 + 1.14 \log DDT82_{-1} + 0.87 \log PDDT_{-1} + 0.060 RM2NM1 - 0.050 RTB \tag{10}$$

respectively. To allow for the endogeneity of the transactions and price level variables, their lagged values are used as predictors of their current values. 1/

There are a couple of noteworthy features in these equations. First, in both cases the income and price elasticities fall within two standard deviations of unity. This implies that, abstracting from shifts in relative rates of return, velocity measures will tend to be stable over the long run. Moreover, the equations imply that homogeneity with respect to the price level is satisfied for M2. Second, the coefficients on the own and competing rate of return variables are approximately of equal and opposite signs, indicating that the demand for nominal M2 is in this respect primarily affected by the opportunity cost of holding money. 2/ Converting the reported semi-elasticity values to elasticity values, at 10 percent nominal interest rates the coefficients imply own and competing elasticities of 0.4 when DDT82 is the scale variable and 0.5 to 0.6 when GNP82 is the scale variable.

IV. Short-run Dynamics of Money Demand and Prices 3/

This section presents error-correction representations of the demand for nominal M2 for the cases where the scale variable is real GNP and total domestic demand (with corresponding price variables). These representations elucidate the short-run dynamics of money demand and result in equations for nominal M2 which can be evaluated with a view to determining whether a stable money demand function exists. 4/ The regressions are run on quarterly data from 1959:4 to 1989:4.

1/ The estimation problems caused by the endogeneity of variables is discussed in Phillips and Hansen (1990).

2/ As already noted, the opportunity cost can change, for example, if the own rate of return on money balances is subject to nominal rigidities with important implications for the short-run dynamics of money demand. See Moore, Porter, and Small (1988).

3/ The empirical work in this section uses PC-GIVE, version 6.1, copyright David Hendry, Oxford Institute of Economics and Statistics.

4/ The concepts of error-correction and cointegration are closely related. The Granger Representation Theorem (Granger (1983)) demonstrates that if a set of variables are cointegrated (which has already been demonstrated) then there exists a valid error-correction representation of the data.

$$\Delta\log M2 = \underset{(-0.382)}{-0.001} + \underset{(7.608)}{0.471}\Delta\log M2_{-1} + \underset{(2.801)}{0.164}\Delta\log GNP82_{-1} \tag{11}$$

$$+ \underset{(3.373)}{0.258}\Delta\log PGNP_{-2} - \underset{(-5.106)}{0.004}\Delta RM2NM1_{-1} - \underset{(-5.892)}{0.114}ECM_{-1}$$

$\bar{R}^2 = 0.609$ $\quad F(5,115) = 35.86$ $\quad \sigma = 0.0054$

LM test for autocorrelation 1/

$\eta_1(1,114) = 0.71$ $\quad \eta_2(1,114) = 5.20$ $\quad \eta_3(4,111) = 1.52$

ARCH: 2/ $F(4,107) = 0.93$

Heteroskedasticity: 3/ $F(10,104) = 1.239$

$$\Delta\log M2 = \underset{(-1.015)}{-0.002} + \underset{(7.272)}{0.459}\Delta\log M2_{-1} + \underset{(2.477)}{0.139}\Delta\log DDT82_{-1} \tag{12}$$

$$+ \underset{(4.447)}{0.355}\Delta\log PDDT_{-3} - \underset{(-4.870)}{0.004}\Delta RM2NM1_{-1} - \underset{(-5.484)}{0.084}ECM_{-1}$$

$\bar{R}^2 = 0.606$ $\quad F(5,114) = 35.02$ $\quad \sigma = 0.0054$

$\eta_1(1,113) = 0.84$ $\quad \eta_2(1,113) = 11.83$ $\quad \eta_3(4,110) = 3.11$

ARCH: $F(4,106) = 0.69$

Heteroskedasticity: $F(10,103) = 1.672$

1/ η_1 (1,T-k-1) denotes a Lagrange multiplier test for residual serial autocorrelation of order 1 with k regressors, η_2 is for simple fourth-order autocorrelation, and η_3 is for orders 1 through 4. The test is distributed as χ^2 in large samples under the null hypothesis that there is no autocorrelation. However, for finite samples, the F-form reported here is preferable as a diagnostic test (Harvey (1981)). Note that this test is valid for models with lagged dependent variables.

2/ Engle's "ARCH" test (Auto Regressive Conditional Heteroskedasticity) see Engle (1982).

3/ Due to White (1980).

The t-ratios are in parentheses and ECM refers to the residuals derived from the corresponding long-run equation estimated above. Although differing in detail, both equations are broadly similar in terms of overall performance. Specifically, they both satisfy a broad range of statistical tests.

Concerning the specifics of the equations, with particular attention on equation (11) which includes the GNP scale variable, the coefficient on the error-correction term (ECM), which can be interpreted as a speed of adjustment parameter, indicates that in common with much of the empirical literature in this area that the speed with which money demand adjusts to shocks is very slow. 1/

Given the concern with the ability of monetary aggregates to track macroeconomic variables, an important question is how the equation performs over time. In Chart 2, the one-step residuals ($Y_t - X_t'\beta_t = u_t$ where β_t is the estimated β using data up to and including t) are graphed together with their current standard errors ($\pm 2\sigma_t$). This graph indicates that the residuals have tended to become larger in recent decades--the standard-error bounds have widened indicating that the variance has increased--and that on occasions the residuals have exceeded the bounds. This suggests caution in using M2 as an indicator.

Further insight into the behavior of equation (11) can be found by considering the one-step ahead forecasts for the period 1987:3 to 1989:4 (Chart 3). The forecasting bounds are never exceeded. Moreover, a χ^2 test comparing within and post-sample residual variances for parameter constancy cannot reject at the 5 percent confidence level the hypothesis of parameter constancy. However, the forecasts are static. The chart indicates a systematic tendency in recent quarters to overpredict money demand, implying the possibility of cumulative errors, which potentially could be serious.

