Interest Rates and M2 in an Error Correction Macro Model

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December 1997

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Abstract

With annual data, real M2 is shown to have a surprisingly strong contemporaneous and leading relationship to GDP, robust to the inclusion of other explanatory variables. When combined and tested with parsimonious error correction equations for money demand, price determination, and a monetary policy reaction function, an overall macroeconometric model is revealed with an unusually good fit, aside from a velocity shift adjustment needed for the early 1990s and better inflation performance than expected of late. A regime shift is evident in the stronger response of the Federal Reserve to inflation in the 1980s than in the previous two decades.

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Introduction

This paper explores the indicator properties of M2 in the presence of interest rates and spreads and within the context of a parsimonious error correction macro model. For estimation purposes, the paper concentrates on a period of time when M2 has been thought to perform quite well--the 1960s through the 1980s. Out of sample simulations are then undertaken for the last five years; using cross-equation restrictions, endogenous estimates are obtained of the timing of a shift in the long-run velocity of M2.

This paper differs from a number of recent studies in using annual data. Monthly and even quarterly monetary data may be subject to noise and measurement errors that obscure underlying macroeconomic relationships. Using calendar year data avoids possible distortions in data associated with, for example, seasonal adjustments and the allocation by the Department of Commerce of some of the components of GDP, as well as problems associated with overlapping observations. As Thoma and Gray (1995) have pointed out, the distortions arising from even a single month's observation have at times contributed importantly to the explanatory power of macroeconomic indicators, while impairing their out-of-sample performance. Using annual data also facilitates investigating longer-lagged relationships, which are known to be important in monetary relationships. While a number of recent empirical studies have used lag lengths on money of less than a year [e.g., Estrella and Mishkin (1997), Feldstein and Stock (1994), Bernanke and Blinder (1992), and Friedman and Kuttner (1992)], this paper identifies key relationships with lags longer than that.

The paper also focuses on real M2 as an indicator, which is shown to have a closer relationship to real GDP than the relationship evident between the two nominal series.[1]

The paper begins by depicting the puzzle that the nominal federal funds rate is a better predictor of real GDP growth than are measures of the real federal funds rate. The puzzle is shown to be explained by the leading indicator properties of M2. After testing M2 in the presence of several interest rates and spread variables, the rest of the paper develops a macro model in which the indicator role of M2 can be better assessed.

The Nominal Interest Rate Puzzle

Theory argues that the real interest rate should matter in real spending decisions, not the nominal interest rate. However, the data seem to call for the opposite. Table 1 shows that when real GDP growth (dlyr) is regressed on changes in both the nominal and real funds rate (dff and dffr), the real funds rate is driven out by the nominal rate.[2] The data are annual and the range for this regression, along with all others in the paper, unless otherwise noted, is 1962 to 1991.[3]

Table 1. OLS. Dependent variable = dlyr

	Coefficient	t-stat
constant	0.032652	9.38
lag(dff)	-0.006593	-2.80
lag(dffr)	-0.002658	-0.83

Adj. R-squared: 0.44 Model Std. Error: 0.019
Range: 1962 to 1991

1. Perhaps for such reasons, real but not nominal M2 has long been a component of the traditional leading indicator series.

2. Abbreviations of variables used in the paper are given in appendix 1. In this paper, growth rates of quantities and GDP prices are Q4-to-Q4. Interest rates are annual averages. The real federal funds rate is defined as the nominal rate deflated by the Q4-to-Q4 growth of the chain-weighted GDP price index. Other measures of the real federal funds rate give similar results.

3. The sample begins in the early 1960s when the federal funds rate can realistically begin to be interpreted as the key instrument of monetary policy.

Aside from money illusion or other nominal rigidities, macro theory has a natural place for a nominal interest rate--as a variable explaining the demand for money. In the absence of movement in deposit interest rates, changes in nominal interest rates represent changes in the real cost of money holding. Do nominal interest rates matter so much for GDP because of their relationship to the demand for real money balances? Table 2 shows a regression of real GDP growth on both real M2 growth (dlm2r) and changes in the nominal funds rate.[4] In the presence of money, the nominal funds rate is no longer significant in explaining real GDP growth.

Table 2. OLS. Dependent variable = dlyr

	Coefficient	t-stat
constant	0.013683	2.52
dlm2r	0.244498	2.20
lag(dlm2r)	0.341875	3.30
lag(dff)	-0.002692	-1.44

Adj. R-squared: 0.64 Model Std. Error: 0.0152

M2 as an Indicator

This section examines the apparent strong indicator role for real M2 over the 1962-91 period in the presence of other interest rate variables and spreads that have been important macroeconomic indicators. Table 3 shows that M2 alone explains 62 percent of the variance of real GDP growth over the period. The coefficients on current and lagged money are not significantly different, suggesting the use of a two year average of real M2 growth (dlm2r2y), as in table

4. Real M2 is M2 deflated by the chain-weighted GDP price index. Lagged income terms were insignificant in this and other regressions for income where M2 was included, a feature of using annual data.

4. The resulting bivariate relationship, depicted in chart 1, has a correlation coefficient of 0.80.[5]

Table 3. OLS. Dependent variable = dlyr.

	Coefficient	t-stat
constant	0.008714	2.04
dlm2r	0.330055	3.45
lag(dlm2r)	0.404260	4.22

Adj. R-squared: 0.62 Model Std. Error: 0.0155

Table 4. OLS. Dependent variable = dlyr

	Coefficient	t-stat
constant	0.008797	2.09
dlm2r2y	0.734222	7.17

Adj. R-squared: 0.63 Model Std. Error: 0.0153

The relationship between the nominal growth rates of these variables is much weaker than the above real growth rate relationship. In table 5, nominal GDP growth (dly) is regressed on nominal M2 growth (dlm2), giving an adjusted R^2 of only 0.40, versus R^2 values of over 0.60 when using real growth rates. Furthermore, contemporaneous nominal money growth is not significant at the 5 percent level.

Table 5. OLS. Dependent variable = dly

	Coefficient	t-stat
constant	0.01758	1.27
dlm2	0.27434	1.78
lag(dlm2)	0.51205	3.12

Adj. R-squared: 0.40 Model Std. Error: 0.0194

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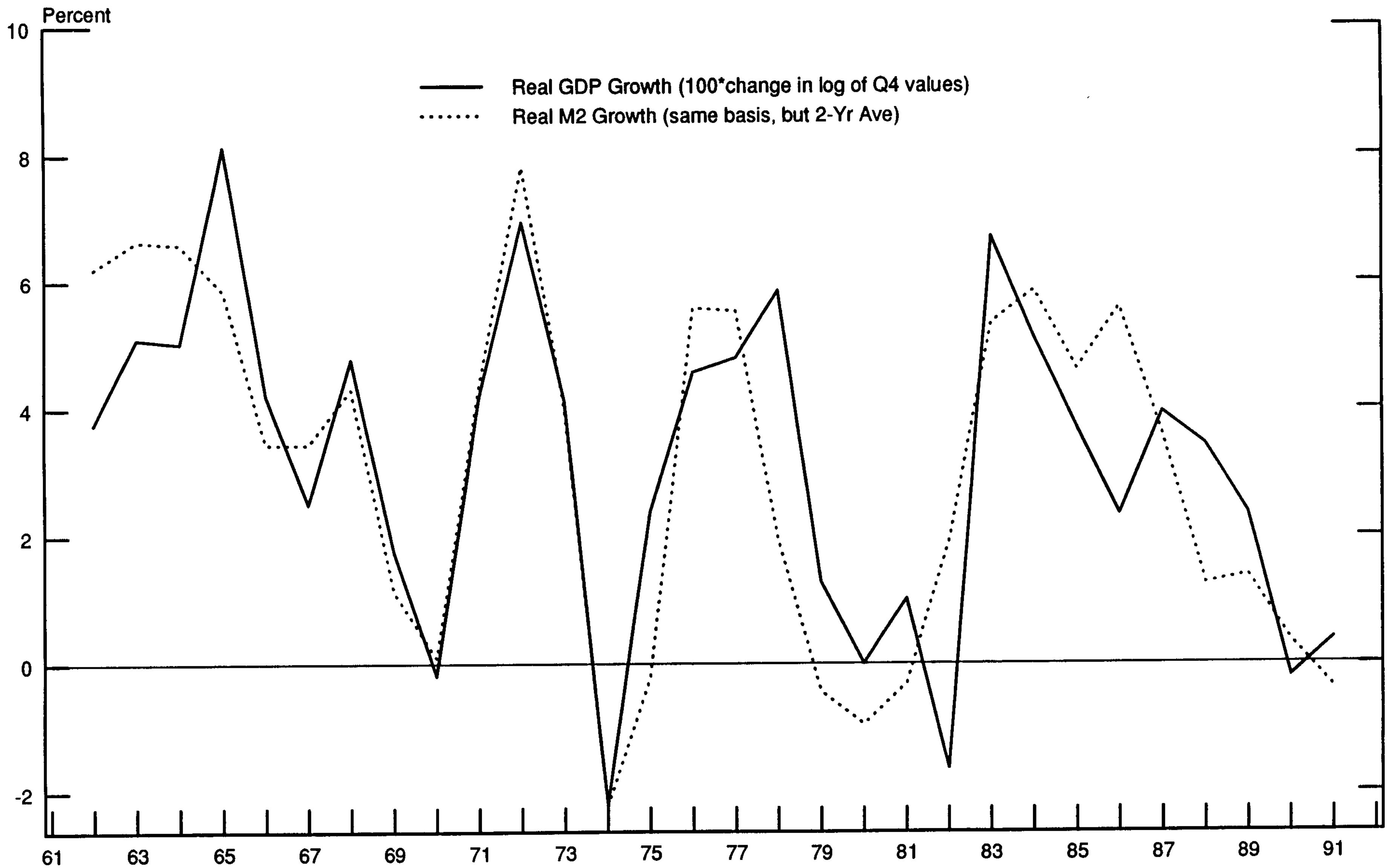
5. The strong correlation is not attributable to measurement error in the inflation measure. A regression of real GDP growth on the two-year growth rates of nominal M2 and the GDP chain-weighted price index, entered separately, gave t-statistics of over 5 for each explanatory variable, and coefficients that were insignificantly different (although it did make the constant term insignificant). This check was suggested by Christopher Hanes.