Charts 4 and 5 track the recursive least squares coefficients for the ECM term and the lagged difference in the own rate of return. Chart 4 shows that the coefficient on the ECM term shifted in the early 1980s, possibly reflecting the impact of financial deregulation. The

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1/ Ebrill (1988). Note, however, consistent with the earlier cointegration results, the coefficient is significantly different from zero supporting the existence of a well-defined long-run money-demand function. The presumed slow speed with which money demand adjusts to shocks has never been fully satisfactorily explained. Reinterpretations of this result have included the possibility of its reflecting measurement errors in the variables rather than economic behavior (Goodfriend (1985)).

coefficient on the own rate of return variable 1/ clearly shows the impact of financial deregulation in the early 1980s when the coefficient became significant--prior to that, the variable would have exhibited insufficient variation. 2/

To this point the focus has been on estimating the demand function for nominal M2 balances. As noted earlier, this paper is primarily concerned with the possibility that M2 might be a useful predictor of inflation. As a first step to evaluating this possibility, the residuals from the long-run relationship were included in an error-correction formulation of inflation behavior to see if information obtained from an empirical analysis of the money market could enhance inflation forecasts. The outcome of the resulting testing down procedure was an autoregressive process in inflation--in particular, the ECM term derived from the relevant long-run money demand equation had no significant impact. 3/

V. Adjustment in the Money and Goods Markets and Inflation

While a stable long-run relationship exists between M2 and the price level, the inflation process may be better represented by developments in both the goods and money markets rather than by those in the money market alone. This can be achieved by substituting a measure of potential output for actual demand in the long-run relationship. Specifically, consider the form of long-run equations (9) and (10)

$$\log M2 = \beta_0 + \beta_1 \log Y + \beta_2 \log P + \beta_3 RTB + \beta_4 RM2NM1 + e. \tag{12}$$

1/ Ideally, one would prefer to consider the coefficient on the level of the own rate of return rather than its first difference. However, that term has been subsumed within the ECM term. Nonetheless, the observations made here concerning the coefficient on the difference term likely apply more generally.

2/ The specific value for the term is negative. However, this reflects only the short-run dynamics of money demand. As equation (9) above indicates, the long-run effect of an increase in the own rate of return is positive--the long-run effect is contained within the ECM term. The other notable feature of Chart 5 is that although not of statistical significance the coefficient jumped in 1973/74. This coincides with the "missing money" episode in 1974. See Judd and Scadding (1982) and Goldfeld (1976).

3/ This result held for both GNP and domestic demand scale variables.

Substituting potential output (YP) results in,

$$\log M2 = \beta_0 + \beta_1 \log YP + \beta_2 \log P + \beta_3 RTB + \beta_4 RM2NM1 + \hat{e}. \tag{13}$$

Setting equation (12) equal to equation (13),

$$\hat{e} = e + \beta_1(\log Y - \log YP) \tag{14}$$

That is, the residuals in equation (14) can be decomposed into those from the estimated equation for money-market equilibrium and an output gap measure. The residual ê is the counterpart to the difference between P and P* in the framework of Hallman et al.. Since e has already been shown to be I(0) and tests indicate that the output gap measures are also I(0), it follows that ê is also I(0), 1/ indicating that M2 is cointegrated with measures of the price level, own and competing rates or return, and potential output.

The following error-correction representations of the inflation process were estimated for the cases of the GNP and total domestic demand deflators:

$$\underset{}{\Delta \log PGNP} = \underset{(2.547)}{0.003} + \underset{(10.193)}{0.651 \Delta \log PGNP_{-1}} + \underset{(3.008)}{0.164 \Delta \log M2_{-1}} + \underset{(3.161)}{0.033 ECMGAP_{-3}} \tag{15}$$

$\bar{R}^2 = 0.621$ $\quad F(3,116) = 63.28$ $\quad \sigma = 0.004$

$\eta_1(1,115) = 13.33$ $\quad \eta_2(1,115) = 0.34$ $\quad \eta_3(4,112) = 4.77$

ARCH: $F(4,108) = 0.66$

Heteroskedasticity: $F(6,109) = 0.536$

1/ This has an economic interpretation reflecting the fact that, in the long-run, demand for goods and services is not expected to deviate persistently from their potential supply in view of the economy's tendency to close any output gap over time and its intertemporal budget constraint.

$$\underset{}{\Delta \log PDDT} = \underset{(1.693)}{0.002} + \underset{(2.951)}{0.265}\Delta \log PDDT_{-1} + \underset{(3.248)}{0.287}\Delta \log PDDT_{-2} \tag{16}$$

$$+ \underset{(2.713)}{0.231}\Delta \log PDDT_{-3} + \underset{(2.961)}{0.154}\Delta \log M2_{-2}$$

$$+ \underset{(2.456)}{0.001}\Delta RTB + \underset{(3.042)}{0.025}ECMGAP_{-3}$$

$\eta_1(1,112) = 0.25$ $\eta_2(1,112) = 0.19$ $\eta_3(4,109) = 1.17$

ARCH: $F(4,105) = 1.32$

Heteroskedasticity: $F(12,100) = 0.799$.

The period of both regressions is 1960:1 to 1989:4. ECMGAP refers to the residuals derived from the corresponding long-run equations.

Concerning their statistical properties, there is evidence of significant first-order autocorrelation in equation (15). Since there is no such evidence in equation (16), the problem may arise from the differing definitions of the alternative scale and inflation variables. 1/

As regards the content of the equations, in contrast to the earlier result where the inflation equation degenerated into an autoregressive process with no role for developments in the money market, the residuals from the long-run relationship that also includes goods market behavior are significant. Moreover, in both cases, knowledge of the behavior of changes in the stock of M2 contain information about future inflation, suggesting that the decision of how much money to hold reflects forward-looking behavior by private agents. Changes in the competing rate of return to holding M2 are also helpful when the domestic demand deflator is under consideration.

To elaborate on these results, equations (15) and (16) were re-estimated allowing for the decomposition of the residuals in equation (14). This resulted in the following two equations.

1/ It should also be noted that equation (15), but not (16), also fails standard tests for normality, a result due to a large outlier in the case of the former regression.

$$\Delta \log PGNP = \underset{(0.617)}{0.001} + \underset{(5.117)}{0.438} \Delta \log PGNP_{-1} + \underset{(3.934)}{0.327} \Delta \log PGNP_{-2} \tag{17}$$

$$+ \underset{(2.506)}{0.118} \Delta \log M2_{-1} + \underset{(-3.068)}{0.043} GNPGAP_{-2}$$

$\bar{R}^2 = 0.664$ $F(4,116) = 57.19$ $\sigma = 0.004$ 1959:4 to 1989:4

$\eta_1(1,115) = 11.21$ $\eta_2(1,115) = 0.32$ $\eta_3(4,112) = 3.11$

ARCH: $F(4,108) = 0.36$

Heteroskedasticity: $F(8,107) = 0.225$

$$\Delta \log PDDT = \underset{(-0.328)}{-0.0003} + \underset{(3.332)}{0.294} \Delta \log PDDT_{-1} + \underset{(3.704)}{0.326} \Delta \log PDDT_{-2} \tag{18}$$

$$+ \underset{(3.014)}{0.266} \Delta \log PDDT_{-3} + \underset{(2.075)}{0.084} \Delta \log M2_{-1} + \underset{(3.761)}{0.038} DDTGAP_{-1}$$

$\bar{R}^2 = 0.754$ $F(5,114) = 69.94$ $\sigma = 0.004$ 1960:1 to 1990:4

$\eta_1(1,113) = 0.01$ $\eta_2(1,113) = 0.04$ $\eta_3(4,110) = 0.12$

ARCH: $F(4,106) = 1.12$

Heteroskedasticity: $F(10,103) = 0.371$

GNPGAP and DDTGAP refer to the relevant output gaps. 1/

Concerning their statistical properties, there is again evidence of significant first-order autocorrelation in the equation focusing on the GNP deflator (equation (17)).

As regards the form of these equations, the most notable feature is that the ECM term is not included in the final equation. This implies that deviations of money from its long-run relationship--the analogue of Hallman *et al.*'s velocity gap--are not useful in the present context in predicting inflation, a result that is consistent with the earlier empirical analysis. The close parallels between the equations above and those reported by Hallman *et al.* naturally suggest the question of where the discrepancy arises. In this connection it is worth noting that the

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1/ We are grateful to the Federal Reserve Board for supplying their inhouse estimates of potential GNP.

velocity gap term reported in Hallman et al.'s preferred equation is significant only at about the 7 percent level. Moreover, their regressions terminated in 1988:1 and inspection using recursive least squares indicated that the additional seven quarters of data in the regressions presented here if added to the time series used in their regressions would further weaken their result.

That the primary influence of money on inflation is captured by the output gap has been noted before. Specifically, Gordon (1985) showed how to decompose "excess" nominal GNP growth (his analogue of the output gap) into the sum of "excess" money growth and actual velocity growth. If money's influence on inflation arises solely through this decomposition, then the money and velocity terms, when entered in place of his output gap measure, should have the same coefficient values. When estimated in unrestricted form, he finds the two estimated coefficient values to be statistically indistinguishable and concludes that money has no influence in predicting inflation apart from its effect on the output gap.

It should be emphasized that this is a statistical rather than a theoretical result. It reflects the endogeneity of M2, a broad monetary aggregate, and indicates that the price level leads money (M2) rather than vice versa. This conclusion was confirmed by some Granger causality tests. 1/ Finally, note that there is a long-run relationship between money and prices as evidenced by equations (9) and (10).

While M2 may not be a useful anchor for the price level, it is worth noting that changes in the stock of M2 do contain information about future inflation as evidenced from equations (17) and (18). One explanation for this result is that the demand for money reflects forward-looking behavior by private agents.

Finally, Charts 6 and 7 present the one-step residuals and one-step ahead forecasts for the period 1987:3 to 1989:4 for equation (17). By both criteria, except for an outlier around the time of the first oil-price shock (Chart 6), the equation is well-behaved. In particular, the one-step ahead forecasts indicate that thee is no persistent tendency to over- or underpredict inflation suggesting that dynamic forecasts on the basis of this equation would perform in a relatively satisfactory manner.

1/ Specifically, when four lags are used, changes in the price level Granger-cause changes in M2 at a 5 percent significance level. Moreover, on testing, it emerged that M2 does not Granger-causes the price level for a broad range of lags.

VI. Concluding Observations

The principal results of this paper may be briefly summarized as follows. First, a dynamic optimization model indicates that, although sensitive to changes in regulation and payments technology, the demand for money reflects real expenditure plans, expectations about the price level, and own- and competing-rates of return to holding money.

Second, empirical tests indicate that all of the basic time series considered in this appendix have unit roots (I(1)). The tests also indicate that for the case of M1, money, price, income, and the relevant rate of return variables are not cointegrated. For the case of M2, these variables are cointegrated, although the evidence suggests that if a velocity framework is adopted, and thus the rate of return variables are excluded, the relevant variables are not cointegrated. The velocity approach underlies the Federal Reserve's P* relationship.

Third, focusing on M2, estimates of long-run relationships that include this aggregate are not inconsistent with a unitary income elasticity of the demand for money and homogeneity with respect to prices. The empirical analysis also indicates that there is a stable well-defined money-demand function for M2. However, the estimated inflation equations based on information obtained from money market behavior collapse to autoregressions indicating that M2 adjusts in the short run to the price level rather than vice versa.

Fourth, when its scope is expanded to allow for developments in both money and goods markets, the empirical analysis points to the conclusion that deviations of money from its long-run relationship do not significantly enhance inflation forecasts based on conventional output gap models. However, changes in M2 do contain information about future inflation, suggesting that the demand for M2 reflects forward-looking behavior by private agents.

Data Sources

The data in the regressions are quarterly and, except for the interest rate variables, seasonally adjusted. The basic data for the monetary aggregates, scale, price, and competing rate of return variables were from Data Resources Incorporated USCEN databank.