Chart 1

Real M2 and Real GDP Growth



Theory predicts that real--but not nominal--money holdings are a choice variable for private economic agents. Furthermore, King et al (1991) have previously shown that, while the logs of real income and real money are difference stationary, log nominal values are each integrated of order two. Nevertheless, nominal money is often the focus of analysis in the literature. One reason perhaps is the traditional textbook story of the money supply as the exogenous instrument of monetary policy. Such a story, though at times having some truth for reserves and narrow money, is inappropriate for a broad measure of money like M2 that has never been directly controlled by the Federal Reserve. Another possible reason for the previous focus on nominal variables is the typical interpretation of nominal GDP as a proxy for aggregate demand. In simple IS/LM models, money helped explain nominal spending, while the labor market and price expectations determined the split between real output and prices. However, aggregate demand, and the complete effects of monetary policy decisions, may not be captured by nominal GDP, as suggested *inter alia* by other papers on real output effects, such as Stock and Watson (1989), as well as the P* model [Hallman, Porter, and Small (1991)].

A number of researchers, such as Bernanke and Blinder (1992), have found interest rate spreads to be better macroeconomic indicators than either money or a single nominal interest rate. As shown in table 6, the spread between the ten-year and three-month Treasury yields (t10tb) is a significant explanatory variable for real GDP growth.[6]

Table 6. OLS. Dependent variable = dlyr

	Coefficient	t-stat
constant	0.01636	2.72
lag(t10tb)	0.01237	3.34

Adj. R-squared: 0.26 Model Std. Error: 0.0218

6. The contemporaneous value and longer lags of the yield curve slope were insignificant in this regression, and had a negative coefficient--the "wrong" sign.

However, when real M2 growth was included in the regression, the slope of the yield curve became insignificant, as shown in table 7. This result does not rule out the role of the yield curve slope in explaining shorter-term fluctuations in real GDP growth over the period of analysis, of course.

Table 7. OLS. Dependent variable = dlyr

	Coefficient	t-stat
constant	0.007119	1.57
dlm2r2y	0.668215	5.45
lag(t10tb)	0.003050	0.98

Adj. R-squared: 0.63 Model Std. Error: 0.0153

Another variable that has been found to outperform many macroeconomic indicators in some studies [Stock and Watson (1989) and Friedman and Kuttner (1992)] is the spread of the six-month commercial paper interest rate over the six-month Treasury bill rate (cptb6). The significance of this variable in a bivariate relationship with annual real GDP growth is shown in table 8, with a high R^2 of 50 percent.

Table 8. OLS. Dependent variable = dlyr

	Coefficient	t-stat
constant	0.06486	9.33
cptb6	-0.03955	-4.46
lag(cptb6)	-0.01796	-2.03

Adj. R-squared: 0.51 Model Std. Error: 0.0178

However, when real M2 was added to this regression, the commercial paper spread also became insignificant, as shown in table 9. Again, this result does not rule out the potential usefulness of the commercial paper spread in explaining shorter-term movements in real GDP growth.

Table 9. OLS. Dependent variable = dlyr

	Coefficient	t-stat
constant	0.027230	2.18
dlm2r2y	0.538307	3.41
cptb6	-0.016839	-1.68
lag(cptb6)	-0.004469	-0.53

Adj. R-squared: 0.65 Model Std. Error: 0.015

One interest rate variable that did have a significant relationship to annual real GDP growth, even in the presence of M2, was the real federal funds rate (dffr), as shown in table 10 below.[7]

Table 10. OLS. Dependent variable = dlyr

	Coefficient	t-stat
constant	0.012525	3.15
dlm2r	0.225475	2.47
lag(dlm2r)	0.393018	4.66
lag(dffr)	-0.005303	-2.98

Adj. R-squared: 0.71 Model Std. Error: 0.0136

When compared with table 3, the inclusion of the lagged real funds rate weakened somewhat the size of the coefficient on contemporaneous money growth, but had little effect on the lagged money growth term.

The IS-Relationship and Macroeconomic Model

In part because of potential simulaneity bias, the regression from table 10 is an incomplete macroeconomic finding. However, it could be interpreted as a candidate for an IS-type relationship within a more complete macroeconomic model, as developed below. The model is constructed from single equation techniques and the use of two-stage least squares. However, it is equivalent to a vector error correction (VEC) model of the following form:

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7. Using longer lags of inflation to deflate the nominal funds rate reduced the significance of the resulting real funds rate in this regression. Also, longer lags of changes in the real funds rate, and changes in nominal long-term interest rates proved to be insignificant in this regression.

$$A_0\Delta x_t = A_1\Delta x_{t-1} + A_2x_{t-1} + A_3z_t, \qquad \text{<1>}$$

where the endogenous variables are given by:

x = [log real output, the inflation rate, the funds rate, log real M2]'

and the exogenous variables are included in:

z = [a constant, log of potential GDP, commodity price inflation]'.

The specification analysis undertaken below can be interpreted as a means of arriving at identifying restrictions and testing overidentifying restrictions in the coefficient matrices A_0-A_3 for the above VEC model. The four equations of the model can be interpreted as an IS relationship, money demand, a Federal Reserve reaction function, and an aggregate supply/price determination equation. The model developed here differs from the identified VAR IS/LM model of Gali (1992) in allowing for error correction, and it differs from the VEC model of Hoffman and Rasche (1997) by allowing contemporaneous correlations among differenced variables. While some restrictions are imposed a priori, or after observing single-equation regressions, identification ultimately relies on a two-stage least squares procedure.

The first candidate equation for the model is the IS-type regression from table 10, which is repeated as the first column of appendix 2. As a growth rate relationship, it is not a standard IS curve. Columns 2 through 4 of appendix 2 show the effect of adding levels terms to the regression, in effect testing for an error correction relationship. These terms prove to be generally insignificant (the best candidate is a lagged velocity term that is significant only at the 10 percent level).

Money Demand

The LM curve in this model involves a money demand relationship and a Federal Reserve reaction function. The first column of appendix 3 shows that a decent fit ($R^2 = 0.69$) is obtainable for real M2 growth using only current year real GDP and changes in the nominal funds rate. It suggests a unitary coefficient on income, which is imposed in column 2. Levels terms for velocity and the nominal funds rate also belong in the regression, as shown in column 3. The diagnostic tests for this relationship, given in appendix 3-2, call for a linear trend and only narrowly pass a Chow test. After introducing a linear trend, a lagged dependent variable also becomes needed. With both these terms included, as shown in column 6, the R^2 rises from 72 percent (column 3) to 83 percent.

The same regressions (through 1991) run with nominal money growth reduce the R^2 values to 53 percent for the appendix 3 column 3 specification and to 71 percent for the model with time trend, despite a lower variance of nominal versus real money growth over the period. This finding strengthens the view from theory that private agents choose real money balances based on their real expenditures for goods.

Whether the money demand relationship is specified with or without a time trend, the semi-elasticity of real M2 to a funds rate change is a bit less than unity within the year of change. The long-run semi-elasticity is also about unity in the absence of a time trend, and about 0.4 with a time trend. Regressing the log level of velocity on the funds rate alone gives a semi-elasticity near unity, and adding leads and lags of changes in the funds rate [as in the dynamic OLS procedure of Stock and Watson (1993)] also gives a result close to unity. Because of its parsimony and perhaps more reasonable long-run semi-elasticity, the model without time trend is used in the basic macro model below, but the choice is discussed further in the discussion of long-run properties.[8]

Reaction Function

The Federal Reserve's reaction function, with the federal funds rate as its

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8. Using a measure of M2 opportunity costs gave a slightly better fit, but no error correction, in the basic specification, and a slightly worse fit in the model with time trend. Perhaps error correction to opportunity costs occurs somewhat faster than is well modelled with annual data. Using a log of the interest rate or opportunity cost term gave about the same fit as with the above semi-log specification.

policy instrument, is modelled in appendix 4. The first column shows a bivariate error correction relationship between the funds rate and inflation. The change in the nominal funds rate (dff) is regressed on the current year change in inflation (ddlycp), and on a lag of the funds rate and the inflation rate. This formulation captures the data surprisingly well. As shown in columns 2 and 3, neither the GDP gap (lgap) nor real GDP growth come in significantly when added to this regression.[9] Nevertheless, the simple error correction relationship failed a Chow test, suggesting parameter instability. The sample was then split in 1979. As shown in column 4, in the earlier period, policy seemed to respond to lagged income growth (the GDP gap was not significant). However, as shown in column 5, in the period since 1979, lagged income growth was insignificant, and policy seemed to respond to the current GDP gap, to the exclusion of the current change in inflation--which may indicate a more forward-looking policy regime. Another important difference between the regressions in columns 4 and 5 is that the long-run response of the funds rate to inflation became much stronger in the recent period. Column 6 shows a regression over the entire sample in which the coefficient on lagged inflation is allowed to differ after 1980 (a term is added with the inflation rate multiplied by a dummy variable that equals unity beginning in 1980). In this regression, in which lagged real income proved to be significant, the adjusted R^2 of 78 percent outperforms that for either of the subperiod models in columns 4 and 5. This is the relationship used in the macro model; diagnostics statistics are shown in appendix 4-2.[10]

<u>The Supply Side and Price Determination</u>

For the supply side of the economy, appendix 5, column 1 shows a simple

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9. The output gap is the log of the Federal Reserve Board's potential GDP series less the log of actual GDP.

10. Clarida *et al* (1997) estimate a policy rule with partial adjustment that differs from the above, as it is based on a model of forward-looking targeting of inflation and GDP. They also find a break in properties in 1979.

Phillips curve type of regression. Changes in inflation (ddlycp) are regressed on a lag of the output gap.[11] As shown in column 2, the gap was broken into its two pieces--the log of potential output (lpot) and logged real income (lyr)--and a log of real M2 was added to test for a P*-type of result [Hallman, Porter, and Small (1992)]. Indeed, real M2 did dominate real output. Column 3 shows a regression involving only real M2 and potential output, with the constant term reflecting long-run velocity. The right-hand-side variables can then be interpreted as $p^* - p$, where:

$$p^* = m + v^* - q^*, \qquad \text{<2>}$$

with m as nominal M2, v^* as long-run average velocity, and q^* as potential GDP, all in logs.

The macro model developed here differs from the original, single-equation P* model in allowing for a non-constant the implicit long-run level of velocity. The money demand function forming a component of this macro model incorporates a level term in velocity that embodies a long run relationship to the federal funds rate.

It has always been difficult to interpret a P* result. Here, the IS-type equation shows that real M2 is a leading indicator of real spending. Apparently, households build up real liquidity well in advance of making actual real expenditures. Nevertheless, actual spending relative to the economy's capacity to supply goods is not as well related to the acceleration of prices as intended spending, proxied by real money holdings. Indeed, if current real GDP is added to the regression of column 2, it comes in insignificant and with the wrong sign. Perhaps the gap between notional demands, proxied by real liquidity, and long-run aggregate supply is what in fact results in inflation pressures in the economy.

Column 4 is a simple attempt to account for the mid-1970s oil price shock

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11. A contemporaneous gap term and a constant were insignificant here. Using the level of inflation as the dependent variable, lagged inflation came in with a coefficient very close to unity.

by including a dummy variable for the level of inflation in 1974.[12] An alternative using the PPI component for crude fuels proved to have no explanatory power except over the 1974-80 period. However, a measure of general commodity price inflation based on the Commodity Research Bureau index (dlcrb) works very well over the sample period as a whole. Column 5 shows that current and lagged values of inflation in the CRB index have about the same sign; they are combined as a two-year average in column 6. Column 7 instruments for this variable, using lagged values of commodity and general inflation rates and of the P* term.

The Macro System

The simple macroeconomic system that arises from the above analyses is summarized below.

	Adjusted R^2
IS-Type Equation	
dlyr = .013 + .23*dlm2r + .39*lag(dlm2r) - .0053*lag(dffr)	.71
Money Demand	
dlm2r = -.20 + 1*dlyr - .0088*dff -.43*[.01*lag(ff) - lag(lv2)] (restricted coefficient on dlyr)	.72
Federal Reserve Reaction Function	
dff = 79*ddlycp + .7*[87(1 + dum80on)*lag(dlycp) - lag(ff)] + 32*lag(dlyr)	.78
Price Determination	
ddlycp = .057 + .11*lag(lm2r-lpot) + .080*dlcrb2y	.65

Tests of the stationarity of these variables are shown in appendix 6. Both the federal funds rate and the inflation rate appear to require differencing to be stationary. Nonstationarity of residuals of the estimated cointegrating vector in the price equation could be rejected, but the failure to reject nonstationarity of the

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12. This is equivalent to adjusting the change in inflation by a variable that takes a +1 in 1974 and a -1 in 1975.

other cointegrating vectors and of the real funds rate was unexpected.[13]

Because of possible simultaneity bias, the above system cannot yet be interpreted as a structural model. Having instrumented for commodity prices already, however, the last two equations can be taken as a triangular block. Taking potential output and lagged variables to be predetermined, the change in the rate of inflation can be obtained from the price equation. Then the change in the federal funds rate can be obtained from the reaction function. However, the first two equations are not yet identified, as they each include a contemporaneous value of the other's dependent variable; to deal with this, a two-stage least squares procedure was employed. As reported in appendix 3, column 4, there was little effect on the basic money demand regression from using 2SLS.[14] However, as shown in appendix 2, column 6, the coefficient on the contemporaneous money term in the IS equation became insignificant in the second stage of the 2SLS procedure.[15]

If the contemporaneous money growth term is dropped from the IS equation, real output growth is then a function only of lagged variables, and an OLS procedure can be used. The result is as follows:

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13. A vector system test (Johansen, 1991) suggested the presence of a single cointegrating vector (see table A6-2 in appendix 6). The above velocity relationship could be interpreted as such if the nominal funds rate reflected a nonstationary inflation component that was cointegrated with velocity and a stationary real interest rate. The univariate tests did not corroborate such an interpretation, however, perhaps (at least partly) because of measurement error in inflation expectations.

14. As shown in column 6 of appendix 3, a 2SLS procedure did have a noticeable effect on the extended money demand model (with time trend and lagged dependent variable)--the coefficient on the lagged dependent variable became insignificant in a second stage regression for that equation.

15. Another effect in the IS equations was to reduce the t-statistic for a lagged velocity term so that it failed significance at the 10 percent level (it had previously failed at the 5 percent level).