The own rate of return variables for M1, M2, and M2 exclusive of M1, were created by taking a weighted average of the rates of return on the components of each aggregate, the weights being the shares of the components in each aggregate. We are grateful to the Federal Reserve for supplying the basic data.

As noted in the text, the data for the potential output series underlying the GNP gap measure was provided by the Federal Reserve. These estimates are based on an Okun's law procedure which in turn requires an estimate of the natural rate of employment. The interested reader is referred to Braun (1984, 1987).

Table 1. Phillips-Perron Tests for Unit Roots

(Univariate Regression Equation:

$X_t = \mu + \beta(t-T/2) + \alpha X_{t-1} + u_t$)

(ADF 1/ Regression Equation: $\Delta X_t = \mu + \sum_{i=1}^{4} \delta_i \Delta X_{t-1} + \theta X_{t-1}$)

Statistics	Newey-West Lag Windows 1	4	7	10
Y = log M1 (α = 0.97)				
ADF(4) = 1.22				
$z(\alpha)$	-4.38	-4.68	-4.81	-4.70
$z(t_\alpha)$	-2.84	-2.71	-2.67	-2.70
$z(\phi_3)$	11.64	9.77	9.18	9.65
$z(\phi_2)$	69.44	55.88	51.59	55.04
Y = log M2 (α = 0.96)				
ADF(4) = -0.26				
$z(\alpha)$	-5.54	-7.33	-8.21	-8.31
$z(t_\alpha)$	-2.21	-2.34	-2.41	-2.42
$z(\phi_3)$	2.75	2.92	3.07	3.08
$z(\phi_2)$	149.48	96.07	81.78	80.50
Y = log GNP82 (α = 0.96)				
ADF(4) = -0.79				
$z(\alpha)$	-6.16	-8.04	-8.25	-7.75
$z(t_\alpha)$	-1.95	-2.17	-2.19	-2.14
$z(\phi_3)$	2.25	2.61	2.65	2.55
$z(\phi_2)$	22.67	17.09	16.65	17.73
Y = log PGNP (α = 0.97)				
ADF(4) = -0.45				
$z(\alpha)$	-3.49	-4.23	-4.87	-5.42
$z(t_\alpha)$	-3.08	-2.54	-2.42	-2.39
$z(\phi_3)$	8.39	4.94	4.09	3.77
$z(\phi_2)$	87.52	41.46	28.75	23.03
Y = log DDXGF82 (α = 0.96)				
ADF(4) = -0.88				
$z(\alpha)$	-6.11	-8.36	-8.50	-7.80
$z(t_\alpha)$	-1.84	-2.12	-2.14	-2.05
$z(\phi_3)$	2.00	2.47	2.50	2.35
$z(\phi_2)$	16.86	12.65	12.48	13.43

Table 1. Phillips-Perron Tests for Unit Root (Concluded)

Statistics	Newey-West Lag Windows 1	4	7	10
Y = log (PDDXGF) (α = 0.98)				
ADF(4) = -0.29				
$z(\alpha)$	-3.34	-4.08	-4.70	-5.19
$z(t_\alpha)$	-3.02	-2.48	-2.37	-2.34
$z(\phi_3)$	8.75	4.96	4.09	3.77
$z(\phi_2)$	80.69	36.96	25.86	21.01
Y = log (DDT82) (α = 0.96)				
$z(\alpha)$	-6.15	-8.53	-8.97	-8.46
$z(t_\alpha)$	-1.86	-2.15	-2.20	-2.14
$z(\phi_3)$	1.93	2.46	2.56	2.44
$z(\phi_2)$	17.60	12.98	12.45	13.09
Y = log (PDDT) (α = 0.97)				
ADF(4) = -1.48				
$z(\alpha)$	-3.38	-4.17	-4.84	-5.37
$z(t_\alpha)$	-2.97	-2.46	-2.36	-2.34
$z(\phi_3)$	7.94	4.61	3.87	3.60
$z(\phi_2)$	80.00	36.67	25.59	20.76
Y = RTB (α = 0.89)				
ADF(4) = -1.85				
$z(\alpha)$	-13.20	-13.70	-15.02	-15.17
$z(t_\alpha)$	-2.60	-2.64	-2.77	-2.78
$z(\phi_3)$	3.38	3.50	3.83	3.87
$z(\phi_2)$	2.30	2.38	2.59	2.62
Y = RM1 (α = 0.99)				
ADF(4) = -0.11				
$z(\alpha)$	-1.35	-1.79	-2.08	-2.45
$z(t_\alpha)$	-1.02	-1.10	-1.16	-1.23
$z(\phi_3)$	4.99	3.58	3.11	2.74
$z(\phi_2)$	7.24	4.99	4.20	3.56
Y = RM2NM1 (α = 0.89)				
ADF(4) = -1.72				
$z(\alpha)$	-13.70	-13.48	-14.43	-14.62
$z(t_\alpha)$	-2.65	-2.63	-2.71	-2.73
$z(\phi_3)$	3.53	3.48	3.71	3.76
$z(\phi_2)$	2.48	2.45	2.60	2.62

1/ The critical values at the 5 percent confidence level for ADF(4) and $z(t_\alpha)$ statistics is -3.41, that for the $z(\alpha)$ statistic is -21.8, that for $z(\phi_3)$ is 6.25, and that for $z(\phi_2)$ is 4.68. See Perron (1986).

Table 2. Phillips-Perron Tests for Unit Root

(Univariate Regression Equation: $X_t = \mu^* + \alpha^* X_{t-1} + u_t^*$)

Statistics	Newey-West Lag Windows 1	4	7	10
Y = RTB3 (α^* = 0.93)				
$z(\alpha^*)$	-7.92	-7.82	-8.28	-8.16
$z(t_{\alpha^*})$	-2.10	-2.10	-2.15	-2.14
$z(\phi_1)$	2.28	2.26	2.37	2.34
Y = RM1 (α^* = 1.01)				
$z(\alpha^*)$	1.42	1.25	1.12	0.97
$z(t_{\alpha^*})$	1.80	1.26	1.01	0.78
$z(\phi_1)$	7.08	4.28	3.28	2.53
Y = RM2NM1 (α^* = 0.95)				
$z(\alpha^*)$	-6.28	-5.72	-5.74	-5.55
$z(t_{\alpha^*})$	-1.93	-1.86	-1.87	-1.84
$z(\phi_1)$	2.06	1.95	1.96	1.92

The critical value of the 5 percent confidence level of the $z(\alpha^*)$ statistic is -14.1, that for the $z(t_{\alpha^*})$ statistic is -2.86, and that for the $z(\phi_1)$ statistic is 4.59. Ser Perron (1986).

Table 3. Phillips-Perron Tests for Unit Roots

(Univariate Regression Equation: $X_t = \hat{\alpha} X_{t-1} + \hat{u}_t$

Statistics	Newey-West Lag Windows 1	4	7	10
Z = RM1 ($\hat{\alpha}$ = 1.02)				
z ($\hat{\alpha}$)	2.20	2.06	1.96	1.84
z ($t_{\hat{\alpha}}$)	3.24	2.40	2.02	1.69

The critical values at the 5 percent confidence level for z($\hat{\alpha}$) statistic is -15.64 and for the z($t_{\hat{\alpha}}$) statistic is -2.76. See Phillips and Ouliaris (1990).

Table 4. Cointegration Tests for M1 1/

Cointegrating Regression

$$\text{Log } M_1 = \beta_0 + \beta_1 \text{ Log } Y + \beta_2 \text{ Log } P + \beta_3 \text{RTB3} + \beta_4 \text{RM1} + \beta_5 \text{Time}$$

Statistic	Newey-West Lag Windows 1	4	7	10
Y = DDXGF82, P = PDDXGF				
ADF(4) = -2.66				
$Z(\alpha)$	-18.70	-18.75	-21.92	-22.54
$Z(t_a)$	-3.41	-3.41	-3.62	-3.67
Y = GNP82, P = PGNP				
ADF(4) = -2.64				
$Z(\alpha)$	-22.53	-21.83	-24.86	-25.51
$Z(t_\alpha)$	-3.78	-3.73	-3.92	-3.96
Y = DDT82, P = PDDT				
ADF(4) = -2.72				
$Z(\alpha)$	-18.77	-18.63	-21.44	-21.81
$Z(t_\alpha)$	-3.40	-3.40	-3.59	-3.61

1/ The critical value at the 5 percent level for the ADF(4) and $z(\bar{t}_\alpha)$ statistics is -4.74 and that for the $z(\alpha)$ statistic is -42.46. See Phillips and Ouliaris (1990).

Table 5. Cointegrating Tests for M2 1/

Cointegrating Regression

$$\text{Log } M_2 = \beta_0 + \beta_1 \text{ Log } Y + \beta_2 \text{ Log } P$$

Statistics	Newey-West Lag Windows			
	1	4	7	10
Y = GNP82, P = PGNP				
ADF(4) = -3.22				
$Z(\alpha)$	-13.36	-15.73	-16.00	-14.39
$Z(t_\alpha)$	-2.61	-2.83	-2.85	-2.70
Y = DDXGF82, P = PDDXGF				
ADF(4) = -2.85				
$Z(\alpha)$	-15.26	-16.22	-15.64	-13.75
$Z(t_\alpha)$	-2.78	-2.87	-2.81	-2.64
Y = DDT82, P = PDDT				
ADF(4) = -3.15				
$Z(\alpha)$	-14.74	-15.80	-15.96	-14.53
$Z(t_\alpha)$	-2.88	-2.96	-2.98	-2.86

1/ The critical value at the 5 percent confidence level for the ADF(4) and $z(t_\alpha)$ statistics is -3.77 and that for the $z(\alpha)$ statistic is -26.09. See Phillips and Ouliaris (1990).

Table 6. Cointegrating Tests for M2 1/

Cointegrating Regression

$$\text{Log } M_2 = \beta_0 + \beta_1 \text{ Log } Y + \beta_2 \text{ Log } P + \beta_3 \text{ RTB3} + \beta_4 \text{ RM2NM1}$$

Statistics	Newey-West Lag Windows			
	1	4	7	10
Y = GNP82, P = PNDP				
ADF(4) = -4.62				
$Z(\alpha)$	-60.83	-55.51	-52.37	-46.06
$Z(t_\alpha)$	-6.21	-6.01	-5.90	-5.66
Y = DDXGF82, P = PDDXGF				
ADF(4) = -4.53				
$Z(\alpha)$	-57.07	-51.87	-48.08	-44.38
$Z(t_\alpha)$	-5.99	-5.79	-5.67	-5.49
Y = DDT82, P = PDDT				
ADF(4) = -4.48				
$Z(\alpha)$	-55.58	-55.10	-49.18	-44.87
$Z(t_\alpha)$	-5.89	-5.71	-5.63	-5.46

1/ The critical value at the 5 percent confidence level for the ADF(4) and $z(t_\alpha)$ statistics is -4.45 and that for the $z(\alpha)$ statistic is -37.15. See Phillips and Ouliaris (1990).

CHART No 1

UNITED STATES
OWN RATES OF RETURN ON M1 AND M2

(IN PERCENT)