IS-Type Structural Equation | *Adjusted R^2*

dlyr = .017 + .47*lag(dlm2r) - .0070*lag(dffr) .65

This result allows the macro system to be represented in triangular matrix form, and OLS can be used for each structural equation. This can be seen by rewriting the system in the form of matrix equation <1>. The A_0 matrix gives the coefficients among contemporaneous growth rates; to show the triangularity, the order of the equations is set to be output growth, inflation change, funds rate change, and real money growth. For information, the A_1 matrix indicates lags of dependent variables, the A_2 matrix shows coefficients for the lagged level terms, while the A_3 matrix gives the constants and coefficients on exogenous variables.

$$A_0 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & a_1 & 1 & 0 \\ -1 & 0 & a_2 & 1 \end{bmatrix}, \quad A_1 = \begin{bmatrix} 0 & 0 & a_3 & a_4 \\ 0 & 0 & 0 & 0 \\ a_5 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix},$$

$$A_2 = \begin{bmatrix} 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & a_6 \\ 0 & a_7{}^* & a_8 & 0 \\ a_9 & 0 & a_{10} & a_9 \end{bmatrix}, \quad A_3 = \begin{bmatrix} a_{11} & 0 & 0 \\ a_{12} & a_6 & a_{13} \\ 0 & 0 & 0 \\ a_{14} & 0 & 0 \end{bmatrix}. \qquad \text{<3>.}$$

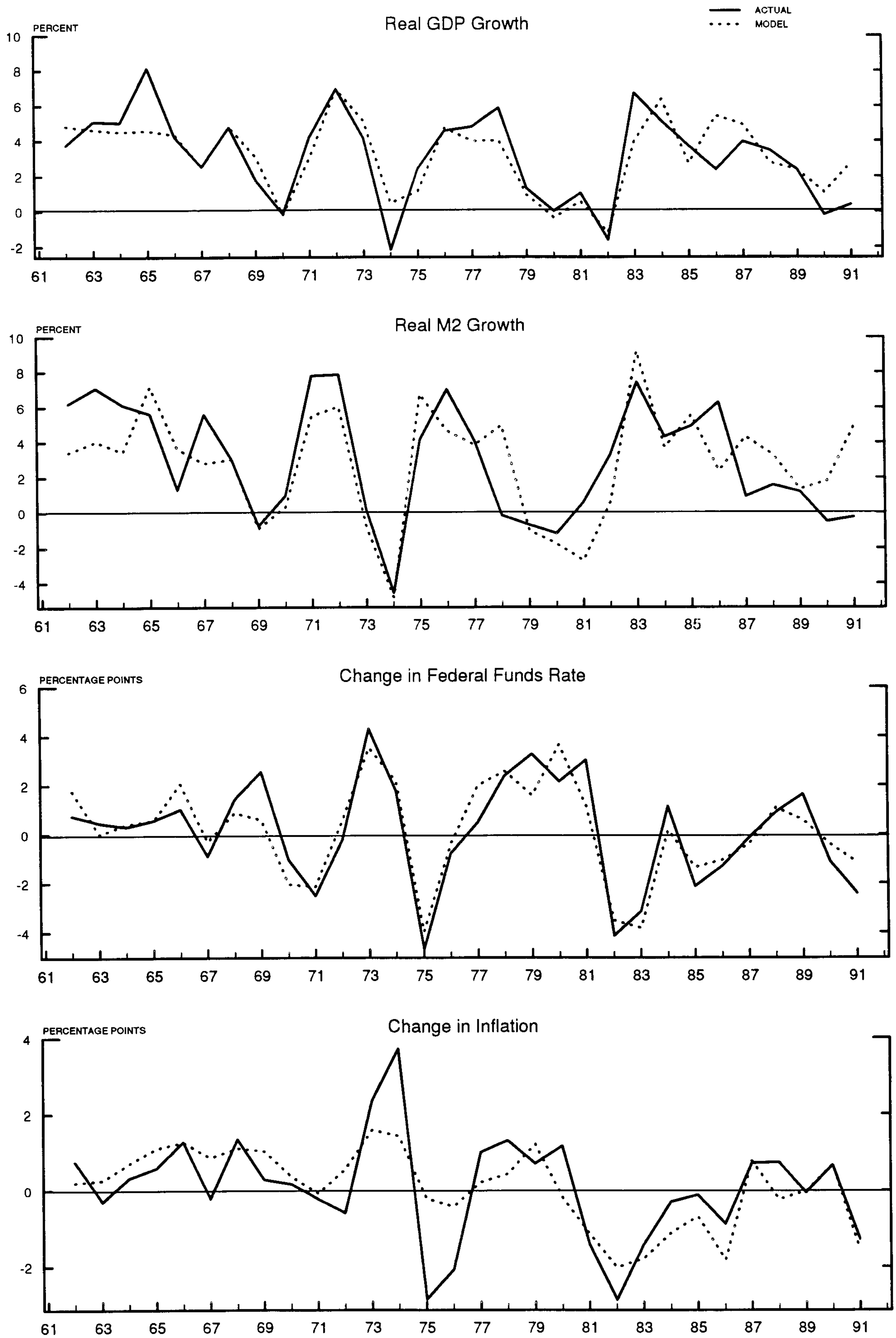
* a_7 is allowed to shift after 1979.

The structural model is repeated in appendix 7, and chart 2 depicts each actual and fitted variable over the estimation period.

Long Run Properties of the Model

A steady state is defined to occur when output equals potential, the inflation rate is constant, and interest rates are unchanged. From the money demand equation, given the federal funds rate, long-run velocity is fixed, implying that output growth equals money growth. From the IS equation, with no change in the real funds rate, dlyr = dlm2r = 3.2 percent over the period shown. The

Chart 2: ACTUAL AND FITTED VALUES



absence of a time trend in the IS equation seems to leave little room for a slowdown in potential output growth over the period.

In a steady state, given money and output growth, the last three equations constitute a simultaneous equation system in three unknowns, the federal funds rate, the log of velocity, and the inflation rate. If the nominal federal funds rate is specified, the money demand equation determines velocity. When the level of aggregate demand consistent with real money balances equals potential output, the inflation rate stabilizes. If inflation has stabilized at the target inflation rate implied from the Federal Reserve's reaction function, the funds rate no longer changes.

It is possible to interpret the estimated model as having a unique steady state for each of the two policy regimes. The estimates of steady state values, however, are a nonlinear function of the estimated coefficients and subject to considerable estimation error. Solving the three simultaneous equations for the implied steady state values gives the results in table 11 below.

Table 11: Implied Steady State Values

	1962-79 Period	1980-91 Period
Inflation	26.0%	4.1%
Funds rate	24.4%	8.6%
M2 Velocity	2.0	1.7

In the 1962-79 period, the policy regime was estimated as having a long-run response to the inflation rate of less than unity. With the inflation rate rising through 1979, it might be expected to settle down at a rate higher than those experienced up to that time, as suggested by the estimated steady state value of over 20 percent. The Federal Open Market Committee was of course not explicitly aiming at such a target rate; nevertheless, its sluggish reaction to the cumulating price pressures over the period were evidently sufficient to imply a very high steady state inflation rate.

The reaction function for the 1980 to 1992 period embodied a much stronger long-run response to inflation, and the estimated steady state inflation rate was about 4 percent for this period. That result is consistent with the substantial disinflation that in fact occurred after 1979.

It is not clear, however, that the assumptions underlying a linear regression model like the above would continue to hold as the economy moved all the way toward the steady states estimated above. The substantial difference in implied real federal funds rates across the two steady states raise a particular doubt in this regard. An inverse observed relationship between real interest rates and inflation rates, and a higher average real interest rate in the 1980s than in the previous two decades are both well-known results. However, a negative real funds rate in a steady state seems implausible. If the sluggish responses to inflation of the 1970s had in fact persisted, the higher resulting inflation may well have impaired potential output growth in a way that made such a regime inconsistent with a steady state; a change in policy to a regime that reacted more strongly to inflation increases may then have become a necessity.

Interpretation: Money and GDP

The above two-stage least square results suggest that current income causes current money, not vice versa, but that lagged real money growth does have important predictive power for real output, even in the presence of interest rate variables and lagged output terms. Does that explanatory power of lagged money only reflect the portion of money that can be explained by money demand, and thus represent merely some complicated, lagged, and perhaps nonlinear responses of output to interest rates and to its own lags? Is there some truly independent information about future output in money data?

To investigate this issue further, real M2 growth was broken into two pieces--the fitted value from the money demand relationship (mfit) and the residual (mres). Both pieces were then used in a regression for real GDP growth, and the results are given in table 12. The residual proved to have a significant and much larger coefficient than the fitted value. This finding held up even after including in the regression (insignificant) lags of real income growth (up to two years), a second year lag of the change in the real funds rate, the nominal funds rate, the yield curve spread, or the commercial paper spread.