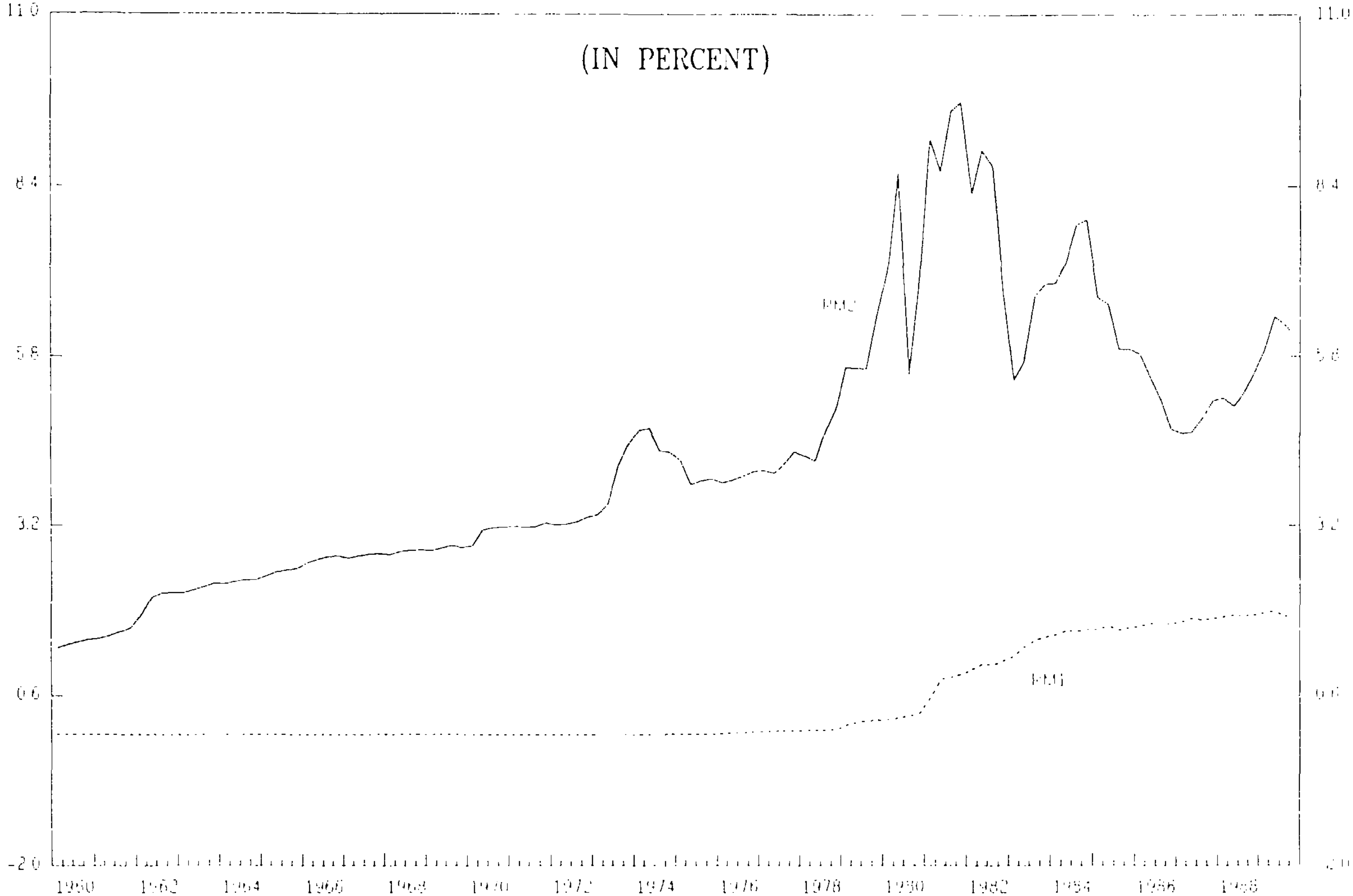
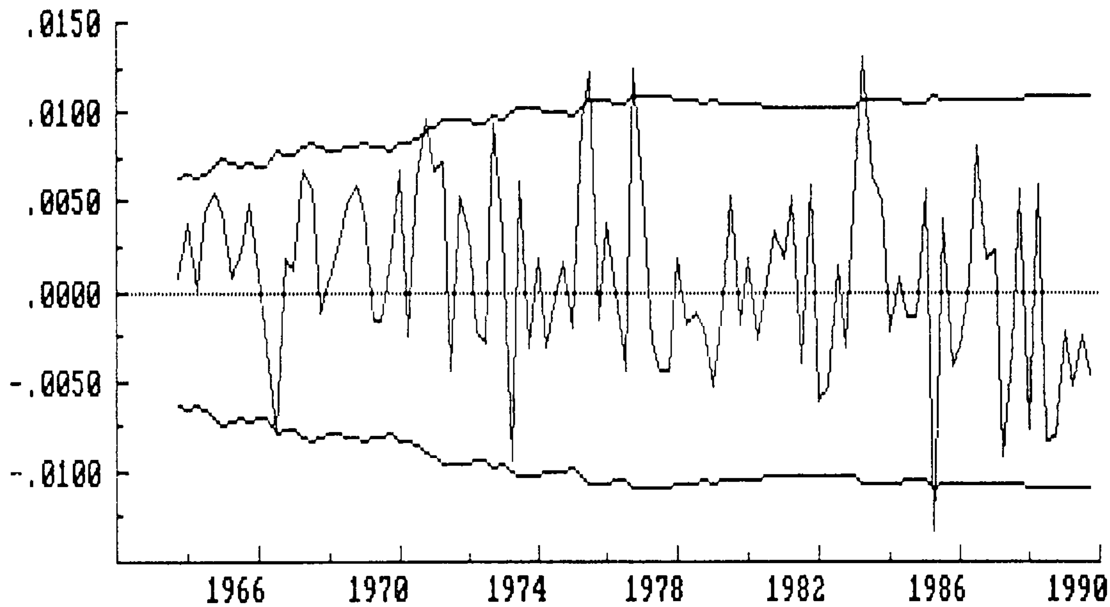