Table 12. OLS. Dependent variable = dlyr

	Coefficient	t-stat
constant	0.018826	4.59
lag(mfit)	0.407316	3.99
lag(mres)	0.700684	3.72
lag(dffr)	-0.007737	-4.15

Adj. R-squared: 0.67 Model Std. Error: 0.0148
Range: 1963 to 1991

A further attempt to break the fitted money demand value into the interest rate contribution (mint), the scale variable contribution (mscale), and the constant and lagged own values (mother), and their use in a real output regression is shown in table 13. The separation of these sources of money demand tend to make each insignificant in the real output regression. Of the three pieces of the fitted money demand values, the interest rate contribution shows the largest coefficient and highest t-value. The residual from the money demand regression continues to exhibit the strongest coefficient overall, however, and it remains significant in explaining real GDP growth.

Table 13. OLS. Dependent variable = dlyr

	Coefficient	t-stat
constant	0.150690	1.38
lag(mint)	0.496519	1.91
lag(mscale)	0.300491	1.68
lag(mother)	0.334773	1.75
lag(mres)	0.575699	2.86
lag(dffr)	-0.006652	-2.34

Adj. R-squared: 0.68 Model Std. Error: 0.0146
Range: 1963 to 1991

Using the alternative specification for money demand with a time trend and lagged money growth, a similar result was found, as shown below. Under this specification, the fitted value (mfit2) and the residual (mres2) from the money demand regression had about the same coefficient value, and while both appear significant, the fitted value has a substantially larger t-statistic.

Table 14. OLS. Dependent variable = dlyr

	Coefficient	t-stat
constant	0.017041	4.23
lag(mfit2)	0.475857	5.13
lag(mres2)	0.509998	2.10
lag(dffr)	-0.007036	-3.79

Adj. R-squared: 0.65 Model Std. Error: 0.0153
Range: 1963 to 1991

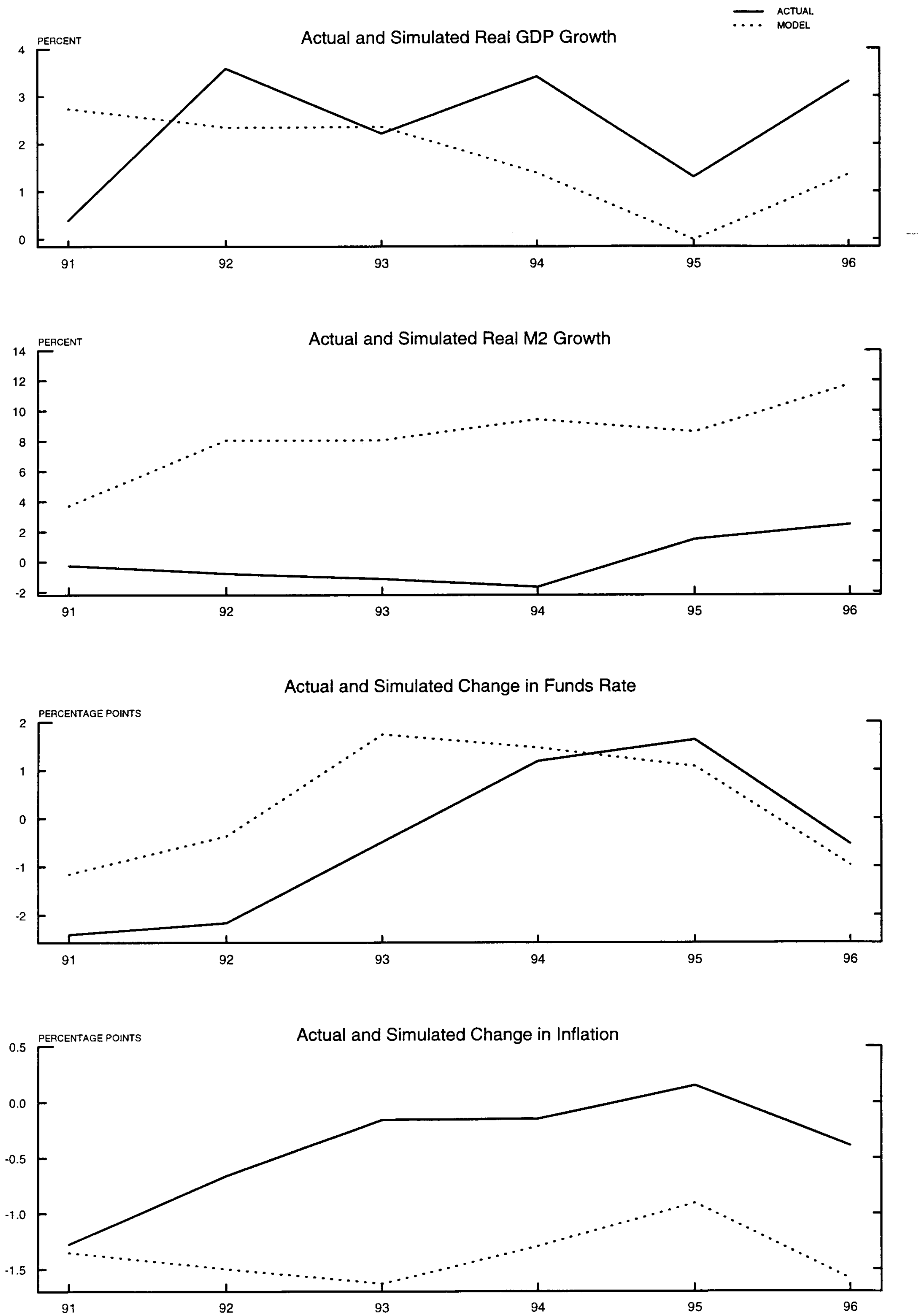
Out of Sample Results for the 1990s

Chart 3 shows the results of an out of sample simulation of the model over the 1992-96 period. Table 15 below presents summary measures of how badly the estimated model relationships went off track over this period. The results show that M2 continued to perform fairly well in the IS relationship, and that the estimated Federal Reserve reaction function was fairly close to actual results over

Table 15

	Estimated Model Standard Errors 1962 - 1991	Root Mean Square Simulation Errors 1992 - 1996
	-------percentage points-------	
Real output growth	1.5	1.5
Real M2 growth	1.8	9.2
Changes in funds rate	1.0	1.3
Change in inflation	0.8	1.2

Chart 3


ACTUAL
MODEL
Actual and Simulated Real GDP Growth
PERCENT
4
3
2
1
0
91
92
93
94
95
96
Actual and Simulated Real M2 Growth
PERCENT
14
12
10
8
6
4
2
0
-2
91
92
93
94
95
96
Actual and Simulated Change in Funds Rate
PERCENTAGE POINTS
2
1
0
-1
-2
91
92
93
94
95
96
Actual and Simulated Change in Inflation
PERCENTAGE POINTS
0.5
0.0
-0.5
-1.0
-1.5
91
92
93
94
95
96

the period. However, changes in inflation were consistently underpredicted, and money demand was consistently overpredicted, with errors of unprecedented size--both these results were apparently attributable to the failure of real money balances to error-correct to their previous levels relationship with actual or potential output.

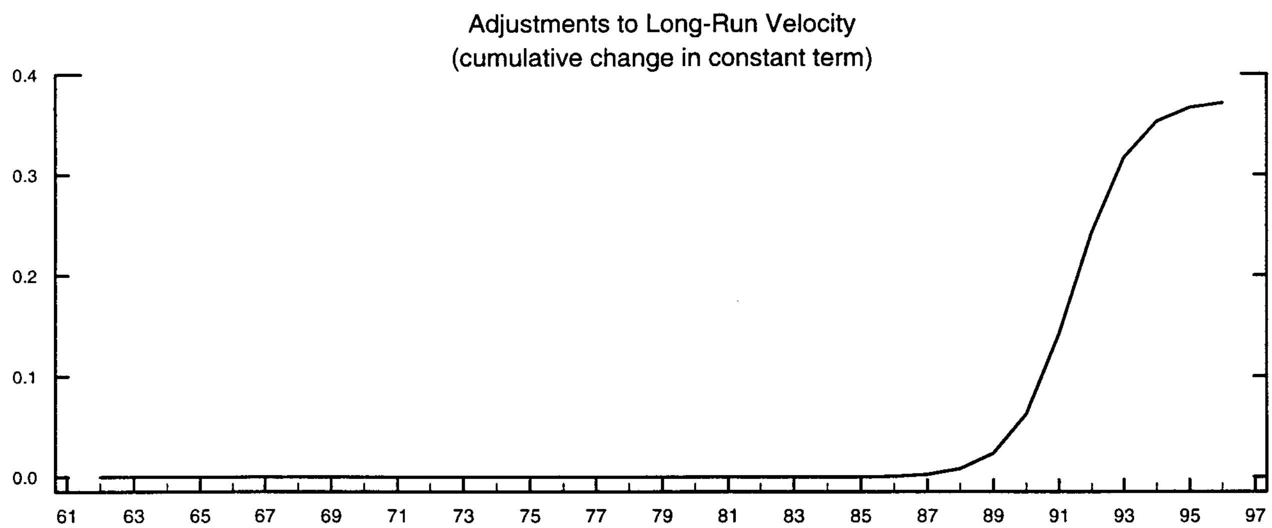
Estimates of the M2 Velocity Shift

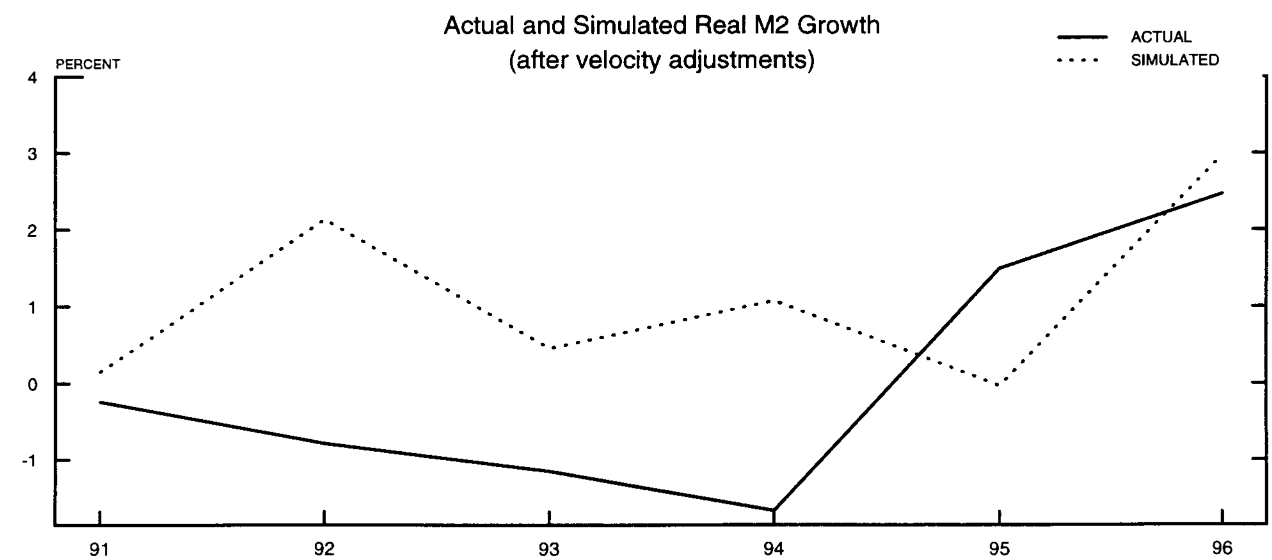
The steady state velocity of M2 appears in two places in the model: the money demand equation and the price determination relationship. By imposing cross-equation restrictions, an estimate of the shift in long-run velocity of M2, consistent with both equations, was obtained. A parametric representation of the shift was used, based on a logistic learning function, which makes endogenous the timing, magnitude and degree of completion of any shift. The procedure involved adding the term, $\alpha_i/(1 + e^{(\beta t+\gamma)})$, to each of the two equations, and then reestimating them through 1996, as shown in appendix 8. The coefficients β and γ were constrained to be equal across the two equations, implying the same **timing** of the shift in long-run velocity. The coefficients α_i were also constrained across the two equations in a manner that equated the **size** of the long run velocity shift in each case.

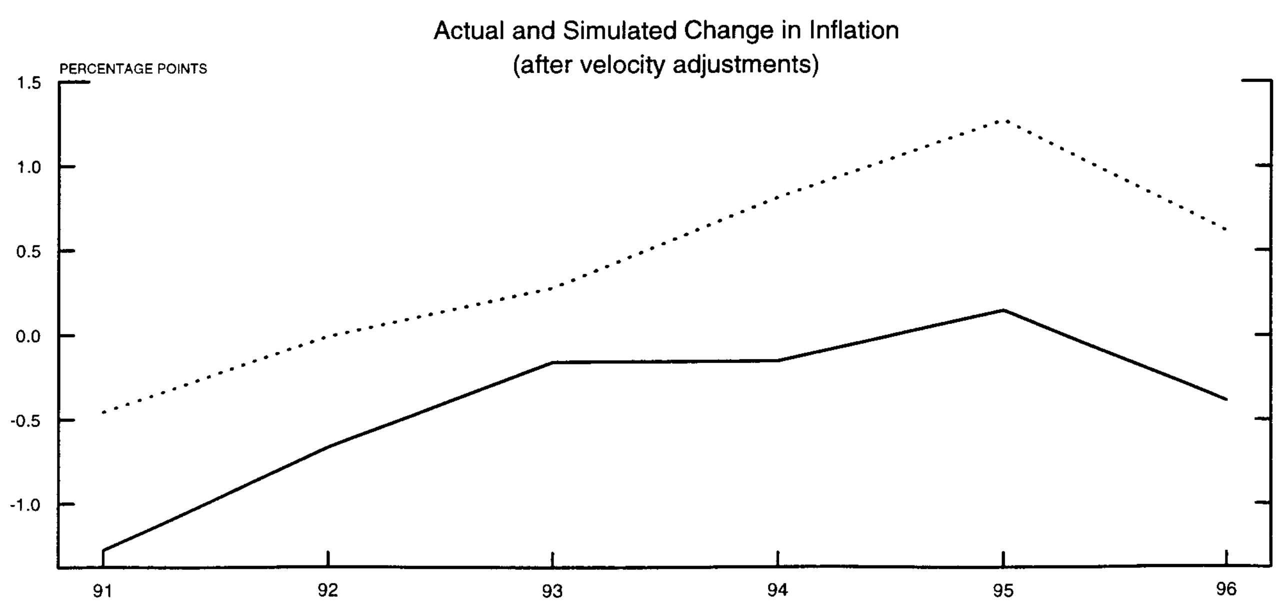
The resulting estimated steady state velocity shift is depicted in the top panel of chart 4. The statistical analysis indicated an incipient movement in long-term velocity at the end of the 1980s, rapid adjustment over the 1991-1993 period, and a leveling off in the last three years.

The bottom two panels of chart 4 show the out-of-sample simulations for real money growth and the change in inflation after adjustment for the velocity shift. Money demand is still substantially overpredicted in the early 1990s, as might be expected, owing to temporary credit crunch effects present at that time in addition to shifts in long-run velocity. However, money demand appears to have come back on track in the last two years, without further velocity shifts. By contrast, the effect of the velocity adjustment on the price equation is to switch

Chart 4


Adjustments to Long-Run Velocity
(cumulative change in constant term)
0.4
0.3
0.2
0.1
0.0
61 63 65 67 69 71 73 75 77 79 81 83 85 87 89 91 93 95 97


Actual and Simulated Real M2 Growth
(after velocity adjustments)
PERCENT
ACTUAL
SIMULATED
4
3
2
1
0
-1
91 92 93 94 95 96


Actual and Simulated Change in Inflation
(after velocity adjustments)
PERCENTAGE POINTS
1.5
1.0
0.5
0.0
-0.5
-1.0
91 92 93 94 95 96

from an underprediction, with no long-run velocity adjustment (the bottom panel of chart 3), to an overprediction after making the adjustment (the bottom of chart 4). The overprediction persists through 1996, which is consistent with the unusually favorable performance of inflation of late relative to historical patterns.

Conclusion

This study showed that real M2 growth was an important indicator of real GDP growth over the three decades ending in the early 1990s. While the correlation between concurrent values of these series was explainable as the response of money demand to income, the residual from a money demand function helped to explain GDP growth in the following year. Although other studies, using shorter lag lengths, have at times found that interest rates and spreads have dominated M2 as an indicator, the reverse was shown to be the case using the smoothing and longer-lagged relationships inherent in annual data.

The indicator properties of M2 were investigated here in the context of a parsimonious macro model, developed using simultaneous equations and error correction procedures. The model included a modified P* relationship for price determination, with the long-run velocity of M2 being a function of the level of the funds rate and the rate of inflation in a steady state. The model featured the crucial role of a Federal Reserve reaction function. An error correction relationship between the funds rate and the inflation rate, with an output growth term, seemed to provide a good fit for monetary policy choices over the 1962-91 period. A single break in the reaction function at the end of 1979 was needed, when the strength of the long-run response of the nominal funds rate to inflation about doubled.