Chart 2

United States

M2 Equation: Residuals 1/

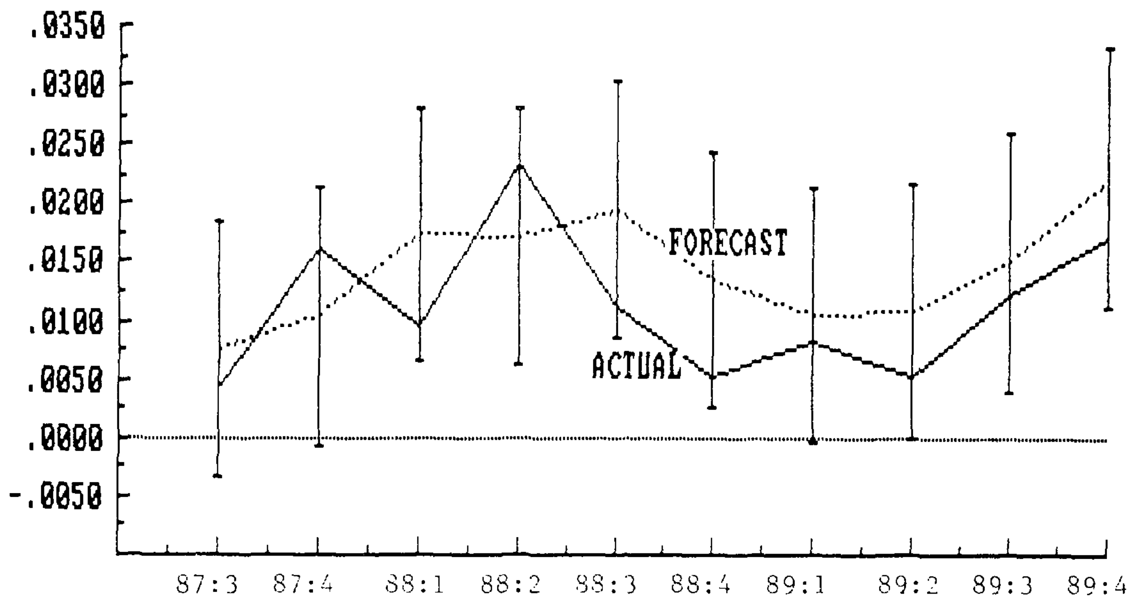


1/ One-step residuals ($Y_t - X_t'\hat{\beta}_t = \bar{u}_t$ where $\hat{\beta}_t$ is the estimated β using data up to and including t) bounded by the current standard errors ($\pm$ 2 $\hat{\sigma}_t$).

Chart 3

United States

M2 Equation: Forecast Performance 1/

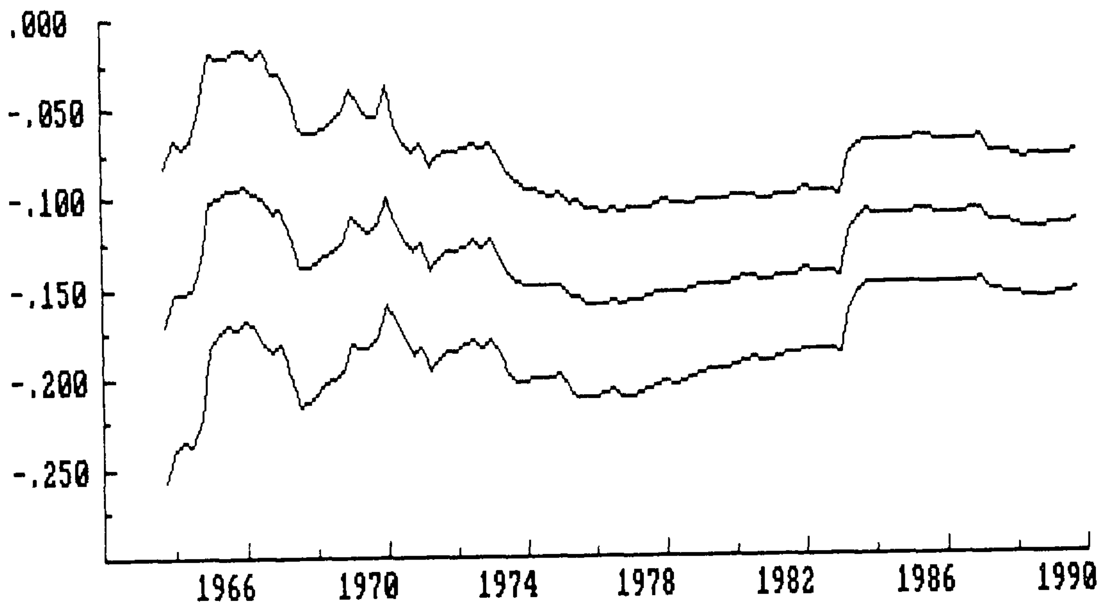


1/ The error bars show plus or minus two standard errors of the estimated value for the dependent variable, yielding an approximately 95 percent confidence interval for the one-step forecast.

Chart 4

United States

M2 Equation: Bounded Recursive Least Squares
Coefficient for ECM_{-1} 1/

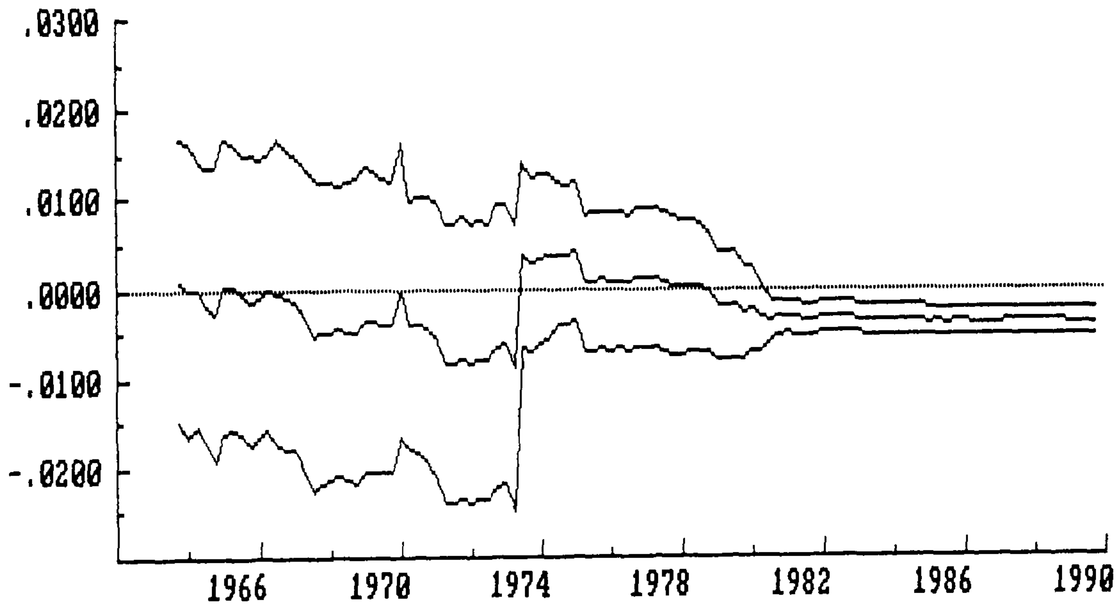


1/ The estimated value of the coefficient of the variable calculated by recursive least squares and bounded by plus or minus two standard errors of that estimated value.

Chart 5

United States

M2 Equation: Bounded Recursive Least Squares
Coefficient for $\Delta RM2NM1_{-1}$ 1/

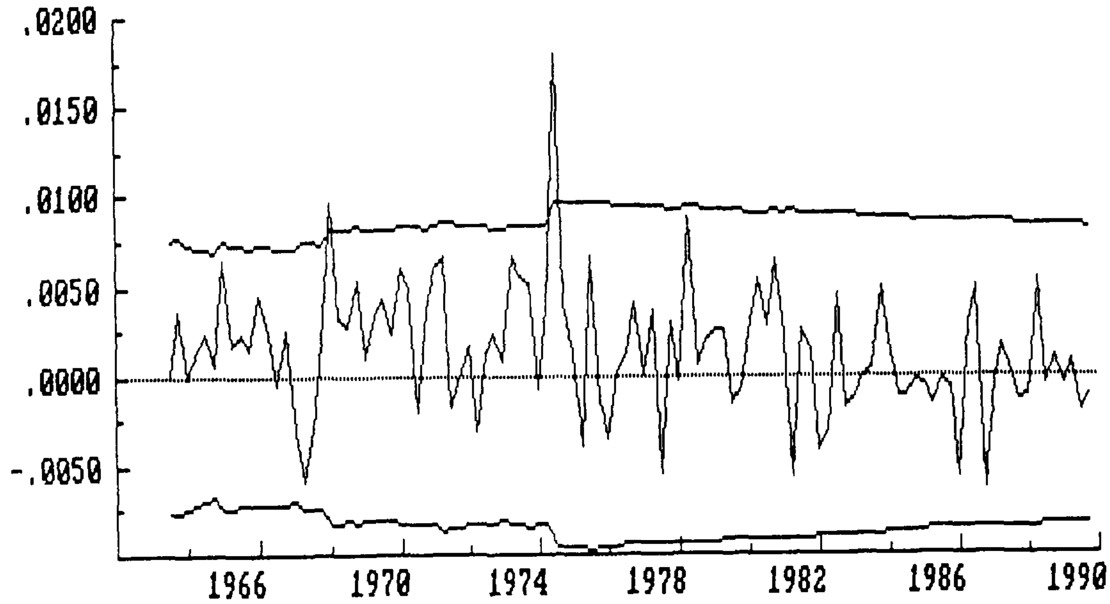


1/ The estimated value of the coefficient of the variable calculated by recursive least squares and bounded by plus or minus two standard errors of that estimated value.

Chart 6

United States

ΔPGNP Equation: Residuals 1/

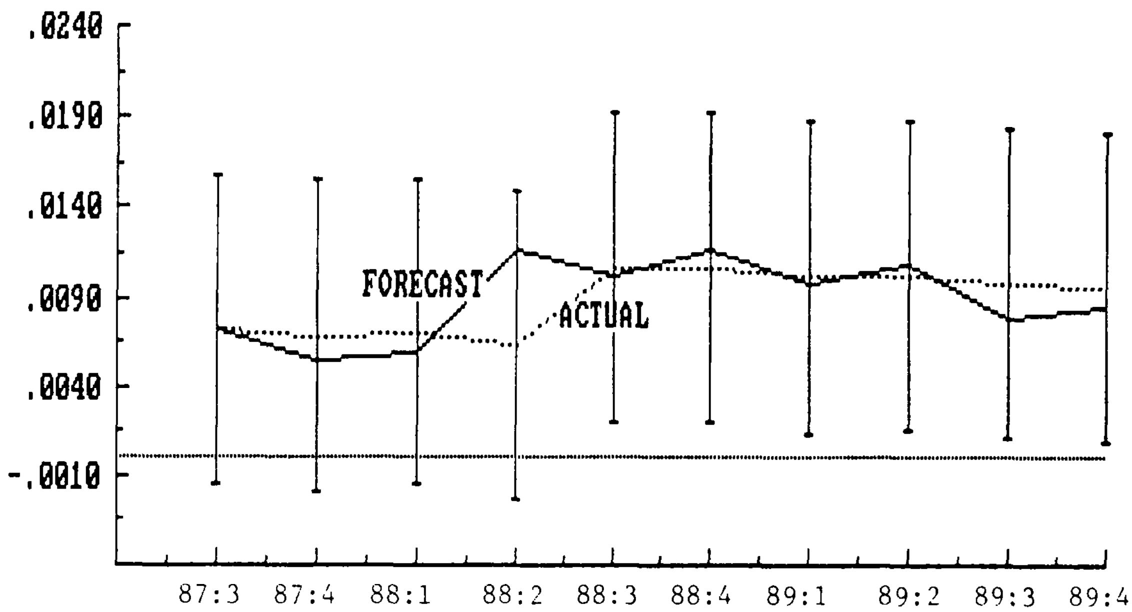


1/ One-step residuals ($Y_t - X_t'\hat{\beta}_t = \bar{u}_t$ where $\hat{\beta}_t$ is the estimated β using data up to and including t) bounded by the current standard errors ($\pm\ 2\ \hat{\sigma}_t$).

Chart 7

United States

ΔPGNP Equation: Forecast Performance 1/



1/ The error bars show plus or minus two standard errors of the estimated value for the dependent variable, yielding an approximately 95 percent confidence interval for the one-step forecast.

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