The model was employed to estimate the shift in the steady state velocity of M2 in recent years, through the use of cross equation restrictions in the money demand and price determination equations. The methodology allowed endogenous determination of the timing and size of the shift; it supported the notion that the sharp upshift in long-run velocity was largely completed by 1994.

Out of sample simulations of the model in the 1992-96 period showed that M2 did not lose its indicate properties in a growth rate relationship with GDP over this period. However, the above-estimated velocity correction offset only part of the overpredictions of money demand relationship in recent years; transitory effects (such as the credit crunch) apparently were also important. After making adjustments for a shift in long-run velocity, the simulated inflation forecasts came in above the actual readings, corroborating the impression that inflation has been more favorable recently than historical relationships would have suggested.

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Appendix 1

Variable Names

Note: l at the beginning of a variable means taking the log;
d at the beginning of a variable means taking a first difference.

crb = Commodity Research Bureau index of raw industrial commodity prices, annual average.
dlcrb2y = two-year average of dlcrb.
ff = nominal federal funds rate, annual average.
ffr = real federal funds rate (deflated by the Q4-to-Q4 growth of the chain-weight GDP price index), annual average.
lgap = Q4 output gap, defined as the log of potential GDP (FRB estimate) less log of actual real GDP.
m2 = Q4 nominal M2.
m2r = Q4 m2 deflated by chain-weighted GDP price index.
dlm2r2y = two-year average of dlm2r.
mint = estimated interest rate contribution to money growth.
mfit = fitted value from money demand regression.
mother = estimated contribution to money growth from constant and lagged own terms.
mres = residual from the money demand regression.
mscale = estimated GDP contribution to money growth.
pot = Q4 potential GDP.
t10tb = yield on 10-year Treassury note less three-month Treasury bill rate, annual average.
tyme = a linear time trend.
v2 = Q4 velocity of M2.
y = Q4 level of nominal GDP.
ycp = Q4 level of chain-weighted GDP price index.
yr = Q4 level of real (chain-weighted) GDP.

Appendix 2

IS-Type Regressions

	1	2	3	4	5	6	7
Method:	OLS	OLS	OLS	OLS	2SLS*	2SLS*	OLS
Explan-atory variables	Dependent Variable: dlyr Coefficient (t-statistic)						
constant	.0125 (3.15)	.1116 (2.04)	.1035 (1.55)	.0175 (3.54)	.1000 (1.69)	.0162 (3.45)	.0169 (4.37)
dlm2r	.2255 (2.47)	.2480 (2.81)	.2510 (2.76)	.2068 (2.10)	.0765 (0.57)	.0383 (0.28)	
lag (dlm2r)	.3930 (4.66)	.2585 (2.36)	.2671 (2.25)	.3955 (4.64)	.3350 (2.68)	.4557 (4.71)	.4685 (5.46)
lag (dffr)	-.0053 (-2.98)	-.0043 (-2.42)	-.0042 (-2.26)	-.0041 (-2.18)	-.0057 (-2.77)	-.0067 (-3.26)	-.0070 (-3.91)
lag (lv2)		-.1796 (-1.82)	-.1638 (-1.32)		-.1526 (-1.42)		
lag (lgap)				.1130 (1.15)			
lag (ffr)			-.0003 (-0.22)	-.0020 (-1.60)			
Adj. R^2	0.71	0.73	0.72	0.72	0.69	0.66	0.65
Estimation Period (yrs)	62-91	62-91	62-91	62-91	62-91	62-91	62-91

*The first stage of the two-stage least squares regression involved the following predetermined variables: dff, a constant, and lags of dlyr, dlm2r, lv2, dffr, and ff.

Appendix 2-2

OLS. Dependent variable = dlyr

	Coefficient	t-stat	Std. Error	White Std. Error
constant	0.016929	4.37	0.003873	0.003524
lag(dlm2r)	0.468494	5.46	0.085763	0.073555
lag(dffr)	-0.006998	-3.91	0.001791	0.001599

Adj. R-squared: 0.66 Model Std. Error: 0.015
Range: 1962 to 1991

Tests for Serial Correlation

	DGF	Statistic	Probability
Auto(1)	1	0.05859	0.1913
Auto(1)	1	0.05859	0.1913

Dependent Variable Lags

	DGF	Statistic	Probability
Ylag(1)	1	1.399	0.7631
Ylag(1)	1	1.399	0.7631

Other Tests

	DGF	Statistic	Probability
Xlag(1)	2	3.394	0.8167
Linear Trend	1	1.847	0.8259

Heteroskedasticity Tests

	DGF	Statistic	Probability
Het w/YFIT	1	0.6898	0.5938
Trending Variance	1	0.2133	0.3558

Test for parameter stability

		Statistic	Probability
Chow Test	F(3, 24)	0.7319	0.4569

Appendix 3

Money Demand Regressions

	1	2	3	4	5	6	7
Method:	OLS	OLS	OLS	OLS	2SLS*	OLS	2SLS#
Explan-atory variables	Dependent Variable: dlm2r Coefficient (t-statistic)						
constant			-.1996 (-2.34)	-.1896 (-1.88)	-.2194 (-1.90)	-.3428 (-4.07)	-.3839 (-3.97)
dlyr	.9443 (11.14)	1.0 fixed	1.0 fixed	.9656 (5.41)	1.068 (4.10)	.8496 (5.46)	1.098 (3.87)
dff	-.0080 (-5.07)	-.0081 (-5.20)	-.0088 (-5.37)	-.0089 (-5.24)	-.0087 (-5.07)	-.0095 (-7.15)	-.0090 (-6.08)
lag (lv2)			.4335 (2.36)	.4170 (2.02)	.4665 (2.06)	.7279 (4.25)	.7970 (4.16)
lag (ff)			-.0044 (-2.11)	-.0044 (-2.08)	-.0044 (-2.06)	-.0031 (-1.90)	-.0030 (-1.77)
lag (dlm2r)						.3577 (2.84)	.2646 (1.76)
tyme						-.0016 (-3.98)	-.0016 (-3.86)
Adj. R^2	0.69	0.70	0.72	0.71	0.70	0.83	0.82
Estimation Period (yrs)	62-91	62-91	62-91	62-91	62-91	62-91	62-91

* The first stage of the two-stage least squares regression involved the following predetermined variables: dff, a constant, and lags of dlyr, dlm2r, lv2, dffr, and ff.

\# Tyme was added to the other predetermined variables for the first stage regression.

Appendix 3-2

OLS. Dependent variable = dlm2r

	Coefficient	t-stat	Std. Error	White Std. Error
constant	-0.199574	-2.34	0.0852761	8.534e-02
dlyr	1.000000	fixed	0.0000176	1.212e-09
dff	-0.008831	-5.37	0.0016449	1.657e-03
lag(lv2)	0.433541	2.36	0.1837082	1.876e-01
lag(ff)	-0.004359	-2.11	0.0020614	2.137e-03

Adj. R-squared: 0.72 Model Std. Error: 0.018
Range: 1962 to 1991

Tests for Serial Correlation

	DGF	Statistic	Probability
Auto(1)	1	1.966	0.8391
Auto(1)	1	1.966	0.8391

Dependent Variable Lags

	DGF	Statistic	Probability
Ylag(1)	1	1.845	0.8257
Ylag(1)	1	1.845	0.8257

Other Tests

	DGF	Statistic	Probability
Xlag(1)	3	2.573	0.5377
Linear Trend	1	8.668	0.9968

Heteroskedasticity Tests

	DGF	Statistic	Probability
Het w/YFIT	1	11.17	0.9992
Trending Variance	1	11.97	0.9995

Test for parameter stability

		Statistic	Probability
Chow Test	F(5, 20)	2.539	0.9381

Appendix 3-3

OLS. Dependent variable = dlm2r

	Coefficient	t-stat	Std. Error	White Std. Error
constant	-0.367667	-4.59	8.014e-02	6.038e-02
lag(dlm2r)	0.301357	2.70	1.117e-01	7.970e-02
dlyr	1.000000	fixed		
dff	-0.009179	-7.13	1.287e-03	1.106e-03
lag(lv2)	0.769710	4.65	1.656e-01	1.262e-01
lag(ff)	-0.003061	-1.88	1.625e-03	1.390e-03
tyme	-0.001603	-4.06	3.945e-04	3.551e-04

Adj. R-squared: 0.83 Model Std. Error: 0.014
Range: 1962 to 1991

Tests for Serial Correlation

	DGF	Statistic	Probability
Auto(1)	1	0.8835	0.6527
Auto(1)	1	0.8835	0.6527

Dependent Variable Lags

	DGF	Statistic	Probability
Ylag(1)	NA	NA	NA
Ylag(1)	NA	NA	NA

Other Tests

	DGF	Statistic	Probability
Xlag(1)	4	2.196	0.3002
Linear Trend	NA	NA	NA

Heteroskedasticity Tests

	DGF	Statistic	Probability
Het w/YFIT	1	10.163	0.9986
Trending Variance	1	9.971	0.9984

Test for parameter stability

		Statistic	Probability
Chow Test	F(7, 16)	0.5231	0.1955

Appendix 4

Reaction Function Regressions

	1	2	3	4	5	6
Method:	OLS	OLS	OLS	OLS	OLS	OLS
Explan-atory variables	Dependent Variable: dff					
	Coefficient (t-statistic)					
ddlycp	104.1 (5.12)	94.98 (3.97)	80.00 (3.28)	87.90 (4.23)		78.89 (4.63)
lag(dlycp)	32.60 (2.06)	30.97 (1.92)	31.92 (2.09)	55.96 (2.71)	124.3 (4.95)	61.43 (5.11)
dum80on* lag(dlycp)						60.13 (5.36)
lag(ff)	-.2062 (-1.97)	-.1819 (-1.65)	-.2575 (-2.44)	-.6311 (-3.37)	-.4768 (-3.59)	-0.694 (-6.32)
lgap		-8.635 (-0.73)			-70.99 (-3.94)	
lag (dlyr)			16.34 (1.66)	28.46 (3.36)		31.77 (4.26)
Adj. R^2	0.51	0.50	0.54	0.72	0.75	.78
Estimation Period (yrs)	62-91	62-91	62-91	62-79	80-91	62-91

Appendix 4-2

OLS. Dependent variable = dff

	Coefficient	t-stat	Std. Error	White Std. Error
ddlycp	78.892	4.63	17.0276	11.744
lag(dlycp)	61.433	5.11	12.0115	12.664
dum80on*lag(dlycp)	60.129	5.36	11.2255	14.239
lag(ff)	-0.694	-6.32	0.1099	0.110
lag(dlyr)	31.772	4.26	7.4611	5.707

Adj. R-squared: 0.78 Model Std. Error: 1.031
Range: 1962 to 1991

Tests for Serial Correlation

	DGF	Statistic	Probability
Auto(1)	1	1.082	0.7018
Auto(1)	1	1.082	0.7018

Dependent Variable Lags

	DGF	Statistic	Probability
Ylag(1)	1	0.2249	0.3646
Ylag(1)	1	0.2249	0.3646

Other Tests

	DGF	Statistic	Probability
Xlag(1)	4	6.6049	0.8417
Linear Trend	2	0.8657	0.3513

Heteroskedasticity Tests

	DGF	Statistic	Probability
Het w/YFIT	1	2.3444	0.8743
Trending Variance	1	0.1443	0.2959

Appendix 5

Price Setting Regressions

	1	2	3	4	5	6	7
Method:	OLS	OLS	OLS	OLS	OLS	OLS	IV*
Explan-atory variables	Dependent Variable: ddlycp Coefficient (t-statistic)						
constant			.0862 (4.24)	.0704 (4.61)	.0550 (3.36)	.0551 (3.51)	.0565 (3.45)
lag (lgap)	-.2644 (-4.04)						
lag (lpot)		-.2265 (-3.45)					
lag (lyr)		.0717 (0.66)					
lag (lm2r)		.1656 (2.26)					
lag (lm2r - lpot)			.1528 (4.22)	.1300 (4.57)	.1068 (3.56)	.1069 (3.72)	.1093 (3.67)
dum7475				.0278 (4.46)			
dlcrb					.0422 (3.03)		
lag(dlcrb)					.0417 (3.17)		
dlcrb2y						.0839 (4.79)	.0796 (3.50)
Adj. R^2	0.37	0.43	0.37	.62	.63	.65	.65
Estimation Period (yrs)	62-91	62-91	62-91	62-91	62-91	62-91	62-91

* Instruments for dlcrb2y were lags of dlycp, dlcrb, (lm2r-lpot), and a constant.

Appendix 5-2

Instrumental Variables. Dependent variable = ddlycp

	Coefficient	t-stat	Std. Error	White Std. Error
constant	0.05651	3.45	0.01639	0.01844
lag(lm2r-lpot)	0.10929	3.66	0.02982	0.03321
dlcrb2y	0.07956	3.50	0.02272	0.03264

Adj. R-squared: 0.65 Model Std. Error: 0.008
Range: 1962 to 1991

Tests for Serial Correlation

	DGF	Statistic	Probability
Auto(1)	1	0.2726	0.3984
Auto(1)	1	0.2726	0.3984

Dependent Variable Lags

	DGF	Statistic	Probability
Ylag(1)	1	1.553	0.7873
Ylag(1)	1	1.553	0.7873

Other Tests

	DGF	Statistic	Probability
Xlag(1)	2	2.736	0.7453
Linear Trend	1	1.392	0.7619

Heteroskedasticity Tests

	DGF	Statistic	Probability
Het w/YFIT	1	0.03772	0.1540
Trending Variance	1	0.32255	0.4299

Test for parameter stability

		Statistic	Probability
Chow Test	F(3, 24)	0.6599	0.4152

Appendix 6

Table A6-1: Stationarity Tests		
	Variable or Expression to Test	Test Statistic
1	dlyr	-4.05**
2	dlm2r, 1 lag of ddlm2r	-4.65**
3	lv2	-1.81
4	ff	-1.99
5	ffr	-1.89
6	dlycp	-2.03
7	dlcrb, 1 lag of ddlcrb, no constant	-4.86**
8	-.2 + .43*lv2 - .0044*ff	-2.61
9	-.37 + .77*lv2 - .0031*ff - .0016*tyme	-3.01
10	.057 - .11*(lm2r-lpot) + .08*dlcrb2y, with one lagged first difference	-3.68*

** (*) Rejects the null of nonstationarity at the 5 (10) percent level.
Unless otherwise specified, each univariate test was a Dickey-Fuller test with a constant term with -3.00 (-2.63) critical 5 (10) percent levels for 25 observations. The 5 (10) percent critical value for cointegrating vector tests, from Engle and Yoo (1987), is -3.67 (-3.28) for 50 observations.

Table A6-2: Johanson Analysis of Cointegrating Relationships (for lm2r, lyr, ff, dlycp)				
Number of Cointegrating Relationships	Maximum Eigenvalue Test		Trace Test	
	Statistic	Cutoff	Statistic	Cutoff
0	58.91	18.03	82.67	49.91
1	11.76	14.09	23.76	31.88
2	7.58	10.29	12.01	17.79

Appendix 7

The Structural Macro Model

	Adjusted R^2
IS-Type Equation	
dlyr = .017 + .47*lag(dlm2r) - .0070*lag(dffr)	.65
Money Demand	
dlm2r = -.20 + 1*dlyr - .0088*dff -.43*[.01*lag(ff) - lag(lv2)]	.72
(restricted coefficient on dlyr)	
Federal Reserve Reaction Function	
dff = 79*ddlycp + .7*[87(1 + dum80on)*lag(dlycp) - lag(ff)] + 32*lag(dlyr)	.78
Price Determination	
ddlycp = .057 + .11*lag(lm2r-lpot) + .080*dlcrb2y	.65

Appendix 8: Estimation of Long-Run Velocity Shift

Method:	NLLS	
Explanatory Variables	Dependent Variable	
	dlm2r	ddlycp
	Coefficient (t-statistic)	
constant	-.3782 (-5.62)	.0475 (3.54)
dlyr	1.0 fixed	
dff	-.0103 (-8.29)	
lv2	.8241 (5.65)	
ff	-.0079 (-4.93)	
lag (lpot - lm2r)		-.0955 (-3.79)
lag (dlcrb2y)		.0853 (5.62)
α	-.1673 (-5.36)	
β	-1.108 (-4.22)	
γ	35.82 (4.30)	
Adj. R^2	0.85	0.64
Estimation Period (yrs)	62-96	62-96

* The equations for the nonlinear least squares estimation were:

$$dlm2r = constant + dlyr + \delta_1 dff + \delta_2 lv2 + \delta_3 ff + \alpha/(1+e^{(\beta t+\gamma)}), \text{ and}$$

$$ddlycp = constant + \delta_4(lpot - lm2r) + \delta_5 dlcrb2y + (\delta_4/\delta_2)(\alpha/(1+e^{(\beta t+\gamma)}).$$